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Mobile Health (mHealth) Technology: Assessment of Availability, Acceptability, and Use in CKD

Sarah J. Schrauben, MD, MSCE¹, Lawrence Appel, MD, MPH², Eleanor Rivera, PhD, RN³, Claudia M. Lora, MD⁴, James P. Lash, MD⁴, Jing Chen, MD, MMSc⁵, L. Lee Hamm, MD⁵, Jeffrey C. Fink, MD⁶, Alan S. Go, MD⁷, Raymond R. Townsend, MD¹, Rajat Deo, MD, MTR¹, Laura M. Dember, MD¹, Harold I. Feldman, MD, MSCE¹, Clarissa J. Diamantidis, MD, MHS⁸ on behalf of the CRIC Study Investigators*

¹Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA, United States.

²Johns Hopkins University School of Medicine and School of Public Health, Baltimore, MD, United States

³University of Pennsylvania School of Nursing, Philadelphia, PA, United States

⁴University of Illinois at Chicago, Chicago, IL, United States.

⁵Tulane University School of Medicine, New Orleans, LA, United States.

⁶University of Maryland, Baltimore, MD, United States.

⁷Kaiser Permanente Northern California, Oakland, CA, United States.

⁸Duke University School of Medicine, Durham, NC, United States.

Abstract

Rationale & Objective: Digital and mobile health (mHealth) technologies improve patient-provider communication and increase information accessibility. We assessed technology use, attitudes toward using mHealth technologies, and the proficiency in using mHealth technologies among individuals with chronic kidney disease (CKD).

Corresponding Author: Sarah J. Schrauben, MD, MSCE, Address: 930 Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104, Sarah.Schrauben@penmedicine.upenn.edu.

*Alan S. Go, MD, Jiang He, MD, PhD, Robert G. Nelson, MD, PhD, MS, Panduranga S. Rao, MD, Mahboob Rahman, MD, Vallabh O. Shah, PhD, MS, MD, Mark L. Unruh, MD, MS

Authors' Contributions: research idea and study design: SJS, CJD; data acquisition: LA, JC, LLH, JCF, ASG, RRT, HIF, JPL, CJD; data analysis/interpretation: SJS, ER, CML, JPL, JC, JCF, RD, LMD, HIF, CJD; statistical analysis: SJS; supervision or mentorship: LMD, HIF, CJD. Each author contributed important intellectual content during manuscript drafting or revision and agrees to be personally accountable for the individual's own contributions and to ensure that questions pertaining to the accuracy or integrity of any portion of the work, even one in which the author was not directly involved, are appropriately investigated and resolved, including with documentation in the literature if appropriate.

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Study Design: Cross-sectional survey with open text responses

Setting & Participants: Chronic Renal Insufficiency Cohort Study participants who completed current use and interest in using mHealth technologies questionnaires, and the eHealth literacy Survey (eHEALS).

Exposures: Participant characteristics

Outcomes: Technology use (internet/email/smartphone/mHealth applications [apps]), interest in future mHealth use, and proficiency in using digital and mHealth technologies, or eHealth literacy, determined by eHEALS score.

Analytic Approach: Poisson regression and a qualitative content analysis of open-ended responses

Results: Study participants (N=932) had a mean age of 68 years, eGFR 54 ml/min/1.73m², and 59% were male. Approximately 70% reported current use of internet/email/smartphones, and 35% used mHealth apps; only 27% had adequate eHealth literacy (eHEALS score ≥ 32). Participants <65 years (vs. ≥ 65), with more education, higher income, better cognition, and adequate health literacy reported more technology use, and greater interest in using technologies. Participants of white (vs. non-white) race reported more internet/email use, but less interest in future mHealth use. Younger age, higher annual income, and greater disease self-efficacy were associated with adequate eHealth literacy. Three themes regarding interest in using digital and mHealth technologies emerged: willingness, concerns, and barriers.

Limitations: Residual confounding, ascertainment bias








Conclusions: Many individuals with CKD currently use the internet and smartphones, and are interested in using mHealth in the future, but few use mHealth apps or have adequate eHealth literacy. mHealth technologies present an opportunity to engage individuals with CKD, especially members of racial or ethnic minority groups since they reported greater interest in using mHealth technology, compared to the non-minority population. Further research is needed to identify strategies to overcome inadequate eHealth literacy.

Plain Language Summary

Mobile health (mHealth) technology improves patient-provider communication and increases access to information. We wanted to explore how extensively patients are using mHealth technology, what they think about using it, and how proficient they are using it. Our study focused on a group of 932 individuals with chronic kidney disease (CKD). We found that 70% currently used internet/email/smartphones, and 35% used health-specific apps. Less than a third of our patients reported proficient use of mHealth technology. Individuals who were under 65, had more education, and higher income were more likely to use mHealth technology and had a greater interest in it. Black and Hispanic individuals had less technology use overall but were more interested in using mHealth technology. mHealth technology presents an opportunity to engage individuals with CKD.

Graphical Abstract

mHealth Technology: Availability, Acceptability, and Use in CKD

Setting & Participants	mHealth & eHealth Literacy	Perspectives of mHealth						
 <p>2016-2018</p>  <p>932 participants</p> <ul style="list-style-type: none"> • Mean age 68 • 41% Female • 62% Black or Hispanic • mean eGFR 54 ml/min/1.73m² 	 <p>Internet and smartphone use was high (>70%), but mHealth app use was low (36%)</p>  <p>Black and Hispanic participants more likely to report interest in using mHealth compared to Whites</p>  <p>Adequate eHealth literacy was low (27%) overall</p>	 <p>Qualitative analysis of open-text responses, 3 themes emerged:</p> <table border="1"> <tr> <td>Concerns</td> <td> <ul style="list-style-type: none"> • Intrusive • No face-to-face </td> </tr> <tr> <td>Barriers</td> <td> <ul style="list-style-type: none"> • Physical limitations • Assistance needed • Lack of access </td> </tr> <tr> <td>Willingness</td> <td> <ul style="list-style-type: none"> • More participants were enthusiastic than opposed </td> </tr> </table>	Concerns	<ul style="list-style-type: none"> • Intrusive • No face-to-face 	Barriers	<ul style="list-style-type: none"> • Physical limitations • Assistance needed • Lack of access 	Willingness	<ul style="list-style-type: none"> • More participants were enthusiastic than opposed
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Willingness	<ul style="list-style-type: none"> • More participants were enthusiastic than opposed 							
<p>CONCLUSION: Many CKD patients use internet/smartphones and are interested in using mHealth technologies, but few use mHealth apps, and overall proficiency to use mHealth is low.</p>								
<p>Sarah J. Schrauben, Lawrence Appel, Eleanor Rivera, et al. (2020) @AJKDonline DOI: 10.1053/ajkd.2020.10.013</p> 								

Keywords

mobile health; mHealth; chronic kidney disease; eHealth literacy

INTRODUCTION

Mobile health (mHealth) technology pertains to the use of mobile and wireless digital technologies to support health and wellness by extending education, communication, health interventions, and research beyond the reach of traditional clinical care.¹ In chronic disease populations, mHealth has been shown to improve overall patient-provider communication, strengthen patient autonomy, and empower patients to become active participants in their own care,^{2,3} each of which increases the patient-centeredness of care.

Individuals with chronic conditions such as chronic kidney disease (CKD) often need to participate in complicated disease management strategies, but have low levels of participation in self-management behaviors, a characteristic that links to poor outcomes.⁴ mHealth technology has the potential to improve the management of CKD by facilitating patient education, supporting behavior engagement (such as medication adherence and dietary modification), and aiding in patient-provider communication.⁵ mHealth is also an attractive option to supplement the taxed resources of health care providers, resulting, in part, from the increasing prevalence of CKD. In addition, the global coronavirus pandemic has necessitated that nephrology care be delivered remotely to improve social distancing and thus, has created the need to harness the potential of using mHealth technologies.

Despite the potential of mHealth to support CKD management, few mHealth strategies have been used to assist individuals with this condition.^{5,6} To date, little is known about the availability and use of mHealth technologies, attitudes about their use, or level of proficiency in using digital and mHealth technologies for health purposes (i.e., eHealth literacy) among people with CKD.⁷ In this mixed methods study, we describe the use of mHealth technologies, as well as willingness to use mHealth technologies and the level of eHealth literacy among individuals with mild-to-moderate CKD in the Chronic Renal Insufficiency Cohort (CRIC) Study.

METHODS

Study Design and Study Population

This study used data from the CRIC Study, a multi-center, prospective observational cohort of persons with mild-moderate CKD in the US.^{8,9} CRIC participants were recruited from seven clinical centers (University of Pennsylvania, Johns Hopkins University, Case Western Reserve University, University of Michigan, University of Illinois at Chicago, Tulane University, and Kaiser Permanent of Northern California) during two phases: 1) Phase I, from 2003 to 2008 (3,939 participants), and 2) Phase III, from 2013 to 2015 (1,560 participants), and prospectively followed annually. The full inclusion and exclusion criteria have been previously reported.^{8,9} In brief, Phase I included adults 21–74 years with age-based estimated glomerular filtration rate (eGFR) 20–70 ml/min/1.73m², and entry into Phase III required eGFR 45–70 ml/min/1.73m² and age 45–79 years. Exclusion criteria included inability to consent and certain severe conditions. For this study, we used data from participants who completed at least one of two surveys (mHealth/Technology Use Survey or e-Literacy Survey), which contained questions related to the use of internet, email, smartphones, or mHealth applications (apps), future interest in using mHealth technologies, and eHealth literacy. Potential survey participants consisted of a convenience sample of CRIC participants who attended annual study visits between late 2016 and mid-2018. Research coordinators offered the mHealth/Technology Use Survey to the first 60 participants at their annual visit at all seven clinical centers, and the e-Literacy Survey was offered at four of the seven clinical centers (see Figure 1). The surveys were self-administered at in-person visits or administered by the research coordinator if the visit was conducted over the phone. The CRIC Study protocol was approved by the Institutional Review Board of all participating centers and is in accordance with the Declaration of Helsinki. All participants provided written informed consent.

Measurements

The mHealth/Technology Use Survey and e-Literacy Survey were developed within the CRIC Study in parallel for distinct, but complimentary reasons (please see Supplementary Methods for more information). In brief, the mHealth/Technology Use Survey consisted of 12 questions that were developed to collect information from participants about their willingness to use mHealth technologies, along with their current availability and use in the effort to plan for future research in the CRIC Study. The survey questions were drafted and vetted by CRIC investigators, and then piloted among CRIC research staff. The e-Literacy Survey was developed for use in a CRIC ancillary study to learn about participants' current use of and proficiency of using digital and mHealth technology, and consisted of 19 questions, 11 of which were developed de novo by CRIC ancillary investigators, and eight composed the validated eHealth Literacy Scale (eHEALS).^{10,11}

Study Outcomes

The primary study outcome was technology use, with secondary outcomes of interest in future use of mHealth technologies, and level of eHealth literacy (Table S1). Technology use was categorized as current or not current use of three types of technology: internet or email, smartphones, and mHealth apps. Internet or email use was collapsed into one category, since

email requires the internet. Internet use was assessed by “*do you use the internet?*” or by confirming internet use of at least once per month. Email use was assessed by “*do you use and read email?*” or by confirming the use of email when using the internet or a smartphone. Smartphone use was assessed by “*do you use a smartphone (a cell phone that can access the internet such as an iPhone)?*” or by selecting ‘smartphone’ when asked “*What type of cell/mobile phone do you primarily use?*” mHealth app use was determined by endorsing a response to “*which of the following types of health apps have you used on your cell/mobile phone?*” Interest in future use of mHealth technologies was assessed by answering “*are you willing to answer study questionnaires using: the internet, email, or smartphone?*” since these study questions focus on the participants’ willingness to use mHealth to report on their health status, or by an affirmative response to at least one statement related to the development of a new internet or mHealth tool for the following purposes: “*I’d like more help remembering to take my medications?*”, “*I’d like more help learning about what my medications are for?*”, or “*I’d like more help learning about possible side effects from my medications?*”.

eHealth literacy is the skill set needed to effectively find, appraise, and use health information from electronic or digital materials, including mHealth technology. eHealth literacy was assessed with eHEALS to measure the level of an individual’s knowledge and perceived skills at finding, evaluating, and applying digital health information to their health problems.^{10,11} eHEALS consists of eight questions with 5 response options on a Likert-scale, and scored as a cumulative score of the eight questions (range 8–40, with a score of 32 considered to be adequate) or individually (range 1–5).^{10,11} In our analysis, we used a dichotomous cumulative score of <32 or ≥32 for adequate eHealth literacy.

Covariates

Covariates were chosen for their potential influence on technology use, interest in digital and mHealth technologies, and eHealth literacy.^{12–14} Age was determined by the year of survey completion. Sex, race/ethnicity, education, income, and co-morbidity history were collected through self-report during the CRIC baseline assessment, co-morbidities reported were used to construct a Charlson comorbidity index.¹⁵ Health literacy, depressive symptoms, and cognitive function were also collected at baseline with validated questionnaires, the short version of the Test of Functional Health Literacy in Adults (S-TOFHLA), Beck’s Depression Inventory (BDI), and Modified Mini-Mental State Exam, respectively.^{16–18} Measures of disease management self-efficacy (Self-Efficacy for Management of Chronic Disease) and social network (Lubben Social Network Score) were available only at baseline in Phase III Cohort participants.^{19,20} Blood samples collected at the study visit closest to survey completion were used to determine an eGFR with a CRIC-specific equation using serum creatinine and cystatin C.²¹ Location of recruitment site was included in the models to account for potential geographic differences.

Statistical Analysis

We describe the study population using mean and standard deviation, or median and interquartile range for continuous variables, and frequency and proportion for categorical variables. The Pearson’s chi-square and Kruskal-Wallis test were used to compare

categorical and continuous variables, respectively. We report the prevalence of current technology use and interest in future use of digital and mHealth technologies in the total study sample and by age group (<65 and ≥ 65 years) since age has been shown to be an important influence on digital technology.^{22–26}

We examined the association of sociodemographic and clinical factors with current technology use, interest in mHealth, and eHealth literacy in multivariable adjusted Poisson (log-link) regression models with robust error variance to model rate ratios to approximate prevalence ratios (PR).^{27,28} Poisson regression was preferred over logistic regression since the odds ratio is known to overstate the risk ratio versus the PR in cross-sectional studies with common outcomes.²⁹ Analyses were performed with STATA 14.2. Adjusted PRs with 95% confidence intervals are reported. Significance level was 0.05 for two-sided test.

We also conducted a qualitative content analysis of responses to the open-ended question included in the mHealth/Technology Use Survey, “*Do you have any comments about what we’ve asked you in this questionnaire?*” Given the lack of prior literature on this topic, we did not begin with preconceived codes, but developed them inductively through examination of the data.³⁰ Coding was conducted independently by two members of the author team with qualitative research training (SJS, ER) using Microsoft Excel for Mac, version 16.32. They each examined all of the open question responses and created their own list of codes to categorize the responses with no predetermined structure. They then shared those codes and resolved any coding differences through iterative discussion, finally arriving at a common final coding scheme.

RESULTS

Among the total sample of 932 CRIC participants who reported their technology use, 633 completed the e-Literacy Survey and 424 responded to the mHealth/Technology Use Survey. Please see Table S2 for details of participants who did and did not respond to the surveys. There were 125 participants (13.4%) who completed both sets of questions. The participants who completed either survey were similar, except that the e-Literacy Survey group had more participants from a racial or ethnic minority group, with hypertension, diabetes, lower education, as well as more categorized as having inadequate health literacy, and less representation from the South and West Coast than the mHealth/Technology Use Survey group (Table 1). Younger participants (<65 years) reported more current use of internet/email, smartphones, and mHealth apps, as well as more interest in the future use of digital and mHealth technologies, compared to older participants. The reasons for using an mHealth app were similar across age categories (Table 2).

Associations with Technology Use and Interest in Using Digital and mHealth Technologies

Younger age (per 10 years), high school education or higher (vs. less), and higher annual household income (≥ \$20,000 vs. <\$20,000) were associated with more current use of technology (Table 3). Adequate health literacy was also associated with more internet/email and smartphone use, with a similar trend observed for mHealth app use. Non-Hispanic Black participants reported less internet/email use than Non-Hispanic white participants, and non-white (Non-Hispanic Black and Hispanic) participants reported more interest in future use of

digital and mHealth technologies. Younger age was the only other characteristic associated with more interest in future use of digital and mHealth technologies.

Associations with eHealth Literacy

Younger age (per 10 years), an annual income of \$20,000 (vs. <20,000), and a higher disease self-efficacy score associated with adequate eHealth literacy (Table 3). There was no apparent association of education or race/ethnicity with eHealth literacy. Individual eHEALS question scores were associated with participant characteristics in a similar manner as the cumulative eHEALS score (Table S3).

Patient Perspectives regarding mHealth Technologies

Of the 424 participants who completed the mHealth/Technology Use Survey, 66 provided open text responses. Three themes emerged from the coding of the participant perspectives regarding mHealth technologies: concerns, barriers, and willingness (Table 4). Reported concerns generally related to apprehensions about the level of intrusiveness of monitoring and losing face-to-face interactions with clinic staff as illustrated by an 80-year-old female participant that said “I love coming to the clinic and the interaction between the personal contact with all of the staff”, as well as needing more details about the technologies. Concerns were predominantly reported by those older than 65 years. Barriers to technology use were mainly related to physical limitations, as highlighted by a 76-year-old female participant who shared “I had a stroke three years ago and now have problems trying to read on the internet”. Some participants reported they would require assistance from others, or they lacked technology access. Of the participants who reported barriers to technology use, less than half reported current use of smartphone technology and only half used internet/email. In regard to the willingness to use digital and mHealth technologies, more participants were enthusiastic compared to those who opposed it. Those opposed reported slightly lower use of internet/email than those who were enthusiastic and were more likely to be older than 65 years.

DISCUSSION

Among a cohort of individuals with non-dialysis dependent CKD, we identified patient characteristics that likely impact the current uptake of and future interest in using digital and mHealth technologies, including age, health literacy, annual income, and education level. Interestingly, members of racial or ethnic minority groups reported less internet/email use, but more interest in future use of mHealth technologies than white individuals. Another important finding was that approximately three-quarters of our sample did not report an adequate level of eHealth literacy. Prior to this study, mHealth and digital technology use among individuals with kidney diseases in the United States (US) had not been well described, nor had the level of interest in using mHealth technologies or the level of eHealth literacy in this population, despite the growing interest and need to use mHealth technologies for chronic disease management.

Estimates of technology use among those with kidney disease have been reported to be lower than the general US population^{24,31,32}, but they were based largely on individuals with

end-stage kidney disease (ESKD). In the current study of individuals with non-dialysis dependent CKD, we found a higher use of the internet or email and smartphones than these prior reports. Greater technology use could be due to more recent timing of data collection and potentially due to the exclusion of individuals with ESKD, who tend to be older and have more co-morbidities, which has been associated with decreased technology use.^{23,25,33}

Despite the substantial use of digital and mHealth technologies in the US, a “digital divide” remains, with an uneven distribution in the access to, use of, and potential benefits of these technologies³⁴, which is driven by socioeconomic status, age and racial minority status.^{26,35,25,33,36} We also found that a digital divide is present in the population with CKD, observing that older age, membership in a racial or ethnic minority group, and lower socioeconomic status (as measured by education level and yearly income) had strong negative relationships with use of all forms of technology. However, smartphone technology may offer an opportunity to bridge the digital divide since smartphones provide more Internet access to underserved communities than in-home internet.^{36–38} Additionally, we observed that that Black and Hispanic individuals reported more interest in using mHealth technologies than White participants, and that this interest was not linked to education level and yearly income, further supporting that smartphone technology may help overcome the digital divide to facilitate remote health management.

As of 2014, more than half (62%) of smartphone users in the US reported using their phones to look up information about a health condition³⁹, and 32% specifically used medical-related apps.^{39–42} We also found that about one-third of participants (35.9%) reported use of an mHealth app, primarily for learning about health conditions, looking up nutrition or diet information, or accessing their medical record, which is likely driven by the types mHealth apps available for those with kidney disease that focus mainly on patient education rather than tracking health information.⁴³ mHealth apps that focus on tracking health parameters, facilitating remote monitoring and supporting self-management behaviors could represent a major opportunity to improve management of CKD, which are particularly relevant to the remotely delivered nephrology care that has exponentially grown during the coronavirus pandemic.⁴⁴ Importantly, a recent systematic review found that mHealth self-management interventions were highly feasible, usable and acceptable, and have the potential to improve CKD patients’ management and health outcomes.⁴⁵ However, the effectiveness of the interventions is still inconclusive and warrants further research.

Among this cohort of individuals with non-dialysis CKD, several participants opposed the future use of mHealth technologies. Those opposed tended to be older and not currently use the internet or email, and therefore might have a low level of ‘digital readiness’, which is the willingness to use technology to navigate one’s environment, solve problems, or make decisions. A recent report has shown that many US adults have low digital readiness.⁴⁶ This willingness, or ‘digital readiness’, highlights that in order for mHealth technologies to be effective, one must not only have access to technology, but also be willing to use it. More research is needed to assess the readiness of using mHealth technology among those with CKD.

A major concern reported by CRIC participants about using digital and mHealth technologies included the fear of losing face-to-face interaction with clinic staff. In prior reports, individuals with chronic disease have reported an overwhelming preference to receive health-related education and advice from a professional⁴⁷ and most patients prefer mHealth in conjunction with visits to the doctors.⁴⁸ Therefore, mHealth is likely an accessory to, rather than a replacement for the perceived quality of patient provider interactions in the management of chronic diseases.

Reported barriers to using mHealth technologies closely linked to physical limitations, which likely relates to the advancing age and growing number of comorbidities among individuals with CKD. In general, internet and mHealth use has been shown to be inversely related to age and number of medical conditions,^{25,33} with many older adults reporting comorbid conditions, disabilities, or other types of physical limitations that might prevent them from fully utilizing health related digital technologies.²³ More research is needed to more clearly identify the reasons why certain populations such as older adults do not use mHealth technologies, and if supporting the use of mHealth technologies for CKD management can improve outcomes.

It is important to target a population's eHealth literacy level to successfully leverage the capabilities of digital and mHealth technologies for disease management. Assessing eHealth literacy is especially vital for the CKD population since many are already at risk for low technology use due to older age, lower socioeconomic status, and inadequate health literacy. To date, eHealth literacy has not been well characterized among individuals with CKD. In our study, approximately three-quarters of the individuals had inadequate eHealth literacy, suggesting that lack of adequate eHealth literacy will likely serve as a barrier to fully leveraging the benefits of mHealth technologies in this population. Older age and less technology use were associated with inadequate eHealth literacy; both of which likely relate to the level of familiarity and confidence in utilizing technology to carry out tasks, as demonstrated by findings from a 2017 Pew Research Survey in which 34% of internet users aged 65 and older reported they had little-to-no confidence in their ability to use electronic devices to perform online tasks²³ and our observation that confidence in managing one's chronic disease was associated with adequate eHealth literacy. In combination, these findings support the potential role for perceived confidence and adequate eHealth literacy in the CKD population.

This study's strengths include representation of a large number of well-characterized individuals from multiple locations across the US and inclusion of a wide range of ages, including older adults, as well as several racial and ethnic groups. Additionally, this is the largest study to date to describe technology use and eHealth literacy in the population with CKD in the US. However, there are several limitations. Due to the observational study design, we are not able to assess causality and are susceptible to residual confounding, particularly by socio-economic status, since we were only able to adjust for education and household income, and by location (urban vs. rural), which has been shown to influence technology access in other studies.²⁴ To best account for location, we adjusted for recruitment site. Additionally, not all survey questions were validated, and we had incomplete data on response rates, which both limit the external validity of our findings.

Questions assessing the interest in future use of mHealth specifically focused on medication management or participation in a research study, and this interest may not apply to other mHealth applications. Furthermore, our qualitative data collection did not give the opportunity to expand on identified themes due to lack of follow up or formal interview, which limits the depth of exploration of individual experiences. Lastly, ascertainment bias is a concern since the study utilized a convenience sampling strategy and healthier and more engaged individuals may have decided to complete the surveys and participate in the CRIC Study in general.

In summary, many individuals with non-dialysis CKD currently use the internet/email and smartphones, and are interested in using mHealth in the future, but few use mHealth apps or have adequate eHealth literacy. mHealth technologies have the potential to allow for greater digital equity, given that internet accessibility is more available via smartphones among underserved communities, racial minorities, adults with less education, and lower incomes, and since minorities reported more interest in using mHealth and digital technologies. Leveraging mHealth represents a potential opportunity to engage individuals with CKD, but further research needs to be conducted regarding barriers to use, inadequate eHealth literacy, and low digital readiness.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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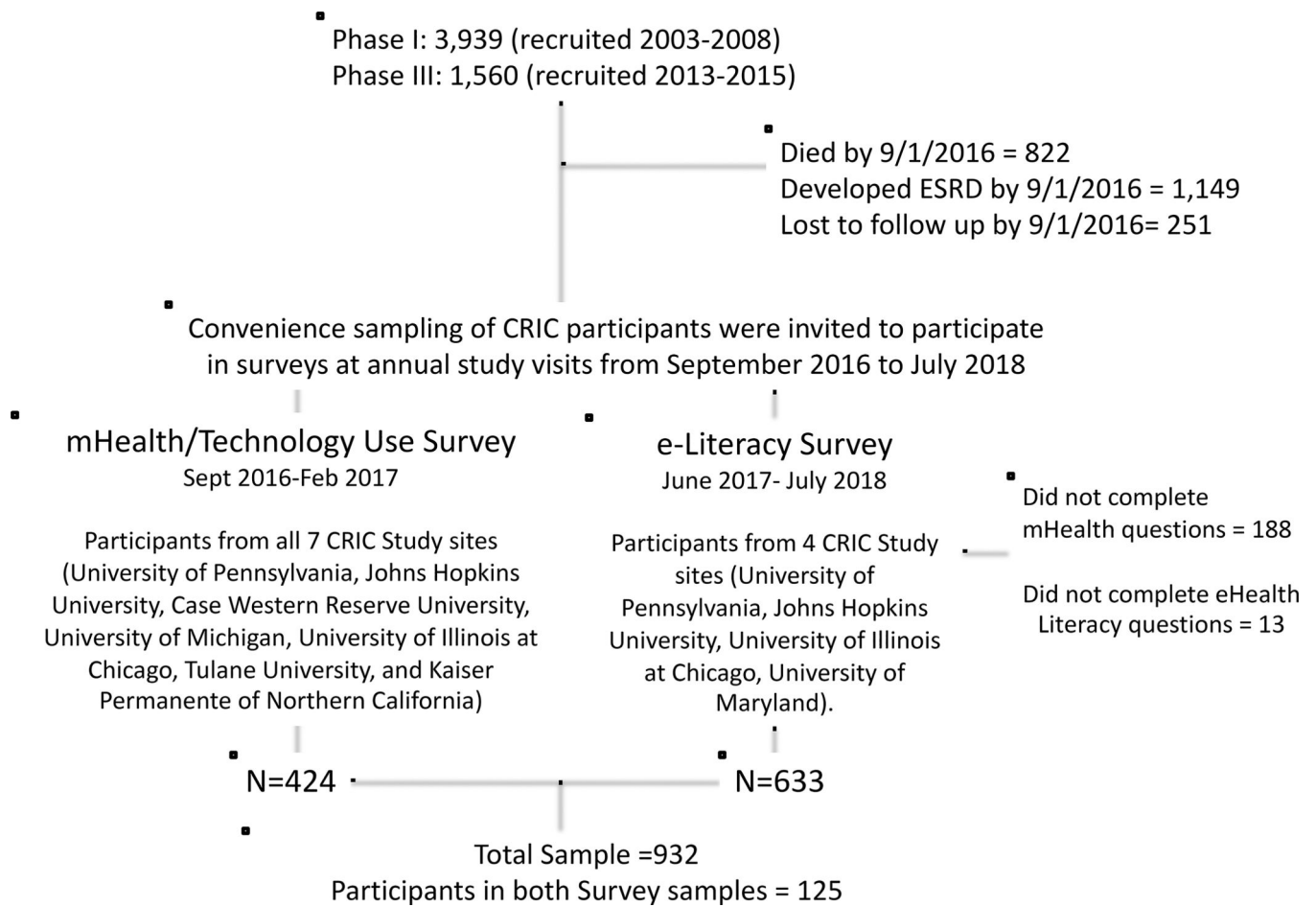


Figure 1:
Flow diagram of study sample selection.

Table 1:

Demographic and Clinical Characteristics of Study Sample, and by Survey type.

	Total Sample (N=932)	e-Literacy Survey Sub-sample (N=633)	mHealth/Technology Use Survey Sub-sample (N=424)	P-value
Age, mean (SD)	67.9 (9.3)	67.6 (9.2)	68.5 (9.2)	0.06
Male gender, %	58.5	60.5	56.1	0.08
Race/Ethnicity, %				<0.001
Non-Hispanic White	37.9	31.9	42.9	
Non-Hispanic Black	51.4	54.8	49.8	
Hispanic	7.6	10.7	3.5	
Other	3.1	2.5	3.8	
Annual Household Income, %				0.18
<\$20,000	25.4	26.2	25.5	
\$20–50,000	25.1	26.9	23.6	
>\$50,000	34.2	31.4	35.9	
Prefer not to answer	15.2	15.5	15.1	
Education, %				<0.001
<High school	15.2	18.5	12.7	
High school/some college	47.0	47.6	47.2	
College or higher	37.8	33.9	40.1	
Clinical Recruitment Site[*], %				<0.001
East Coast	50.6	67.3	28.5	
Midwest	35.9	32.4	42.2	
South	6.4	0	14.2	
West Coast	7.0	0.3	15.1	
Adequate Health Literacy¹, %	89.0	87.4	90.8	0.04
Cognition score², mean (SD)	91.7 (8.0)	91.1 (8.5)	92.2 (6.9)	0.02
Depressive symptom score³, mean (SD)	7.6 (8.0)	7.8 (8.3)	7.3 (7.3)	0.69
eGFR, ml/min/1.73m², mean (SD)	54.4 (15.3)	53.6 (15.7)	54.4 (14.6)	0.06

	Total Sample (N=932)	e-Literacy Survey Sub-sample (N=633)	mHealth/Technology Use Survey Sub-sample (N=424)	P-value
Prevalent cardiovascular disease, %	25.5	25.6	26.4	0.85
Diabetes, %	46.6	49.3	44.3	0.04
Hypertension, %	85.2	88.2	81.6	<0.001
Charlson Comorbidity score, mean (SD)	5.1 (2.0)	5.2 (2.0)	5.1 (2.0)	0.05
Disease self-efficacy ⁴ , mean (SD)	41.3 (8.7)	41.3 (9.1)	41.2 (7.9)	0.25
Social support score ⁵ , mean (SD) [^]	16.0 (5.9)	15.7 (6.0)	16.4 (5.9)	0.33
Adequate eHealth Literacy ⁶ , %	--	27.2	--	--

eGFR – estimated glomerular filtration rate

* East coast (Philadelphia, PA, Baltimore, MA), Midwest (Ann Arbor, MI; Cleveland, OH; Chicago, IL), South (New Orleans, LA); West Coast (San Francisco, CA; Oakland, CA)

¹ Assessed with S-TOFHLA instrument (adequate score >16, out of 36)¹⁶

² Assessed with modified mini-Mental State Exam (score range 0–100)¹⁸

³ Assessed with Becks depression inventory (score range 0–63)¹⁷

⁴ Assessed with disease self-efficacy²⁰ (score range 5–50); only assessed in Phase III cohort participants (N=462)

⁵ Assessed with Lubben social network scale, score range (0–30)¹⁹; only assessed in Phase III cohort participants 65 years of age (N=235)

⁶ Assessed with eHEALS survey (adequate score 32, out of 40)^{10,11}

[^] X² testing of difference across survey type sub-samples for categorical variables and Kruskal-Wallis for continuous variables

Table 2:

Current Technology Use and Future Interest in Use of mHealth Technologies.

	All Ages	<65 years	65 years	p-value*
Current technology use¹, Yes % (N)				
Internet or email	75 (690)	87 (265)	68 (425)	<0.001
Smartphone	70 (648)	88 (267)	61 (381)	<0.001
mHealth apps ²	36 (226)	50 (107)	29 (119)	<0.001
If yes, reported purpose of mHealth app:				
Access personal medical record	51 (116)	56 (60)	47 (56)	
Look up nutrition or diet information	49 (110)	54 (58)	44 (52)	
Learn about health conditions	48 (109)	57 (61)	40 (48)	
Track exercise activity or weight	46 (103)	48 (51)	44 (52)	
Keep track of medications	26 (59)	28 (30)	24 (29)	
Track eating	18 (40)	22 (23)	14 (17)	
Record blood pressure	11 (24)	13 (14)	8 (10)	
Record blood sugars	10 (22)	10 (11)	9 (11)	
Interest in Future Use of Digital and mHealth Technologies, Yes % (N)				
Internet/email/smartphone for kidney research purposes ³	77 (328)	89 (114)	75 (215)	0.001
mHealth apps for medication knowledge and management ²	80 (501)	82 (177)	78 (324)	0.21

* χ^2 testing of difference between age groups (<65 vs. 65 years)

¹ Sample sizes: All Ages (N=922), <65 years (N=302), 65 years (N=620)

² Available only in the e-Literacy Survey sub-sample: All Ages, N=630 (N=215 <65 years, N=415 65 years)

³ Available only in the mHealth/Technology Use Survey sub-sample: All Ages, N=424 (N=128 <65 years, N=296 65 years)

Table 3:

Associations of participant characteristics with current use and interest in future use of mHealth technologies, and adequate eHealth Literacy. Prevalence ratios (PR), and 95% Confidence Intervals (CI) reported.

Characteristic	Internet/Email Use ¹	Smartphone Use ¹	mHealth app Use ²	Interest in mHealth Technology Use ¹	Adequate eHealth Literacy ²
Age (per 10 years)	0.87 (0.84–0.91)	0.84 (0.80–0.88)	0.71 (0.63–0.80)	0.92 (0.88–0.95)	0.74 (0.63–0.85)
Race/Ethnicity Groups					
Non-Hispanic White	REF	REF	REF	REF	REF
Non-Hispanic Black	0.88 (0.81–0.95)	1.08 (0.98–1.19)	0.89 (0.71–1.10)	1.17 (1.08–1.27)	1.01 (0.75–1.36)
Hispanic	0.87 (0.71–1.07)	1.16 (0.97–1.38)	1.02 (0.64–1.63)	1.20 (1.03–1.41)	1.27 (0.76–2.12)
Other	0.90 (0.72–1.11)	1.00 (0.77–1.31)	1.09 (0.59–2.02)	1.01 (0.81–1.26)	1.04 (0.44–2.46)
Education level					
<High school	REF	REF	REF	REF	REF
High school	1.56 (1.20–2.04)	1.27 (1.04–1.56)	2.62 (1.32–5.17)	1.05 (0.93–1.19)	1.90 (1.01–3.61)
Annual Income					
<\$20,000	REF	REF	REF	REF	REF
\$20,000	1.32 (1.16–1.49)	1.13 (1.00–1.28)	1.46 (1.07–2.00)	1.06 (0.97–1.16)	1.90 (1.28–2.83)
No answer	1.22 (1.05–1.41)	1.20 (1.03–1.38)	1.31 (0.90–1.90)	1.05 (0.93–1.18)	1.78 (1.12–2.84)
Health Literacy					
Inadequate Health Literacy	REF	REF	REF	REF	REF
Adequate Health Literacy	1.61 (1.21–2.13)	1.25 (1.00–1.57)	1.92 (0.98–3.77)	1.05 (0.93–1.20)	2.07 (0.95–4.52)
Cognition score (per SD)	1.09 (1.01–1.17)	1.05 (0.98–1.13)	1.04 (0.87–1.25)	1.00 (0.95–1.05)	1.10 (0.87–1.38)
eGFR (per ml/min/1.73 ²)	1.00 (0.99–1.00)	1.00 (0.99–1.01)	1.00 (0.99–1.01)	1.00 (0.99–1.00)	1.00 (1.00–1.01)
Comorbidity score					
<4	REF	REF	REF	REF	REF
4–6	1.05 (0.97–1.13)	1.00 (0.91–1.10)	1.15 (0.90–1.48)	1.08 (0.99–1.18)	1.32 (0.95–1.82)
>6	1.01 (0.90–1.14)	0.96 (0.84–1.10)	0.98 (0.69–1.39)	1.09 (0.98–1.22)	1.01 (0.64–1.61)
Depression symptom score (per SD)	0.99 (0.96–1.03)	1.01 (0.98–1.05)	1.09 (1.00–1.19)	1.03 (0.93–1.20)	1.01 (0.89–1.14)
Only assessed in Phase III cohort:					
Disease self-efficacy* (per SD)	1.05 (0.9–1.13)	1.03 (0.96–1.11)	1.11 (0.93–1.32)	1.01 (0.96–1.06)	1.26 (1.01–1.58)

Characteristic	Internet/Email Use ¹	Smartphone Use ¹	mHealth app Use ²	Interest in mHealth Technology Use ¹	Adequate eHealth Literacy ²
Social support [^] (per SD)	0.99 (0.92–1.07)	1.10 (0.99–1.22)	1.11 (0.90–1.37)	0.99 (0.92–1.07)	1.04 (0.77–1.39)

¹Total study sample without missing variables (N=827)

²e-Literacy Survey sub-sample without missing variables (N=567)

Models adjusted for age, sex, race, income, education, clinical recruitment site, health literacy, cognition, depression, baseline eGFR, baseline comorbidity score

* Model above + self-efficacy: assessed only in Phase III participants (N=403 for all models except eHealth literacy; N=291 for eHealth Literacy)

[^] Model above + social support: assessed only in Phase III participants 65 years of age (N=207 for all models except eHealth Literacy; N=146 for eHealth Literacy)

Table 4:

Themes of participant perspectives of future use of digital and mHealth technologies with exemplar quotations.

Major Themes	Minor themes	Exemplar quotations
Concerns about use	Intrusiveness	“I work full time, so answers are contingent on devices being unobtrusive in a work environment” (Female, Age 55, Record 310) “Do not want any kind of constant monitoring” (Female, Age 61, Record 9)
	Losing face-to-face interaction	“I love coming to the clinic and the interaction between the personal contact with all of the staff” (Female, Age 80, Record 44) “I like coming here. Less I have to do at home; the better I like it” (Male, Age 74, Record 40)
	Needs more details	“More details needed” (Female, Age 79, Record 294) “What are the side effects?” (Male, Age 68, Record 161)
Barriers to use	Physical limitations	“Had stroke 3 years ago and now have problems trying to read on the internet” (Female, Age 76, Record 326) “I am blind, but willing to use talking instruments” (Female, Age 58, Record 184)
	Requires assistance	“Would need assistance from spouse for email/internet” (Male, Age 69, Record 68) “Good instruction, including video would be important for me to make sure I was doing it correctly” (Male, Age 51, Record 291)
	Lack of technology access	“Do not own a smartphone but is willing to learn” (Female, Age 66, Record 22) “Do not have internet access” (Female, Age 59, Record 1)
Willingness to use	Enthusiasm	“It would be easier for me at home” (Female, Age 74, Record 269) “Great idea!” (Male, Age 57, Record 29)
	Opposition	“I am old school and would rather write” (Male, Age 64, Record 91) “Do not use smartphone and have no desire to do so” (Male, Age 68, Record 222)