frontiers | Research Topics

Benefits and challenges to using health-related information and communication technologies among older adults

Edited by
Ronald W. Berkowsky, Alexander Seifert and Timothy M. Hale

Published in
Frontiers in Public Health

ISSN 1664-8714
ISBN 978-2-8325-2834-1
DOI 10.3389/978-2-8325-2834-1

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Benefits and challenges to using health-related information and communication technologies among older adults

Topic editors

Ronald W. Berkowsky — California State University, Channel Islands, United States
Alexander Seifert — University of Zurich, Switzerland
Timothy M. Hale — University of Illinois at Urbana-Champaign, United States

Citation

Berkowsky, R. W., Seifert, A., Hale, T. M., eds. (2023). *Benefits and challenges to using health-related information and communication technologies among older adults*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-2834-1

Table of contents

frontiers | Frontiers in Public Health

TYPE Editorial
PUBLISHED 13 June 2023
DOI 10.3389/fpubh.2023.1224606

OPEN ACCESS

EDITED AND REVIEWED BY
Marcia G. Ory,
Texas A&M University, United States

*CORRESPONDENCE
Ronald W. Berkowsky
✉ ronald.berkowsky@csuci.edu

RECEIVED 17 May 2023
ACCEPTED 31 May 2023
PUBLISHED 13 June 2023

CITATION
Berkowsky RW, Seifert A and Hale TM (2023) Editorial: Benefits and challenges to using health-related information and communication technologies among older adults.
Front. Public Health 11:1224606.
doi: 10.3389/fpubh.2023.1224606

Editorial: Benefits and challenges to using health-related information and communication technologies among older adults

Ronald W. Berkowsky[1]*, Alexander Seifert[2] and Timothy M. Hale[3]

[1]Health Sciences Program, California State University Channel Islands, Camarillo, CA, United States, [2]School of Social Work, University of Applied Sciences Northwestern Switzerland, Olten, Switzerland, [3]Department of Kinesiology and Community Health, University of Illinois Urbana-Champaign, Champaign, IL, United States

KEYWORDS

older adults, elders, aging, information and communication technologies, ICT, health technology, digital divide, human-computer interaction

Editorial on the Research Topic
Benefits and challenges to using health-related information and communication technologies among older adults

To accommodate the current and anticipated cost and care demands of a rapidly aging global society (1), relevant stakeholders in public health and clinical care have turned toward health-related information and communication technologies (ICTs) to help mitigate these growing issues (2). Internet-connected devices and their associated programs and applications have been shown to increase digitally-supported healthcare access among older adults, such as through expanding and enhancing interactions with healthcare providers via telehealth during the COVID-19 pandemic (3, 4). ICTs have also been shown to assist older patients in managing or mitigating physical (5), mental (6), and social (7) health and wellbeing issues. Despite these known benefits, and despite trends indicating that overall use of ICTs among older adults is increasing (8), many still encounter significant barriers to access and use of health-related ICTs (9). In this Research Topic, scholars from across the globe provide theoretical insight and current empirical findings on both the benefits and barriers associated with health-related ICT use among older adults. This work frames ICT use among older adults as a public health issue—that, in addressing and eliminating the barriers to health-related ICT use, older adults will benefit physically, mentally, and socially.

Three manuscripts in the collection specifically examine the potential impacts of ICT use among older adults. He et al. examine the potentially mitigating effects of Internet use in the relationship between visual impairment and depressive symptomatology. They find that Internet use is negatively associated with depression among Chinese middle-aged and older adults, and Internet use serves as a significant mediator between visual impairment and depression such that Internet use lowers the risk of depression. Li et al. examine the efficacy of a medication management intervention delivered via pharmacist-led telemedicine among patients with hypertension during COVID-19, finding that telemedicine can improve patient outcomes and increase medication adherence—this adds to a growing body of literature underscoring the value of digital care delivered across various specialties and disciplines (10). Finally, building on other's work examining the relationship between ICT use and mental health (11), Schuster et al. investigate the potentially bi-directional relationship between online health information-seeking and anxiety among older adults using longitudinal data. Interestingly, they find that while elevated levels of anxiety may contribute to elevated levels of online health-information seeking behavior, it does not appear that changes in online health information-seeking significantly impacts anxiety.

A majority of the studies in the collection highlight barriers to use of health-related ICTs among older adults, with many focusing on factors related to willingness and readiness to adopt ICTs. Jokisch et al. expand upon previous work examining factors predicting technology adoption among older adults, finding that perceived usefulness, self-efficacy in utilizing digital technologies, privacy/security concerns, support from family, and support from formal and institutional settings all showed significant associations with intention to use digital health services. This work supports similar studies (12) showing that perceived value and confidence in learning are significant predictors of willingness to adopt technology among older adults. The findings by Jokisch et al. were echoed in the Seinsche et al. study which examined older adult and health practitioner perspectives on use of exergames (i.e., digital games targeting physical and cognitive functions). They find that while older adults may report less motivation and interest in using general ICTs, they report higher interest in exergames due in part to their perceived value, contrary to the expectations of health practitioners. Other factors motivating use include simplicity in set-up, detailed user instructions, having more personalized (i.e., more valuable) training, and having a reachable contact for assistance and guidance. Wang and Zhao examine intention to use a different ICT (patient-accessible electronic health records, or PAEHRs)—applying concepts from ecological psychology (13), they find that multiple PAEHR characteristics, such as serving multiple functions and flexibility in navigation, significantly predict attachment to PAEHRs and doctors which in turn predicts intention to use.

Additional studies in the collection examine other predictors of technology adoption and use among the general older population. Gray and Charness examine ICT age and find that older adults are more likely to use more dated devices (i.e., non-smart cellular phones) and older desktop computers, laptop computers, and smartphones, implying that many older adults may not utilize the necessary updated ICTs to engage in certain health practices (e.g., participate in an online health intervention). Barriers to use of smart senior care devices is explored by Kong et al. via qualitative semi-structured interviews with 15 older adults in Southwest China. They find that while those interviewed recognized a value in smart care devices and found them to be relatively implementable, numerous obstacles to use were identified including a lack of awareness of the devices and their functions, technophobia, not wanting to upset living habits, and concerns with cost and security. Finally, Cao et al. contribute to the growing literature examining social capital as a positive predictor of digital health information-seeking (14) and, more specifically, eHealth literacy (15) among older adults. Interestingly, the results of this investigation contrast with findings from similar studies—social support was not found to be a significant predictor, nor was gender, underscoring the importance of identifying differences in variable measurement and in contextual factors of data collection (e.g., geographic location, cultural influences).

Two of the manuscripts in the collection identify barriers to successful use of ICTs among specific segments of the older adult population which have received less attention. In their qualitative work, van Leersum et al. examine the use of the virtual personal assistant Anne4Care among elder migrants in the Netherlands (majority Turkish), identifying various barriers (e.g., lack of trust in the technology or those that prescribe them, need for support, language barriers) but also finding that these elders found worth in the technology. Xu et al. examine the subjective experiences of deaf and hard-of-hearing Chinese elders in using digital technologies during COVID-19 and find that deaf and hard-of-hearing older adults are often barred from health and socialization benefits due to limits in digital access, less experience in using the technologies, and a lack of accommodation to their ability status—this can limit health information-seeking ability and promote isolation, further underscoring the need for adapting technologies based on need. This need—to adapt technologies to the user—is the central thesis of the final manuscript in the collection by Cevallos et al.. In it, the authors re-examine the concept of *aging in place*, referring to preferences of older adults to age in the home or in communities that promote identity, autonomy, independence, and comfortability (16), and argue for consideration of implementing continuous accommodations via ICTs into the residential space of older adults. This reconceptualization, referred to as *(st)aging in place*, argues that technologies utilized in the home should adapt to the preferences of the aging individual through the life course as their needs change.

Despite the strength of the research and diversity in topical area provided in this collection, it is not without limitations which echo criticisms levied on the broader scholarship—as an example, the studies included do not specifically examine benefits and challenges of ICT use in long-term care settings, and there is a lack of diversity in scholarship by geographic location. These limitations, along with the swiftness in which health-related ICTs update and evolve, underscore the need for continued research in this area to fully elucidate the ways in which ICTs can be positively and successfully incorporated into the daily lives and care of older adults across the globe. Future work can also more fully elucidate the ways in which public health professionals can best harness the potential of health-related ICTs in managing the care of older adults and reducing the costs associated with this care.

Author contributions

RB was responsible for writing the initial draft of the editorial. AS and TH were responsible for reviewing and revising the draft. All authors approved the current version prior to submission.

Acknowledgments

We kindly thank all of the authors who contributed their work to this Research Topic. We also express our sincere gratitude toward all reviewers who accepted invitations to review the submitted manuscripts, as their work helped improve the manuscripts and the collection overall.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Bloom DE, Canning D, Lubet A. Global population aging: facts, challenges, solutions & perspectives. *Daedalus.* (2015) 144:80–92. doi: 10.1162/DAED_a_00332

2. Fares N, Sherratt RS, Elhajj IH. Directing and orienting ICT healthcare solutions to address the needs of the aging population. *Healthcare.* (2021) 9:147. doi: 10.3390/healthcare9020147

3. Kim YK, Ang S. Older adults with functional limitations and their use of telehealth and during COVID-19. *Res Aging.* (2022). doi: 10.1177/01640275221147642 [Epub ahead of print].

4. Seifert A, Batsis JA, Smith AC. Telemedicine in long-term care facilities during and beyond COVID-19: challenges caused by the digital divide. *Front Publ Health.* (2020) 8:601595. doi: 10.3389/fpubh.2020.601595

5. Schulz R, Wahl HW, Matthews JT, De Vito Dabbs A, Beach SR, Czaja SJ. Advancing the aging and technology agenda in gerontology. *Gerontologist.* (2015) 55:724–34. doi: 10.1093/geront/gnu071

6. Cotten SR, Ford G, Ford S, Hale TM. Internet use and depression among retired older adults in the United States: a longitudinal analysis. *J Gerontol Ser B Psychol Sci Soc Sci.* (2014) 69:763–71. doi: 10.1093/geronb/gbu018

7. Schlomann A, Seifert A, Zank S, Woopen C, Rietz C. Use of information and communication technology (ICT) devices among the oldest-old: loneliness, anomie, and autonomy. *Innov Aging.* (2020) 4:igz050. doi: 10.1093/geroni/igz050

8. Hung LY, Lyons JG, Wu CH. Health information technology use among older adults in the United States, 2009–2018. *Curr Med Res Opin.* (2020) 36:789–97. doi: 10.1080/03007995.2020.1734782

9. Seifert A. The digital exclusion of older adults during the COVID-19 pandemic. *J Gerontol Soc Work.* (2020) 63:674–6. doi: 10.1080/01634372.2020.1764687

10. Kruse C, Fohn J, Wilson N, Patlan EN, Zipp S, Mileski M. Utilization barriers and medical outcomes commensurate with the use of telehealth among older adults: systematic review. *JMIR Med Inform.* (2020) 8:e20359. doi: 10.2196/20359

11. Cotten SR, Goldner M, Hale TM, Drentea P. The importance of type, amount, and timing of internet use for understanding psychological distress. *Soc Sci Q.* (2011) 92:119–39. doi: 10.1111/j.1540-6237.2011.00760.x

12. Berkowsky RW, Sharit J, Czaja SJ. Factors predicting decisions about technology adoption among older adults. *Innov Aging.* (2017) 1:igy002. doi: 10.1093/geroni/igy002

13. Zhao YC, Zhang Y, Tang J, Song S. Affordances for information practices: theorizing engagement among people, technology, and sociocultural environments. *J Document.* (2020) 77:229–50. doi: 10.1108/JD-05-2020-0078

14. Ahn S, Lee CJ, Ko Y. Network social capital and health information acquisition. *Patient Educ Couns.* (2022) 105:2923–33. doi: 10.1016/j.pec.2022.05.007

15. Hayat T, Brainin E, Neter E. With some help from my network: supplementing eHealth literacy with social ties. *J Med Intern Res.* (2017) 19:e98. doi: 10.2196/jmir.6472

16. Wiles JL, Leibing A, Guberman N, Reeve J, Allen RE. The meaning of "aging in place" to older people. *Gerontologist.* (2012) 52:357–66. doi: 10.1093/geront/gnr098

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 06 October 2022
DOI 10.3389/fpubh.2022.1005822

OPEN ACCESS

EDITED BY
Timothy M. Hale,
University of Illinois at Urbana-Champaign, United States

REVIEWED BY
Seong Man Park,
Dankook University, South Korea
Elizabeth Yost,
Washington College, United States

*CORRESPONDENCE
Nicholas Gray
gray@psy.fsu.edu

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 28 July 2022
ACCEPTED 14 September 2022
PUBLISHED 06 October 2022

CITATION
Gray N and Charness N (2022) Technology obsolescence across the adult lifespan in a USA internet sample. *Front. Public Health* 10:1005822. doi: 10.3389/fpubh.2022.1005822

Technology obsolescence across the adult lifespan in a USA internet sample

Nicholas Gray[1,2]* and Neil Charness[1,2]

[1]Department of Psychology, Florida State University, Tallahassee, FL, United States, [2]Institute for Successful Longevity, Florida State University, Tallahassee, FL, United States

We know that older adults are less likely to own certain technological devices, such as smartphones, a technology now integral to telehealth. However, for those older adults who do own devices, we know very little about how their devices may differ from those of younger adults. The age of a device can determine the types of programs it can run, as well as the level of protection it has against malicious code. The following study is an attempt to understand the ages of devices owned by different demographic groups. An electronic survey was sent to American adults from ages 19–97, querying the types of devices they own, how old those devices are, when they plan on replacing them, and demographic information. Regression models were employed to determine the factors that predict device ownership and the age of the devices owned. We replicate the finding that older adults are less likely to own certain devices, like smartphones and laptops. However, they may be more likely to own more dated devices, such as non-smart mobile phones. Models of device age showed that older adults are more likely to own older smartphones, as well as older desktop and laptop computers. Thus, older adults may be more susceptible to hacking, due to obsolete technology. In some cases, they also may not have devices modern enough for technology-based health interventions. Thus, obsolete devices may present an additional barrier for adoption of technology-based interventions by older adults.

KEYWORDS

smartphone, telehealth, mobile device, computer, tablet, smartwatch, home digital assistant

Introduction

Making the conveniences of information and communication technology (ICT) accessible to the widest range of individuals possible is a goal shared by many researchers and technology designers (1). Beyond convenience, ICT adoption also has the potential to promote healthy behavior through monitoring of health practices and implementation of technology-based interventions. Periodic surveys of technology ownership have provided estimates of the proportion of individuals in different demographic groups that have adopted certain ICTs [see (2) for USA data]. Population trends show a consistent increase in the proportion of individuals who own smartphones and use the internet year after year, even among older adults. However, for certain devices, such as smartphones, rates of ownership for older adults still lag significantly behind those of younger adults.

For example, in 2021 in the USA, roughly 95% of those under the age of 50 owned a smartphone, while 61% of those aged 65 and older owned one. Yet different rates of adoption are seen for different classes of ICT devices. In 2021, 44% of those aged 65 and older owned a tablet, which is commensurate with the 46% ownership seen in those aged 18–29 (3).

Empirically tested models of technology adoption such as (4)'s Universal Theory of Adoption and Use of Technology (UTAUT), and Chen and Lou's (5) Senior Technology Adoption Model (STAM), and others [e.g., (6, 7)] have identified a large set of factors that influence adoption and use, though these may vary across technology types [e.g., (8)]. Factors can be roughly classified into costs (e.g., financial, ease of use, privacy) and benefits (e.g., perceived usefulness). Given normative changes in cognition with age [e.g., (9)] which reduce the learning rate for acquiring skill with new technology [e.g., (10)], it can be expected that upgrading a device will be more onerous for older than younger adults. Benefits of newer versions of existing technology products, such as increased security, may also not be as salient for older users so that on balance costs of upgrading technology will outweigh benefits. Carstensen's (11) Socioemotional Selectivity Theory of life-span motivation changes also might predict that older adults would favor familiarity, staying with old devices, over exerting effort to acquire necessary information to use newer ones.

The discrepancy in ICT adoption, specifically with smartphones and computers, is noteworthy for those who posit that internet connected devices may have considerable potential for keeping older adults socially engaged (12) and possibly staving off cognitive decline (13), although the latter is a contested matter [see (14, 15)]. Mobile devices in particular are quite promising tools for health monitoring and interventions for older adults (16). Indeed, numerous electronic applications have been created specifically to aid older adults [e.g., (17)]. Mobile devices can be used to monitor health in ways that can increase effectiveness of health interventions (18). Internet connected ICT devices can also help provide health interventions that are specifically tailored to individual needs in meaningful ways (19). Unfortunately, only a limited number of older adults will be able to access these resources, given that ICT ownership among that age group is far from ubiquitous. However, lack of ownership may not be the only barrier preventing the use of these health aids. Obsolete devices, which, for the purpose of this text, are defined as those devices that are incapable of supporting a desired function that is supported by more modern devices of the same ICT class (i.e., smartphone, tablet, laptop, etc.), may present an additional barrier. Obsolete devices are also likely to be less secure and hence expose their users to hacking and to malware that can enroll their devices in Botnets (20). For instance, operating system security updates have typically become unavailable after 2 to 3 years for many Android smartphones in the USA. Very recently, Samsung decided to transition to providing 4 years of software support for most Galaxy phones and tablets (21). However, this promise will not apply retroactively to any devices released before 2019. Meanwhile, German government officials are currently negotiating with the European Union in an attempt to enforce a minimum of 7 years of support for Android and iOS devices (22). It is unclear how the negotiations will conclude, or whether devices that were manufactured earlier will be retroactively included, but it may prove difficult to enforce new laws on products that have already been released. Therefore, current trends seem to indicate meaningful extensions to device lifetimes are upcoming, but those who already own obsolete devices may still be at risk for malicious attacks. This could be particularly worrisome if a device is monitoring sensitive health information. For example, data from 2019 indicated that "two in five (40%) Android users worldwide are no longer receiving vital security updates from Google, potentially putting them at risk of data theft, ransom demands and a range of other malware attacks" (23). This alarming finding raises questions about the wisdom of housing sensitive medical information on smartphone devices for a sizable portion of the population.

While the ages of the individuals owning smartphones has been evaluated, the ages of the technological devices themselves is not well documented. At present, it is uncertain whether some demographic groups tend to have more up-to-date devices than others. For example, older adults may occasionally receive "hand-me-up" devices, passed to them by their children or relatives who have bought newer devices. If an older adult were to own a smartphone that they received second hand, or if they merely held on to their device for a long time, the kinds of services they could access might be limited and the security of the devices might be compromised. Therefore, it is important to investigate differences in the ages of technological devices owned by different demographic groups, particularly older vs. younger adults. In this study, we sampled a wide age range for ownership rather than comparing older vs. younger cohorts.

We present results from a survey of adults across the lifespan concerning the technology that they own. Survey questions asked participants about the types of technological devices they own, how long they have owned those devices, how they acquired them, and other questions about their use.

Based on the existing literature about age and technology ownership and use, we aimed to test three hypotheses:

H1: Age would be a significant negative predictor of technology ownership.

Even in a convenience sample that are users of ICT devices, we expect to replicate robust findings about technology ownership and use lagging as a function of age/birth cohort.

H2: Age would be a significant positive predictor of the age of owned technology devices.

Much as older adults are more likely to age in place in older homes that are ill-suited to their needs (24), and are more likely to own older vehicles that are not equipped with modern safety features to combat the dangers of age-related frailty (25, 26),

we expect that they are less likely to refresh technology devices hence own older, less secure ones than younger adults. For the purposes of this paper, when we discuss older technology, we are referring to specific devices that are owned for a longer period of time. We are not drawing reference to the class of ICT device (desktop, laptop, smartphone etc.) and when that class of device was invented.

H3: Income would moderate the relationship between participant age and device ownership age, and the relationship between participant age and device age.

US Taxpayer average adjusted gross income tends to rise with age from the teen years to age 55–65 years, then incurs a substantial decline after the age of 65, the age when retirement from full-time work typically occurs (38). We expect that those with higher income will have fewer financial barriers for owning various technological devices and more likely to own newer devices than their lower income age-matched peers.

Materials and methods

An online survey was administered to 407 participants across various age groups ranging from 19 to 97 (Mean = 60.6, SD = 16.9). Fifty-eight percent of participants were female, and 86% identified white as their primary racial group (For comparison, 76% of the United States population consider themselves "white alone," (27). Median reported household income was between $60,000 and $79,999, while the median reported education level was a bachelor's degree. In the general population of the United States, median household income in 2020 was $64,994, and 33% of those 25 or older had attained a bachelor's degree or a higher level of education (27).

American participants were recruited using three separate methods, Mechanical Turk ($n = 41$), Prolific.co ($n = 165$), and a database of older adults ($n = 201$) who agreed to participate in research in association with the Institute for Successful Longevity at Florida State University. Mechanical Turk and Prolific participants were restricted to American residents using tools built into each platform which limit to whom the survey is visible. Surveys were completed using Qualtrics software.

The demographic variables of interest were age, income, gender, education, race, and marital status. Age was treated as a continuous variable in all regression models, but Figure 1 and Supplementary Table S3 report averages for age categories. Income was stratified into categories based on $10,000 increments where the first category was, "Less than $10,000," and the final category was "$80,000 or more." Gender was analyzed using categories "male" and "female," as only three participants reported non-binary status. Categories of educational attainment ranged from "No formal education" to "Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)," while the lowest reported level of education was "High school graduate/GED." Due to a lack of racial diversity in this sample, race was categorized as white or non-white. Marital status was analyzed as either married or non-married, which served to indicate the likely presence of another person in the household. Note that because the data were gathered using the internet, the survey would be expected to overestimate technology ownership (technology was needed to participate), and possibly to underestimate technology obsolescence as those who own but have abandoned technology products would not have been able to participate.

Participants were asked whether they owned seven different types of technology: smartphone, mobile phone (non-smartphone), desktop computer, laptop computer, tablet, smartwatch, and home digital assistant. The age of each device owned was measured using a Likert scale in which participants selected the category that represented how long they had owned their device, from "less than 1 month," to "8 years or more." Participants who selected "8 years or more" for a device were asked to enter the number of years that they owned that device. A specific length of time was assigned to each categorical response, which was the midpoint of the category that was selected. For example, if a participant selected that they had owned a device for "6 months < 1 year", a length of 9 months was assumed for that device. Demographic information can be seen in Supplementary Table S1, and correlations between demographics used as predictors in regression models can be seen in Supplementary Table S2.

Multiple logistic regression analysis was used to ascertain the relationships between the demographic variables discussed above and rates of ownership of different ICT devices. Multiple linear regression analysis was used for predicting the ages of the devices owned. Regression models were calculated in R. For each analysis, a result was deemed significant if $p < 0.05$. To create a more conservative estimate of the associations between different demographic variables and the measures of interest, any reported age of a device that was 3 or more standard deviations from the mean was not included in the analyses, helping accounting for typing errors and mistaken answers. For example, one respondent reported having owned their current smartphone for 30 years. While it may be possible that this individual owned one of the very first devices that could have been called a smartphone, created by IBM the early 1990's, it is highly unlikely that this device is still being used, especially given the fact that the frequencies that cell providers support have changed over time, many currently adopting a fifth-generation technology standard. Therefore, outliers were assessed to exclude potentially erroneous responses that could lead to overestimates of the ages of devices.

Ethics approval was attained through the Institutional Review Board (IRB) at Florida State University. This remote survey was determined to be exempt from the need to attain signed consent. Participants were presented with a description of the survey on the first screen they saw after clicking the survey link, along with contact information for the researchers

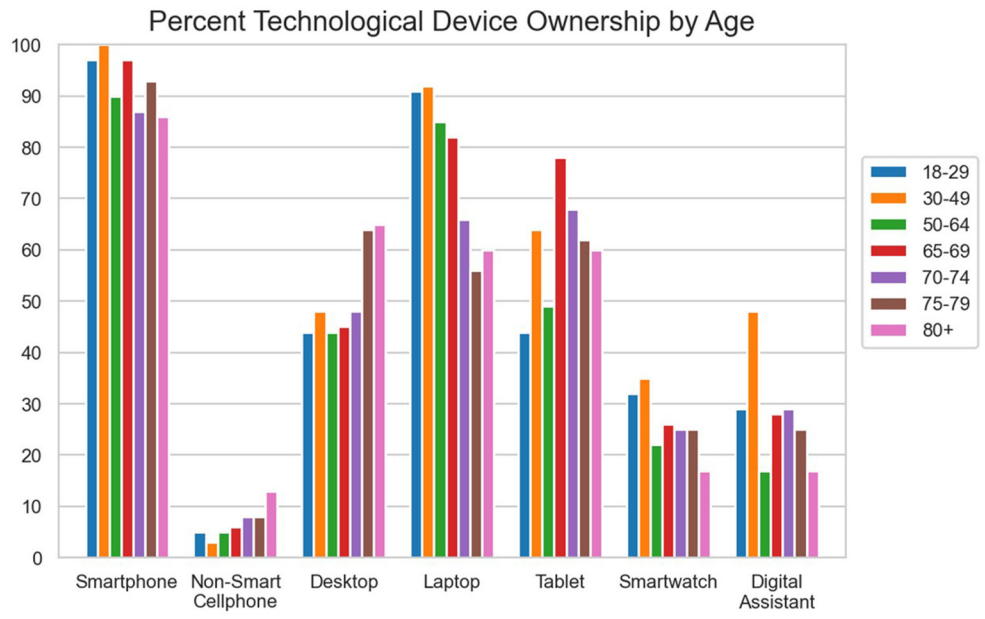


FIGURE 1
Rates of ownership of different ICT devices separated by age group.

and Florida State University IRB, should they have any concerns or questions.

Results

As a test of H3 (i.e., income would moderate the relationship between a participant's age and whether they own a device or the age of that device), an interaction term for the relationship between age and income was initially added to each regression model. However, this interaction term was not significant in any model, nor did it contribute any significant improvement to model fit estimates. To ease interpretation of the main effects of the predictors in each model, the interaction term was dropped in the analyses reported here.

Device ownership and use

Rates of ownership of each device for each age group can be seen in Figure 1 (numerical values shown in Supplementary Table S3). Logistic regression models were run to ascertain which demographic factors were associated with technology ownership (coefficient estimates and significance can be seen in Supplementary Tables S4– S10).

As predicted (H1), older age was negatively associated with ownership of smartphones, laptops, smartwatches, and home digital assistants. However, age was not associated with ownership of desktop computers or tablets.

Income was also associated with ownership of a number of devices. Higher levels of reported income had a significant positive association with ownership of smartphones and smartwatches. This association was inverted for non-smart mobile phones, where lower income was associated with higher likelihood of ownership.

Males were shown to be more likely to own desktop computers than females, yet females were more likely to own home digital assistants than males.

Some demographic measures had significant associations with certain types of devices and not others. Higher levels of education were associated with ownership of laptop computers yet were unrelated to any other device. White respondents were more likely to own home digital assistants than other races. Finally, married participants were more likely to own tablets than unmarried participants.

Age of devices

The same demographic information used in the previous logistic regression models was used in a new set of linear regression models to predict the age of each of the technological devices currently owned by respondents. Average device ages after removal of outliers, and number of outliers removed, can be seen in Supplementary Table S11. Regression estimates can be seen in Supplementary Tables S12– S18.

As predicted, a participant's age had a significant association with the age of several of the devices that they own. Older reported chronological age was related to ownership of older smartphones, desktop computers, and laptop computers.

Female participants were more likely to have older desktop computers. Those with lower income were more likely to own older laptops. Those who were unmarried were more likely to own older smartwatches. Finally, white participants were more likely to own older smart home assistant devices (M = 2.3 years) than other races (M = 1.4 years).

Respondents were also asked whether the device that they currently use was purchased new or not (either purchased used or given to them). Age had no significant association with likelihood of getting any device new or used (p's > 0.10). Also, if a participant was planning on replacing their device in the future, the participant's age was not significantly associated with how long they planned to wait until replacing their device (p's > 0.05 for all types of devices). However, in a logistic regression model higher age was associated with an increased probability that a participant did not plan on replacing the smartphone (odds ratio = 1.04) or home digital assistant (odds ratio = 1.08), that they currently own.

Discussion

Our survey results confirmed expectations (H1) that older adults would be less likely to own certain kinds of technological devices. However, this was not true for some classes of ICT devices which have been present in society for longer, such as desktop computers, tablets, or non-smart mobile phones. Desktop computers were introduced to the consumer population in the 1980's with the dawn of the microprocessor, which means that a desktop has been an integral part of society for far longer than all of the other devices in the current survey. Its sustained role in our society means that modern day older adults are likely much more familiar with their purpose and use. Tablets, on the other hand, are newer than desktop computers. While older adults have had less experience with tablets than their less portable desktop counterparts, tablets offer some usability advantages that desktop computers do not in terms of interaction *via* a direct positioning device (finger or stylus) rather than indirect positioning (e.g., mouse), though also some disadvantages (software keyboard vs. a keyboard with movable keys) (28). Tsai et al. (29) report that the touchscreen of a tablet offers a certain simplicity and ease of use for older adults, who may find a series of clicks with a mouse and inputs on a keyboard to be a bit complex if they are not familiar with the modern interface of a new desktop or laptop. Finally, the positive association between old age and ownership of a non-smart mobile phone is consistent with Pew Research data showing that although older adults are highly likely to own a cell phone, it is less likely to be a smartphone.

Critical to our hypothesis, H2, the age of our respondents was also associated with the age of a number of devices that they owned. Older respondents tended to own older smartphones, desktop computers, and laptop computers. As modern interfaces change, older adults may choose to retain the devices that they have experience with and know well given that their cost of new learning is much higher than for younger adults (10) and their expressed willingness to learn new technology is more highly discounted if they do not see value in the technology (30). Rosales and Fernández-Ardèvol (31) have also reported that older adults spend less time using the smartphones that they own, meaning that those devices may need to be replaced less often for reasons of wear and tear. However, age was not associated with whether a respondent bought any of their devices new or not, perhaps disconfirming the notion that older adults disproportionately receive older "hand-me-up" devices instead of buying them new. It may be the case that a more representative sample would show such an effect, as discussed later, but evidence for this donation process is not apparent here.

While evidence for income moderating the relationship between respondent age and device ownership or device age was not found (H3), income did have a significant positive association with ownership of several different devices. Thus, it is possible that high costs of technology could be preventing lower-income individuals from adopting certain devices. The one exception was ownership of a non-smart phone, which could be considered a less contemporary class of ICT device than the more modern smartphone. However, among those who own a given device, income was not a significant predictor of the age of the device, save for laptops. It may be the case that individuals for whom buying a certain technological device is within budget are also able to update their device on a regular basis. While some devices can be expensive, updating is an occurrence that most often happens on the scale of years, and not months, so if income is sufficient to purchase the initial device, income may not tend to be a limiting factor to updating a couple of years later. However, once again, a sample that is not collected using remote survey technology may show differing results.

The present results reveal important associations between the age of an individual and the status of the devices they own. One of the most worrisome implications of these findings could be the potential for hacking of obsolete devices that tend to be owned by older adults. Without the support of consistent software updates to protect against the most recently developed cyber threats, older adults would be more vulnerable to attacks. Older adults over age 60 reported more cases of fraud in 2020 than any other age group, and a portion of that fraud was in the form of phishing, ransomware, malware, etc., causing millions of dollars in reported losses that year (32). Even among more modern devices, protective measures are never immediate, because new threats need to be detected and countered by developers before updates can be sent out. The threats present for completely unsupported devices could be

especially financially troublesome, particularly for someone on a restricted budget after retirement.

Although the noted relationships have emerged as significant, it is important to note that effect sizes, as indicated by odds ratios and regression coefficients in supplemental tables, remained modest. For example, participant age predicted smartphone age with a coefficient of 0.03, indicating that roughly 33 years of age difference between participants would result in a 1-year difference in device age. While these differences seem small in scale, they may still be meaningful. Average smartphone age for those participants aged 35 and younger was 2.15 years. One additional year in the age of a device may mean that the device is no longer supported by critical security updates. As an example, our survey data was collected in March of 2021. Nine of our respondents reported owning a pixel 3 smartphone, which received its last security update in October of 2021, when the planned 3 years of support ran out (33). Of these nine respondents, eight were over the age of 55, and six were over the age of 65. Five of the nine participants reported when they were planning on replacing their device, and only one of them reported an intent to replace it in less than a year. This means that among our respondents with this model of smartphone, there may be individuals currently unprotected by security updates.

It is also important to consider older adults' access to new applications, some of which may be specifically designed for health benefits [e.g., cognitive training or health monitoring (16)]. Obsolete and unsupported operating systems may not be capable of incorporating these newly designed applications. Even if there are workarounds for older adults to use such applications on an obsolete device, their technological proficiency is typically lower than that of younger adults (34–37), and could limit their ability to find such solutions.

While informative, this sample also has shortcomings. Our respondents are not representative of the population at large, being more highly educated and wealthier, two factors shown in national and international surveys to be positively associated with technology adoption. Thus, we likely overestimate technology ownership and underestimate the degree of technology obsolescence in the general population. We reported a much higher rate of technology ownership among older adults than is reported elsewhere, particularly for smartphones, which may be because our survey was conducted electronically. This electronic survey may have selected for participants with higher levels technology ownership and potentially more modern devices than would be seen in the general population, even among younger adults, which should be taken into consideration. The COVID-19 pandemic has limited in-person interaction with participants, particularly older adults, but conducting this survey in a manner that does not rely on an internet connected device (either in person or over the phone) should provide a more representative sample. Our participant pool also lacked racial/ethnic diversity, preventing us from making nuanced assessments of the role of race/ethnicity.

Conclusion

This study reveals the importance of considering technology obsolescence when designing or implementing a technology-based health intervention. Older adults, many of whom can benefit from effective health monitoring and intervention technology, tend to own slightly older devices, which may put them past a critical threshold for receiving necessary security updates, particularly on mobile devices. As a result, any sensitive health information stored on these devices could be vulnerable.

While the current study indicates potential vulnerabilities, it could be an underestimation of the problem. The current sample was collected through electronic surveys, which may imply that these data represent a more technologically savvy sample than would typically exist in the larger population. For this reason, further research is needed to properly assess the broader societal impact of technology obsolescence.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Florida State University Office For Human Subjects Protection. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

NG gained institutional ethics approval, dealt with participant recruitment, and conducted statistical analyses. Both authors collaborated on searching the literature, generating survey questions, and writing the manuscript.

Funding

This work was supported in part by a grant from the National Institute on Aging, under the auspices of the Center for Research and Education on Aging and Technology Enhancement (CREATE), 1P01AG073090.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1005822/full#supplementary-material

References

1. Charness N, Boot WR. A grand challenge for psychology: reducing the age-related digital divide. *Curr Dir Psychol Sci.* (2022) 31:187–9. doi: 10.1177/09637214211068144

2. Publications. Pew Research Center. Available online at: https://www.pewresearch.org/publications/?formats=fact-sheetandresearch-teams=internet-tech (accessed December 30, 2019).

3. Faverio M. *Share of those 65 and older who are tech users has grown in the past decade*. Pew Research Center. Available online at: https://www.pewresearch.org/fact-tank/2022/01/13/share-of-those-65-and-older-who-are-tech-users-has-grown-in-the-past-decade/ (accessed January 13, 2022).

4. Venkatesh V, Thong JYL, Xu X. Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS Q.* (2012) 36:157–78. doi: 10.2307/41410412

5. Chen K, Lou VWQ. Measuring senior technology acceptance: development of a brief, 14-item scale. *Innov Aging.* (2020) 4:1–12. doi: 10.1093/geroni/igaa016

6. Golant SM. A theoretical model to explain the smart technology adoption behaviors of elder consumers (Elderadopt). *J Aging Stud.* (2017) 42:56–73. doi: 10.1016/j.jaging.2017.07.003

7. Peek STM, Wouters EJM, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJM. Factors influencing acceptance of technology for aging in place: a systematic review. *Int J Med Inform.* (2014) 83:235–48. doi: 10.1016/j.ijmedinf.2014.01.004

8. Berkowsky RW, Sharit J, Czaja SJ. Factors predicting decisions about technology adoption among older adults. *Innov Aging.* (2017) 1:igy002. doi: 10.1093/geroni/igy002

9. Salthouse TA. Consequences of age-related cognitive declines. *Annu Rev Psychol.* (2012) 63:201–26. doi: 10.1146/annurev-psych-120710-100328

10. Charness N, Kelley CL, Bosman EA, Mottram M. Word-processing training and retraining: effects of adult age, experience, and interface. *Psychol Aging.* (2001) 16:110. doi: 10.1037/0882-7974.16.1.110

11. Carstensen LL. Socioemotional selectivity theory: the role of perceived endings in human motivation. *Gerontologist.* (2021) 61:1188–96. doi: 10.1093/geront/gnab116

12. Cotten SR, Anderson WA, McCullough BM. Impact of internet use on loneliness and contact with others among older adults: cross-sectional analysis. *J Med Internet Res.* (2013) 15:e39. doi: 10.2196/jmir.2306

13. Klimova B. Use of the internet as a prevention tool against cognitive decline in normal aging. *Clin Interv Aging.* (2016) 11:1231. doi: 10.2147/CIA.S113758

14. Gray N, Yoon JS, Charness N, Boot WR, Roque NA, Andringa R, et al. Relative effectiveness of general versus specific cognitive training for aging adults. *Psychol Aging.* (2021) 37:210–21. doi: 10.1037/pag0000663

15. Zhang S, Boot WR, Charness N. Does computer use improve older adults' cognitive functioning? evidence from the personal reminder information and social management trial. *Gerontologist*. (2022) 62:1063–70. doi: 10.1093/geront/gnab188

16. Charness N, Boot WR, Gray N. Mobile monitoring and intervention technology (MMI) for adaptive Aging. In: *National Academies of Sciences, Engineering, and Medicine 2020. Mobile Technology for Adaptive Aging: Proceedings of a Workshop*. Washington, DC: The National Academies Press (2020). p. 21–40.

17. Portenhauser AA, Terhorst Y, Schultchen D, Sander LB, Denkinger MD, Stach M, et al. Mobile apps for older adults: systematic search and evaluation within online stores. *JMIR Aging.* (2021) 4:e.23313. doi: 10.2196/23313

18. Laranjo L, Ding D, Heleno B, Kocaballi B, Quiroz JC, Tong HL, et al. Do smartphone applications and activity trackers increase physical activity in adults? Systematic review, meta-analysis and metaregression. *Br J Sports Med.* (2020) 55:bjsports-2020-102892. doi: 10.1136/bjsports-2020-102892

19. Lustria M, Noar SM, Cortese J, Van Stee SK, Glueckauf R, Lee J. A meta-analysis of web-delivered tailored health behavior change interventions. *J Health Commun.* (2013) 18:1039–69. doi: 10.1080/10810730.2013.768727

20. Haner JK, Knake RK. Breaking botnets: a quantitative analysis of individual, technical, isolationist, and multilateral approaches to cybersecurity. *J Cybersecur.* (2021) 7:tyab003. doi: 10.1093/cybsec/tyab003

21. Metz A. How future Android updates for Samsung phones will work. TechRadar (2021). Available online at: https://www.techradar.com/nz/news/how-future-android-updates-for-samsung-phones-will-work (accessed April 13, 2021).

22. Humphries M. Germany Wants Android, iOS Devices to Include 7 Years of Support. PCMAG. Available online at: https://www.pcmag.com/news/germany-wants-android-ios-devices-to-include-7-years-of-support (accessed September 6, 2021).

23. Void Android: More than one billion Android devices at risk of hacking attacks. Which? (2020). Available online at: https://press.which.co.uk/whichpressreleases/void-android-more-than-one-billion-android-devices-at-risk-of-hacking-attacks/ (accessed March 6, 2020).

24. US Census Bureau. (2021). *Is America's Housing Ready for an Aging Population?* Census.Gov. Available online at: https://www.census.gov/library/stories/2020/06/old-housing-new-needs.html (accessed October 8, 2021)

25. Cox AE, Cicchino JB, Teoh ER. *Changing vehicles to reduce older driver fatalities: an effective approach?* IIHS-HLDI Crash Testing and Highway Safety (2021). Available online at: https://www.iihs.org/topics/bibliography/ref/2242 (accessed January 14, 2022).

26. Metzger KB, Sartin E, Foss RD, Joyce N, Curry AE. Vehicle safety characteristics in vulnerable driver populations. *Traffic Inj Prev.* (2020) 21:S54–9. doi: 10.1080/15389588.2020.1805445

27. US Census Bureau. QuickFacts (2021). Available online at: https://www.census.gov/quickfacts/fact/table/US/PST045221 (accessed September 2, 2022).

28. Czaja SJ, Boot WR, Charness N, Rogers WA. *Designing for older adults: Principles and creative human factors approaches (3rd Edition)*. Boca Raton: CRC Press (2019).

29. Tsai HYS, Shillair R, Cotten SR, Winstead V, Yost E. Getting grandma online: are tablets the answer for increasing digital inclusion for older adults in the US? *Educ Gerontol.* (2015) 41:695–709. doi: 10.1080/03601277.2015.1048165

30. Sharit J, Moxley JH, Czaja SJ. Investigating older adults' willingness to invest time to acquire technology skills using a discounting approach. *Innov Aging.* (2021) 5:igab017. doi: 10.1093/geroni/igab017

31. Rosales A, Fernández-Ardèvol M. Smartphone usage diversity among older people. *Perspectives on Human-Computer Interaction research with older people*. Springer, Cham (2019). p. 51–66. doi: 10.1007/978-3-030-06076-3_4

32. IC3 (2021). Available online at: https://www.ic3.gov/Media/PDF/AnnualReport/2020_IC3ElderFraudReport.pdf (accessed January 14, 2022).

33. Amadeo R. *Android's November patch leaves behind the Pixel 3, fixes Pixel 6 issues. Ars Technica*. Available online at: https://arstechnica.com/gadgets/2021/11/androids-november-security-patch-brings-pixel-6-fixes-ends-pixel-3-support/ (accessed November 2, 2021).

34. Roque NA, Boot WR. A new tool for assessing mobile device proficiency in older adults: the mobile device proficiency questionnaire. *J Appl Gerontol.* (2016) 37:131–56. doi: 10.1177/0733464816642582

35. Roque NA, Boot WR. A new tool for assessing older adults' wireless network proficiency: the wireless network proficiency questionnaire. *J Appl Gerontol.* (2021) 40:541–6. doi: 10.1177/0733464820935000

36. Moret-Tatay C, Beneyto-Arrojo MJ, Gutierrez E, Boot WR, Charness N. A spanish adaptation of the computer and mobile device proficiency questionnaires (CPQ and MDPQ) for older adults. *Front Psychol.* (2019) 10:1165. doi: 10.3389/fpsyg.2019.01165

37. Petrovčič A, Boot WR, Burnik T, Dolničar VV. Improving the measurement of older adults' mobile device proficiency: results and implications from a study of older adult smartphone users. *IEEE Access.* (2019) 7:150412–22. doi: 10.1109/ACCESS.2019.2947765

38. York E. *Average Income Tends to Rise with Age | Measuring Income Inequality*. Tax Foundation. Available online at: https://taxfoundation.org/average-income-age/ (accessed July 31, 2020).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 17 November 2022
DOI 10.3389/fpubh.2022.957586

OPEN ACCESS

EDITED BY
Alexander Seifert,
University of Zurich, Switzerland

REVIEWED BY
Ronald W. Berkowsky,
California State University, Channel Islands, United States
Qian Liu,
Hunan Normal University, China

*CORRESPONDENCE
Wei Zhang
weizhanghx@163.com

†These authors have contributed equally to this work and share first authorship

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 31 May 2022
ACCEPTED 28 October 2022
PUBLISHED 17 November 2022

CITATION
He W, Li P, Gao Y, You J, Chang J, Qu X and Zhang W (2022) Self-reported visual impairment and depression of middle-aged and older adults: The chain-mediating effects of internet use and social participation. *Front. Public Health* 10:957586. doi: 10.3389/fpubh.2022.957586

Self-reported visual impairment and depression of middle-aged and older adults: The chain-mediating effects of internet use and social participation

Wenbo He[1,2†], Peiyi Li[3,4,5†], Yinyan Gao[6], Jiuhong You[7], Jiangeng Chang[2], Xing Qu[1] and Wei Zhang[8*]

[1]Institute of Hospital Management, West China Hospital of Sichuan University, Chengdu, China, [2]Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore, [3]Department of Anesthesiology, West China Hospital, Sichuan University, Chengdu, China, [4]Laboratory of Anesthesia and Critical Care Medicine, National-Local Joint Engineering Research Center of Translational Medicine of Anesthesiology, West China Hospital, Sichuan University, Chengdu, China, [5]The Research Units of West China (2018RU012)-Chinese Academy of Medical Sciences, West China Hospital, Sichuan University, Chengdu, China, [6]Xiangya School of Public Health, Central South University, Changsha, China, [7]School of Rehabilitation Sciences, West China Hospital of Sichuan University, Chengdu, China, [8]West China Biomedical Big Data Center, West China Hospital of Sichuan University, Chengdu, China

Background: Visual impairment (VI) is a strong predictor of depression in middle-aged and older adults. However, the underlying mechanisms and pathways have not been well characterized. The purpose of this study was to determine whether Internet use and social participation mediate the effects of self-reported VI on depression.

Methods: The study used the fourth wave of cross-sectional data from the China Health and Retirement Longitudinal Study, including 19,766 Chinese adults. Depression was assessed according to the CES-D 10 International Scale. Logistic regression models were used to examine the relationship between self-reported VI and depression. While adjusting for relevant covariates, the PROCESS macro (model nos. 6 and 91) was used to assess the chain-mediating effects of Internet use and social participation.

Results: A total of 17,433 respondents were included in this study. The CES-D 10 results showed that 7,327 middle-aged and older adults had depressive symptoms, of whom 39.5% were male and 10.2% were ≥75 years old. 32.1% of respondents self-reported VI. Regression analysis showed a positive association between VI and depression, while Internet use and social participation had a negative predictive effect on depression. In the mediation analysis, the social participation pathway contributed the most to the total effect, accounting for 52.69% of it. The proportion of Internet use is 37.72%. When these two mediators were considered together in the full model, they accounted for 9.58% of the total effect of VI on depression.

Conclusion: Internet use and social participation were important mediators that mitigated the effects of VI on depression. Combined with previous evidence, online activities such as e-health and m-health can effectively promote disease monitoring and diagnosis, and various offline social participation activities can also play a role in regulating emotions. Therefore, Internet use and social participation factors may serve as relevant entry points for the development of intervention programs that may further improve the mental health of the visually impaired.

KEYWORDS

vision impairment, depression, internet use, social participation, chain-mediating effects

Introduction

The term visual impairment (VI) refers to self-reported blindness or difficulty with distance/near vision. According to the definition proposed by the World Health Organization, which used the International Classification of Diseases 11 (ICD-11) definition of VI and blindness, a person is said to be visually impaired if he or she presents with worse than 3/60 of the visual acuity (VA) of the better eye. In this revised definition, near VI is also included; it is defined as presenting with poorer near VA than N6 with the available correction (1). As recently estimated by the Global Burden of Disease Study, it is suggested that VI ranked second among all contributing causes of years of disability worldwide, ahead of depression (2). VI affects more than 250 million people worldwide, 90% of them live in low- and middle-income countries, and 82% are aged 50 years or older (3). As the most populous country in the world, China has a large number of people with VI or blindness which will increase substantially (4). The prevalence of vision loss increased with age, and 61% to 67% of adults aged over 35 years are affected by VI in China (5). The impacts of VI and blindness are wide reaching, such as an increased risk of falls (6), cognitive impairment and dementia (7), depression (8), and loss of independence (9). Clinically significant sub-threshold depression has been found in one-third of older adults with VI, approximately two times as high as the lifetime prevalence rates in older adults without VI, where depressive symptoms are present roughly in 15% (10, 11). Depression is a serious medical condition, and even mild symptoms may affect the quality of life (12). Therefore, the treatment of depression has increasingly gained attention within eye care settings as shown by numerous mental healthcare programs that have been tested and often found effective (13).

Behavioral factors are the leading cause of ill health worldwide. More health knowledge and self-efficacy positive health behavior change may promote better depression prevention and management (14, 15). According to the behavior change theory, effective Internet intervention could produce changes in health behaviors *via* effective Internet use and adherence (16, 17). The Internet is a powerful tool that can connect the older population with online resources, online social activities, and other people (18). Substantial efforts have been made by researchers across the world to utilize the power of the Internet to promote health outcomes. Older cohorts could use the Internet to reconcile their feeling of loneliness by engaging themselves in online activities and interactions with others and strengthening their connectedness with social members. For instance, chatting and watching the news could increase their sense of independence, while entertainment-oriented use of the Internet such as playing games could provide them with emotional support and relieve the pressure of life (19). Such enhanced connection through the Internet would alleviate loneliness and enhance the sense of social inclusion for older adults (20). Similarly, Internet use frequency has also been evidenced with a significant potential to alleviate older adults' depression (21). Social media and Internet use frequency had been detected a significant relationship with Chinese netizens' adoption of Web-based healthcare advice and changes to their preventive behaviors. Thus, frequency may be having a more weighted effect on health behaviors change (22). Additionally, the previous study has provided support for the beneficial role of social participation, such as joining community activities in preserving mental health (23, 24). Potential advantages to engagement in community activities and higher levels of social cohesion were associated with better mental health status among the older population (25, 26). In addition, studies have shown that social media is an effective tool for mobilizing people to participate in social movements, which further promotes people's willingness to engage in social activities (27). The use of the Internet is defined by its online interactivity, which allows users to also contribute content and receive feedback on it from others through comments or "likes." This promotes users' willingness to engage in social action by increasing their sense of psychological empowerment (28).

Vision disorders with activity limitations were always associated with decreased social participation (29). Initially, visually impaired people experienced significant barriers to using mobile phones for other purposes than making calls;

however, with the introduction of the iPhone in 2009 and improvements in services, such as voice capabilities, people with VI were able to expand the use of their phones beyond just making phone calls (30). In addition, the use of the Internet has been suggested to be a means of providing interaction Opportunities and reducing negative emotions for the VI group, the relationships between Internet use, social participation, and depression in older adults with vision disorders, which might be more complex than previously reported for normal vision population. Therefore, it is necessary to investigate the impact of Internet use and social participation on negative emotions to inform policies and programs to help seniors with vision disorders optimize their quality of life while aging. However, studies related to the impact of Internet use and social participation on mental health for people with VI have not been actively conducted, and also, the impact intensity and interaction have not yet been investigated. Given the Chinese rapidly growing aging population, we aim to investigate the relationship between VI and depression through a nationwide survey and further clarify the pathway of mediating effects of Internet use and social engagement in it.

Methods

Data and sample

The data collected for this study were from wave 4 of the China Health and Retirement Longitudinal Study (CHARLS). In brief, the CHARLS is a longitudinal study assessing the health, social, and economic status of a nationally representative sample covering 450 villages and 150 counties in 28 provinces in China (31). The CHARLS collected high-quality data through one-on-one interviews with a structured questionnaire, using multilevel stratification probabilities proportional to sample size to select residents aged 45 years and older from constituting a nationally representative sample. The fourth wave of data was collected in 2018 using an on-site survey, yielding a total sample of 19,766 adult respondents aged 40–98 years (32). The variables related to Internet use included in this study were newly added during wave 4 data collection, so only wave 4 data were used in this study for analysis.

Inclusion and exclusion criteria

In the Chinese population, uncorrected refractive error was relatively less affected by population aging, and the populations affected are becoming younger (4). Therefore, we expand the scope of the analysis by including people ≥45 years and sub-analysis differences between middle-aged and older groups. In this study, 45–64 years were defined as the middle-aged group and ≥65 years were defined as the older group.

We excluded participants who were aged <45 years; those with or who had intellectual disabilities, malignancies, and memory-related disorders, as this group may have experienced recall bias due to poor physical or mental status during data collection, thus becoming a confounding factor in the study results (32); and those who did not complete the depression test in wave 4. Finally, a total of 17,433 eligible individuals remained in the study.

Measures

Vision impairment

In the CHARLS, respondents were asked about vision ("Are you blind or unable to see at all?", "Are you usually wear glasses or corrective lenses?", "Seeing things at a distance," "Seeing things up close," "Have you ever had ever been treated for glaucoma or cataract?"). In this study, if middle-aged and older adults reported one of "blindness, poor-looking far away, poor-looking near, cataracts, and glaucoma," they were judged to have VI (5). In order to ensure the accuracy of the characteristics of the included population, we excluded the item "Are you usually wear glasses or corrective lenses?" in the screening of the population with VI by referring to the ICD-11 definition of VI.

Internet use

Respondents were asked whether they had used the Internet in the last month (Yes = 1 and No = 0) and frequency of Internet use (Never = 0, Not regularly = 1, Almost every week = 2, Almost daily = 3). At the same time, we judge the specific situation of their Internet use through the analysis of several common Internet behaviors, including online chatting, mobile payments, reading news, watching videos, playing games, financial management, and others. Each type of network function usage is assigned a value of 1, and Internet use as a continuous variable was assigned a score range of 0–7.

Depression

The score of depression was measured with 10 questions from the Center for Epidemiologic Studies Depression Scale (CES-D10)(33, 34). The CES-D10 was derived from the original version of the 20-item CES-D, and it was highly validated for use in general populations and indicated adequate reliability and validity for the middle and older population in China (35). Respondents were asked how frequently in the last week they: were bothered by things; had trouble keeping on things; felt depressed; felt everything was an effort; felt hopeful about the future; felt fearful; had restless sleeping; were happy; felt lonely;

10.3389/fpubh.2022.957586

TABLE 1 Basic characteristics of the sample.

Variables	Total ($n = 17,433$)	Non-depression ($n = 10,106$)	Depression ($n = 7,327$)	Effect sizes[b]	*P*-value
Gender, %				0.138	0.000
Male	(8289) 47.5	(5398) 53.4	(2891) 39.5		
Female	(9144) 52.5	(4708) 46.6	(4436) 60.5		
Age (years), %				0.001	0.002
45–54	(5,006) 28.7	(3,013) 29.8	(1,993) 27.7		
55–64	(6,006) 34.5	(3,440) 34.0	(2,566) 35.0		
65–74	(4,680) 26.8	(2,662) 26.3	(2,018) 27.5		
≥75	(1,741) 10.0	(991) 9.8	(750) 10.2		
Area, %				0.010	0.000
Central of city/town	(3,468) 19.9	(2,312) 22.9	(1,156) 15.8		
Urban–rural integration zone	(1,470) 8.4	(940) 9.3	(530) 7.2		
Rural	(12,495) 71.7	(6,854) 67.8	(5,641) 77.0		
Education level, %				0.018	0.000
Below middle School	(11,258) 64.6	(5,992) 59.3	(5,266) 71.9		
Below college degree	(5,818) 33.4	(3,839) 38.0	(1,976) 27.0		
College degree and above	(360) 2.0	(275) 2.7	(85) 1.2		
Marital status, %				0.008	0.000
Married	(15,065) 86.4	(8,999) 89.0	(6,066) 82.8		
Divorced or widowed	(2219) 12.7	(1041) 10.3	(1178) 16.1		
Never married	(149) 0.9	(66) 0.7	(83) 1.1		
Health status (self-reported), %				0.264	0.000
Good	(12,962) 74.4	(8,506) 84.2	(4,456) 60.8		
Bad	(4,471) 25.6	(1,600) 15.8	(2,871) 39.2		
Chronic diseases (M±SD)	0.71 ± 1.03	0.60 ± 0.94	0.81 ± 1.11	0.204	0.000
VI, %				0.184	0.000
No	(11,844) 67.9	(7,605) 75.3	(4,239) 57.9		
Yes	(5,589) 32.1	(2,501) 24.7	(3,088) 42.1		
Internet use, %				0.094	0.000
No	(15,027) 86.2	(8,432) 83.4	(6,595) 90.0		
Yes	(2,406) 13.8	(1,674) 16.6	(732) 10.0		
Social participation, %				0.004	0.000
No	(8,697) 49.9	(4,807) 47.6	(3,890) 53.1		
Mild	(3,322) 19.1	(1,943) 19.2	(1,379) 18.8		
Moderate	(2,434) 14	(1,446) 14.3	(988) 13.5		
Heavy	(2,980) 17	(1,910) 18.9	(1,070) 14.6		

Note: [a]VI: vision impairment. [b]Effect sizes: chi-square test using Cramer's, ANOVA using η^2, and *t*-test adapted to Cohen's d.

and could not get going. Responses ranged from 0 to 3, where 0 = <1 day, 1 = 1–2 days, 2 = 3–4 days, and 3 = 5–7 days, and were summed to create a total score ranging from 0 to 30. A binary measure for scoring 10 or greater was considered to have depressive symptoms (36, 37).

Social participation

In the CHARLS, respondents were asked to choose which social activities they participated in during the past month, including (1) interacting with friends, (2) playing Ma-Jong, playing chess, playing cards, or going to the community club, (3) providing help to family, friends, or neighbors who do not live with you and did not pay you for the help, (4) going to a sport, social, or other kinds of the club, (5) taking part in a community-related organization, (6) doing voluntary or charity work, (7) caring for a sick or disabled adult who does not live with you and who did not pay you for the help, and (8) attending an educational or training course. We generated social participation as a binary variable (participating in at least one of these activities in the past month = "1" vs. no participation

= "0"). Those who reported any of these activities were then asked a follow-up question about how often in the last month did they do (Almost daily = 3, Almost every week = 2, Not regularly = 1). We multiply the number and frequency of social participation to generate a multi-categorical variable for the social participation intensity (0 = No, 1–2 = Mild, 3–4 = Moderate, Above 4 = Heavy). Previous research has verified the reliability of this evaluation index (38).

Covariates

A parsimonious set of sociodemographic factors were included: (1) gender, (2) age (45–54, 55–64, 65–74, and ≥75 years), (3) area (central city/town, urban–rural integration zone, and rural), (4) education level (below the middle school, below college degree, and college degree and above), (5) marital status (married vs. not married including unmarried, divorced, and widowed), (6) health status (self-rated health that was obtained by asking respondents, "Would you say your health is very good, good, fair, poor, or very poor?" We redefined "very good," "good," and "fair" as good health and assigned a value of 1; we redefined "poor" and "very poor" as bad health and assigned a value of 2), and (7) the chronic disease information of respondents that can be obtained by asking: have you been diagnosed with hypertension/dyslipidemia/diabetes or high blood sugar/chronic lung diseases/liver disease/heart problems/stroke/kidney disease/stomach or other digestive diseases/arthritis or rheumatism/asthma by a doctor? If the respondents were informed by the doctor and know that he/she has one of these chronic diseases, the value is "1"; otherwise, it is "0".

Data analysis

Statistical analyses were performed using the SPSS Statistics 22.0 (IBM Corporation, Armonk, New York, USA). We performed a listwise deletion of the data with missing key variables. Some covariates contained missing values, and the proportion of missing values was <5%. To ensure the completeness of the sample of key variables, we replaced the missing data with the mean of their integrity items (39). Frequency and case percentages were calculated to describe sociodemographic parameters and level distributions among participants.

Differences in characteristics between groups were investigated with chi-square tests for dichotomous variables. One-way between-group analyses of variance were employed to examine differences between depression subgroups and continuous variables (e.g., the number of chronic diseases). To fully appreciate the relationship between VI and depressive symptoms, the CES-D 10 was both dichotomized and continuous variable (CES-D10 cut-off ≥10) (34, 39). We assessed the association between VI and depression using multivariate logistic regression, adjusting for covariates and various mediators. Variance inflation factor (VIF) was used to measure multiple co-linearity in the logistic analysis; parameters with VIF≥10 were considered to be co-linear. Parameters with co-linearity were excluded from the logistic regression analysis. In the base model, adjustments were made for covariates including age, gender, area, education level, chronic disease, etc., Key outcomes were presented by odds ratios (ORs) and 95% confidence interval (95% CI). The chain-mediating effects of Internet use and social participation, as well as the moderating effect of Internet use frequency on the first half of the mediation pathway, were then tested using the PROCESS macro of SPSS 22.0 (model no. 6 and model no. 91), and a further test of the mediating effect was performed with the deviation proofreading method of bootstrap of non-parametric percentile (40). β-coefficient was used to describe the strength of association between paths, and statistical significance was set at $P < 0.05$ using a two-sided test.

Results

Sample characteristics

Among the 19,766 adult respondents in the fourth wave of the CHARLS, 17,433 respondents over the age of 45 years were selected. Of them, 42.0% [7,327] of the respondents had depressive symptoms and 32.1% ($n = 5,589$) reported that they had VI.

Table 1 presents the characteristics of participants by depression condition (non-depression group vs. depression group). Participants in the depression group were more female (46.6 vs. 60.5%), were older, and had worse self-reported health (15.8 vs. 39.2%), and only 57.9% had normal vision compared with those in the non-depression group. They were also found to be more likely to live in rural areas (77.0%) and have a relatively low level of education, with 71.9% having below middle school. In terms of Internet use, participants in the depression group were less likely to use the Internet (16.6 vs. 10.0%). Regarding social participation, depression participants were less exposed to different levels of social engagement, especially heavy group (18.9 vs. 14.6%).

The relationship between VI and depression

Table 2 reveals that after controlling for sociodemographic characteristics, health status, and chronic diseases, as expected, people who got VI had significantly higher odds of depression (OR = 1.61, 95% CI: 1.50–1.73). In terms of other significant

TABLE 2 Association of VI and depression: Logistic regression results.

Variable	Depression, OR (95% CI)	*P* value
VI		0.000
No	1 (ref)	
Yes	1.61(1.50–1.73)	
Gender		0.000
Male	1 (ref)	
Female	1.55 (1.45–1.65)	0.000
Age (years)		
45-54	1 (ref)	
55–64	1.03 (0.95–1.12)	0.505
65–74	0.85 (0.78–0.93)	0.000
≥75	0.76 (0.67–0.87)	0.000
Area		
Central of city/town	1 (ref)	
Urban-Rural Integration Zone	1.06 (0.92–1.21)	0.413
Rural	1.38 (1.26–1.50)	0.000
Education level		
Below middle School	1 (ref)	
Below college degree	0.79 (0.73–0.85)	0.000
College degree and above	0.63 (0.49–0.82)	0.001
Marital status		
Married	1 (ref)	
Divorced or widowed	1.47 (1.33–1.63)	0.000
Never married	1.84 (1.30–2.60)	0.001
Health status (self-reported), %		
Good	1 (ref)	
Bad	2.63 (2.44–2.84)	0.000
Chronic diseases	1.15 (1.11–1.19)	0.000

Note: VI: vision impairment.

covariates, female was associated with higher odds of depression (OR = 1.55, 95% CI: 1.45–1.65). When compared with respondents living in the central city/town, those living in rural areas had greater odds of depression (OR = 1.38, 95% CI: 1.26–1.50). Moreover, being divorced or widowed, being never married, having bad health status, and having more chronic diseases were associated with higher odds of depression. Being in 65–74 years and ≥75 years and having below college degree and college degree and above were associated with lower odds of depression.

Verification of chain-mediating effect

The results showed that there are significant relationships between VI, Internet use, social participation, and depression. After controlling for gender, age, region, educational level, marital status, health status, and chronic diseases, the analysis chain-mediating effects of Internet use and social participation in the relationship between VI and depression. The results confirmed that Internet use and social participation played a partial mediating role between VI and depression, i.e., when VI influenced depression, part of it was direct and part went through the mediating variables Internet use and social participation (Supplementary Table 1).

The present study then further examined the path and proportion of the mediating effect by using the bias-corrected non-parametric percentile bootstrap method (Table 3). With VI as the independent variable, depression as the dependent variable, and Internet use and social participation as the mediating variables, the bootstrap sampling number was 5,000, and a 95% confidence interval was set. The results showed that VI effectively predicted depression (positive), Internet use (negative) and social participation (negative), Internet use effectively predicted social participation (positive) and depression (negative), and social participation effectively predicted depression (negative) (Figure 1).

The results of the test for mediating effects are given in Table 3. VI had significant direct effects on the prediction of depression (effect = 0.017, 95% CI: 0.009, 0.025), Internet use (effect = 0.006, 95% CI: 0.002, 0.012), and social participation (effect = 0.009, 95% CI: 0.003, 0. 015) and a significant chain-mediating effect of both (effect = 0.002, 95% CI: 0.001, 0.003), with the total indirect (mediating) effect accounting for 1.33% of the total effect; the proportions of Internet use, social participation, and chain-mediating effects in the total mediating effect were 37.72, 52.69, and 9.58%, respectively.

Verification of moderated mediating effect

To determine whether the chain-mediating effects of Internet use and social participation in the relationship between VI and depression differ with the frequency of Internet use, we validated the moderated mediation model using PROCESS Macro model no. 91. It was confirmed that the indirect effects of VI on depression through Internet use and social participation did not vary with the frequency of Internet use (Supplementary Table 2 and Figure 1).

The overall size of the conditional indirect effects of this study, that is, the index of moderated mediation, was 0, and the 95% bootstrap CI for this was [−0.001, 0.0008]. As the 95% CI was 0, the moderated mediating effect was not significant.

Discussion

The present study used a novel approach to examine the interaction effects of Internet use and social participation for depression in patients with VI, helping shed light on the targeted feasible responses for the vulnerable population. Some

TABLE 3 The proportion of mediating effect.

	Effect	Boot SE	Boot LLCI	Boot ULCI	% of the total effect (%)	% of total mediating effect (%)
Total mediating effect	0.017	0.004	0.009	0.025	1.33	100.00
Ind1:VI->Internet use->Depression	0.006	0.002	0.002	0.012	0.50	37.72
Ind2:VI->Social participation->Depression	0.009	0.003	0.003	0.015	0.70	52.69
Ind3:VI->Internet use->Social participation->Depression	0.002	0.001	0.001	0.003	0.13	9.58

Note: Boot SE is the standard error for estimating indirect effects by the percentile bootstrap method of bias correction. Boot CI lower limit and boot CI upper limit refer to the lower limit and upper limit of 95% confidence interval, respectively.

previous studies have identified a cross section between VI and depression (41, 42) and longitudinal (43) relationship. The formation pathway in the relationship between VI and depression has not been systematically studied. Especially with the development of social and network technology, the effect of the Internet and social participation on depression is more worthy of attention. Therefore, the present findings provided a more comprehensive pathway to the relationship between VI and depression and analyzed the mediating role of Internet use and social participation in the relationship between VI and depression.

This study investigated 17,433 Chinese participants using cross-sectional data from a nationally representative cohort of middle-aged and older adults in China. The findings suggested an association between VI and depression, controlling for gender, age, region, education level, marital status, health level, and chronic disease. This association was attenuated and mitigated when mediating factors were added to the regression, indicating a significant negative mediating effect of mediating factors. A certain percentage (2.74%) of the effect of VI on depression was mediated by two sets of explanatory factors. In the chain-mediated analysis, social participation had the largest effect on the VI–depression association, with an indirect effect of 1.85%, followed by Internet use (0.63%) and a chain mix of both factors (0.27%). Furthermore, this study examined the moderating mediating effect of Internet use frequency and found it to be not statistically significant.

Our findings have shown that VI is strongly associated with depression, which is consistent with other research in different regions. Several reports showed a relatively consistent association between VI and mental health among different age populations. Cosh (44) surveyed the Norwegian population over 60 years and found that vision loss would lead to an increase in depressive symptoms over time and bring additional long-term risks to depression severity. In addition, Xiaowei Dong et al. reported that the participants with VI had 43% higher odds of depression than those with normal vision in China (10). Although the reasons for this result were not fully understood, the activity limitation model of depressive emotions posited that chronic health conditions could lead to depression, partly as individuals' social participation and daily activities are restricted (42, 45). The social participation of middle-aged and older adults with VI was related to the individual's physical and mental health (41), which highlighted the necessity of lifestyle modification, especially among those with severe VI who were invulnerable to social participation and daily activities (41, 45).

Our results also provided support for the hypothesized mediation model in which increased levels of Internet use and social participation lead to lower levels of depression, which we found to be partially mediated—populations with VI who are accompanied by some level of Internet use and social participation have a correspondingly mitigated risk of depression. Dovetailing with the research about how both Internet and social factors are important significant control factors of depression (46, 47), our results suggested that the Internet and social engagement play a key role in the mental health of older adults. This is consistent with previous research, which indicated that Internet use leads to improvements in social connectedness, social support, mental health, and depression in older adults (48, 49).

Aging highlights the revelation that more older adults suffer from depression and social isolation, and both online and offline social engagement activities provide us with effective alternatives. On the one hand, our findings suggested that measures to encourage appropriate Internet use among older adults, especially those with VI, may prevent depression in this population. Contrary to previously published studies, Banjanin et al. believed that Internet use was positively correlated with depressive symptoms in adolescents (47). The reason for this result may be that the target population and age of the two studies were not consistent, and there were differences in Internet usage habits and time. Correspondingly, several studies have focused on the role of the Internet in relieving the symptoms of depression in older adults. Atsushi et al. (48) pointed out that online communication with family and friends had a significant role in preventing clinical depression in older

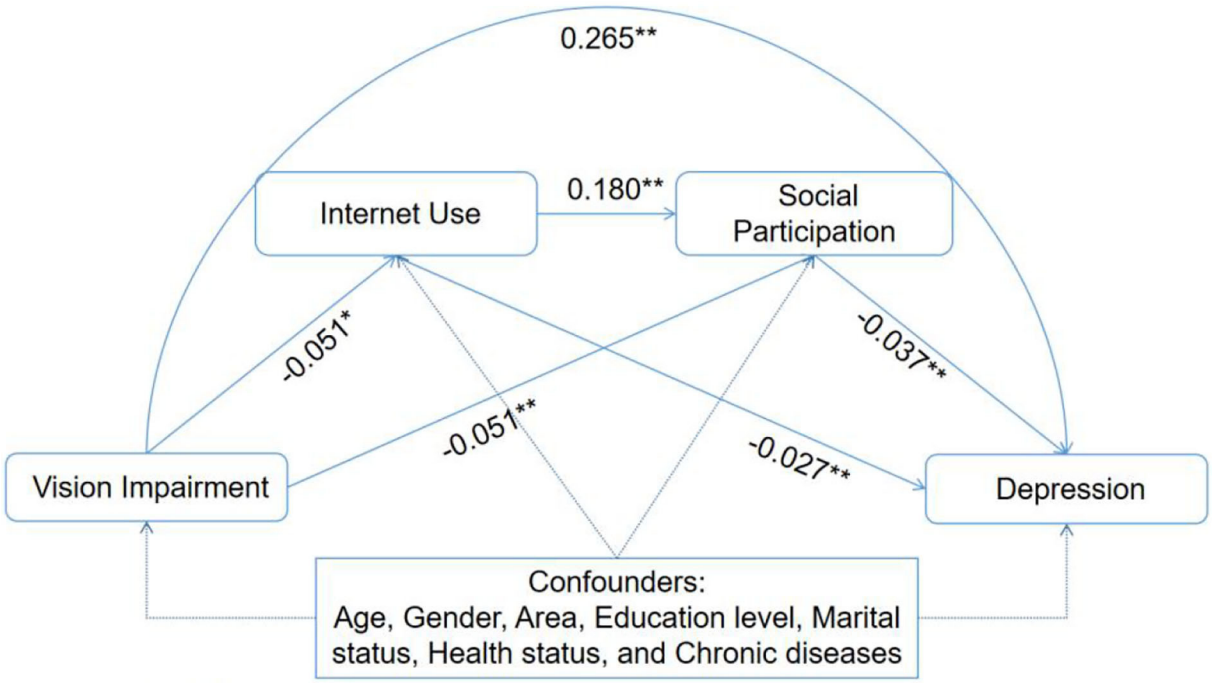


FIGURE 1
Statistical model of chain-mediating effect.

adults, especially during the new coronary pneumonia crisis. Chatting and watching videos online could significantly alleviate the loneliness of middle-aged and older adults and improve their social participation ability, and the use of the Internet for communication purposes was associated with better mental health (21). For the VI group, the intelligent call, barrier-free voice conversion function, and screen magnification function provided by the Internet could narrow the gap between them and the normal population and strengthen its sense of social participation. Notably, Internet-based eHealthcare and mHealth could provide patients with VI with timely and convenient vision testing, diagnosis, and treatment services, which could effectively alleviate their anxiety and depression caused by the disease (50).

On the other hand, we found that a range of offline social participation may also be a key variable in mitigating the negative association between VI and depression. The study showed that older adults involved in social activities, volunteer work, and donations had a reduced risk of depressive symptoms, while more frequent and diverse participation activities further reduced the risk (51). Furthermore, the current findings are consistent with previous research by Yanni et al. (52), who showed in a previous study that the combination of full-time work and volunteer activities was particularly protective against depression compared with any activity alone. Related to this, we found an additional beneficial effect of participating in both online and offline social activities. The more types of activities older adults participated in, the less likely they were to experience depressive symptoms. This finding is consistent with role accumulation theory, which suggests that occupying multiple roles helps individuals experience more social networks, resources, and self-esteem (53). Not only the frequency of engagement but also the diversity of activity types is important (54).

Furthermore, while Internet use and social participation may alleviate depression in VI, it is important to note that only 50.1% of the Chinese middle-aged and older adults reported engaging in offline social engagement and only 13.8% had Internet use habits. These results appear to be consistent with several other studies focusing on different populations (55, 56). Thus, this suggests the need for further attention to a range of social engagement activities between middle-aged and older adults, especially the VI group. In terms of offline activities, the current Chinese government has proposed a series of measures to encourage middle-aged and older adults to actively engage in social participation. For example, it is exploring flexible employment models for older adults, encouraging localities to establish a talent database for older adults, providing career guidance services for older adults who are willing to work, carrying out in-depth "Silver Age Action," and guiding the older adults to actively participate in community activities in the form of volunteer services. Concerning further trends in the use of online Internet features, policymakers should consider supporting research and development of assistive technologies

and designs to help middle-aged and older Internet users overcome health-related difficulties in using the Internet, such as redesigning interfaces to use larger fonts and simpler layouts (57), but more work is needed to understand the needs of these middle-aged and older adults. For the VI group, it is almost certain that they are limited by their health status and rarely use the Internet. Therefore, they certainly need to understand the current applications and value of the Internet in alleviating depression and providing medical care. Perhaps, convenient teleconsultation on the Internet could provide them with the medical and health services they need.

The study has a few limitations. First, VI was self-reported, with no data on the timing of onset or further disease progression, while depression was based on CES-D10 judgment rather than a medical diagnosis. Therefore, we do not know the trends in VI and depression over time. Second, only cross-sectional data on Internet use were collected in this study, and the cross-sectional study design does not allow for the establishment of causal relationships and restricts chronological order, which means that the findings need to be interpreted with caution. Third, there are still untested mediators.

Conclusions

Both online and offline social participation has shown a mitigating effect on improving depression in middle-aged and older adults, especially in the population with VI. As more and more daily social activities (e.g., living payments, online shopping, financial management, etc.,) and medical care services require the use of the Internet, it is becoming increasingly important to promote Web-based technology for social engagement behaviors and medical care behaviors between middle-aged and older adults. Based on a large nationwide cohort in China, Internet use and social engagement were found to play a mediating utility in the effect of VI on depression. Therefore, targeted Internet services and social engagement promotion services should be designated for middle-aged and older adults, especially those with VI, and the inequities caused by other social determinants for those with VI should be considered.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The China Health and Retirement Longitudinal Study (CHARLS) was a survey approved by the Ethical Review Committee of Beijing University, and all participants signed informed consent at the time of participation. There is no need for additional ethics approval for the approved data users.

Author contributions

WH and WZ conceptualized the study. WH, PL, YG, and XQ collected and analyzed the data. WH and PL wrote the manuscript. WZ, JC, and JY revised and finalized the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the National Science Foundation of China (Grant No. 81871061), 1·3·5 Project for Disciplines of Excellence, West China Hospital, Sichuan University (No. ZYJC21004), and Clinical Research Innovation Project from West China Hospital, Sichuan University (Grant No. 2019HXCX03).

Acknowledgments

The authors would like to express their gratitude to the China Health and Retirement Longitudinal Study (CHARLS) research team and the field team for their collecting the data.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.957586/full#supplementary-material

References

1. Kv V, Vijayalakshmi P. Understanding definitions of visual impairment and functional vision. *Commun Eye Health.* (2020) 33:S16–s7. Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8115704/

2. Steinmetz JD, Bourne RRA, Briant PS, Flaxman SR, Taylor HRB, Jonas JB, et al. Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the right to sight: an analysis for the global burden of disease study. *Lancet Global Health.* (2021) 9:e144–e60. doi: 10.1016/S2214-109X(20)30489-7

3. Bourne RR, Flaxman SR, Braithwaite T, Cicinelli MV, Das A, Jonas JB, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Global Health.* (2017) 5:e888–e97. doi: 10.1016/S2214-109X(17)30293-0

4. Xu T, Wang B, Liu H, Wang H, Yin P, Dong W, et al. Prevalence and causes of vision loss in China from 1990 to 2019: findings from the global burden of disease study 2019. *Lancet Public Health.* (2020) 5:e682–e91. doi: 10.1016/S2468-2667(20)30254-1

5. Zhang Q, Cao GY, Yao SS, Wang C, Chen ZS, Hu YH. et al. Self-reported vision impairment, vision correction, and depressive symptoms among middle-aged and older Chinese: findings from the China health and retirement longitudinal study. *Int J Geriatric Psychiatry.* (2021) 36:86–95. doi: 10.1002/gps.5398

6. Society AG. Guideline for the prevention of falls in older persons. *J Am Geriatr Soc.* (2001) 49:664–72. doi: 10.1046/j.1532-5415.2001.49115.x

7. Maharani A, Dawes P, Nazroo J, Tampubolon G, Pendleton N. Visual and hearing impairments are associated with cognitive decline in older people. *Age Ageing.* (2018) 47:575–81. doi: 10.1093/ageing/afy061

8. Zhang X, Kai MKB, Cotch MF, Wilson MR, Saaddine JB. Association between depression and functional vision loss in persons 20 years of age or older in the United States, NHANES 2005–2008. *JAMA Ophthalmol.* (2013) 131:1–9. doi: 10.1001/jamaophthalmol.2013.2597

9. Canet-Vélez O, Botigué T, Santamaría AL, Masot O, Cemeli T, Roca J. The perception of training and professional development according to nursing students as health workers during COVID-19: a qualitative study. *Nurse Educ Pract.* (2021) 53:103072. doi: 10.1016/j.nepr.2021.103072

10. Dong X, Ng N. Contribution of multiple pathways to the relationship between visual impairment and depression: explaining mental health inequalities among older Chinese adults. *J Affect Disord.* (2020) 278:350–6. doi: 10.1016/j.jad.2020.09.068

11. van der Aa HP, Comijs HC, Penninx BW, van Rens GH, van Nispen RM. Major depressive and anxiety disorders in visually impaired older adults. *Invest Ophthalmol Vis Sci.* (2015) 56:849–54. doi: 10.1167/iovs.14-15848

12. Cui R. A systematic review of depression. *Curr Neuropharmacol.* (2015) 13:480. doi: 10.2174/1570159X1304150831123535

13. Parravano M, Petri D, Maurutto E, Lucenteforte E, Menchini F, Lanzetta P, et al. Association between visual impairment and depression in patients attending eye clinics: a meta-analysis. *JAMA Ophthalmol.* (2021) 139:753–61. doi: 10.1001/jamaophthalmol.2021.1557

14. Zhong B, Chen J. Health information helps mitigate adolescent depression: a multivariate analysis of the links between health information use and depression management. *Child Care Health Dev.* (2021) 47:201–7. doi: 10.1111/cch.12831

15. Bennett B, Sharma M, Bennett R, Mawson AR, Buxbaum SG, Sung JH. Using social cognitive theory to predict medication compliance behavior in patients with depression in southern United States in 2016 in a cross-sectional study. *J Caring Sci.* (2018) 7:1. doi: 10.15171/jcs.2018.001

16. Ritterband LM, Thorndike FP, Cox DJ, Kovatchev BP, Gonder-Frederick LA. A behavior change model for internet interventions. *Ann Behav Med.* (2009) 38:18–27. doi: 10.1007/s12160-009-9133-4

17. Rejeski WJ, Fanning J. Models and theories of health behavior and clinical interventions in aging: a contemporary, integrative approach. *Clin Interv Aging.* (2019) 14:1007. doi: 10.2147/CIA.S206974

18. Wang R, Chen Z, Zhou Y, Shen L, Zhang Z, Wu X. Melancholy or mahjong? Diversity, frequency, type, and rural-urban divide of social participation and depression in middle-and old-aged Chinese: a fixed-effects analysis. Social Sci Med. (2019) 238:112518. doi: 10.1016/j.socscimed.2019.112518

19. Liu Q, Pan H, Wu Y. Migration status, internet use, and social participation among middle-aged and older adults in China: consequences for depression. *Int J Environ Res Public Health.* (2020) 17:6007. doi: 10.3390/ijerph17166007

20. Werner-Seidler A, Afzali MH, Chapman C, Sunderland M, Slade T. The relationship between social support networks and depression in the 2007 National Survey of Mental Health and Well-being. *Soc Psychiatry Psychiatr Epidemiol.* (2017) 52:1463–73. doi: 10.1007/s00127-017-1440-7

21. Lam S, Jivraj S, Scholes S. Exploring the relationship between internet use and mental health among older adults in England: longitudinal observational study. *J Med Internet Res.* (2020) 22:e15683. doi: 10.2196/15683

22. Li P, Chen B, Deveaux G, Luo Y, Tao W, Li W, et al. Cross-verification of COVID-19 information obtained from unofficial social media accounts and associated changes in health behaviors: web-based questionnaire study among Chinese netizens. *JMIR Public Health Surveillance.* (2022) 8:e33577. doi: 10.2196/33577

23. Wang R, Feng Z, Liu Y, Lu Y. Relationship between neighbourhood social participation and depression among older adults: a longitudinal study in China. *Health Soc Care Commun.* (2019) 28:247–59. doi: 10.1111/hsc.12859

24. Sibalija J, Savundranayagam MY, Orange JB, Kloseck M. Social support, social participation, & depression among caregivers and non-caregivers in Canada: a population health perspective. *Aging Ment Health.* (2020) 24:765–73. doi: 10.1080/13607863.2018.1544223

25. Choi NG, Kim J, DiNitto DM, Marti CN. Perceived social cohesion, frequency of going out, and depressive symptoms in older adults: examination of longitudinal relationships. *Gerontol Geriatr Med.* (2015) 1:2333721415615478. doi: 10.1177/2333721415615478

26. Hao G, Bishwajit G, Tang S, Nie C, Ji L, Huang R. Social participation and perceived depression among elderly population in South Africa. *Clin Interv Aging.* (2017) 12:971. doi: 10.2147/CIA.S137993

27. Hwang H, Kim KO. Social media as a tool for social movements: The effect of social media use and social capital on intention to participate in social movements. *Int J Consum Stud.* (2015) 39:478–88. doi: 10.1111/ijcs.12221

28. Schumann S, Klein O, Douglas K, editors. Talk to act: how internet use empowers users to participate in collective actions offline. In *International Conference on Persuasive Technology*. Berlin: Springer (2012). doi: 10.1007/978-3-642-31037-9_7

29. Jin S, Trope GE, Buys YM, Badley EM, Thavorn K, Yan P, et al. Reduced social participation among seniors with self-reported visual impairment and glaucoma. *PLoS ONE.* (2019) 14:e0218540. doi: 10.1371/journal.pone.0218540

30. Park E-Y. Relation between the degree of use of smartphones and negative emotions in people with visual impairment. *Front Psychol.* (2021) 12:653796. doi: 10.3389/fpsyg.2021.653796

31. Zeng Z, Bian Y, Cui Y, Yang D, Wang Y, Yu C. Physical activity dimensions and its association with risk of diabetes in middle and older aged Chinese people. *Int J Environ Res Public Health.* (2020) 17:7803. doi: 10.3390/ijerph17217803

32. Zhao Y, Atun R, Oldenburg B, McPake B, Tang S, Mercer SW, et al. Physical multimorbidity, health service use, and catastrophic health expenditure by socioeconomic groups in China: an analysis of population-based panel data. *Lancet Global Health.* (2020) 8:e840–e9. doi: 10.1016/S2214-109X(20)30127-3

33. Lei X, Sun X, Strauss J, Zhang P, Zhao Y. Depressive symptoms and SES among the mid-aged and elderly in China: evidence from the China Health and Retirement Longitudinal Study national baseline. *Soc Sci Med.* (2014) 120:224–32. doi: 10.1016/j.socscimed.2014.09.028

34. Hu H, Cao Q, Shi Z, Lin W, Jiang H, Hou Y. Social support and depressive symptom disparity between urban and rural older adults in China. *J Affect Disord.* (2018) 237:104–11. doi: 10.1016/j.jad.2018.04.076

35. Zhou L, Ma X, Wang W. Relationship between cognitive performance and depressive symptoms in Chinese older adults: the China health and retirement longitudinal study (CHARLS). *J Affect Disord.* (2021) 281:454–8. doi: 10.1016/j.jad.2020.12.059

36. Cao PY, Luo HQ, Hou LS, Yang XX, Ren XH. Depressive symptoms in the mid- and old-aged people in China. *J Sichuan Univ Med Sci Edn.* (2016) 47:763–7. doi: 10.13464/j.scuxbyxb.2016.05.027

37. Nikoloski Z, Zhang A, Hopkin G, Mossialos E. Self-reported symptoms of depression among Chinese rural-to-urban migrants and left-behind family members. *LSE Res Online Documents Econ.* (2019) 2:e193355. doi: 10.1001/jamanetworkopen.2019.3355

38. Su D, Chen Z, Chang J, Gong G, Chen Y. Effect of social participation on the physical functioning and depression of empty-nest elderly in China: evidence from the china health and retirement longitudinal survey (CHARLS). *Int J Environ Res Public Health.* (2020) 17:9438. doi: 10.3390/ijerph17249438

39. Luo F, Guo L, Thapa A, Yu B. Social isolation and depression onset among middle-aged and older adults in China: Moderating effects of education and gender differences. *J Affect Disord.* (2021) 283:71–6. doi: 10.1016/j.jad.2021.01.022

40. Bolin JH. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. *JSTOR.* (2014) 51:335–7. doi: 10.1111/jedm.12050

41. Bookwala J, Lawson B. Poor vision, functioning, and depressive symptoms: a test of the activity restriction model. *Gerontologist.* (2011) 51:798–808. doi: 10.1093/geront/gnr051

42. Abou-Hanna JJ, Leggett AN. Vision impairment and depression among older adults in low- and middle-income countries. *Int J Geriatr Psychiatry.* (2021) 36:64–75. doi: 10.1002/gps.5394

43. Hong T, Mitchell P, Burlutsky G, Gopinath B, Liew G, Wang JJ. Visual impairment and depressive symptoms in an older Australian cohort: longitudinal findings from the blue mountains eye study. *Br J Ophthalmol.* (2015) 99:1017–21. doi: 10.1136/bjophthalmol-2014-306308

44. Cosh S, von Hanno T, Helmer C, Bertelsen G, Delcourt C, Schirmer H. The association amongst visual, hearing, and dual sensory loss with depression and anxiety over 6 years: the Tromsø study. *Int J Geriatr Psychiatry.* (2018) 33:598–605. doi: 10.1002/gps.4827

45. van Nispen RM, Vreeken HL, Comijs HC, Deeg DJ, van Rens GH. Role of vision loss, functional limitations and the supporting network in depression in a general population. *Acta Ophthalmologica.* (2016) 94:76–82. doi: 10.1111/aos.12896

46. Kempen GIJM, Ranchor AV, Ambergen T, Zijlstra GAR. The mediating role of disability and social support in the association between low vision and depressive symptoms in older adults. *Quality Life Res.* (2014) 23:1039–43. doi: 10.1007/s11136-013-0536-0

47. Banjanin N, Banjanin N, Dimitrijevic I, Pantic I. Relationship between internet use and depression: Focus on physiological mood oscillations, social networking and online addictive behavior. *Comput Hum Behav.* (2015) 43:308–12. doi: 10.1016/j.chb.2014.11.013

48. Nakagomi A, Shiba K, Kondo K, Kawachi I. Can online communication prevent depression among older people? A longitudinal analysis. *J Appl Gerontol.* (2022) 41:167–75. doi: 10.1177/0733464820982147

49. Cotten SR, Ford G, Ford S, Hale TM. Internet use and depression among retired older adults in the United States: a longitudinal analysis. *J Gerontol B Psychol Soc.* (2014) 69:763–71. doi: 10.1093/geronb/gbu018

50. Wang K, Varma DS, Prosperi M. A systematic review of the effectiveness of mobile apps for monitoring and management of mental health symptoms or disorders. *J Psychiatr Res.* (2018) 107:73–8. doi: 10.1016/j.jpsychires.2018.10.006

51. Choi E, Han KM, Chang J, Lee YJ, Ham BJ. Social participation and depressive symptoms in community-dwelling older adults: emotional social support as a mediator. *J Psychiatr Res.* (2021) 137:589–96. doi: 10.1016/j.jpsychires.2020.10.043

52. Yanni H. Productive activities and psychological well-being among older adults. *J Gerontol Ser B Psychol Sci Social Sci.* (2008) 63:S64–72. doi: 10.1093/geronb/63.2.S64

53. Sieber SD. Toward a theory of role accumulation. *Am Sociol Rev.* (1974) 39:567–78. doi: 10.2307/2094422

54. Park MJ, Park NS, Chiriboga DA. A latent class analysis of social activities and health among community-dwelling older adults in Korea a latent class analysis of social activities and health among community-dwelling older adults in Korea. *Aging Mental Health.* (2017) 22:625–630. doi: 10.1080/13607863.2017.1288198

55. Choi NG. DiNitto DM. Internet and health information technology use and psychological distress among older adults with self-reported vision impairment: case-control study. *J Med Internet Res.* (2020) 22:e17294. doi: 10.2196/17294

56. Lyu S, Sun J. Internet use and self-rated health among Chinese older adults: the mediating role of social capital. *Geriatr Gerontol Int.* (2021) 21:34–8. doi: 10.1111/ggi.14090

57. Langdon P, Thimbleby H. Inclusion and interaction: designing interaction for inclusive populations. *Interact Comput.* (2010) 22:439–48. doi: 10.1016/j.intcom.2010.08.007

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 13 December 2022
DOI 10.3389/fpubh.2022.1073756

OPEN ACCESS

EDITED BY
Alexander Seifert,
University of Zurich, Switzerland

REVIEWED BY
Vera Gallistl,
University of Vienna, Austria
Friedrich Wolf,
Goethe University Frankfurt, Germany

*CORRESPONDENCE
Laura I. Schmidt
laura.schmidt@psychologie.uni-heidelberg.de

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 18 October 2022
ACCEPTED 24 November 2022
PUBLISHED 13 December 2022

CITATION
Jokisch MR, Schmidt LI and Doh M (2022) Acceptance of digital health services among older adults: Findings on perceived usefulness, self-efficacy, privacy concerns, ICT knowledge, and support seeking.
Front. Public Health 10:1073756.
doi: 10.3389/fpubh.2022.1073756

Acceptance of digital health services among older adults: Findings on perceived usefulness, self-efficacy, privacy concerns, ICT knowledge, and support seeking

Mario R. Jokisch[1,2], Laura I. Schmidt[3]* and Michael Doh[2]

[1]Institute of Gerontology, Heidelberg University, Heidelberg, Germany, [2]Catholic University of Applied Sciences Freiburg, Freiburg, Germany, [3]Institute of Psychology, Heidelberg University, Heidelberg, Germany

Background: Over the last decade, the rapid advancements in information and communication technologies (ICTs) have also driven the development of digital health services and applications. Older adults could particularly benefit from these technologies, but they still have less access to the Internet and less competence in using it. Based on the empirical literature on technology acceptance among older adults, this study examines the relations of perceived usefulness, self-efficacy, privacy concerns, ICT knowledge, and support seeking (family, informal, formal/institutional) with older adults' intention to adopt new digital health services.

Methods: The study included 478 older adults who participated in an online or paper/pencil questionnaire (M = 70.1 years, SD = 7.8; 38% male). Sociodemographic characteristics, subjective health status, and variables related to technology acceptance were assessed.

Results: Latent structural equation modeling revealed that higher perceived usefulness, higher self-efficacy regarding digital health technologies, and lower privacy concerns contributed to a higher intention to use digital health services among older adults. Contrary to our expectations, general ICT knowledge was not a significant predictor. Older adults who reported seeking more support regarding technology problems from family members and formal/institutional settings also reported higher usage intentions, whereas informal support was not as relevant. Furthermore, higher age was associated with higher perceived usefulness and lower self-efficacy.

Discussion: Future studies should further explore mediating factors for intention and actual use of digital health services and develop educational programs including follow-up assessments.

KEYWORDS

ICT, public health, TAM, digital health, older adults, self-efficacy, support

Introduction

Over the last decade, the rapid advancements in information and communication technologies (ICTs) have also driven the development of digital health services and applications. In a similar manner to the US, European national health care systems have started to include digital services, i.e., remote communication with health care providers, e-prescription, scheduling medical appointments online, redirecting to online portals for health information or education, and online personal health records (1, 2).

However, most digital health services are just in the phase of implementation and are not yet accessible to a large extent. For Germany, the "Act to Improve Healthcare Provision through Digitalization and Innovation" (Digital Healthcare Act—DVG) (3) was approved in November 2019 by the German Bundestag, but central services such as the electronic medical record, medication prescriptions, and sick notes for the employer were first introduced in 2021 or later (4).

Although persons of all ages are meant to profit from digital health solutions, older adults could particularly benefit: With the frequency and complexity of medical issues rising with age alongside potential mobility impairments, such solutions might empower older people to still manage their health actively and safely. However, access to those services delivered over digital platforms may represent a challenge to some older adults. Diffusion of ICTs is still ongoing, with older adults still being less likely to use the Internet and web-connected ICTs in comparison to the general population (5–7). Moreover, in 2021, 92% of people aged 60–70 were expected to have used the Internet, but only 51% of people over 80 were expected to have done so (8). On the one side, this shows that many older adults can draw on ICT skills and knowledge when it comes to adapting new digital health services, on the other side, it can be a challenge for those who have limited access to the internet and/or less previous experience. Besides access as a necessary precondition, little is known regarding the views and beliefs of older people regarding digital health services.

Acceptance of digital (health) technologies among older adults

Although the usage of digital health applications might come with large potential for the individual as well as for public health strategies, the bottleneck might be a lack of acceptance among older adults. The technology acceptance model (TAM) represents one of the widely used frameworks and assumes that perceived usefulness and perceived ease of use are major predictors of intention to use a given technology (9). Studies addressing empirical evidence related to the TAM with old and very old adults are rare, as are studies with an explicit focus on digital health services (10). However, there is evidence that associations of the TAM change with increasing age (11). In the "young-old" age between 60 and 75 years, when many resources are still available for most individuals, perceived usefulness has been shown to be crucial. In more advanced age (75+), tech-related self-efficacy has seemed to gain importance, whereas ease of use has appeared to be less relevant. Technology-related self-efficacy is relevant for older adults, regardless of whether they have a high or low level of digital competence, and is positively associated with various technology-related biographical experiences (12). Correspondingly, an increasing body of research does not confirm the relevance of perceived ease of use among the older population [e.g., (13, 14)]. With regard to new digital health solutions, for which less experience is available, this points to the high importance of exploring respective self-efficacy beliefs that may represent future starting points for interventions.

Fewer studies based on the TAM are available regarding acceptance of digital health technologies among older adults. Zheng et al. (15) state that in addition to social support and computer self-efficacy, the search for health information can be a key motivator for Internet use among older adults. Chang and Im (16) showed that perceived usefulness and simplicity were important predictors of health information seeking. In addition, those older adults who did not search for health information on the Internet had lower computer self-efficacy (17). Harris and Rogers (18) conducted a qualitative study and interviewed older adults with chronic health conditions about their acceptance of health technologies. The TAM factors were confirmed and, in addition, technic-specific factors such as advice acceptance, compatibility, convenience, facilitating conditions, subjective norm, trust, and privacy issues were also relevant for acceptance. Also from a more general perspective on smart technologies, privacy concerns are among the most common barriers preventing older adults from using digital devices and services (19).

Only remotely related to the TAM, the role of digital competence as well as (social) support for the use of digital health services among older adults has been investigated recently. For example, in a representative population-based Finnish study ($N > 4{,}400$), high digital competence was able to mediate the age-related decline in online services use (i.e., receiving test results, renewing prescriptions, and scheduling appointments), but only up to around the age of 80 years (20). This can be seen as an indication that general ICT knowledge and skills are an important predictor for the acceptance of new digital health services. Regarding level of support, initial qualitative and mixed-method data from the US and Israel indicate positive associations of support by either family members or non-kin intergenerational mentoring regarding the use of online health services (21, 22).

Research questions

Following these promising but still limited findings, our research aim was to test associations based on an extended TAM in order to predict the intention to use digital health services among older adults. In detail, and in accordance with the core of the TAM, we assume that perceived usefulness emerges as most important in predicting the intention to use digital health services. For self-efficacy beliefs tailored to digital health services, we hypothesize higher scores to be associated with a high level of intention. Additionally, we assume a positive relation with perceived usefulness, as people with high self-efficacy might recognize more opportunities to integrate digital health services in their lives. Regarding potential barriers, we expect that higher privacy concerns with respect to digital health services have a negative effect on the intention to use such digital applications. Regarding prior experience, we assume that older adults who report having higher knowledge about ICTs in general also have a higher intention to use digital health services.

For support, we hypothesize that older people who report higher support-seeking behavior also express higher intentions, perceived usefulness, and self-efficacy regarding digital health services. We exploratively aim to analyze if patterns differ with regard to support seeking among family members, voluntary/informal sources, or professional sources. On an exploratory level, we also wanted to investigate whether high ICT knowledge contributes to fewer privacy concerns and higher digital health self-efficacy.

Design and methods

Recruitment and sample

The study is part of a larger project, called "Healthy Aging in Baden-Wuerttemberg," funded by the Ministry of Social Affairs and Integration Baden-Württemberg, which aimed to provide educational services with a focus on digital health services for older adults. In 2021, 256 events were provided for older people in which information and practice possibilities on digital health functions were offered (i.e., electronic patient record, electronic health card, digital services in pharmacy care, video contact with one's doctor, health apps). A total of 2,510 people attended the events, of whom 559 individuals participated in an online or paper/pencil questionnaire. Of these, 81 were excluded because they were under 50 years old, yielding a cohort of 478 older adults who were included in the study. On average, participants were 70.1 years old (SD = 7.8, age range: 50–91 years), more often female (63%), with a high degree of education (high 54%, medium 31%, low 15%), and mainly reporting a good to sufficient health status ($M = 4.6$, SD = 0.8) (Table 1).

Measures

Intention to use digital health services (e.g., "assuming I had access to digital health services, I intend to use it") and *perceived usefulness* (e.g., "using digital health services is useful for my life") were measured with two items each, based on Davis et al. (9). Evaluations of *privacy concerns* were assessed *via* two items from the Tele-healthcare Satisfaction Questionnaire—Wearable Technology [e.g., "The storage or further processing of my personal health data may have negative consequences"; TSQ-WT, (23)]. To assess self-efficacy related to digital health services, two items based on the Short Scale for Measuring General Self-Efficacy Beliefs (24) were adopted (e.g., "If problems arise when using digital health services, I can solve them on my own"). *Support seeking* in the case of need for help with digital health services was assessed *via* three self-developed items asking for the level of agreement regarding support from (1) family members (e.g., "When I need help with digital health services, I seek it from family members"), (2) informal/voluntary sources (e.g., "…I seek it from volunteer peer support"), or formal/institutional sources (e.g., "…I seek it from information events, training courses"). All items mentioned above were answered on a five-point Likert scale ranging from 1 (do not agree at all) to 5 (fully agree). *General ICT knowledge* was measured by asking respondents to rate their knowledge regarding computers, smartphones, tablets, wearables, and the Internet on a scale from 1 (very poor) to 6 (very good). Participants' current health status was assessed using the same response scale. Internal consistency was good to excellent (intention: $\alpha = 0.76$; perceived usefulness: $\alpha = 0.86$; self-efficacy: $\alpha = 0.88$; privacy concerns: $\alpha = 0.74$; ICT knowledge: $\alpha = 0.83$).

Statistical analysis

Statistical analyses were performed using SPSS 28.0 for descriptive statistics and Amos 24.0 for latent structural equation modelling. We applied a latent structural equation model for the entire sample. Four latent factors were indicated by two items each (perceived usefulness, self-efficacy, privacy concerns) and one latent factor by five items (ICT knowledge). Support in the form of family members, informal/voluntary support services, and formal/institutional support services were included as a manifest variable with one item each. Sex, subjective health, age, and education were also entered as manifest variables with relations to perceived usefulness, self-efficacy, privacy concerns, support, and ICT knowledge.

Model fit was tested using the comparative fit index (CFI) and the root-mean-square error of approximation (RMSEA). A CFI score ≥ 0.90 and a RMSEA score ≤ 0.08 were interpreted as an acceptable model fit, while a CFI score ≥ 0.95 and a RMSEA score below ≤ 0.05 represented a good model fit (25). With

regard to missing data treatment, full information maximum likelihood was applied (26).

Results

Descriptive and correlational results are presented in Table 1. Mean scores of all items were settled around the average or in the positive range of the scales, with considerable variation.

Latent structural equation modelling

The model including all study variables yielded good overall fit indices (CFI = 0.973; RMSEA = 0.036). Detailed results can be derived from Table 2, and the path model including β coefficients is depicted in Figure 1. The overall model explained 60% of the variance in intention to use digital health services. Additionally, 26% of the variance in perceived usefulness, 22% of the variance in self-efficacy and 7% in privacy concerns could be explained.

As assumed, perceived usefulness was positively related to the intention to use digital health services ($\beta = 0.63, p < 0.001$). This was also the case for health-related self-efficacy ($\beta = 0.12$, $p = 0.008$) and privacy concerns ($\beta = 0.15, p < 0.001$). In terms of support, older adults who reported seeking family support ($\beta = 0.16$, $p < 0.001$) and formal/institutional support ($\beta = 0.08$, $p = 0.038$) reported higher intention levels. Contrary to our assumption, informal support was not a significant predictor for the intention to use digital health services ($\beta = -0.04$, $p = 0.286$). Also contrary to our assumptions, general ICT knowledge was not related to the intention to use digital health services ($\beta = 0.06, p = 0.209$).

As hypothesized, there was a clear positive association between perceived usefulness and health-related self-efficacy in using digital health services ($\beta = 0.36$, $p < 0.001$). Similarly, fewer privacy data concerns contributed to higher perceived usefulness ($\beta = 0.26, p = <0.001$). Regarding the role of support, older people who reported seeking more formal/institutional support exhibited higher scores in perceived usefulness ($\beta = 0.25$, $p < 0.001$). In addition, there was a marginal association between informal support seeking and perceived usefulness ($\beta = 0.11$, $p = 0.050$) and no relation with support from family members ($\beta = -0.45, p = 0.342$).

With regard to health-related self-efficacy, there was no connection with support seeking *via* family ($\beta = -0.00$, $p = 0.974$), but a association between informal support sources and health-related self-efficacy ($\beta = 0.16$, $p = 0.003$). Older adults who reported seeking significant formal/institutional support showed higher health-related self-efficacy ($\beta = 0.18, p = 0.003$).

Also contrary to our assumptions, general ICT knowledge was not related to the intention to use digital health services ($\beta = 0.06$, $p = 0.209$). The explorative analyzed relation between perceived usefulness and ICT knowledge could not be established ($\beta = 0.10, p = 0.129$). However, older adults with a high level of ICT knowledge reported a higher self-efficacy ($\beta = 0.382$, $p = <0.001$) and less privacy concerns ($\beta = 0.271$, $p = <0.001$).

Regarding the control variables, age showed no relation with either intention ($\beta = 0.04$, $p = 0.296$) or privacy concerns ($\beta = 0.00$, $p = 0.116$). However, age was positively related to perceived usefulness ($\beta = 0.14$, $p = 0.005$) and negatively

TABLE 1 Descriptive statistics and correlations for study variables.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	70.1	7.8	–											
2. Gender (male %)[a]	37.61		−0.02	–										
3. Education (high %)[b]	53.64		−0.25***	−0.15**	–									
4. Subjective health [c]	4.6	0.8	−0.12*	−0.06	0.08	–								
5. Intention[d]	3.8	1.0	−0.05	0.10*	0.15**	−0.04	–							
6. Perceived usefulness[d]	3.6	0.9	0.06	0.04	0.03	−0.03	0.58***	–						
7. Self-efficacy	3.2	1.0	−0.16**	−0.02	0.09	0.09	0.31***	0.34***	–					
8. Privacy concerns[d]	3.0	0.9	0.03	0.00	0.07	−0.05	0.28***	0.25***	0.15**	–				
9. ICT knowledge[c]	4.0	1.0	−0.20***	−0.04	0.17**	0.22***	0.13**	0.12*	0.29***	0.23***	–			
10. Family support[d]	3.6	1.3	0.06	−0.05	0.04	0.15**	0.06	−0.03	−0.002	0.09	0.04	–		
11. Informal support[d]	3.1	1.2	0.13*	0.06	−0.13*	−0.01	−0.01	0.03	0.14**	−0.01	−0.07	−0.01	–	
12. Formal/institution support[d]	3.6	1.2	−0.001	0.06	−0.12*	−0.03	0.18***	0.26***	0.17***	0.07	0.11*	−0.05	0.31***	–

$N = 478$.
[a]Male = 0, women = 1.
[b]Education: low = 1, medium = 2, high = 3.
[c]1 = "very bad" to 6 = "very good".
[d]1–5, higher scores indicate more positive scores.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 2 Results of the study variables in the structural equation model for digital health services.

Path	*b*	*ß*	*SE*	*p*
Intention ← Perceived usefulness	0.666	0.627	0.053	< 0.001
Intention ← Self-efficacy	0.131	0.124	0.049	0.008
Intention ← Privacy concerns	0.227	0.150	0.061	< 0.001
Intention ← Family support	0.12	0.160	0.026	< 0.001
Intention ← Informal support	−0.033	−0.042	0.031	0.286
Intention ← Formal/institution support	0.067	0.082	0.033	0.038
Intention ← ICT knowledge	0.068	0.060	0.054	0.209
Perceived usefulness ← Self-efficacy	0.359	0.361	0.059	< 0.001
Perceived usefulness ← Privacy concerns	0.365	0.257	0.076	< 0.001
Perceived usefulness ← Family support	−0.032	−0.045	0.034	0.342
Perceived usefulness ← Informal support	0.086	0.114	0.040	0.050
Perceived usefulness ← Formal/institution support	0.192	0.247	0.040	< 0.001
Perceived usefulness ← ICT knowledge	0.106	0.099	0.070	0.129
Self-efficacy ← Family support	−0.009	−0.012	0.035	0.808
Self-efficacy ← Informal support	0.12	0.158	0.041	0.003
Self-efficacy ← Formal/institution support	0.092	0.118	0.041	0.025
Self-efficacy ← ICT knowledge	0.411	0.382	0.074	< 0.001
Privacy concerns ← ICT knowledge	0.204	0.271	0.057	< 0.001

N = 478; Total variance explanation in intention: 60%.

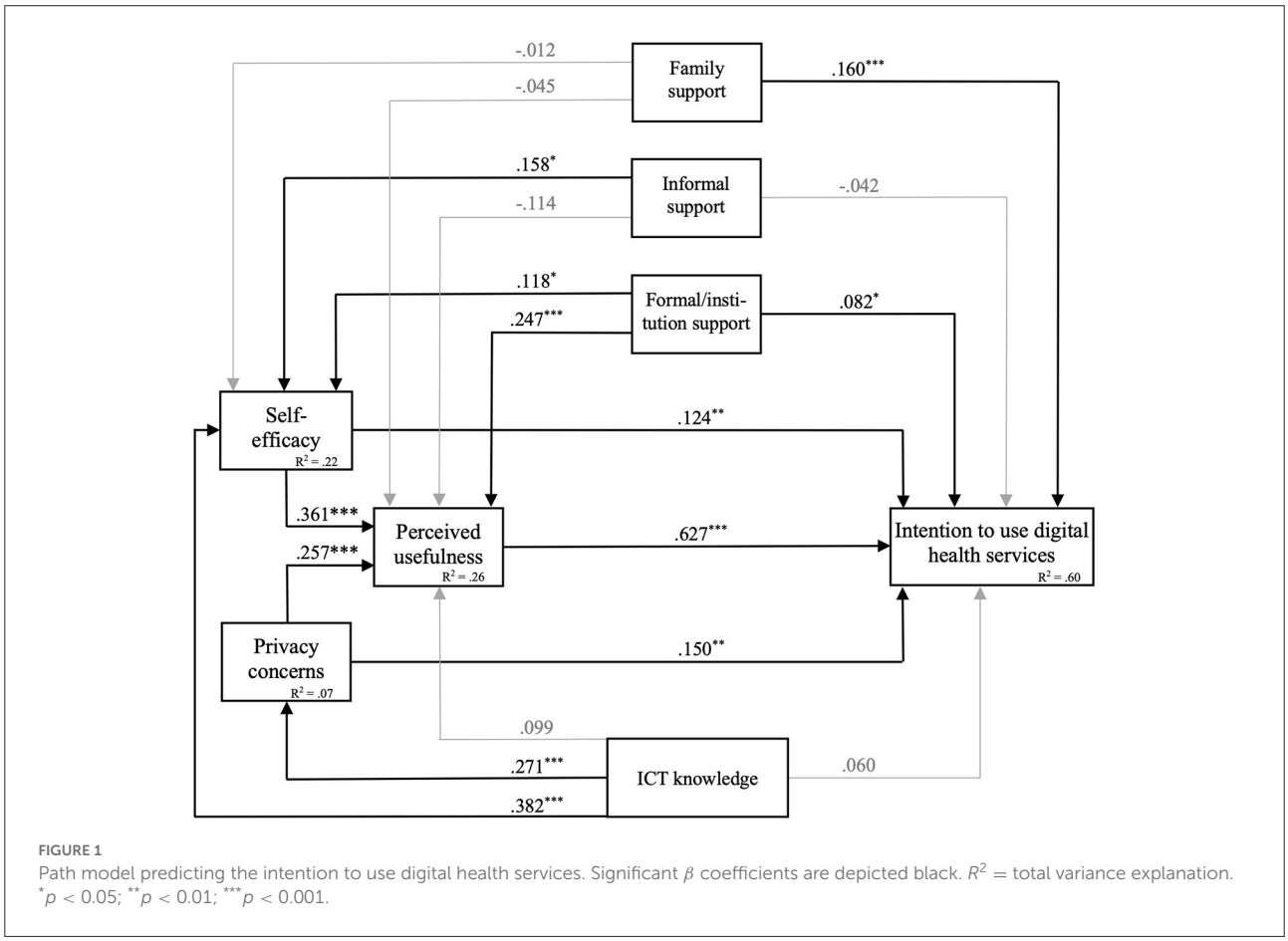


FIGURE 1
Path model predicting the intention to use digital health services. Significant β coefficients are depicted black. R^2 = total variance explanation. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

related to health-related self-efficacy ($\beta = -0.16$, $p = 0.003$), indicating that participants who were older recognized higher perceived usefulness of digital health services but reported lower health-related self-efficacy to use them. Gender was positively associated with intention ($\beta = 0.091$, $p = 0.007$), with women reporting a higher intention to use digital health services. Higher education status contributed to a higher intention to use digital health services ($\beta = 0.12$, $p = 0.002$) but did not show significant relations otherwise. ICT knowledge also declined with increasing age ($\beta = -0.27$, $p = 0.001$) and was positively related to better health status ($\beta = 0.20$, $p = 0.001$). All results are depicted in Supplementary Table 1.

Discussion

Our study aimed to explore older adults' perceptions regarding digital health services, in order to provide initial insights on associations within an extended TAM framework. In summary, higher perceived usefulness and self-efficacy, more perceived family and formal support, and low privacy concerns contributed to a higher intention to use digital health services, among our relatively well-educated and healthy sample of older adults.

First, these results show that established factors that predict technical acceptance in other technology areas such as digital health services are also relevant among older adults. Second, perceived usefulness was the dominant factor in the model, whereas health-related self-efficacy and privacy concerns were also significant but exhibited lower contributions to the intention to use digital health services. Age itself was not directly linked to usage intentions but was predictive of higher perceived usefulness, highlighting the importance that digital health services offers for the oldest age group. As older age was also associated with lower health-related self-efficacy beliefs, self-efficacy or related constructs such as perceived control should be investigated more deeply and longitudinally as potential mediators between age and acceptance with respect to digital health services and tools. Furthermore, it should be taken into account that if newly developed digital health services have lower or insufficient usability, factors such as ease of use might gain importance for the decision-making process.

Older adults with more ICT knowledge were found to have higher self-efficacy and reported less privacy concerns, but there was no relation to perceived usefulness and intention. This could be taken as a first indication that general ICT knowledge is not directly related to the decision to use a digital health service and that this technologies may be a separate issue from overall ICT adoption. However, the selectivity of the sample should be considered in this context. Our respondents were older adults with a relatively high level of education and above-average ICT knowledge, and can be classified as early adopters who engaged with ICT at an early stage (27). In a more diverse sample including less privileged older adults with insufficient ICT background skills, effects on acceptance might still be expected.

Our finding that women reported higher intentions to use digital health services might also relate to gender roles and social norms in general, as women tend to be the family caregiver, i.e., they were in charge of making health care decisions for children earlier in life and often take care of medical appointments for husbands or older relatives, whereas traditional masculine behavioral patterns can prevent men from further dealing with health-related services [i.e., (28, 29)]. However, more research is needed that also focuses on women with lower education levels as well as those from rural areas, as our sample was also biased in terms of having a large percentage of well-educated women in our survey.

Limitations

Our study has some limitations that need to be acknowledged. First, as addressed above, our sample was selective with regard to mainly higher education levels as well as the fact that participants were recruited *via* events that relate to technology issues. Second, our cross-sectional results do not allow causal interpretation, and longitudinal research is needed that investigates actual adoption of digital health services at the time they are available for the public, which can be expected in the next year for some services (i.e., e-prescription). Third, our data collection took place during the COVID-19 pandemic, which might have (positively) influenced perceptions of digital health services that in part replace physical contact and thus protect against infection. Fourth, we used predominantly short scales and parsimonious measures that might profit from extensions in future studies. For example, to better understand the role of ICT knowledge and also competencies, we recommend using comprehensive questionnaires such as the Mobile Device Proficiency Questionnaire (30).

Practical implications and outlook

This study provides initial indications regarding the type of support that is relevant for older adults when adopting new digital health services. In particular, formal education was rated as important and was associated with more favorable scores regarding self-efficacy, usage intention, and usefulness of digital health services. This indicates two points: first, formal education seems to be relevant for the decision to use new digital health services. It is therefore important to provide suitable educational offerings to accompany the introduction of new innovations in the health sector. Second, it can be assumed that for this highly educated sample, formal educational opportunities are marked by high visibility and easy availability. However, this might not be the case for people with a low level of education who do not

make (continuous) use of these existing educational structures, or for older adults with (mild) cognitive impairment (31, 32).

In this context, non-formal education programs can play an important role. Voluntary programs can be tailored more closely to the needs of older people who do not feel addressed in traditional courses offered by formal education programs (33). Older adults who are representative of those surveyed here, who exhibit a high interest in new digital health services, have a high level of ICT knowledge, and recognize the benefits of technology, should be recruited as volunteers. This creates role models who have already overcome problems with technologies that inexperienced groups face. *Via* vicarious experience, role models offer a means to increase self-efficacy (34). Moreover, volunteering has numerous positive effects for those who engage in it. For example, older adults who were active in ICT-related contexts have been shown to gain more ICT knowledge, to experience increases in general self-efficacy, and to exhibit reduced feelings of obsolescence (35). As the field of digital health services is embedded in a dynamic innovative process of digital transformation within health care systems, more research is needed to determine preferences and identify facilitators or barriers among older adults. Educational programs should be carefully designed with older adults involved as active partners and should be tested using robust experimental and longitudinal designs.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MJ: conceptualization, investigation, writing—original draft, methodology, and formal analysis. LS: conceptualization, validation, and writing—review and editing. MD: writing—review and editing, resources, and project administration. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by the Ministry for Social Affairs, Health and Integration Baden-Wuerttemberg, Germany. For the publication fee we acknowledge financial support by Deutsche Forschungsgemeinschaft within the funding programme Open Access Publikationskosten as well as a personal funding for LS within the Young Marsilius Fellow Program for interdisciplinarity and science communication at Heidelberg University.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1073756/full#supplementary-material

References

1. WHO. *Global Diffusion of eHealth: Making Universal Health Coverage Achievable: Report of the Third Global Survey on eHealth*: World Health Organization (2017).

2. Barbabella F, Melchiorre MG, Quattrini S, Papa R, Lamura G, Richardson E, et al. *How Can eHealth Improve Care for People With Multimorbidity in Europe?* Copenhagen: World Health Organization, Regional Office for Europe (2017).

3. BMG (2022). Available from: https://www.bundesgesundheitsministerium.de/en/digital-healthcare-act.html

4. BMG (2022). Available from: https://www.bundesgesundheitsministerium.de/elektronische-patientenakte.html

5. Mitzner TL, Savla J, Boot WR, Sharit J, Charness N, Czaja SJ, et al. Technology adoption by older adults: findings from the PRISM trial. *Gerontologist.* (2019) 59:34–44. doi: 10.1093/geront/gny113

6. König R, Seifert A, Doh M. Internet use among older Europeans: an analysis based on SHARE data. *Univ Access Inf Soc.* (2018) 17:621–33. doi: 10.1007/s10209-018-0609-5

7. Poushter J, Bishop C, Chwe H. *Social Media Use Continues to Rise in Developing Countries but Plateaus Aaross Developed Ones*. Pew research center (2018) 22:2–19. Availablle form: http://www.pewglobal.org/2018/06/19/2-smartphone-ownership-on-the-rise-in-emerging-economies/

8. Rathgeb T, Doh M, Jokisch MR, Tremmel F, Groß A-K. *Senior*innen, Information, Medien. Basisuntersuchung zum Medienumgang von Personen ab 60 Jahren in Deutschland*. Stuttgart: Medienpädagogischer Forschungsverbund Südwest. (2022).

9. Davis FD, Bagozzi RP, Warshaw PR. User acceptance of computer technology: a comparison of two theoretical models. *Manage Sci.* (1989) 35:982–1003. doi: 10.1287/mnsc.35.8.982

10. Chen K, Chan AHS. A review of technology acceptance by older adults. *Gerontechnology*. (2011) 10:1–12. doi: 10.4017/gt.2011.10.01.006.00

11. Jokisch MR, Scheling L, Doh M, Wahl H-W. Contrasting Internet adoption in early and advanced old age: does Internet self-efficacy matter? *J Gerontol.* (2022) 77, 312–20. doi: 10.1093/geronb/gbab096

12. Jokisch MR, Schmidt LI, Doh M, Marquard M, Wahl H-W. The role of Internet self-efficacy, innovativeness and technology avoidance in breadth of internet use: comparing older technology experts and non-experts. *Comput Human Behav.* (2020) 111:106408. doi: 10.1016/j.chb.2020.106408

13. Mitzner TL, Rogers WA, Fisk AD, Boot WR, Charness N, Czaja SJ, et al. Predicting older adults' perceptions about a computer system designed for seniors. *Univ Access Inf Soc.* (2016) 15:271–80. doi: 10.1007/s10209-014-0383-y

14. Wong CKM, Yeung DY, Ho HCY, Tse K-P, Lam C-Y. Chinese older adults' Internet use for health information. *J Appl Gerontol.* (2014) 33:316–35. doi: 10.1177/0733464812463430

15. Zheng R, Spears J, Luptak M, Wilby F. Understanding older adults' perceptions of Internet use: an exploratory factor analysis. *Educ Gerontol.* (2015) 41:504–18. doi: 10.1080/03601277.2014.1003495

16. Chang SJ, Im E-O, A. path analysis of Internet health information seeking behaviors among older adults. *Geriatr Nurs.* (2014) 35:137–41. doi: 10.1016/j.gerinurse.2013.11.005

17. Hall AK, Bernhardt JM, Dodd V, Vollrath MW. The digital health divide: evaluating online health information access and use among older adults. *Health Educ Behav.* (2015) 42:202–9. doi: 10.1177/1090198114547815

18. Harris MT, Rogers WA. Developing a healthcare technology acceptance model (H-TAM) for older adults with hypertension. *Age Soc.* (2021) 1–21. doi: 10.1017/S0144686X21001069

19. Harris MT, Blocker KA, Rogers WA. Older adults and smart technology: facilitators and barriers to use. *Front Comp Sci.* (2022) 41:835927. doi: 10.3389/fcomp.2022.835927

20. Heponiemi T, Kaihlanen A, Kouvonen A, Leemann L, Taipale S, Gluschkoff K. The role of age and digital competence on the use of online health and social care services: a cross-sectional population-based survey. *Digital Health*. (2022) 8:1–10. doi: 10.1177/20552076221074485

21. Mizrachi Y, Shahrabani S, Nachmani M, Hornik A. Obstacles to using online health services among adults age 50 and up and the role of family support in overcoming them. *Isr J Health Policy Res.* (2020) 9:1–10. doi: 10.1186/s13584-020-00398-x

22. Lee OE-K, Kim D-H. Bridging the digital divide for older adults via intergenerational mentor-up. *Res Soc Work Pract.* (2019) 29:786–95. doi: 10.1177/1049731518810798

23. Chiari L, van Lummel R, Pfeiffer K, Lindemann U, Zijlstra W. *Deliverable 2.2: Classification of the User's Needs, Characteristics and Scenarios-Update. Unpublished Report From the EU Project (6th Framework Program, IST Contract no 045622) Sensing and Action to Support Mobility in Ambient Assisted Living.* London: Department of Health (2009).

24. Beierlein C, Kovaleva A, Kemper CJ, Rammstedt B. *Ein Messinstrument zur Erfassung subjektiver Kompetenzerwartungen: Allgemeine Selbstwirksamkeit Kurzskala (ASKU)*, Köln (2012).

25. McDonald RP, Ho M-HR. Principles and practice in reporting structural equation analyses. *Psychol Methods.* (2002) 7:64–82. doi: 10.1037/1082-989X.7.1.64

26. Schafer JL, Graham JW. Missing data: our view of the state of the art. *Psychol Methods.* (2002) 7:147–77. doi: 10.1037/1082-989X.7.2.147

27. Rogers EM. *Diffusion of Innovations*. 5th ed. New York, NY: Free Press (2003). 576 p.

28. Matoff-Stepp S, Applebaum B, Pooler J, Kavanagh E. Women as health care decision-makers: implications for health care coverage in the United States. *J Health Care Poor Underserved.* (2014) 25:1507–13. doi: 10.1353/hpu.2014.0154

29. Sieverding M, Matterne U, Ciccarello L. What role do social norms play in the context of men's cancer screening intention and behavior? Application of an extended theory of planned behavior. *Health Psychol.* (2010) 29:72. doi: 10.1037/a0016941

30. Roque NA, Boot WR. A new tool for assessing mobile device proficiency in older adults: the mobile device proficiency questionnaire. *J Appl Gerontol.* (2018) 37:131–56. doi: 10.1177/0733464816642582

31. Schmidt LI, Wahl H-W. Predictors of performance in everyday technology tasks in older adults with and without mild cognitive impairment. *Gerontologist.* (2019) 59:90–100. doi: 10.1093/geront/gny062

32. Schmidt L, Wahl H-W. Does education level-out expectable everyday technology device differences in older adults with and without mild cognitive impairment? *Psychother Alter.* (2020) 17:49–66. doi: 10.30820/1613-2637-2020-1-49

33. Jokisch MR, Doh M, Brehm M, Tatsch I. 16 Digitales Ehrenamt im Alter–Ein Schulungskonzept für ältere Begleitende im Rahmen des Projekts KommmiT. *Divers Altersbildung.* (2022) 201.

34. Jokisch, M. R. (2022). *Altern in einer digitalisierten Gesellschaft: Studien zur Selbstwirksamkeit, Technikakzeptanz und dem Obsoleszenzerleben bei älteren Erwachsenen [Aging in a Digitalized Society: Studies on Self-efficacy, Technology Acceptance and Perceived Obsolescence Among Older Adults]* (Dissertation). Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany. doi: 10.11588/heidok.00032076

35. Jokisch MR. *Aging in a Digitalized Society: Studies on Self-efficacy, Technology Acceptance and Perceived Obsolescence Among Older Adults* (Dissertation). Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany (2022).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 16 December 2022
DOI 10.3389/fpubh.2022.1091484

OPEN ACCESS

EDITED BY
Alexander Seifert,
University of Zurich, Switzerland

REVIEWED BY
Sadia Shakeel,
DOW University of Health Sciences (DUHS), Pakistan
Hooi Min Lim,
University of Malaya, Malaysia

*CORRESPONDENCE
Xiaoyu Li
✉ li.xiaoyu@zs-hospital.sh.cn
Qianzhou Lv
✉ 13916088938@163.com

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 07 November 2022
ACCEPTED 30 November 2022
PUBLISHED 16 December 2022

CITATION
Li X, Hu J, Yao Y, Zuo C, Wang Z, Li X and Lv Q (2022) Evaluation of pharmacist-led telemedicine medication management for hypertension established patients during COVID-19 pandemic: A pilot study.
Front. Public Health 10:1091484.
doi: 10.3389/fpubh.2022.1091484

Evaluation of pharmacist-led telemedicine medication management for hypertension established patients during COVID-19 pandemic: A pilot study

Xiaoye Li[1†], Jialu Hu[2†], Yao Yao[1], Chengchun Zuo[1], Zi Wang[1], Xiaoyu Li[1*] and Qianzhou Lv[1*]

[1]Department of Pharmacy, Zhongshan Hospital, Fudan University, Shanghai, China, [2]Department of Cardiology, Zhongshan Hospital, Fudan University, Shanghai, China

Aim: To evaluate the impact of a telemedicine medication management service in patients with hypertension.

Methods: Participants were allocated to either a telemedicine service ($N = 173$) or usual care (UC) ($N = 179$). The primary outcome was blood pressure (BP) reduction from baseline to the 6-month follow-up visit, the proportion of the target BP achievement, overall adherence to prescribed medication as well as a composite of non-fatal stroke, non-fatal myocardial infarction and cardiovascular death.

Results: At 6 months, BP was controlled in 89.6% ($n = 155$) of intervention patients and 78.8% ($n = 141$) of UC patients (OR = 1.14, 95% CI = 1.04–1.25, $P = 0.006$), giving a mean difference of −6.0 (−13.0 to −2.5 mmHg) and −2.0 mmHg (−4.0 to −0.1 mmHg) in SBP and DBP, respectively. 17.9% ($n = 31$) of the patients in the intervention group were non-adherent with medications, compared with 29.1% ($n = 52$) in the UC group ($P = 0.014$). The composite clinical endpoints were reached by 2.9% in the intervention group and 4.5% in the control group with no significant differences (OR = 1.566, 95% CI = 0.528–4.646).

Conclusion: Telemedicine medication management for hypertension management had led to better BP control and medication adherence improvement than UC during COVID-19 epidemic, resulting in a reduction of overall adverse cardiovascular events occurrence.

KEYWORDS

telemedicine medication management, usual care, hypertension management, COVID-19 pandemic, blood pressure

1. Introduction

The COVID-19 pandemic has dramatically affected and overloaded healthcare systems across the globe and strained healthcare resources on many levels (1, 2). Services like medication counseling and care proved to be challenging for overloaded medical practitioners to provide (3). According to the 2018 Report on Cardiovascular Diseases in China, hypertension was an important public disease burden in China with 245 million patients (prevalence 23.2%) (4). Notwithstanding, the disease control was still suboptimal, well contributing to high risk of adverse cardiovascular outcomes, which requires long-term treatment with anti-hypertensives to control blood pressure (BP) (5). Appearing in person in clinic for routine hypertension monitoring and follow-up often exposed elderly and vulnerable patients to infectious risk. Telemedicine offers the prospect of remote management of BP for vulnerable individuals while avoiding the risks of in-person care in a pandemic (6, 7).

It was challenging to provide routine medication management for patients with hypertension and other chronic cardiovascular diseases during the pandemic (8, 9). To reduce the risk of infectious exposures, non-contact treatment models have been advocated in some settings, including China. The pharmaceutical department of the Zhongshan Hospital has built an efficient telemedicine pharmaceutical service model which leverages remote communication methods such as WeChat or telephone, to improve the service quality, reduce the risk of infection, and ensure the safety of patients (10). Telemedicine, by limiting person-to-person contact, might reduce the possibility of viral transmission, and offer the possibility of more timely care for chronic diseases. By leveraging pharmacist input, the telemedicine approach enables rapid remote review and evaluation of medication lists, indications, dosing particulars, storage methods, precautions and drug interactions.

Patients with adequate clear medication information are better equipped to make informed choices about managing their anti-hypertensives, and potentially might have more incentive and support to adhere to their prescribed medications. Therefore, this study aimed to evaluate the pharmaceutical telemedicine care service in patients with existing hypertension, as compared to usual care (UC).

2. Methods

2.1. Study design and patient information

This prospective single-site cohort study was designed to compare a telemedicine intervention to usual care for people with hypertension seeking care at the Zhogshan Hospital (Shanghai, China) between January 2021 and June 2021. In our study, hypertension was defined as an average office systolic BP of >140 mmHg or an average office diastolic BP of >90 mmHg or self-reported use of antihypertensive medication in the past 2 weeks according to the American Hypertension Management Guidelines (11). Patients with uncontrol hypertension were finally enrolled. Integrated care, such as health screenings, providing patient education and modifying medication regimens under collaborative practice agreements, was available for all patients who were diagnosed as hypertension including antihypertensive therapy and inconsistent approaches to cardiovascular risk reduction. All drugs were prescribed as single doses by pharmacists under the doctor's supervision. For follow-ups, BP was measured during outpatient clinic visits by specialized cardiologists or other certified specialists.

All patients involved met the following eligibility criteria: (1) age $\geq$ 18 years; (2) high risk for cardiovascular diseases in terms of diabetes, dyslipidemia, smoking, poor diet, and obesity; and (3) primary hypertension prescribed with antihypertensive drugs/daily. The main exclusion criteria included the following: (1) secondary hypertension; (2) severe renal dysfunction (estimated glomerular filtration rate [eGFR] <30 ml/min^{-1}·1.73 m^2); and (3) unable to communicate *via* WeChat or phone. This study was approved by the Ethics Committee of Zhongshan Hospital (Approval Number: B2021-021R). Written informed consent was signed by all participants before the commencement of the clinical studies.

2.2. Study procedure

2.2.1. Procedure

The eligible participants were identified from clinical codes recorded in the electronic medical record system and invited to learn about this clinical study. Written informed consent for participation was obtained before the participants were determined to be eligible and we collected their baseline information *via* electronic health records. The BP was measured by standard mercury sphygmomanometers in a sitting position. At least two BP measurements should be taken in the sitting position, spaced 1–2 min apart and the average value was used for diagnosis (12). Consecutive participants were allocated to receive either the pharmacist-led telemedicine care and follow-up service or UC according to patients' demand and willingness.

The medication decision on patients' drugs was performed by clinicians' discretion throughout the whole study procedure. The participating pharmacists reviewed the medication for BP control and perform an individualized medication titration plan for the enrolled participants after allocation. Three and six months after allocation, scheduled follow-up appointments were performed to measure and record BP for attended participants for both groups.

2.2.2. Pharmacist-led telemedicine pharmaceutical intervention

Continuous participants were assigned to telemedicine pharmaceutical intervention or UC group according to patients' demand and willingness. In the intervention group, there were five cardiovascular pharmacists in total who provided the interventions, mainly including the administration time and dosage of antihypertension drugs, the management of adverse reactions, the drug interactions and BP monitoring, which as indicated in Supplementary Figure 1. The antihypertension medication guidance was listed in Supplementary Table 1. Firstly, medication review was established to collect participants' demographic and clinical factors, and their understanding of current medication status. Then, intervention was conducted based on medication guidance including educational materials and individualized pharmacotherapy.

The participants were well trained in: (i) reviewing how to use a mercury sphygmomanometer to measure their BP at home; (ii) visiting the Web-based dashboard through smartphone or WeChat, entering the personalized goals, and getting to know how to enter and view their data; and (iii) developing a personalized BP management plan (e.g., frequency of contacts for check-ins, goal-setting, and data upload) informed by the baseline home BP measurements. Then they were asked to: (i) measure their BP at home use a mercury sphygmomanometer, while sitting, after a rest period of at least 10 min; (ii) send their BP data report to the researcher through smartphone or WeChat; and (iii) set BP targets weekly. 2 The role of the pharmacist in this study was to make medical intervention or lifestyle recommendations according to the BP data and description retrieving. Participants could withdraw from the study at any time.

2.2.3. Pharmacist-led usual care

Participants who were allocated to UC group were not provided with an online drug counseling platform, but obtained online access for web information on hypertension control including classification and causes of hypertension, guidance for the hypertension management in terms of lifestyle improvement and medication adjustments. The participants received routine services by referring to an outpatient clinic for hypertension care which was typically composed of BP measurements for titrate drugs and antihypertensive adjustments to maintain target BP.

2.3. Data collection and follow-ups

The demographic information and baseline assessments including age, sex, body mass index (BMI), complications, and initial BP were obtained through electronic medical recorder (EMR). Laboratory measurements including serum sodium, potassium, creatinine, estimated glomerular filtration rate, and concomitant medication record were collected from EMR.

For each eligible participants, follow-up controls were scheduled every 3 months, up to at least 6 month. BP measurements were performed at the screening visit. Physicians provided medication related interventions to make every reasonable effort to control BP in accordance with international and local hypertension management guidelines. The medication related interventions were classified into 8 categories by pharmacist in this study, including stopped therapy, side effect, adherence improvements, costs, drug-drug interaction, liver function, renal function and inappropriate doses. Other than this, duration for the first outpatient revisit and the time to first or recurrent cardio-cerebral vascular events were recorded throughout follow-ups.

2.4. Adherence to antihypertensive therapy

Adherence to antihypertensive therapy was estimated by the self-report method at the point of 6-months follow-up *via* telephone interview or clinic visit (13, 14). Specifically, medication adherence was measured by proportion of days covered (PDC), defined as the number of days patients taking prescriptions divided by the interval of observation period. PDC above 80% was considered as full or high adherence (15). Conversely, the patient was considered to be non-adherent when he reported omitting dose of the medication, or making errors in dosage or frequency, or if he interrupted treatment. Reasons for medication non-adherence were recorded.

2.5. Clinical outcomes

The primary outcome was systolic and diastolic BP and heart rate reduction from baseline to the 6-month follow-up visit, the proportion of the target BP achievement, overall adherence to prescribed medication as well as a composite of non-fatal stroke, non-fatal myocardial infarction and cardiovascular death.

The secondary outcomes were adherence and persistence to antihypertensive agents, antiplatelet agents, lipid-lowering agents, proton pump inhibitor (PPI) and antiarrythmic drugs and cumulative incidence of any cardio-cerebral vascular event.

2.6. Sample size consideration

A sample size of 140 consecutive participants per group were required to have 90% power according to previously reported literature (16). The level of the statistical significance test (Class I error rate α) is 0.05 (Using two-sided inspection), the statistical effect is 90% (Class II error rate $\beta = 0.1$), and the sample size is estimated using PASS 11 statistics software. To accommodate an anticipated dropout rate of 10%, 308 participants were enrolled to achieve 280 evaluable participants.

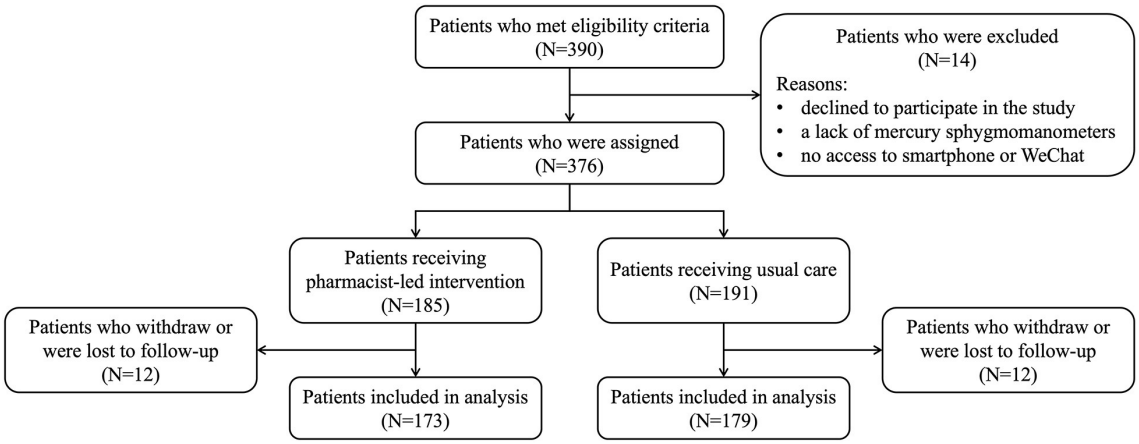


FIGURE 1
The flowchart of study screen and selection.

2.7. Statistical analysis

This clinical study is a single-center and prospective cohort study, whose primary endpoint was to detect a difference of systolic and diastolic BP between the telemedicine pharmaceutical intervention and usual care group. The baseline characteristics were compared between intervention and usual groups by *t*-tests and χ^2 tests/Fisher's precision probability test where appropriate. The comparison including the changes of SBP/DBP/heart rate (presented as means ± standard deviations) to baseline were analyzed by *t*-tests; the proportion of the target BP achievement, adherence with anti-hypertensive medications and medication related interventions were expressed with frequencies or percentages n (%) and compared with χ^2/Fisher's precision probability test. Kaplan–Meier curves were constructed to compare the duration for the first outpatient revisit and the time to first or recurrent cardio-cerebral vascular events.

A two-sided *P*-value was used to determine significance (threshold, $P < 0.05$). Statistical analysis was performed using SPSS (IBM SPSS Statistics 22.0) and Prism 5 (GrandPad Software). A *P*-value of 0.05 was considered to be the threshold for statistical significance.

3. Results

3.1. Baseline characteristics of study population

After screening for eligibility, a total of 390 patients consented to participate in this study. The whole recruitment progress of the study and the exclusive reasons were presented in Figure 1. 14 patients declined to take part in this study and gave their reasons for the lack of mercury sphygmomanometers and no access to smartphone or WeChat. The remaining 376 (96.4%) participants were divided into intervention ($N = 185$) and usual care group ($N = 191$). During the whole recruitment period, 12 in the intervention and 12 in the usual care group were subsequently withdrawn due to the withdraw and follow-up failure of the study. The adherence rate to intervention and usual care was 93.5 and 93.7% throughout whole study.

There were 173 subjects in the intervention group and 179 subjects in the UC group at the end of the follow-up periods. No notable differences between the group were found regarding baseline demographics, clinical characteristics and laboratory indicators of the population (Table 1). Most participants were male (62.2%) with a mean age of 68.10 ± 8.82 years. The mean baseline clinical BP for intervention group and usual care group were 151.47/88.45 and 150.77/88.83 mmHg respectively.

3.2. Effect of intervention (compared with UC) on BP and HR

Overall, greater BP lowering effects were observed after intervention from the numerical BP results. As for SBP, intervention group showed differences of −7.0 (−10.0 to −2.0) mmHg at Month 3 and −6.0 (−13.0 to −2.5) mmHg at Month 6 compared to UC group. The absolute reduction in DBP was also larger with intervention: −3.0 (−4.0 to −2.0) and −7.0 (−11.0 to −5.5) mmHg at Month 3 and 6, respectively, as shown in Figure 2. Besides, intervention showed difference on HR decrease with −5.0 (−7.0 to −1.5) and −4.0 (−9.0 to −3.0) beats/min as compared to UC group at Month 3 and 6, respectively.

TABLE 1 Baseline demographic and clinical factors between intervention and UC groups.

	Intervention ($N = 173$)	UC ($N = 179$)	*P*-value
Baseline characteristics			
Gender, male; *n* (%)	102 (59.0%)	117 (65.4%)	0.215
Age, years; mean (SD)	68.28 ± 8.50	67.93 ± 9.15	0.715
BMI, kg/m^2; mean (SD)	24.77 ± 3.21	24.25 ± 3.15	0.124
Smoking (%)	26 (15.0%)	29 (16.2%)	0.762
Alcohol (%)	17 (9.8%)	19 (10.6%)	0.807
SBP, mmHg; mean (SD)	151.47 ± 7.27	150.77 ± 8.16	0.394
DBP, mmHg; mean (SD)	88.45 ± 3.60	88.83 ± 4.36	0.365
Heart rate; mean (SD)	76.40 ± 8.96	76.51 ± 10.36	0.917
Comorbidities			
Hyperlipidemia (%)	60 (34.7%)	52 (29.1%)	0.257
Diabetes (%)	56 (32.4%)	48 (26.8%)	0.254
Atrial fibrillation (%)	7 (4.0%)	8 (4.5%)	0.844
CHD, (%)	16 (9.2%)	17 (9.5%)	0.936
Liver dysfunction, (%)	15 (8.7%)	15 (8.4%)	0.922
Heart failure, (%)	37 (21.4%)	36 (20.1%)	0.768
stroke/TIA, (%)	30 (17.3%)	37 (20.7%)	0.426
PAD, (%)	6 (3.5%)	6 (3.4%)	0.952
Laboratory tests			
ALT, IU/L; median [IQR]	20.00 [15.00–31.00]	24.00 [17.00–30.00]	0.603
Hb, g/L; mean (SD)	136.08 ± 16.56	134.99 ± 19.03	0.558
PLT, $*10^9$/L; mean (SD)	191.34 ± 55.45	185.85 ± 55.76	0.355
eGFR, mL/min/1.73 m^2; median [IQR]	77.00 [68.00–86.00]	76.00 [67.00–83.00]	0.830
LDL-C, mmol/L; mean (SD)	2.20 ± 0.83	2.30 ± 0.88	0.269
HbA1c; mean (SD)	6.10 ± 0.84	5.99 ± 0.98	0.245
APTT, s; mean (SD)	31.38 ± 6.10	30.82 ± 5.31	0.353
PT, s; mean (SD)	12.86 ± 2.36	12.67 ± 2.58	0.460
TT, s; median [IQR]	18.00 [17.25–18.95]	17.60 [17.00–18.50]	0.925
FIB, mg/dL; median [IQR]	264.00 [228.25–310.25]	275.00 [225.50–319.75]	0.941
D-D, mg/L; median [IQR]	0.19 [0.06–0.44]	0.23 [0.19–0.31]	0.318
INR; median [IQR]	0.98 [0.93–1.10]	0.99 [0.96–1.06]	0.260
CK-MB, U/L; median [IQR]	13.44 ± 4.30	13.35 ± 4.68	0.855
NT-proBNP, pg/ml; median [IQR]	372.30 [178.45–1000.60]	337.70 [101.40–885.90]	0.732
Concomitant medication			
CCB, (%)	92 (53.2%)	91 (50.8%)	0.660
ACEI, (%)	67 (38.7%)	68 (38.0%)	0.887

(Continued)

TABLE 1 (Continued)

	Intervention ($N = 173$)	UC ($N = 179$)	P-value
ARB, (%)	47 (27.2%)	48 (26.8%)	0.941
β-receptor antagonists, (%)	64 (37.0%)	71 (39.7%)	0.606
Diuretics, (%)	36 (20.8%)	28 (15.6%)	0.209
Oral antiplatelet, (%)	54 (31.2%)	50 (27.9%)	0.500
Lipid-lowering agent, (%)	93 (53.8%)	94 (52.5%)	0.815
Anti-arrythmic agent, (%)	15 (8.7%)	14 (7.8%)	0.772
PPI, (%)	18 (10.4%)	18 (10.1%)	0.914

Quantitative variables are shown as mean and standard deviation (SD). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; CHD, coronary heart disease; PAD, peripheral artery disease; ALT, alanine aminotransferase; Hb, hemoglobin; PLT, platelet count; eGFR, estimated glomerular filtration rate, calculated with the CKD-EPI equation; LDL-C, low-density lipoprotein cholesterol; HbA1c, glycosylated hemoglobin type A1c; APTT, activated partial thromboplastin time; PT, prothrombin time; TT, thrombin time; FIB, fibrinogen; D–D, d–dimer; INR, international normalized ratio; CK-MB, creatine kinase-MB; NT-proBNP, N-terminal pro-B-type natriuretic peptide; CCB, calcium channel blocker; ACEI, angiotension converting enzyme inhibitors; ARB, angiotensin receptor blocker; PPI, proton pump inhibitors.

Specifically, there was significant difference in the proportion of subjects who achieved target BP during the 3- and 6-month follow-ups. As shown in Figure 2C, 65.3 ($n = 113/173$) and 44.7% ($n = 80/173$) of patients achieved BP goals after receiving intervention and UC, respectively at month 3 (OR = 1.461, 95% CI = 1.202–1.778, $P < 0.001$), while the proportion of patients achieving target BP for intervention and UC group was 89.6 ($n = 155$) and 78.8% ($n = 141$) (OR = 1.137, 95% CI = 1.038–1.246, $P = 0.006$).

3.3. Adherence with anti-hypertensive medications

Throughout the treatment period, 142 (82.1%) persons in intervention group and 127 (71.0%) persons in usual care group reported full adherence ($P = 0.014$) (Figure 3A). Overall, medication adherence dropped as the number of prescribed medications increased (Figure 3B). Participants exhibited the highest compliance rates to antiarrhythmic agents of over 95%, while the lowest rate of below 75% was reported with PPI (Figure 3C). The most common causes of non-adherence were reported as having script but not refilling (37.4%) and forgetting (32.5%) (Figure 3D).

3.4. Medication related interventions

During the follow-up period, the mean number of active outpatient revisits attended by participants was 2.22 ± 1.09 and 3.30 ± 1.37 in the intervention and usual care groups, respectively ($P < 0.0001$). In addition to the regular check-ups, 299 interventions were provided according to patient questioning online or at the clinic. A comparison of medication therapy interventions between non- and pharmacist intervention groups was shown in Supplementary Figure 2. Compared to usual care group, pharmacist-conducted patients had more concerns about enhancing medication adherence (19.1 vs. 7.3%, $P = 0.001$). Participants who received usual care were more likely to raise questions on drug-drug interaction, side effects and discontinuation of therapy (21.8 vs. 12.7%, $P = 0.025$; 11.2 vs. 5.2%, $P = 0.042$; 11.7 vs. 3.5%, $P = 0.004$, respectively).

3.5. Clinical outcomes assessments

There were 8 (4.5%) and 5 (2.9%) participants experiencing events as a composite of non-fatal stroke, non-fatal myocardial infarction and cardiovascular death in intervention and UC groups, respectively. As illustrated in Figure 4A, cumulative Kaplan-Meier results demonstrated that patients who belonged to UC group were more likely to experience major adverse cardiovascular events, but the difference was not statistically significant ($P = 0.427$, OR = 1.566, 95%CI: 0.528–4.646). Among all the events, 5 patients in the UC group and 4 patients in the intervention group developed non-fatal stroke (Figure 4B, $P = 0.773$, OR = 1.213, 95%CI: 0.328–4.482). With regards to non-fatal myocadiac infarction, cumulative incidence was similar between UC ($n = 2$) and intervention ($n = 1$) groups ($P = 0.581$, OR = 1.940, 95%CI: 0.202–18.660), as demonstrated in Figure 4C. During the study period, one subject from UC group died due to cardiovascular causes (Figure 4D).

4. Discussion

This observational study elucidated the advantage of pharmacist-led telemedicine on antihypertensive pharmacotherapy during the COVID-19 Pandemic. Our findings highlighted that telemedicine could significantly reduce

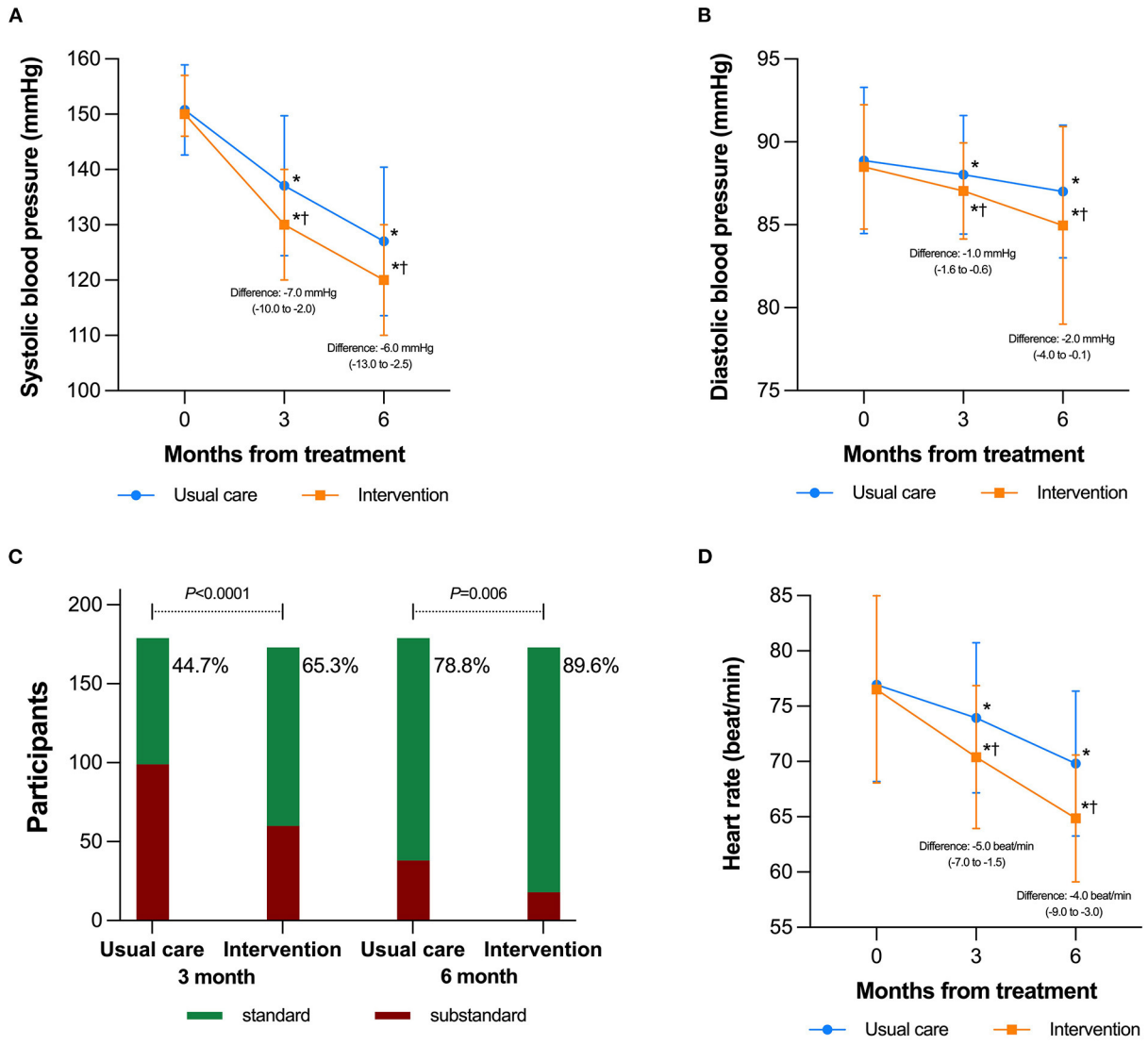


FIGURE 2
Blood pressure changes during the study period by group. **(A)** Mean values and standard deviations in systolic blood pressure (mmHg) among all participants; **(B)** Mean values and standard deviations in diastolic blood pressure (mmHg) among all participants; **(C)** Percentage of subjects achieving treatment goal; **(D)** Changes in heart rate, which were presented as mean and standard deviations (error bar). *$P < 0.05$ within group vs. baseline value; $^{\dagger}P < 0.05$ compared the intervention group with the usual care group.

BP and improved medication adherence at the established endpoint of 6 months. Pharmacist-led telemedicine may prove effective in reducing cardiovascular events in terms of stroke, non-fatal myocardial infarction and cardiovascular death as compared to regular outpatients with a longer duration of intervention.

Providing primary healthcare during COVID-19 pandemic has brought a huge challenge mainly due to inadequate availability of personal protective equipment and high risks of infection from patients and medical practitioners for healthcare service providers (17–19). Telemedicine minimizes in-person communication and reducing face-to-face contact among clinicians and patients (20), which was first officially recommended in 2019 Chinese guidelines for the management of hypertension in the elderly and compliant with the Program for a Healthy China 2030 (21, 22). Currently, pharmacists are playing important role in patient-centered model for hypertension care which required a higher demand on interprofessional collaboration (23). Pharmacists might expand their medication interventions and provide remote services for patients by means of telemedicine. In this study, pharmacist-led telemedicine reduced the patients' offline healthcare

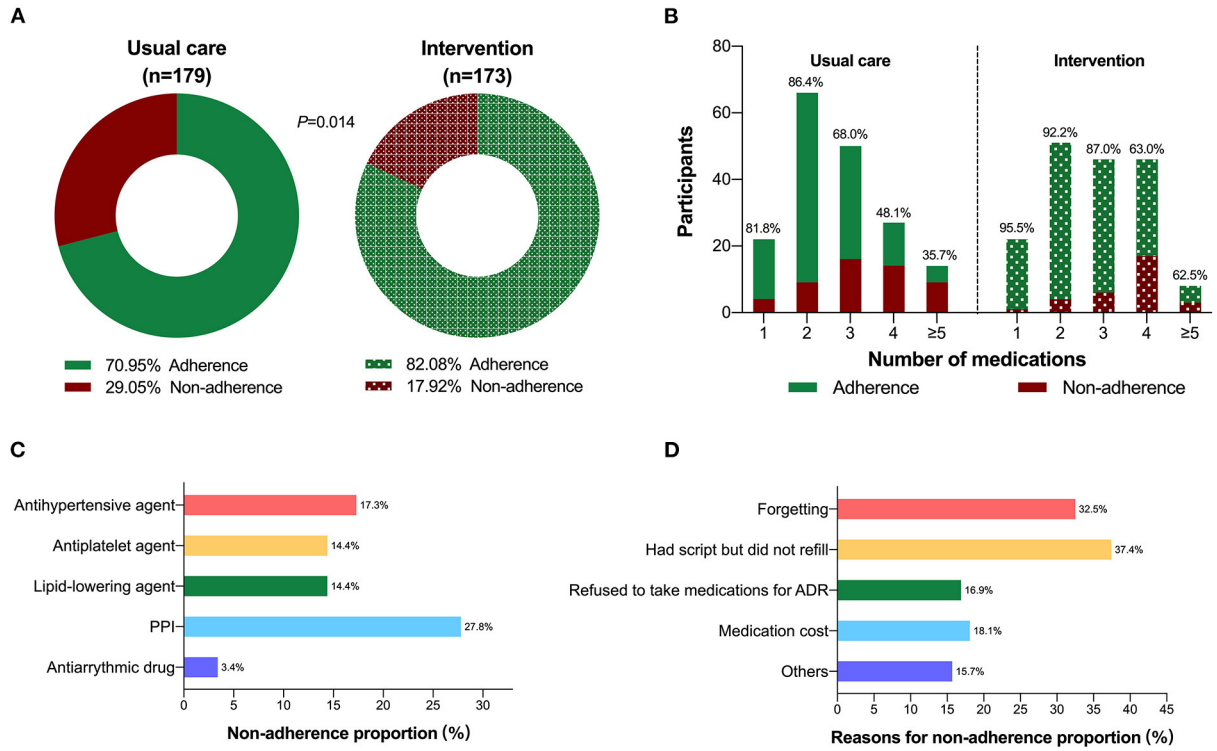


FIGURE 3
Rates of total adherence stratified by group. **(A)** Number of medication prescribed **(B)**; **(C)** Drug nonadherence by different medication classes in all cohort; **(D)** Reasons for non-adherence among non-adherent patients.

consultations, leading to a lower risk of Covid-19 exposure, as well as the reduction of time and cost.

Our study showed that the BP reduction levels following pharmaceutical telemedicine intervention was larger than that in UC groups, either in 3 or 6 months. Telemedicine technology is widely available, inexpensive and widely accepted by doctors and patients (24). A randomized controlled trial about Home and Online Management and Evaluation of Blood Pressure demonstrated the digital intervention resulted in better BP control than UC (12). The improvement could be achieved by overcoming barriers to medication adherence in the management of hypertension. As for most cases, these interventions studies were team-based managements with pharmacist-led care (25, 26). One meta-analysis illustrated an average 10/4 mmHg decrease of SBP/DBP, and an absolute proportion within target BP improved by 20% after receiving telemedicine care (27). Another recent study reported a well-controlled BP at baseline (15 mmHg lower at 12 months follow-ups with a significant difference than UC) (28). Based on the current evidence, the most common practice model of telepharmacy utilized outside licensed pharmacy was scheduled health care interventions *via* WeChat for management of cardiovascular disease, mostly hypertension and diabetes (29). A previous study documented a promotion of adherence to BP monitoring and telemedicine management visits after telepharmacy intervention, thus revealing that this approach is feasible and effective (20). Telemedicine intervention by pharmacist can effectively improve the self-efficacy and medication compliance of patients with hypertension, the drug treatment management can especially reflect the professional value of pharmacists and is of great value to the management of hypertension. In addition, it also plays an important role in helping specialist pharmacists provide convenient, patient-centered pharmacy services.

Based on our findings, the benefits of pharmacist-led intervention became apparent with increasing numbers of medications. Pharmacist intervention might improve patients' understanding on medications, especially for polypharmacy patients, leading to better adherence (30). Our study also found patients exhibited worst adherence in taking PPIs, probably related with neglect and insufficient knowledge, indicating the need of more instruction from pharmacist in this aspect in the future. When regarding the reasons for non-adherence, patients not refilling medications despite having prescriptions and forgetting to take medications occupied more than half proportion, followed by fear of drug induced ADR, similar with

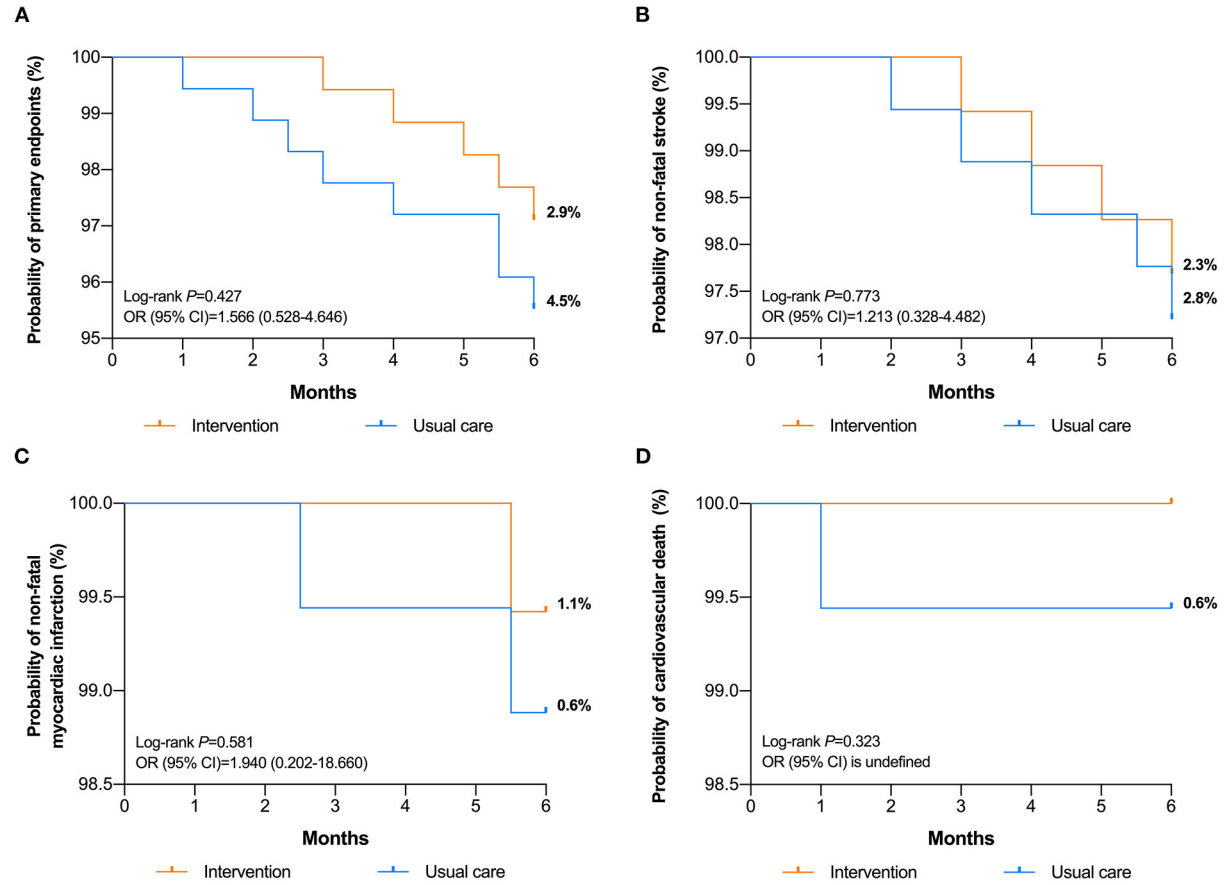


FIGURE 4
Kaplan-Meier cumulative curves for **(A)** composite of events, **(B)** non-fatal stroke, **(C)** non-fatal myocadiac infarction, and **(D)** cardiovascular death between intervention and UC groups.

one published study (31). Thus, pharmacist would better design a remote reminder tool to avoid omitting dose and provide guidance on precautions to cope with ADRs. Moreover, another retrospective study showed the initial pharmacist intervention could be considered most important, as patients completing the initial intervention were less likely to discontinue follow-up and more likely to be adherent (32).

Our study provided additional benefits of the pharmacist intervention. It seemed that pharmacist-conducted patients were more willing to enhance medication adherence (19.1 vs. 7.3%, $P = 0.001$). These positive findings could be replicated in the previous study which demonstrated that pharmacist-led medication counseling could achieve better optimal BP control and enhance compliance (33, 34). Although, another study had the opposite conclusion that there were no significant differences in medication compliance by pharmacist counseling, which may be attributed to the selection patients with low medication adherence in the study (35). Besides, we provided additional results associated with medication related interventions. Participants who received usual care were more likely to raise questions on drug-drug interaction, side effects and discontinuation of therapy (21.8 vs. 12.7%, $P = 0.025$; 11.2 vs. 5.2%, $P = 0.042$; 11.7 vs. 3.5%, $P = 0.004$, respectively). These results were partly supported by a previous pharmacist-led drug counseling study (36), which have evaluated 70–80% of patients were concerned about the solutions of adverse reactions and 50–60% focused on drug interactions. In a word, pharmacist-led interventions have the potential to magnify the health benefits of medications.

Although the incidence of major adverse cardiovascular events pointed in the direction in favor of pharmacists' intervention, no significant differences were found. Previous meta-analysis finds that good compliance to cardiovascular medications decrease 20% risk of cardiovascular events (37). Achievement of long-term BP target value also suggests better outcomes (38). The effects on adherence and BP targets reached in intervention group were not translated into remarkable decrease of cardiovascular events. The main reasons for the non-significant results were attributed to the small sample sizes and short follow-up time. Further large,

long-term follow-up trials are required to evaluate the effect on composite endpoints.

Our study had some limitations. Firstly, this was a prospective analysis with relatively small sample size and further randomized controlled trials are needed to confirm the conclusions. Secondly, the adherence was based on self-report in this study, remaining a degree of subjectivity. Biological measurement and a validated daily reporting system considering medication refill rate are the best ways to measure medication adherence, which were not available at this time. Thirdly, this study was not placebo-controlled, therefore the findings on symptomatic status are subjective to a placebo effect. Finally, the follow-up was too short to detect long-term differences in clinical cardiovascular adverse outcomes.

5. Conclusion

In summary, pharmacist-led telemedicine for hypertension management had led to better BP control and medication adherence improvement than UC during COVID-19 epidemic, resulting in a reduction of overall adverse cardiovascular events occurrence. The further work is to realize clinical benefits for chronic illness care with this implementation strategy during COVID-19 epidemic.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Zhongshan Hospital. The patients/participants provided their written informed consent to participate in this study.

Author contributions

XiaoyeL and JH: writing, original draft preparation, and investigation and data curation. YY: investigation and formal analysis and software. CZ: methodology. ZW: software. XiaoyuL: conceptualization. QL: supervision and writing—reviewing and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1091484/full#supplementary-material

References

1. Wahlster S, Sharma M, Lewis AK, Patel PV, Hartog CS, Jannotta G, et al. The coronavirus disease 2019 pandemic's effect on critical care resources and health-care providers: a global survey. *Chest.* (2021) 159:619–33. doi: 10.1016/j.chest.2020.09.070

2. Nalbandian A, Sehgal K, Gupta A, Madhavan MV, McGroder C, Stevens JS, et al. Post-acute COVID-19 syndrome. *Nat Med.* (2021) 27:601–15. doi: 10.1038/s41591-021-01283-z

3. Greenhalgh T, Koh GCH, Car J. Covid-19: a remote assessment in primary care. *BMJ.* (2020) 368:m1182. doi: 10.1136/bmj.m1182

4. Wang L, Peng W, Zhao Z, Zhang M, Shi Z, Song Z, et al. Prevalence and treatment of diabetes in China, 2013–2018. *JAMA.* (2021) 326:2498–506. doi: 10.1001/jama.2021.22208

5. Burnier M, Egan BM. Adherence in hypertension. *Circ Res.* (2019) 124:1124–40. doi: 10.1161/CIRCRESAHA.118.313220

6. Omboni S, McManus RJ, Bosworth HB, Chappell LC, Green BB, Kario K, et al. Evidence and recommendations on the use of telemedicine for the management of arterial hypertension: an international expert position paper. *Hypertension.* (2020) 76:1368–83. doi: 10.1161/HYPERTENSIONAHA.120.15873

7. Wang JG, Li Y, Chia YC, Cheng HM, Minh HV, Siddique S, et al. Telemedicine in the management of hypertension: evolving technological platforms for blood pressure telemonitoring. *J Clin Hypertens.* (2021) 23:435–9. doi: 10.1111/jch.14194

8. Segal EM, Alwan L, Pitney C, Taketa C, Indorf A, Held L, et al. Establishing clinical pharmacist telehealth services during the COVID-19 pandemic. *Am J Health Syst Pharm.* (2020) 77:1403–8. doi: 10.1093/ajhp/zxaa184

9. Li H, Zheng S, Liu F, Liu W, Zhao R. Fighting against COVID-19: Innovative strategies for clinical pharmacists. *Res Soc Adm Pharm.* (2021) 17:1813–8. doi: 10.1016/j.sapharm.2020.04.003

10. Li X, Zuo C, Lu W, Zou Y, Xu Q, Li X, et al. Evaluation of remote pharmacist-led outpatient service for geriatric patients on rivaroxaban for nonvalvular atrial fibrillation during the COVID-19 pandemic. *Front Pharmacol.* (2020) 11:1275. doi: 10.3389/fphar.2020.01275

11. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American college of cardiology/American heart association task force on clinical practice guidelines. *Hypertension.* (2018) 71:e13–e115. doi: 10.1161/HYP.0000000000000065

12. McManus RJ, Little P, Stuart B, Morton K, Raftery J, Kelly J, et al. Home and online management and evaluation of blood pressure (HOME BP) using a digital intervention in poorly controlled hypertension: randomised controlled trial. *BMJ.* (2021) 372:m4858. doi: 10.1136/bmj.m4858

13. Kulkarni SP, Alexander KP, Lytle B, Heiss G, Peterson ED. Long-term adherence with cardiovascular drug regimens. *Am Heart J.* (2006) 151:185–91. doi: 10.1016/j.ahj.2005.02.038

14. Grymonpre RE, Didur CD, Montgomery PR, Sitar DS. Pill count, self-report, and pharmacy claims data to measure medication adherence in the elderly. *Ann Pharmacother.* (1998) 32:749–54. doi: 10.1345/aph.17423

15. Simpson RJ, Mendys P. The effects of adherence and persistence on clinical outcomes in patients treated with statins: a systematic review. *J Clin Lipidol.* (2010) 4:462–71. doi: 10.1016/j.jacl.2010.08.026

16. Rogers MA, Buchan DA, Small D, Stewart CM, Krenzer BE. Telemedicine improves diagnosis of essential hypertension compared with usual care. *J Telemed Telecare.* (2002) 8:344–9. doi: 10.1258/135763302320939239

17. Monaghesh E, Hajizadeh A. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health.* (2020) 20:1193. doi: 10.1186/s12889-020-09301-4

18. Golinelli D, Boetto E, Carullo G, Nuzzolese AG, Landini MP, Fantini MP. Adoption of digital technologies in health care during the COVID-19 pandemic: systematic review of early scientific literature. *J Med Internet Res.* (2020) 22:e22280. doi: 10.2196/22280

19. Hau YS, Kim JK, Hur J, Chang MC. How about actively using telemedicine during the COVID-19 pandemic? *J Med Syst.* (2020) 44:108. doi: 10.1007/s10916-020-01580-z

20. Bokolo Anthony J. Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic. *J Med Syst.* (2020) 44:132. doi: 10.1007/s10916-020-01596-5

21. Hua Q, Fan L, Li J. 2019 Chinese guideline for the management of hypertension in the elderly. *J Geriat Cardiol JGC.* (2019) 16:67. doi: 10.11909/j.issn.1671-5411.2019.02.001

22. Tan X, Liu X, Shao H. Healthy China 2030: a vision for health care. *Value Health Reg Issues.* (2017) 12:112–4. doi: 10.1016/j.vhri.2017.04.001

23. Omboni S, Sala E. The pharmacist and the management of arterial hypertension: the role of blood pressure monitoring and telemonitoring. *Exp Rev Cardiovasc Ther.* (2015) 13:209–21. doi: 10.1586/14779072.2015.1001368

24. Sharma A, Harrington RA, McClellan MB, Turakhia MP, Eapen ZJ, Steinhubl S, et al. Using digital health technology to better generate evidence and deliver evidence-based care. *J Am Coll Cardiol.* (2018) 71:2680–90. doi: 10.1016/j.jacc.2018.03.523

25. Al Hamarneh YN, Houle SK, Padwal R, Tsuyuki RT. Hypertension Canada's 2016 Canadian hypertension education program guidelines for pharmacists: an update. *Can Pharm J.* (2016) 149:337–44. doi: 10.1177/1715163516671747

26. Omboni S, Tenti M. Telepharmacy for the management of cardiovascular patients in the community. *Trends Cardiovasc Med.* (2019) 29:109–17. doi: 10.1016/j.tcm.2018.07.002

27. Walsh JM, McDonald KM, Shojania KG, Sundaram V, Nayak S, Lewis R, et al. Quality improvement strategies for hypertension management: a systematic review. *Med Care.* (2006) 44:646–57. doi: 10.1097/01.mlr.0000220260.30768.32

28. Margolis KL, Asche SE, Bergdall AR, Dehmer SP, Groen SE, Kadrmas HM, et al. Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control: a cluster randomized clinical trial. *JAMA.* (2013) 310:46–56. doi: 10.1001/jama.2013.6549

29. Niznik JD, He H, Kane-Gill SL. Impact of clinical pharmacist services delivered *via* telemedicine in the outpatient or ambulatory care setting: a systematic review. *Res Soci Adm Pharm.* (2018) 14:707–17. doi: 10.1016/j.sapharm.2017.10.011

30. Delage C, Lelong H, Brion F, Blacher J. Effect of a pharmacist-led educational intervention on clinical outcomes: a randomised controlled study in patients with hypertension, type 2 diabetes and hypercholesterolaemia. *Eur J Hosp Pharm.* (2021) 28:e197–202. doi: 10.1136/ejhpharm-2021-002787

31. Pihau-Tulo ST, Parsons RW, Hughes JD. An evaluation of patients' adherence with hypoglycemic medications among Papua New Guineans with type 2 diabetes: influencing factors. *Patient Prefer Adherence.* (2014) 8:1229–37. doi: 10.2147/PPA.S66655

32. Abughosh S, Wang X, Serna O, Esse T, Mann A, Masilamani S, et al. motivational interviewing intervention by pharmacy students to improve medication adherence. *J Manag Care Spec Pharm.* (2017) 23:549–60. doi: 10.18553/jmcp.2017.23.5.549

33. Lee JK, Grace KA, Taylor AJ. Effect of a pharmacy care program on medication adherence and persistence, blood pressure, and low-density lipoprotein cholesterol: a randomized controlled trial. *JAMA.* (2006) 296:2563–71. doi: 10.1001/jama.296.21.joc60162

34. Vivian EM. Improving blood pressure control in a pharmacist-managed hypertension clinic. *Pharmacotherapy.* (2002) 22:1533–40. doi: 10.1592/phco.22.17.1533.34127

35. Wong MC, Liu KQ, Wang HH, Lee CL, Kwan MW, Lee KW, et al. Effectiveness of a pharmacist-led drug counseling on enhancing antihypertensive adherence and blood pressure control: a randomized controlled trial. *J Clin Pharmacol.* (2013) 53:753–61. doi: 10.1002/jcph.101

36. Fogg A, Staufenberg EF, Small I, Bhattacharya D. An exploratory study of primary care pharmacist-led epilepsy consultations. *Int J Pharm Pract.* (2012) 20:294–302. doi: 10.1111/j.2042-7174.2012.00207.x

37. Chowdhury R, Khan H, Heydon E, Shroufi A, Fahimi S, Moore C, et al. Adherence to cardiovascular therapy: a meta-analysis of prevalence and clinical consequences. *Eur Heart J.* (2013) 34:2940–8. doi: 10.1093/eurheartj/eht295

38. Hermida RC, Ayala DE, Mojón A, Fernández JR. Influence of circadian time of hypertension treatment on cardiovascular risk: results of the MAPEC study. *Chronobiol Int.* (2010) 27:1629–51. doi: 10.3109/07420528.2010.510230

frontiers | Frontiers in Public Health

TYPE Brief Research Report
PUBLISHED 05 January 2023
DOI 10.3389/fpubh.2022.1017946

OPEN ACCESS

EDITED BY
Ronald W. Berkowsky,
California State University, Channel Islands, United States

REVIEWED BY
Krushna Chandra Sahoo,
Regional Medical Research Center (ICMR), India
Elena Remillard,
Georgia Institute of Technology, United States

*CORRESPONDENCE
Di Xu
xudi@hust.edu.cn

†These authors have contributed equally to this work and share first authorship

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 12 August 2022
ACCEPTED 05 December 2022
PUBLISHED 05 January 2023

CITATION
Xu D, Ma S, Yan C and Zhao Z (2023) Technology challenges among deaf and hard of hearing elders in China during COVID-19 pandemic emergency isolation: A qualitative study.
Front. Public Health 10:1017946.
doi: 10.3389/fpubh.2022.1017946

Technology challenges among deaf and hard of hearing elders in China during COVID-19 pandemic emergency isolation: A qualitative study

Di Xu*†, Shiwen Ma†, Chu Yan and Ziqing Zhao

School of Journalism and Information Communication, Huazhong University of Science and Technology, Wuhan, China

Digital technology can be an effective tool to facilitate emergency assistance in a pandemic, but many deaf and hard-of-hearing elders may experience challenges in using and adopting these technologies. In the context of the second wave of the COVID-19 outbreak, this study employs a qualitative research method based on in-depth interviews to explore technology challenges among deaf and hard-of-hearing elders in China. The results showed that this group's technology challenges arose mainly from barriers to the mastery of digital technology tools, among which barriers to the use of smartphones, to the accessibility of online medical consultations, and to the presentation of health codes, were most noteworthy. For the informants, these barriers led to social isolation and technology avoidance. What's more, the expectation of individuals to adopt certain types of digital intelligence technologies can inadvertently create inequities for disadvantaged groups and exacerbate the "digital divide." This study highlights the need for emergency management systems to be inclusive of elders with hearing loss in times of public health crises, by providing effective technology support and training to facilitate individuals' access to services and to safeguard their health, interests, and livelihood.

KEYWORDS

deaf and hard of hearing elders, COVID-19, emergency isolation, technology challenges, Wuhan, qualitative study

Introduction

The COVID-19 outbreak caused/leads to devastating health damage in the aging population, among whom with hearing loss suffered exponential physical and psychological difficulties during the pandemic and are likely to experience extraordinary adjustment disorders as well (1–3). Despite the fact that countries are currently in a regular stage of prevention (4), the plight of older people (5), especially those with disabilities, still deserves continued attention and reflective discussion. Barriers to technology accessibility due to their own limitations and the inability of technology providers to match their demand will make this group face more challenges to survive in the digital society.

The isolating effect of the epidemic has accelerated the digital transformation of all sectors of society, with increased virtual "connectivity" and greater reliance on digital technology (6). The benefits of digital technology for the older deaf and hard of hearing communities have become a great adaptive challenge in terms of emergency assistance. There is a common and prominent psychological predisposition to technophobia among older people (7, 8), a condition that refers to anxiety and overall negative attitudes and emotional reactions to technology, its functioning or social implications (9). Many people with disabilities, especially the deaf and hard-of-hearing, are likely unable to use or normally use certain types of digital technology (due to their hearing loss), and even when using accessible digital technology are still limited by their own ability to read and write. In addition, studies from China have shown that congenitally deaf people have more difficulties interpreting written text than elders whose hearing is lost due to natural aging. The first language of this group is natural sign language, and their thinking patterns are not adapted to written expressions, and their reading and writing skills are relatively inadequate. In contrast, deaf elders with hearing loss caused by age-related degeneration also maintain the verbal thinking they acquired in earlier years and have an easier comprehension of written expressions (10). Moreover, the deaf and hard-of-hearing elders are likely to experience challenges using technology which can lead to unmet needs and limited access to services during an epidemic.

To some extent, the technology barriers and challenges experienced by deaf and hard-of-hearing elders have received attention in the context of epidemic prevention and control efforts in China. On October 20, 2020, the China Disabled Persons' Federation (CDPF), together with the Publicity Department of the CPC Central Committee, the Ministry of Civil Affairs and other departments and units, organized the "Guidelines for Social Support Services for Protection of Persons with Disabilities during Major Infectious Disease Epidemics" (11), which aims to standardize guidances, publicity instructions and social advocacy, to promote the regularization, standardization and normalization of public services related to protection of persons with disabilities under epidemics, to help persons with disabilities overcome the special difficulties and special risks brought about by epidemics, and to guarantee their equal rights to public health security. On November 24, 2020, China's State Council issued the Implementation Plan on Effectively Solving the Difficulties of Using Intelligent Technology for the Elders (12), focusing on the difficulties encountered by the elders in using intelligent technology, insisting on the parallelism between traditional service methods and intelligent service innovations, in order that the elders can better share the fruits of information development. In April 2021, China's Ministry of Industry and Information Technology issued the Notice on Improving the Implementation of Special Actions for the Aging and Accessibility Modification of Internet Applications (13), which aimed to accelerating the accessibility modification of Internet applications to help key beneficiary groups such as the elders and persons with disabilities to access and use the Internet and digital applications equally and conveniently, especially be means of issuing relevant norms and standards. China is continuously improving its social security mechanisms in order for "precise epidemic prevention and control" policies, and the government is increasingly concerned about the needs of elders with disabilities and has introduced a series of policies to promote the solutions to the issues. However, one point to be emphasized here is that the actual effectiveness of the above measures varies and depends on long-term and sustained effective outreach.

On January 23, 2020, Wuhan, the initial epicenter of the outbreak, was subjected to the most severe area-wide emergency isolation measures, which were implemented in a timely manner and achieved positive epidemic prevention results. Then in July of the following year, a new outbreak occurred in Wuhan and the government again implemented emergency isolation measures that had previously proven to be effective. Compared to the first round of outbreak prevention in 2020, the second round of outbreak prevention in 2021 utilized a large number of digital technologies to regulate the human flows by zones, in order to precisely control the spread of the outbreak. At that time, digital technology became a core survival tool, and learning to use and master it became a fundamental prerequisite for people's basic travel and access to part of essential living materials.

According to official statistics, there are 13,000 deaf and hard-of-hearing people in Wuhan (14), and more than half of the disabled population is elders (15). When both hearing impairment and aging status are combined, deaf and hard-of-hearing elders have suffered significant negative physical and psychological effects when an epidemic strikes, with some of them reporting frequent barriers to information communication and health care services (16–18). These barriers come not only from limited accessibility, but also from the technical and operational aspects that prevent access to outside help (19). This group is more vulnerable than the hearing elders, and their requests for help are often overlooked in disaster assistance. In light of this, the study explored technology challenges of deaf and hard of hearing older adults on during COVID-19 pandemic emergency isolation. This qualitative study aims to fill part of the evidence gap on the digital divide that may result from digital technologies and, as a result, technology barriers encounter by the deaf and hard-of-hearing elders since the outbreak of COVID-19, with the purpose of providing practical tactics and strategies for more vulnerable groups when they face greater risk of disparate exposure, vulnerability, and inequitable outcomes.

2. Methods

This study is a narrative research based on in-depth interviews through thematic content analysis that explores

technology challenges among deaf and hard-of-hearing elders during emergency isolation of an epidemic and their impact. An exploratory understanding of the impact of technology challenges on deaf and hard-of-hearing elders during public health emergencies was obtained through a narrative analysis of extreme situations during special times.

2.1. Respondent recruitment

The subjects of this study were older deaf and hard of hearing residents aged 60 years and older from eight urban areas in Wuhan, China. The third and fourth authors of the research team are able to communicate fluently with the deaf community through local natural sign language. The research team reopened an interview list that had been used in an emergency communication study survey of disability groups between October and November 2020. At that time, the research team obtained a preliminary list of voluntary participants from the Wuhan Deaf Association, and through purposive sampling, a total of 56 deaf and hard-of-hearing elders aged 60 years and older who lived alone during the emergency quarantine period of the Wuhan epidemic were selected. The number of people who were not willing to participate in the study through initial contact was 38, the number of people who could not be reached due to no answer or change of phone number was 7, and the number of people who volunteered to participate in the follow-up study was 11, resulting in an initial list of interviewees, which was then snowball sampled to expand the list. The final number of interviewees was 13. All 13 participants on this list were revisited at the initiation of this study and individually solicited for their willingness to participate in the study again. All respondents indicated that they were willing to be interviewed a second time and capable of participating in the entirety of this impact study on technology use for people with disabilities, and all participants provided informed consent.

Among them, 5 (38.5%) were female, 7 (53.8%) were deaf, and the participants' ages ranged from 61 to 72. The participants were mostly high school graduates or less ($n = 7$) and resided centrally in urban areas ($n = 11$). 1 has "congenital" type of hearing loss and 7 have "presbycusis" type of hearing loss. Digital technology use profile: (1) 2 do not have smartphones; (2) 6 could not access outbreak information *via* smartphones; (3) 3 could not present health codes *via* smartphones; and (4) 11 could not use online medical consultations (Table 1).

2.2. In-depth interviews and data analysis

The research team followed semi-structured interview guidelines, starting the interview with an unstructured open-ended question ("Think back to a time when you used digital technology tools/platforms/software during the COVID-19 emergency isolation and tell us how you felt about it"), followed by an in-depth discussion on more specific questions one by one. With the respondents' consent, the research team used audio and video recording equipment to record all interviews, including 13 respondents' self-reported identities. Seven face-to-face interviews were conducted between May and July 2022, with each interview lasting about 2 h. Most of the interviewees used a predominantly written conversation to express their views, and four of them preferred to use natural sign language to communicate. The research team invited volunteers from the Sign Language Association, who were certified as National Professional Standard Sign Language Interpreters, to assist the research team with sign language communication, interview texts, and sign language interpretation at the interview sites. An associate professor from Yunnan Vocational College of Special Education, whose research specialty is Chinese sign language, provided guidance throughout this study's sign language transcription; a chief physician from the Department of Otolaryngology at the Maternal and Child Hospital of Hubei Province, Tongji Medical College, Huazhong University of Science and Technology, provided the medical specialty advice to the research team. The third and fourth authors in the research team, who were proficient in the sign language, were responsible for cross-checking all non-verbal information from the interviewees in the original audio and video recordings after all interviews were completed. All organized source materials were sent back to the interviewees for checking and confirmation. Following the methodological guidelines (20), this study used the thematic content analysis method to complete the data analysis and collation.

3. Results

Through the data analysis of in-depth interviews with 13 respondents, the impact of technology challenges on deaf and hard-of-hearing older adults in China during the emergency isolation of the epidemic was divided into two dimensions: challenges and consequences. This group's technology challenges stems from barriers to mastery of digital technology tools, specifically barriers to smartphone use, barriers to accessibility of online medical consultations, and barriers to presentation of health code. The consequences of widespread technology challenges in this group are mainly in the form of social isolation and social isolation due to the aforementioned predicament of digital technology usage, which in turn reinforces technology barriers (Table 2).

3.1. Barriers to smartphone use and internet use

In tackling the epidemic, China has accelerated its digital development process, with intelligent services and Internet technologies flourishing. However, the elders has been slower

TABLE 1 Basic characteristics of respondents.

ID	Sex	Age	Deaf/Hard-of-Hearing	Education	Residence	Causes of hearing loss (congenital/presbycusis/others)	Have a smartphone (Y/N)	Ability to access outbreak information *via* smartphone (Y/N)	Ability to present health code *via* smartphone (Y/N)	Ever used an online medical consultation (Y/N)
1	Male	63	Deaf	Undergraduate	Qingshan	Others	Y	Y	Y	N
2	Male	67	Hard-of-Hearing	Undergraduate	Jianghan	Presbycusis	Y	Y	Y	N
3	Female	76	Deaf	Elementary school	Hanyang	Presbycusis	N	N	Y	N
4	Male	69	Hard-of-Hearing	Undergraduate	Hanyang	Presbycusis	Y	N	Y	N
5	Male	66	Hard-of-Hearing	Middle school	Qiaokou	Others	Y	N	N	Y
6	Female	65	Deaf	Elementary school	Jiangan	Congenital	Y	N	Y	N
7	Female	71	Deaf	Elementary school	Jianghan	Presbycusis	N	N	N	Y
8	Male	72	Deaf	High school	Hannan	Presbycusis	Y	Y	Y	N
9	Female	70	Deaf	High school	Wuchang	Presbycusis	Y	N	Y	N
10	Female	61	Deaf	Postgraduate	Dongxihu	Presbycusis	Y	Y	Y	N
11	Male	62	Hard-of-Hearing	Junior college	Qiaokou	Others	Y	Y	N	N
12	Male	66	Hard-of-Hearing	High school	Wuchang	Others	Y	Y	Y	N
13	Male	62	Hard-of-Hearing	Postgraduate	Hanyang	Others	Y	Y	Y	N

10.3389/fpubh.2022.1017946

TABLE 2 Interview themes: Technology challenges and consequences.

Challenges	Consequences
Barriers to smart phone and internet use/technophobia	Difficulties using applications
	Limited access to external information
	Feeling stupid or embarrassed
	Social isolation
	Anxiety, depression, and other psychological problems
Barriers to the accessibility of online medical consultations	Inability to obtain appointment and/or meet with medical care team
Barriers to using Health Code program	Inability to enter/exit public places
	Unmet basic necessities of life

to adapt to the changes. According to the China Internet Development Statistics Report, Chinese Internet users aged 60 and above account for 12.2% of the overall population in 2021. More than half of the respondents said they could not use the Internet skillfully and had difficulties with smartphone applications, and about 15.3% said they did not have a smartphone (21). During the emergency isolation period of the epidemic, because they do not use smart phones or APPs, the deaf and hard-of-hearing elders have relatively limited access to external information. Most deaf and hard-of-hearing elders may not be able to keep abreast of and understand the development situation of the epidemic, and their knowledge of basic epidemic prevention is generally inferior, thus easily forming the psychological characteristics of herd panic or stubbornness and conceit, which is not conducive to the implementation of epidemic prevention measures.

In addition, family and friends are the main components of social relationships for the older deaf and hard-of-hearing group, and their ability to communicate with family or friends for emotional support, crisis assistance, and opportunities for social participation has a significant impact on the lives of this group. With limited opportunities for communication and expression, many elders with hearing loss may be lacking in emotional support and comfort. They are unable to talk about their worries and anxieties about the epidemic itself, and are more likely to develop negative emotions such as nervousness, fear, and loneliness. While digital technology might be a virtual bridge for hearing people to maintain interpersonal communication in times of social isolation, for deaf and hard-of-hearing elders, digital technology may not only be the cause of emotional impairment but also does not provide the functionality it should. In this way, it appears that digital technology becomes an enabler of reverse social isolation in the case of the deaf and hard-of-hearing elders.

> *"For information about the epidemic, I only watch sign language broadcasts on the TV news, I don't go online or look at the information on the social media apps on my phone" (Interviewee 4).*
>
> *"You all use things like WeChat (instant messaging software) to check epidemic information and emergency notifications and so on, but I don't very well use my phone. I'm talking about a smartphone, the operation, you know, it's too complicated. Obviously I don't go online either" (Interviewee 9).*
>
> *"Community workers are contacting everyone in the WeChat group, and I'm really not good at using WeChat, and I can't see too many outbreak notifications in the WeChat group" (Interviewee 6).*
>
> *"I couldn't go out during the quarantine period, so I couldn't see my friends or find anyone to talk to, and I had no entertainment to get rid of my loneliness. People said I could chat online, but how could I do that? I typed very slowly and my phone screen was very small, so I felt more and more depressed when I used it" (Interviewee 2).*
>
> *"I was placed in quarantine once. I was so worried when I was under quarantine observation. I prayed every day that the infection would never be confirmed. My children and I had video calls at first, once a day. Watching them through the electronic screen, I gestured and gestured while I was sad, and then I deliberately told them to stop talking every day and that I would call them back if something happened" (Interviewee 13).*

3.2. Barriers to the accessibility of online medical consultations

The epidemic prevention and control has promoted the development of "Internet+" services in China, such as online medical consultation and online procurement of daily necessities. For most deaf and hard-of-hearing elders, online medical consultation or online appointment procurement is problematic, and it is hardly possible for them to effectively obtain the basic necessities of life. Due to the requirements of epidemic prevention and control restricting daily visits from relatives and friends (Interviewee 8), the deaf and hard-of-hearing elders are unable to get help through acquaintances and rely only on community service staff for assistance in purchasing medicine and medical care, in which not only do they face obstacles in communication, but also may increase the psychological burden of the deaf and hard-of-hearing elders and induce anxiety, depression and other psychological problems.

> *"I have high blood pressure and I've been taking antihypertensive pills, and I ran out of antihypertensive pills when I was isolated and didn't know how to buy them. They*

all say buy medication online, buy medication online, I don't even have a smartphone, how can I buy them, the pills? I want to get permission from the neighborhood council to buy medicine out of the community, and I don't know what online process to go through, and which software to buy medicine on" (Interviewee 7).

"During the epidemic I could not buy medicine, hospitals and pharmacies were closed, and access to the community was prohibited, so I could not buy if I was worried about the problem. I was dying of anxiety, and eventually, a community sign language volunteer helped me by teaching me to consult and prescribe medication online" (Interviewee 5).

3.3. Barriers to using Health Code program

Health Code is one of the highlights of China's digital anti-epidemic efforts, bringing great convenience to the management of human flows and the prevention of epidemic transmission. The Health Code is a small program that can be installed on smartphone clients (e.g., WeChat or Alipay), which enables individuals to authenticate and fill in their health status and then use it as an electronic credential for local access. By comparing the data with cell phone roaming trajectory and close contacts, the platform can verify the information filled in by individuals independently and manage the information of administrators in an accurate and dynamic method. With the health code as the identification system, the healthy personnel could pass with the health code in the applicable area (22).

According to official data, 27.2% of Chinese non-Internet users consider that not having access to the Internet will bring various kinds of inconvenience to their lives, and the inability to enter and exit some public places without a "health code" ranks first. For many in the older deaf and hard-of-hearing communities, the lack of proficiency in mastering online skills brought about by aging and a series of derived barriers from hearing impairment make their digital survival a more serious challenge. Worthy of mention is the fact that deaf and hard-of-hearing elders may not be able to self-identify their health using the health code embedded in the smartphone Apps due to a number of factors such as not having a smartphone or not being proficient in using various smartphone functions, which makes their mobility somewhat limited. This important initiative to digitize China's fight against the epidemic has unexpectedly created some difficulties in the use of vulnerable groups.

"To be honest I don't know how to check the health code on my phone, I tried to learn and tried many times but I can't learn it, it makes me look stupid. I don't want to click on this App again. But you need a health code to go anywhere, and of course you can't go anywhere without a green code" (Interviewee 11).

"I didn't have the opportunity to get a good education as a child. It was thanks to my daughter's foresight that I was taught to set up my health code in advance when I was in isolation. I don't know what I would have done without my daughter's help" (Interviewee 6).

"Now you have to show a health code to go anywhere out of the community, and I don't have a smartphone and I don't know how to operate it. Thanks to the community, the staff helped me to issue a paper health certificate so I could go out" (Interviewee 3).

4. Discussion

Based on the China context, this study is framed at the intersection of disability studies and digital technology studies, exploring both the impact of technology challenges and barriers on deaf and hard-of-hearing elders from a technological perspective and insisting on observing the personal feelings and experiences of deaf and hard-of-hearing elders during the emergency isolation of the COVID-19 epidemic. To this end, this study highlights the subjective experience and subjectivity of people with disabilities and focuses on the digital technology use practices of deaf and hard-of-hearing elders during the epidemic through a qualitative research method of in-depth interviews. In particular, the smartphone is a tool for digital technology use, the health code is a carrier of digital technology form, and the online medical consultation is a technical expression of digital to good, one of the bright spots of digital anti-epidemic (23). Based on this, this study examines the effects of technology challenges during COVID-19 emergency isolation on the deaf and hard-of-hearing elders.

China has about 27.8 million people with hearing impairment, accounting for one-third of the total number of people with disabilities in the country, and is the country with the largest number of people with hearing disabilities in the world (14). China also has a very large base of older people, and an official statistic shows that as of December 2020, 11.2% of China's population was aged 60 and above, still the main group of non-Internet users. Due to their physiological hearing deficits, people with hearing loss are unable to use or function normally with certain types of digital technology, and most deaf and hard-of-hearing groups are native speakers of sign language and use written or spoken language as a second language, and are limited in their ability to read and write when using digital technology. Many elders have difficulties in accessing and using digital technology due to factors such as physical and mental decline. Beyond the experience of using technology, digital technology is a relatively new thing for hearing elders to master in a basic way through repeated use over time. Beyond the experience of using the technology, digital technology is

still a new thing for most hearing elders to master in a basic level through repeated use over time. Proficiency in digital technology is an almost impossible task for the vast majority of deaf and hard-of-hearing elders, especially for those with congenital hearing disabilities and low levels of education (Interviewee 6, Interviewee 3). When such digital technologies that could not be mastered through self-learning, or even certain types of digital technologies that are mandatory for emergency purposes, become artificial "digital rift," it could be concluded that the existence of such technologies inadvertently raises the difficulty for the disadvantaged groups to benefit from equitable rights and interests, and intensifies the formation of "digital divide."

During the COVID-19 epidemic, the isolation of living spaces limited face-to-face communication opportunities between the deaf and hard-of-hearing elders and their family and friends, and the deaf and hard-of-hearing elders were unable to use online communication devices and software proficiently due to their physical disadvantages and fear and anxiety about using technology (Interviewee 6), and communicated with their family and friends online less frequently or even disconnected (Interviewee 7, Interviewee 13). Findings suggest that the social ties of the deaf and hard-of-hearing elders during the special period, such as kinship, regional and occupational ties, were no longer tight, and social support networks were forced to be disrupted or even completely broken, which made it difficult for them to receive adequate emotional sustenance during the epidemic. In particular, older adults who are congenitally deaf grew up in an environment where the compulsory education system was not well established more than half a century ago, and their adolescence was characterized by the unavailability of a quality K12 education. The objective factors mentioned above lead to the weak reading and writing ability of these groups, and their later interpersonal communication is mostly confined to a small-scaled community, with limited social contact accomplished through natural sign language. In this case, the technological feedbacks support from their children somewhat alleviate the digital survival predicament (Interviewee 6), but due to the limitations of their education level, they will still be relegated to a branch of the population that is the slowest to complete the acquisition of digital skills during the particular period of interpersonal communication breakdowns. The home isolation during the epidemic caused the elders with hearing loss to move from a group-dependent living space to a highly individualized living space. The living space was compressed and the psychological space was divided, leaving the elders with hearing loss in a double isolation of living space and psychological space during the epidemic, and this isolation was reinforced by technology challenges. From another perspective, the social isolation during the epidemic was also an important cause of technology barriers among the deaf and hard-of-hearing elders. Social isolation cut off this group from learning to use digital technology, which made them more vulnerable to unadaptation to new digital technologies and unmet needs during the epidemic due to technology challenges and barriers. In this way, it appears that digital technology becomes an enabler of reverse social isolation in the case of the deaf and hard-of-hearing elders.

5. Limitations

There are potential limitations of this study to note. First, the sample size used in this study is small and the results obtained could not represent the full sense of the situation. Second, this study is conducted through retrospective interviews and the respondents may have some memory bias, which could have some impact on the results. Finally, the study did not include individuals over age 76, who are likely to experience greater barriers in technology adoption.

6. Conclusion

This study focuses on the impact of technology challenges on the deaf and hard-of-hearing elders during epidemic isolation, how they respond to intelligent technology use, and their perceptions of new digital technologies, and reveals the multifaceted phenomena and diverse experiences of coping technology barriers in this population. Digital technology can be an effective tool to facilitate the provision of emergency assistance in the event of a pandemic, but the deaf and hard-of-hearing elders is likely to experience technology challenges which can lead to serious consequences including limited access to healthcare and essential services as well as social isolation. This study not only attempts to reveal the real existence of this phenomenon, but also expects to shed light on social issues of concern through the presentation of the effects of technology barriers in this particular group. Moreover, this study emphasizes the necessity for emergency management systems to consider the wellbeing of the deaf and hard-of-hearing elders and to provide effective technical support and training to promote social support services for this group and to safeguard the health, interests, and livelihoods of individuals.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation

and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization, methodology, writing—review and editing, and supervision: DX. Investigation, data curation, and writing—original draft preparation: SM, CY, and ZZ. Project administration and funding acquisition: DX and CY. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by Research Project on Optimization of External Communication for deaf and hard-of-hearing People in Public Health Emergencies (Grants 202010487133 and XW2020068) and funded by Research Project on Public Opinion Research in Hubei Province. Also supported by the Fundamental Research Funds for the Central Universities (Grant 2022WKYXZX024) and Ministry of Education in China Project of Humanities and Social Sciences (Project No. 18YJC860038).

Acknowledgments

We would like to thank the ProSigner Public Interest Group, the Wuhan Deaf Association, and the Heartland Sign Language Association of Huazhong University of Science and Technology for their valuable contributions to data collection and in-depth interviews and for authorizing the use of internal documents and information. We would also like to thank Yanbo Wang, associate professor at Yunnan Special Education Vocational College, for providing sign language transcription guidance, and Liu Yang, chief physician at the Department of Otolaryngology, Maternal and Child Health Hospital of Hubei Province, affiliated with Tongji Medical College, Huazhong University of Science and Technology, for providing medical professional advice. The authors accept full responsibility for the content of this paper and any remaining errors or omissions.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. UN (2020). *COVID and Aging Brief. Secretary-General's Policy Brief: the Impact of COVID-19 on Older Persons*. Available online at: https://www.un.org/development/desa/ageing/news/2020/05/covid-19-older-persons/ (accessed May 1, 2020).

2. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet.* (2020) 395:497–506. doi: 10.1016/S0140-6736(20)30183-5

3. Ecio-Barbero M, Sáenz-Herrero M, Segarra R. Deafness and mental health: Clinical challenges during the COVID-19 pandemic. *Psychol Trauma Theory Res Pract Policy.* (2020) 12:S212–3. doi: 10.1037/tra0000729

4. WHO World Health Organization (2020). *WHO Director-General's statement on IHR Emergency Committee on Novel Coronavirus (2019-nCoV).* Available online at: https://www.who.int/zh/director-general/speeches/detail/who-director-general-s-statement-on-ihr-emergency-committee-on-novel-coronavirus-(2019-ncov) (accessed January 30, 2020).

5. Nicklett EJ, Ory MG, Johnson KE, Dwolatzky T. Editorial: COVID-19, aging, and public health. *Front Public Health.* (2022). 10:924591. doi: 10.3389/fpubh.2022.924591

6. Su T, Peng L. Technology and humanities: unthinking on digital survival under the COVID-19 Crisis—a summary of new media research in 2020. *Chin J J Commun.* (2021) 1:49–66. doi: 10.13495/j.cnki.cjjc.2021.01.003

7. Hou J, Wu Y, Harrell E. Reading on paper and screen among senior adults: cognitive map and technophobia. *Front Psychol.* (2017) 8:2225. doi: 10.3389/fpsyg.2017.02225

8. Nimrod G. Technophobia among older internet users. *Educ Gerontol.* (2018) 44:148–62. doi: 10.1080/03601277.2018.1428145

9. Rosen LD, Weil MM. Computers, classroom instruction, and the computerphobic university student. *Collegiate Microcomput.* (1990) 8:275–83.

10. Zhang M. Sign language and deaf culture. *J Suihua Univ.* (2014) 7:54–7. doi: 10.3969/j.issn.2095-0438.2014.07.012

11. China Disabled Persons' Federation. *Guidelines for Social Support Services for Protection of Persons with Disabilities during Major Infectious Disease Epidemics.* (2020). Available online at: https://www.cdpf.org.cn//zwgk/ggtz1/c2b8757d2b304f8fba1419bead4af39e.htm (accessed October 30, 2020).

12. General Office of the State Council of the People's Republic of China. *Implementation Plan on Effectively Solving the Difficulties of Using Intelligent Technology for the Elders.* (2020). Available online at: http://www.gov.cn/zhengce/content/2020-11/24/content_5563804.htm (accessed November 24, 2020).

13. Ministry of Industry and Information Technology of the People's Republic of China. *Notice on Improving the Implementation of Special Actions for the Ageing and Accessibility Modification of Internet Applications.* (2020). Available online at: http://www.gov.cn/zhengce/zhengceku/2021-04/13/content_5599225.htm (accessed April 13, 2020).

14. Zhang S, Chen Z. China's prevention policy for people with disabilities during the COVID-19 epidemic. *Disabil Soc.* (2021) 36:1368–72. doi: 10.1080/09687599.2021.1933913

15. Hubei Disability Monitoring Office. *Monitoring and Analysis Report on Sample Data of Persons with Disabilities in Hubei Province*. (2015). Available online at: http://www.hbdpf.org.cn/gk/tjsj/cjrzkjc/161927.htm (accessed July 23, 2015).

16. Park J. Unraveling the invisible but harmful impact of COVID-19 on deaf older adults and older adults with hearing loss. *J Gerontol Soc Work*. (2020) 63:598–601. doi: 10.1080/01634372.2020.1799282

17. Nicodemus BS, Whynot L, Kushalnagar P. Insights from US deaf patients: interpreters' presence and receptive skills matter in patient-centered communication care. Journal of Interpretation (2020) 28:5.

18. Xu D, Yan C, Zhao Z, Weng J, Ma S. External communication barriers among elderly deaf and hard of hearing people in china during the COVID-19 pandemic emergency isolation: a qualitative study. *Int J Environ Res Public Health*. (2021) 18:11519. doi: 10.3390/ijerph182111519

19. Wei F, Du M. *The Silent Fight Against the "Epidemic": Deaf People in the City of Wuhan*. (2020). Available online at: https://baijiahao.baidu.com/s?id=1658978250156626779&wfr=spider&for=pc (accessed February 19, 2020).

20. Marshall C, Rossman GB, Blanco GL. *Designing Qualitative Research*. London: SAGE Publications (2021).

21. China Internet Network Information Center. *The 48th Statistical Report on China's Internet Development*. (2021). Available online at: http://www.cnnic.cn/hlwfzyj/hlwxzbg/hlwtjbg/202109/P020210915523670981527.pdf (accessed September 15, 2021).

22. Shi C, Ma L. Collaborative governance, technological innovation and smart epidemic prevention: a case study based on "health codes". *Stud Party Government*. (2020) 4:107–16. doi: 10.13903/j.cnki.cn51-1575/d.20200421.001

23. Fang X, Yan F. Research on the challenges of digital social governance behind the "Health QR Code". *Frontiers*. (2020) 16:78–91. doi: 10.16619/j.cnki.rmltxsqy.2020.30.026

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 11 January 2023
DOI 10.3389/fpubh.2022.1076149

OPEN ACCESS

EDITED BY
Jin Han,
University of New South Wales, Australia

REVIEWED BY
Siti Anom Ahmad,
Putra Malaysia University, Malaysia
Jorge Cancela,
Roche, Switzerland

*CORRESPONDENCE
Julia Seinsche
julia.seinsche@hest.ethz.ch

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 21 October 2022
ACCEPTED 19 December 2022
PUBLISHED 11 January 2023

CITATION
Seinsche J, de Bruin ED, Carpinella I, Ferrarin M, Moza S, Rizzo F, Salatino C and Giannouli E (2023) Older adults' needs and requirements for a comprehensive exergame-based telerehabilitation system: A focus group study.
Front. Public Health 10:1076149.
doi: 10.3389/fpubh.2022.1076149

Older adults' needs and requirements for a comprehensive exergame-based telerehabilitation system: A focus group study

Julia Seinsche[1]*, Eling D. de Bruin[1,2], Ilaria Carpinella[3], Maurizio Ferrarin[3], Sotiria Moza[4], Francesco Rizzo[3], Claudia Salatino[3] and Eleftheria Giannouli[1,5]

[1]Department of Health Sciences and Technology, Institute of Human Movement Sciences and Sport, Movement Control and Learning, ETH Zurich, Zurich, Switzerland, [2]Department of Health, OST - Eastern Swiss University of Applied Sciences, St. Gallen, Switzerland, [3]IRCCS Fondazione Don Carlo Gnocchi Onlus, Milan, Italy, [4]Materia Group, Nicosia, Cyprus, [5]Division of Sports and Exercise Medicine, Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

Introduction: Telerehabilitation in older adults using information and communication technologies (ICTs) provides therapy, which is potentially equally effective as traditional rehabilitation, yet more accessible. This study aimed to analyze the needs and requirements of older adults (OA) and healthcare-professionals (HP) toward ICTs and telerehabilitation in general as well as toward a specific novel exergame-based telerehabilitation system (COCARE system, Dividat).

Materials and methods: The COCARE telerehabilitation system enables individual training based on exergames, as well as an assessment system and a digital centralized case management. Six focus groups with in total 34 participants were conducted. A mixed-methods approach was used comprising questionnaires and semi-structured interviews.

Results: Both OA and HP would engage to an exergame-based telerehabilitation program. Major motivating factors are the relevance of such a training for health and the entertainment component of exergames. Main requirements are simplification of the system, variety, a personalized training, a constantly available contact person, and comprehensive instructions for use. Besides, HP praised the system's motivational effect, but remained concerned about risk of falls and social isolation.

Conclusion: ICTs for telerehabilitation are accepted by OA and HP but should be adapted hardware- and software-wise to address OA' age-stemming vulnerabilities (e.g., risk of falls) and low ICT literacy.

KEYWORDS

older adult, exergame, motor-cognitive training, telerehabilitation, information and communication technologies, qualitative research, User-Centered Design

1. Introduction

Age-related declines in physical and cognitive functioning and the associated adverse outcomes such as a restricted mobility, cognitive impairment, falls and others ultimately result in a decrease of older adults' (OA) quality of life (1–3). Therefore, the term "active healthy aging" (AHA) increasingly gains in importance in policy frameworks worldwide. Due to a steep growth of the number of people aged 60 years and over (4), there is increased need for long-term care/treatment, which poses a financial challenge for health care systems due to a lack of resources (time and personnel) (1, 5–7). Consequently, conventional rehabilitation often cannot be provided for a sufficiently long period of time to ensure full recovery, which in turn, prevents geriatric patients from reaching their full recovery potential and/or lead an active and healthy lifestyle (8).

Advances in information and communication technologies (ICTs) can present alternative ways of providing health care services as a response to the increased demands on health services (9). As such, ICT-driven advances may play a key role for enabling active and healthy aging as they are being used to support health, wellbeing, and independence of OA (10, 11). These technological advancements enable – among others – telerehabilitation. Telerehabilitation can be defined as the provision of rehabilitation services over distance with the help of ICTs including technology-based training in the home environment as well as a digital centralized remote management (12). Both technology-based training at home environment and remote management proved to be especially important during the COVID-19 pandemic and the imposed social distancing measures prohibiting physical appointments to healthcare professionals (HP) (13). One training approach which efficiently lends itself to telerehabilitation in OA are so-called exergames, i.e., interactive digital games combining motor and cognitive exercises with video games targeting several physical and cognitive functions (14). Previous studies have shown that exergames lead to improvements in several physical functions such as lower extremity muscle strength (15), step reaction time (16), and balance (17–19) as well as in cognitive functions like short-term attentional span (20), processing speed (20, 21), and executive functioning (21, 22).

In the past 10 years, the EU and other funders have devoted billions for ICT-related Research and Development (R&D) projects for AHA. Yet, many products failed to get traction in the market. Thus, to the best of our knowledge, there is no validated, user-friendly geriatric telerehabilitation approach available for AHA that is based on exergames and able to cover the whole continuum of care. One reason for this is that health technology developers often failed to incorporate a user-centered development and design process while developing their products (6, 23). A User-Centered Design (UCD) is an iterative design process that involves all end-users (e.g., patients, caregivers, and healthcare professionals) motivating them to give their opinion about a tool. This involvement is supposed to take place throughout the whole development phases to continuously refine and reshape the design (6) and is, furthermore, recommended by the UK Medical Research Council (MCR) for complex interventions that target to improve health and healthcare (24, 25). So, by applying UCD, a tool's suitability for a specific target group can be assured and the tool's acceptance, functionality, usability and reliability (23) can be optimized. This is of special importance for technological devices designed for OA who express in general less willingness to adopt new technologies in their lives than younger generations. Charness and Boot (26) could show that this reluctance is mainly dependent on attitudes and abilities conflicting with new technologies which are not created for end-users with reduced physical, cognitive, and sensory functions. Therefore, it is crucial to take age-related changes in capabilities into consideration when developing ICTs and to measure requirements and needs of older users toward an ICT-based telerehabilitation system.

Based on the UCD approach, this study aimed to explore the general needs, requirements, and potential barriers of primary (older adults - OA) and secondary (healthcare-professionals - HP) end-users regarding ICTs and telerehabilitation in general, as well specifically regarding a novel exergame-based telerehabilitation system.

2. Materials and methods

2.1. Materials

The study was based on the COCARE-system (Dividat, Schindellegi, Switzerland) which provides an exemplary ICT-based telerehabilitation tool for home-based, individual training and therapy as well as a digital centralized case management. It comprises three coupled systems (Figure 1) to enable therapists to provide continuous rehabilitation, remote monitoring, and coaching throughout the whole continuum of care:

(1) Technological hardware devices for motor-cognitive training in clinics (Senso) and at home (Senso Flex)
(2) An assessment system for the analysis of physical and cognitive functioning and training recommendations
(3) A digital web-based management system and rehabilitation cockpit to support the rehabilitation process

The Dividat Senso is a stationary training platform with force sensors, linked to a screen (Figure 2) that delivers fifteen exergames [described in previous studies (16, 17)]. It is already widely used in research (17) and clinical practice (16).

Altogether, the COCARE-system theoretically provides a comprehensive telerehabilitation program comprising

Abbreviations: HP, Healthcare Professionals; OA, Older Adults.

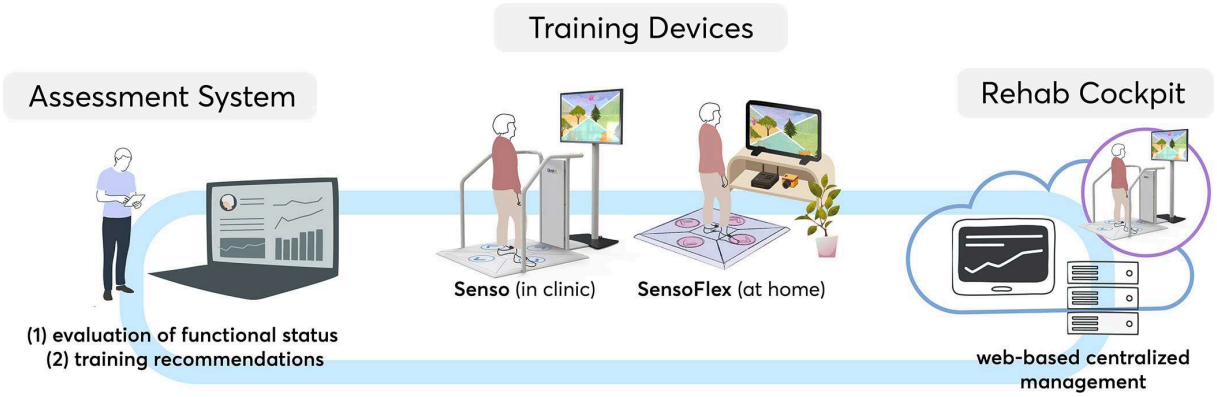


FIGURE 1
The COCARE-system.

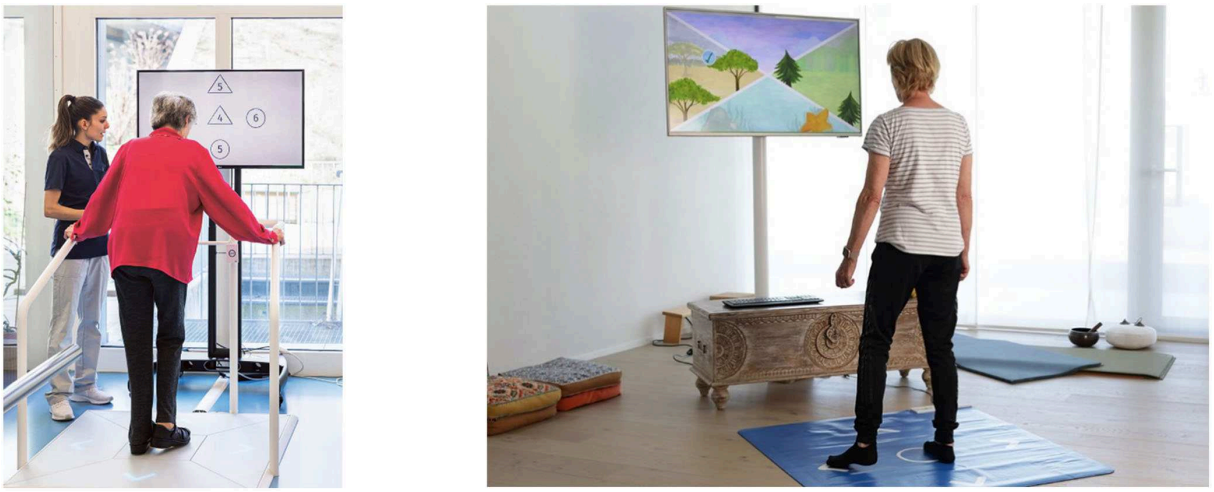


FIGURE 2
Training in an institution on a Senso and at home on a Senso Flex. Informed consent was obtained from the individuals in the picture allowing the usage of the picture for publication.

assessment, training, and management. However, the Senso Flex (a home-based version of the Senso which consists of a foldable sensor-based mat to be connected to a television/tablet) (Figure 2) as well as the assessment system and the rehabilitation cockpit have only recently been developed, respectively are still in the development phase, and their usability has not been assessed using a recommended (24, 25) iterative approach.

2.2. Study design

This was an international, multicenter, cross-sectional study. We used mixed methods to integrate elements of quantitative (questionnaires) and qualitative (focus group interviews) data in three countries (Switzerland (ETH Zurich), Italy (Don Carlo Gnocchi Foundation - FDG) and Cyprus (Materia enterprise)) following Medical Research Council (MRC) guidance (24, 25).

The study design was approved by all local ethics committees (ethics committee of the ETH Zurich (Registration number: 2021-N-104), ethics committee of "IRCCS Fondazione Don Carlo Gnocchi" in Italy (Registration number: 05_09/12/2021) Cyprus National Bioethics Committee (Registration number: ΕΕΒΚ/ΕΠ/2021/51) and complies with the principles of the Helsinki Declaration.

2.3. Recruitment and participants

Participants in Italy were recruited *via* convenience sampling. In Cyprus, OA of existing networks were contacted

and cooperations with multifunctional centers for OA were used. Besides, an open invitation to the general public was published. In Switzerland, primary end-users (OA) were recruited through an announcement/advertisement of the University of the Third Age (https://www.seniorenuni.uzh.ch/de.html) of the University of Zurich. Secondary end-users (HP) were recruited in the VAMED Orthopedic Rehabilitation Clinic in Dussnang, Thurgau, Switzerland.

Interested participants were checked for eligibility *via* telephone or in-person. Inclusion criteria for OA were: (1) ≥60 years old, and (2) community-dwelling. Participants were excluded if they (1) were suffering from any severe diseases affecting functional mobility (e.g., severe sensory or motor impairments), which would prevent them from being potential users of the proposed telerehabilitation system, (2) had any diagnosed cognitive impairments that would prevent them from being actively involved in the discussions, and (3) had previous experience with the Dividat Senso. HP had to (1) be actively involved in conducting physical and/or cognitive training with older people as part of their workplace role, and (2) be registered members of the healthcare community. Similar to the OA, HP were excluded if they had previous experience with the Dividat Senso.

Suitable participants who were willing to take part in the focus groups were informed comprehensively about the objectives and the study procedure and signed a written informed consent form. Additionally, all participants gave informed consent that the data collected in this study will be published in a fully anonymized way.

2.4. Outcome measures

2.4.1. Semi-structured interviews

Semi-structured interviews were conducted *via* focus groups. Focus groups are the first step of a UCD within the scope of this and other R&D projects. They can be defined as a form of group interview and present a qualitative research method to assemble in-depth knowledge about the ideas, experiences, wishes and requirements of end-users regarding for instance a product or an intervention (6, 27). Each of the three trial sites conducted two focus groups, one with primary end-users (OA) and one with secondary end-users (HP).

2.4.2. Questionnaires

Questionnaires for OA and HP were self-designed to collect socio-demographic data of the participants and, furthermore, to analyze their view on older people's interest in and experience with new technologies and more specifically on a technological home-based rehabilitation program. Items of these questionnaires concerning the participants' individual opinions were evaluated on a 5-point Likert scale (from 1 = "strongly disagree" to 5 = "strongly agree") and each item was analyzed separately, thus, no total score was calculated. Additionally, a few open questions were used to get deeper insight into the participants' views. The use of these questionnaires ensured the collection of opinions of less talkative/extroverted persons, who might have been hesitating to actively express their opinions during the focus group interviews. When creating the questionnaires, each question was first formulated in English before being translated into the respective national language of each trial site.

2.5. Study procedure

The sessions with OA were planned to last approximately 60 min, whereas the focus groups with HP were more complex and consequently scheduled for about 90 min. The sessions were audio-recorded to ensure the best possible post-processing analysis of the conversations. For all focus groups, a standardized procedure with guiding questions was applied.

After a short introduction of the participants and the interviewer, and explaining the principles of the meeting, participants were asked to fill out the questionnaires assessing experience with and acceptance of technology in general as well as for the use in rehabilitation. Subsequently, the main components of the COCARE-system - Senso and Senso Flex - were demonstrated with a video briefly showing an exemplary application, as well as through a live-demonstration. Basic principles of the assessment system and the rehabilitation cockpit were demonstrated as well. Afterwards, the discussion began with 1–2 general open-ended questions about the participants' attitudes toward new technologies with the purpose to create a relaxed and productive atmosphere. Next, the moderator used pre-defined guiding questions to lead through the main discussion. These guiding questions were specifically product-related, also including business and dissemination matters. Finally, the participants received the opportunity to address possible remaining topics and to draw conclusions.

2.6. Data analysis

Verbatim anonymized transcripts were obtained from the audio recordings of each focus group interview. Afterwards, an inductive, qualitative content analysis according to Mayring (28) was performed using the software QCAmap (29). This analysis is based on a structured coding of relevant statements to create a structured overview. The coding was validated *via* inter- and intra-coder agreement. Each item of the questionnaires was analyzed and presented in a descriptive manner.

3. Results

In total, six focus groups were conducted (2 focus groups at each site, one with primary and one with secondary end-users) including a total number of 18 OA and 16 HP. Tables 1–6 and Figures 3–5 present the summarized results from all three trial sites. In some cases, when site-specific analysis was performed, it is indicated accordingly.

3.1. Demographics OA

In total, OA included in this study had an average age of 76.1 years (SD = 9.7) and the majority described themselves as physically and cognitively fit and healthy not indicating any walking constraints (Tables 1, 2).

3.2. Demographics HP

HP had a mean age of 35.6 years (SD = 13.0) and worked in healthcare 9.5 years (SD = 10.4). Besides, the majority of HP was female (81.3%) (Table 3).

3.3. Results of the questionnaires—Technological experience and requirements of OA

3.3.1. Technological equipment of OA

Most older participants were well-equipped with different types of technologies in their homes, thus all of them owned a television and about 80% had access to the internet which is a perquisite for using the Senso (Figure 3).

3.3.2. Interest in and experience with new technologies

More than half of OA indicated an interest in (66.6%) and/or a fascination for (70.6%) general modern technologies. Besides, 77.8% expressed a willingness to test new technological devices, although only about 18% indicated having plenty of experience with such devices and although only a small number of OA (16.7%) considered their handling simple. Furthermore, most participants (94.4%) had no experience with video games.

As expected, the majority of OA reported a good basic knowledge and experience with simple operations of common devices like television and a computer/laptop. For instance, about 67% found it easy to turn a computer on and off, to charge a laptop, to navigate through the system and to connect the devices to Wi-Fi. The remaining one third of participants had not tried such operations before. Only connecting the cables of a television or connecting a computer to an external screen posed a challenge for most OA.

More than half of the HP (62.5%) were unsure or tended to be rather pessimistic regarding their perception of older people's interest in new technological devices with only 50% expecting OA to be willing to test them. Table 4 comparing OA's and HP's view on OA's interest in technologies shows that this discrepancy was especially evident in Italy and Switzerland. Accordingly, the vast majority (80%) of all HP was certain that OA would have difficulties handling modern technological devices. Similarly, 56.3% stated that OA have no experience with technological devices and even more (68.8%) that they are unfamiliar with video games.

3.3.3. Important factors for an ICT-based rehabilitation program

The following results are based on questions directed more specifically to telerehabilitation. OA and HP were asked to imagine a technological home-based rehabilitation device which is working with video games and allows an independent training at home. Afterwards, they were invited to evaluate the importance of a series of factors for such a training. The results are presented in Figure 4 and Table 5.

In total, requirements of OA and HP toward such a rehabilitation program resembled one another. Especially the crucial role of an easy use and handling of such devices and continuous feedback on the progress was highlighted by both groups of end-users. However, HP found big screen, an appealing design and entertainment more important than OA did. In contrast, OA rated variety, scientific foundation, and the possibility to select tasks autonomously as more important compared to the HP.

Comparing the two groups of end-users per site (Table 5), the special role of the factors "easy use and handling" and "continuous feedback" was emphasized again, as these factors were rated "rather" or even "very" important by both OA and HP groups of all sites. However, a huge difference between the sites can be detected regarding the importance of the factor "variety" which was essential for all participants in Cyprus (Materia), whereas in Switzerland (ETH) and Italy (FDG) this is only the case for OA and significantly less important for HP. Another interesting finding is that, for all OA, the scientific foundation of the system was a crucial factor – especially in Italy at FDG followed by Cyprus (Materia). At all sites the percentage of HP finding scientific foundation important was about 20% lower. Finally, entertainment was rated as highly important by all HP, whereas only in Switzerland (ETH) OA agreed with HP on this item.

In general, larger discrepancies between views of OA and HP could be observed in Switzerland compared to Italy and Cyprus.

TABLE 1 Characteristics of included OA ($n = 18$).

	Total	Italy	Switzerland	Cyprus
Number	18	6	7	5
Sex (female/male)	10/8	1/5	5/2	4/1
Age (in years) (mean ± SD)	76.1 ± 9.7	73.3 ± 8.2	72.0 ± 8.4	85 ± 8.2
years of education (mean ± SD)	12.7 ± 5.1	14.4 ± 2.2	15.8 ± 5,3	8.0 ± 3.7
Sport: times/week (mean ± SD	3.2 ± 0.8	3.0 ± 1.0	3.7 ± 0.5	2.8 ± 1
Sport: hours/week (mean ± SD)	4.9 ± 2.4	5.5 ± 1.3	5.9 ± 3.1	3.3 ± 1.3

OA, Older adults; SD, Standard Deviation.

TABLE 2 Self-rated health of OA and social factors.

Health-related and social factors	% of all OA ($n = 18$)
Physically fit and healthy	77.7%
Cognitively fit and healthy	94.4%
Self-reported walking constraints	18.8%
Like to meet new people	100,0%
Social networks user	44,4%

OA, Older adults.

3.3.4. Concerns and requirements of OA toward an ICT-based rehabilitation program

In total, the majority of OA (72%) had a positive view on a home-based training and would like to conduct such a telerehabilitation program (Figure 5, statement 7). Moreover, many participants (61%) expressed a willingness to play video games to increase their physical and cognitive functions (Figure 5, statement 5). However, 58.8% OA were worried about cables distracting them from using the device (Figure 5, statement 1) and even more OA (72.2%) reported that they would need a contact person for support (Figure 5, statement 3). Surprisingly, OA did not report being afraid of technical problems and only few of them (27.8%) indicated having a fear of falls or injuries while training at home.

3.3.5. Training time frame

Table 6 displays how often and for how long OA would be willing to conduct such an ICT-based telerehabilitation program. Most participants (55.6%) would use such a system twice per week and for 30 min (66.7%).

3.4. Results of the focus group interviews with OA and HP

According to the moderators' observations, participation in the discussion as well as group interaction were good in all focus group interviews. Hence, a large variety of technology- and therapy-related topics arose, creating a comprehensive picture of end-users' needs and requirements toward a technological home-based rehabilitation program. Figure 6 delivers a broad overview over these topics, which are subsequently described in more detail.

3.4.1. Physical activity and general training/therapy

This first main category comprises topics related to general physical activity and exercise. OA mentioned a series of reasons to be physically active, mainly wellbeing and satisfaction, health, and mobility. Fun is apparently a crucial factor to maintain training motivation *(P103: "It has to be a bit of fun, otherwise you won't do it")*. Moreover, they perceived reaction time, balance, coordination, strength, flexibility, and memory as particularly important functions to be trained.

In general, a major topic arising in both groups of end-users was the importance of social aspects for a successful physiotherapeutic treatment as well as for physical and cognitive training programs. For instance, most end-users agreed on the special importance of guidance, supervision, feedback, and support for effective treatments based on the positive effects of these factors on attention, motivation, adherence, and alignment on shared goals *(P131: "Supervision and feedback from the therapist are important to strengthen motivation and to agree on goals"; P107: the therapist makes sure you're doing it right (…) you can train like crazy, and still do everything wrong")*. Besides, human presence, and possibly even human touch was said to be particularly important for OA, who, according to HP, tend to be more socially isolated.

3.4.2. General and health-related technologies

Modern technologies and technologies in geriatric rehabilitation emerged as the second main category. Regarding general modern technologies, the views of OA varied. Their main concern was a continuous monitoring by technological devices, and, in addition, some perceived technology as invasive

TABLE 3 Characteristics of included HP ($n = 16$).

	Total	Italy	Switzerland	Cyprus
Number	16	5	6	5
Sex (female/male)	13/3	4/1	5/1	4/1
Age (in years) (mean ± SD)	35.6 ± 13.0	43 ± 13.5	33.8 ± 15.5	30.4 ± 6.3
Years of work in healthcare (mean ± SD)	9.5 ± 10.4	17 ± 14.2	7.4 ± 8.3	4.4 ± 2.5
Years of work with OA (mean ± SD)	7.6 ± 6.9	12.8 ± 7.3	6.5 ± 7.2	3.8 ± 2.7

HP,Healthcare professionals; SD,Standard Deviation.

TABLE 4 Site- and user comparisons of opinions regarding OA's interest in modern technologies.

	Italy		Switzerland		Cyprus	
	Agree	Strongly agree	Agree	Strongly agree	Agree	Strongly agree
OA are interested in new technology (OA/HP)	33/0%	50/20%	29/17%	43/0%	40/80%	0/0%
OA like to test new technological devices (OA/HP)	50/20%	17/20%	43/33%	43/0%	80/80%	0/0%

OA, Older adults; HP, Healthcare Professionals; The statements refer to what OA and HP think about older people's interest in new technologies.

tracking their online activities for commercial purposes. Furthermore, OA tended to regard technologies as an issue more relevant for the younger generations *(P203: "I think, most (technologies) are not meant for people in our age")*. Nevertheless, alongside this, other OA saw technology as something useful, enjoyable, and nowadays indispensable in all areas of *life (P305: "Without technology we can't do anything. I would say these things are useful")*. Concerning its purpose in older people's life, they mainly expected technologies to help an older person to remain fit and active, and to be targeted at persons with mobility limitations. Therefore, they would like to see more attention paid to possible physical or cognitive limitations during the development of technologies.

Unlike the opinions on general technologies, OA were generally more open and positive toward technologies specifically designed for the improvement of health. OA recognized their high potential for health-related training programs – especially by providing some form of motivation and feedback to reach a certain goal. Virtual health coaches guiding people toward a healthy lifestyle were mentioned as a good example, as were sleep trackers, pedometers, and heart rate monitors. Nonetheless, some OA remained rather hesitant, mainly due to unfamiliarity with such technologies, while others found them even unnecessary. Some OA, for instance, dismissed technologies like chatbots which were considered demotivating due to the lack of human contact *(P105: "It (the chatbot) was a machine which was talking to me, I could not take it seriously")*.

Similarly, the majority of HP found technologies useful in geriatric rehabilitation. They recognized, as main advantages, the possibility to extend and intensify treatments while simplifying the therapists' work, and the opportunity to increase motivation of the OA *(P111: "I think it's a very good idea (…) I have the feeling that you can attract people better. I've seen it with a MotoMed (a technical, clinical device, which, based on cycling movements, passively or actively trains arm and leg muscles)")*. However, they regarded good instructions and personalization as prerequisites for the introduction of technologies in rehabilitation *(P109: "Older adults already enjoy technology, but simply do not have the confidence to deal with it. I believe, if you instruct them well, it will help")*.

3.4.3. Exergames

The third main emerging topic were the Exergames played on Dividat Senso (Flex). In total, OA perceived the exergames positively mentioning positive aspects like a good variety, the adapting algorithm, the trained functions, the game feature/fun aspect and their motivating effect *(P203: "you see it more as a game and less as an exercise")*. HP shared this positive view, highlighting, in particular, the design, the playful/entertaining aspect which they expect to influence commitment, the variety of games and the possibility to personalize treatments. Moreover, they appreciated the combination of motor and cognitive training/dual-task training *("The importance of these systems is precisely the combination of motor and cognitive aspects")*.

Nevertheless, both groups of end-users suggested a series of further developmental steps and constant system updates. OA proposed more age-appropriate games, and the integration of competitive as well as cooperative games. HP, on the other hand, recommended to establish a reward system and wished for the current games to allow for more freedom, such as being able to freely explore a virtual environment while walking on the Senso

TABLE 5 Site- and user-comparisons regarding important factors for home-based rehabilitation.

Important factors for home-based rehabilitation (OA/HP)	Italy		Switzerland		Cyprus	
	Rather important	Very important	Rather important	Very important	Rather important	Very important
Big screen	33%/40	67/60%	14/50%	57/50%	20/40%	80/40%
Easy use and handling	50/0%	50/100%	14/0%	86/100%	0/20%	100/80%
Tasks autonomously selectable	50/40%	50/40%	43/0%	43/0%	60/40%	40/60%
Tailored training	40/80%	40/0%	43/50%	0/17%	60/40%	40/60%
Variety	67/40%	33/20%	29/33%	71/0%	40/40%	20/40%
Continuous feedback on progress	50/60%	33/20%	29/67%	57/33%	20/40%	60/60%
Data safety	50/20%	17/60%	14/0%	57/50%	40/20%	20/60%
Appealing design	17/40%	0/20%	57/50%	14/0%	0/75%	20/0%
Scientific foundation	50/40%	50/40%	29/17%	43/33%	40/40%	40/20%
Entertainment and fun	33/40%	0/60%	10017%	0/83%	0/40%	60/40%

OA, Older adults; HP, Healthcare Professionals.

TABLE 6 Training frequency and duration of older adults.

	Never	1x	2x	3x	>3x
How often per week would you use such a training program?	0.0%	5.6%	55.6%	38.9%	0.0%
	15 min	20 min	30 min	45 min	60 min
How much time would you invest in one training session?	5.6%	16.7%	66.7%	11.1%	0.0%

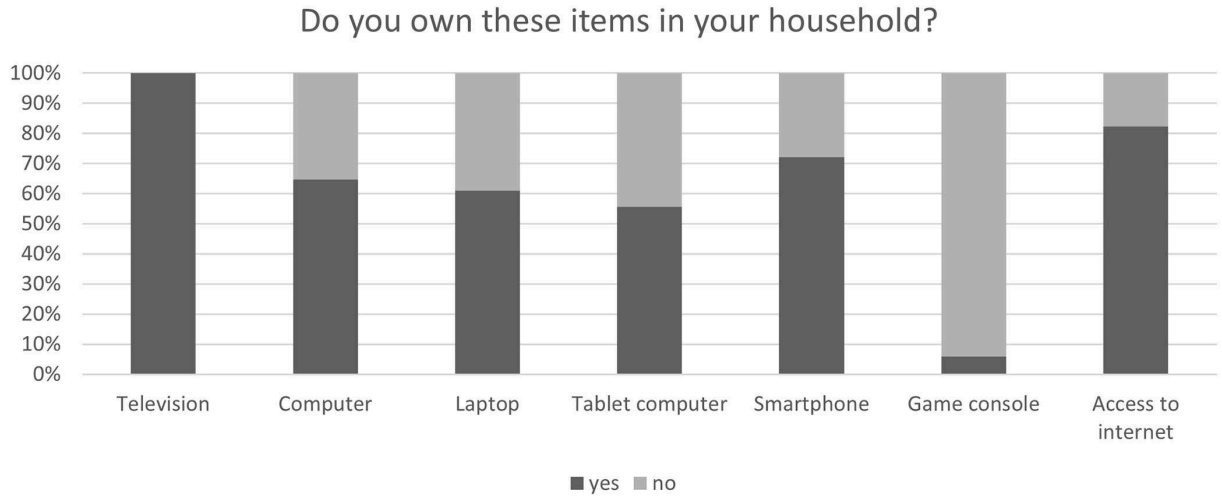


FIGURE 3
Technologies used at home by older adults.

(P210: "it would be nice, whenever possible, for the games not to be very restraining").

A final sub-theme within the topic of Exergames was important data/metrics which should be collected and presented during and/or after training with the exergames. HP named speed, accuracy, number of errors, changes over time, number of repetitions, congruence of responses over time, reaction time, and especially progression.

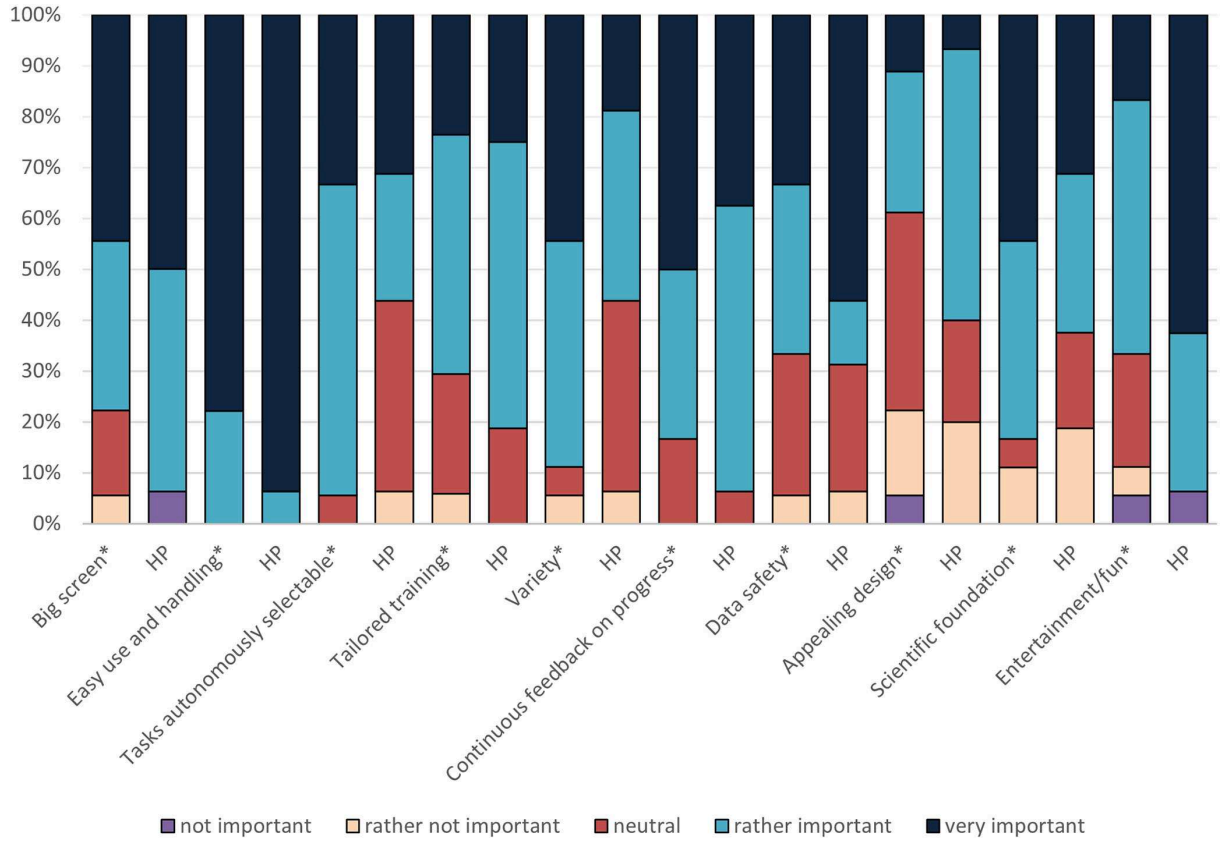


FIGURE 4
Important factors for a technological home-based rehabilitation program expressed by OA and HP. *Older adults' evaluation; HP, Healthcare Professional.

3.4.4. Telerehabilitation and the COCARE-system

Another major topic of the focus group interviews, which included a wide variety of sub-categories, was "telerehabilitation" and "the COCARE system." Starting with the system's main device (i.e., Senso), most OA expressed positive views about it. For instance, many of them praised the feedback on performance and the possibility to track improvements over time *(P201: "It gives more accurate results (than a therapist) (…) and places the patient at a more central point of the overall process")*. However, some participants named limited movements as a major critical aspect *(P308: "(…) limited in terms of movements … to move only between the four arrows")*. The HP's focus remained on the handrail of the Senso. On the one hand, it was associated with a feeling of security, but on the other hand, they feared that older people might seek unnecessary support limiting the training effects on balance. Other therapists suggested that a solution supporting people with standing difficulties would be a meaningful addition to the Senso. Moreover, many HP as well as some OA would endorse the integration of upper body movements and, finally, the further development of the assessment system to detect initial stages of motor and cognitive deterioration.

Concerning the physical and cognitive functions trained on the Senso, most HP found that the following are well-targeted: balance, postural stability, attention, concentration, reaction, and visual-motor integration. However, they would wish for memory and endurance to be addressed more extensively through the exergames. Several HP criticized that, compared to the cognitive demand, the challenge on the motor system remains underdosed. Likewise, OA regarded reactivity as one of the major functions trained on the Senso but indicated the lack of a higher physical demand *(P304: "It seems particularly suitable for improving reaction times (…) by increasing the speed of movements, perception (….) when someone walks on the street (…) he/she is more reactive to potential risks")*. Consequently, according to the OA, people suffering from mobility limitations could represent an appropriate target group for a Senso training, whereas currently they perceive themselves as too fit to be included in the target group *(P106: "We probably feel it's still relatively easy now … but maybe in 10–15 years it won't be")*.

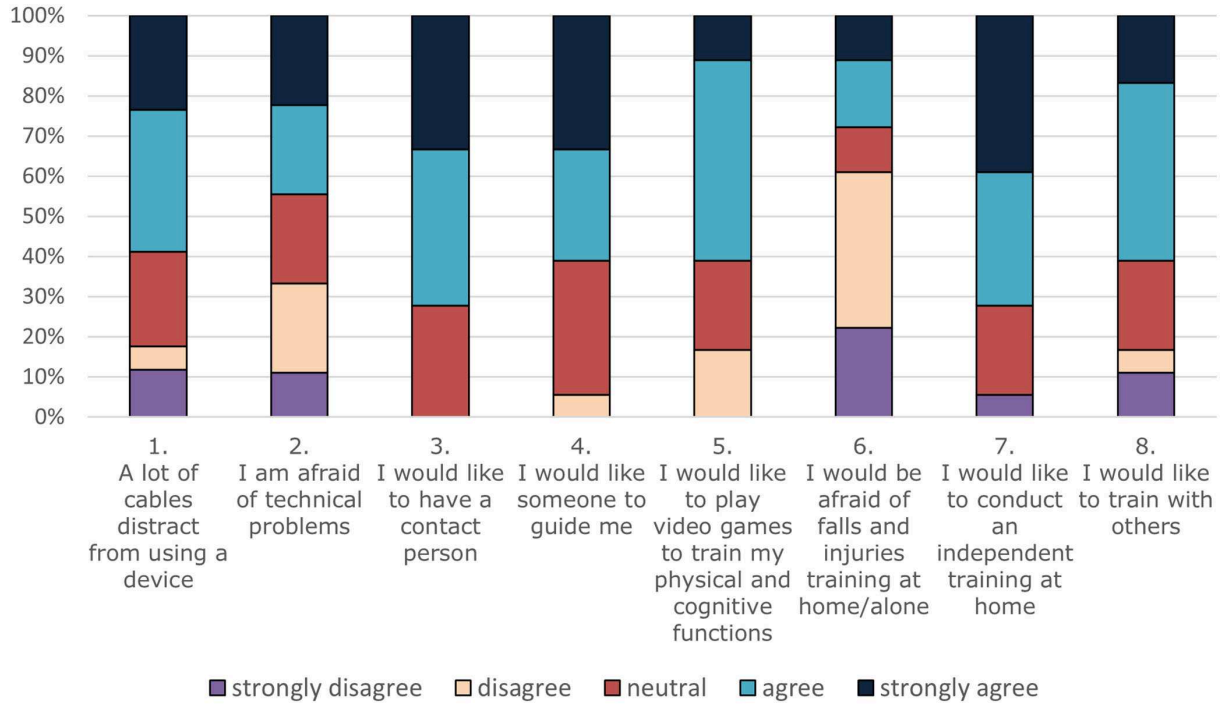


FIGURE 5
Willingness, concerns, and requirements of older adults toward a home-based rehabilitation program.

The second important sub-category within the topic of telerehabilitation is general home-based training. Concerning OA, the number of positive and negative opinions was well-balanced. The most frequently named positive aspect was the possibility to regularly conduct exercises despite possible mobility limitations which currently became even more significant due to the COVID-19 pandemic. Moreover, even the older participants were aware of a possible relief of hospitals due to home-based training. Two negative aspects from the OA' point of view were, however, the risk of falls during training alone, and concerns that especially older people might not want to stay at home in front of the television for physical, social, and psychological reasons – a fear which is shared by HP. Besides, older participants would miss immediate feedback from the therapist. HP saw clear advantages in home-based training as, according to them, training in a familiar environment leads to more wellbeing meanwhile. Furthermore, time and flexibility were presented as crucial arguments - especially during the winter months when leaving the houses poses a higher risk for falls *(P111: "You can use it at any time – it is flexible in terms of time").* Nevertheless, they feared for their patients' adherence due to their lack of control. Eventually, both groups of end-users regarded a therapy plan similar to usual treatments and regular feedback by therapists as perquisites for a successful home-based rehabilitation program *(P309: "(. . .) patient periodically receives feedback from the therapist on how the home rehabilitation process is proceeding").*

The third telerehabilitation related topic was home-based training specifically conducted with the Senso Flex. Most end-users' positive as well as negative views on the Senso Flex were based on their opinions about general home-based training and exergames listed above. Examples of such overlapping statements by OA are the special importance of Senso Flex for people with mobility limitations but also its negative effect on social connectivity. Senso Flex specific positive ratings mainly comprised its small size, the fact that it can provide a diversion in everyday life, and that it can be used for general exercise *(P202: "It could be used not only for rehabilitation but also in terms of general exercising to stay fit").* Senso Flex specific negative evaluations included storage difficulties and space problems. Data safety, however, was not regarded as a major concern. Concerning the view of HP, overall, the Senso Flex received positive evaluations. For instance, they praised the clearly visible markings on the carpet, its thinness, its provision of diversion in everyday life and in time spent with friends for entertainment purposes, and finally the possibility to use it not only for prevention and rehabilitation but also for general *fitness (P111: "You can perhaps do something other than only having the usual coffee with colleagues who are visiting. So, I see advantages here, too").* Still, according to HP, further necessary steps comprise the development of

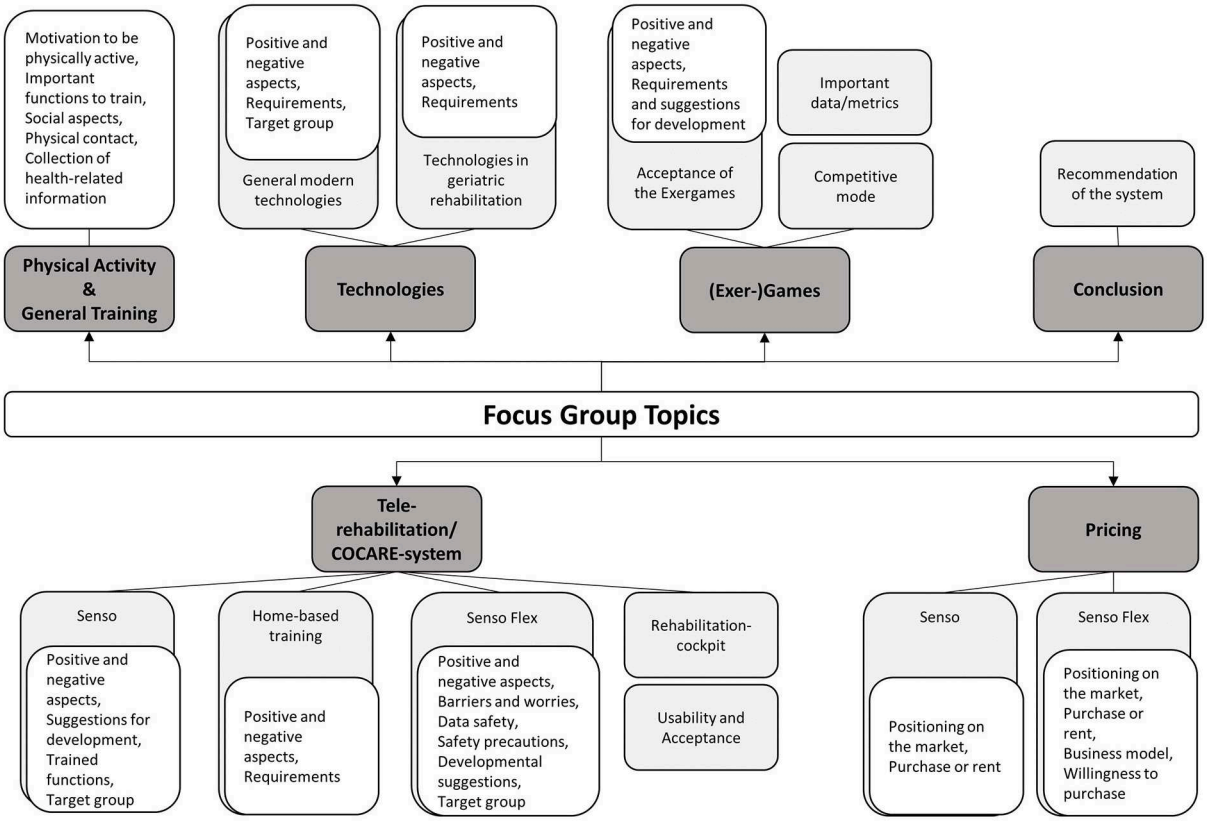


FIGURE 6
Focus group main- and subcategories. In dark gray: main categories, in light gray: sub-categories level 1, in white: sub-categories level 2.

suitable presentations of training data. In addition, a worry both groups of end-users shared were safety issues due to balance problems as well as technological unfamiliarity. For this reason, it was emphasized that therapists would have a responsibility to figure out individual safety precautions *(P109: "The therapist co-decides or advises where the mat should be put to ensure that the environment is safe").* Finally, the term "simplification" repeatedly arose in all focus groups referring to both installation and use of the Senso Flex meaning adaptions like a vocal introduction and feedback and the most possible reduction of buttons and cables *(P107: "It should be very easy to handle so that you can start exercising after just a few actions").* Nevertheless, concerning familiarization with the Senso Flex, a significant majority of participants was optimistic provided that an appropriate guidance or even installation by the therapist as well as a constant contact person are available. Furthermore, both groups of end-users emphasized that a familiarization should already begin in clinics during rehabilitation starting with a supervised training on the Senso before transferring to the Senso Flex *(P108: "we (HP) can also initiate as much as possible from our side, so that they (OA) have as little effort as possible").*

However, regardless of such adaptions or familiarization efforts, many participants would prefer using the COCARE-system as an extension rather than a substitute for usual therapy. Besides, they regard patients in late rehabilitation as the most appropriate target group of the Senso Flex, whereas there was a general conviction that people with cognitive disorders will be incapable of using the system.

In summary, according to the vast majority of OA and HP, usability and acceptance of the Senso Flex are strongly dependent on its ease of use, good instructions and feedback, older people's physical and cognitive abilities, and enjoyment.

Concerning the final sub-category, the rehab-cockpit, healthcare-professionals highly approved its inclusion – however, only in case personal meetings would still take place. Both groups of end-users would, furthermore, appreciate a reward system as well as reminders and recommendations regarding the choice of game to play.

3.4.5. Pricing

The final category, pricing, included topics like positioning on the market, purchase or rent and the participants willingness to purchase the system. Concerning the price, it was difficult for most end-users to estimate a suitable price and consensus could not be reached. However, for most end-users, renting the Senso or Senso Flex would be the preferred model due to financial reasons and difficulties to estimate how long one will be able and willing to use the system *(P203: "It depends on how many years you have to live (…) the older you are the less likely it would be to buy it").* A general concern prevailed, that OA might not be able to afford the system in any way, which is why many participants expected Health Insurance Companies or National Health System to cover the costs.

It can be concluded that the willingness to pay for the Senso Flex is strongly dependent on the costs, effectiveness, and the ability and will to independently use it *(P201: "I would buy it if I was convinced it worked and could improve my health. Especially if my physiotherapists would recommend it").*

4. Discussion

In general, the use of ICTs for telehealth has proven to reduce health care costs, improve self-monitoring of health and enhance the provision of rehabilitation programs to OA (30). Thereby, exergames can be a useful and effective part of an ICT-based telerehabilitation tool as they have proven to be very effective due to the simultaneous conduction of physical and cognitive exercises – a combination which, according to previous research, may be even more effective than conducting them separately (31) or in more traditional exercise programs (32). Thus, exergames enable the training and improvement of a large variety of physical functions (33) such as balance (17–19), aspects of gait, gait initiation (34), dual task walking speed (16), and movement quality (35) as well as cognitive and psychological functions like executive control and processing speed (21), exercise enjoyment (36), decreased depressive symptoms, and an increased mental health-related quality of life (37).

However, negative attitudes based on fear, anxiety and limited motivation and interest form a barrier for the adoption of ICTs by OA (38). This again illustrates the importance of a UCD-approach applied during the development of the COCARE (and any) system to identify the factors necessary for a successful implementation. Indeed, all focus groups delivered a comprehensive picture illustrating needs, requirements, and potential barriers of OA and HP toward the COCARE-system. Therefore, it can be concluded that the study objectives have been achieved.

4.1. Opinions and requirements toward ICTs and the COCARE-system

When specifically discussing the COCARE-system, a term which was repeatedly stated was "simplification," i.e., an easy use and handling, which was mentioned as a prerequisite to reach a good usability and acceptance among OA and HP. This is well in line with previous research (39) which stated that a successful implementation and adoption of technologies depends on perceived costs, for instance cognitive costs and self-efficacy beliefs (40). Technologies which are difficult to handle increase cognitive costs, decrease self-efficacy beliefs and consequently the willingness to use ICTs. To overcome these obstacles, other essential demands by all end-users were the availability of a contact person, good instructions, a personalized therapy plan, and regular as well as immediate feedback concerning training conduction, progression, and recommendations. Summarizing all these factors, it becomes evident that a good education about ICTs and guidance are crucial for the older participants' acceptance of technologies. This is in accordance with previous studies highlighting the special importance of education on how to use new technologies in order to dismantle fears of OA due to unfamiliarity with ICTs and to instead change their attitude toward ICTs (41–43), and increase their wellbeing and confidence in handling them (30, 44–46). Thereby, the focus should be on changing attitudes and self-efficacy beliefs which have proven to have a greater effect on older people's use of ICTs than actual knowledge (40, 47). This points to the necessity of a blended therapy approach where conventional face-to-face care is combined with telerehabilitation (TR) (48, 49). Future iterations within the development process should shed a light on this.

However, next to targeting the perceived costs and technological unfamiliarity, (perceived) benefits are also important. The fact that the older participants' view on technologies for rehabilitation was more positive than their view on general technologies indicates that personal benefits and a meaningful purpose of technologies play a key role for their adoption of technology. This is in line with previous research (50).

Concerning safety aspects, at the beginning, OA indicated no fear of falling, whereas later in the interviews they criticized the risk of falls when using the Senso Flex. An explanation for this seeming discrepancy might be, that in the first case, they were specifically asked about their own fears, whereas in

the second case they might also had other frailer OA end-users in mind. HP were more consistent requiring several safety precautions like handrails for the independent use of the Senso Flex.

4.2. Exergames

All end-users had a positive view on the exergames provided by the Senso – especially due to their entertaining nature leading to a higher motivation, their variety, and the cognitive and physical functions they train. Besides, the possibility to track improvements was repeatedly praised. Enjoyment and health were factors also listed as very important motivators to be physically active which explains these positive responses. This is mirrored in previous research where enjoyment was a key motivator for playing exergames (51).

Based on these positive views on the exergames, we expect increased chances of high training adherence in exergame training. This indeed could be shown by previous research which attributed this mainly to a high enjoyment (51). However, another study (52) observed a decrease in adherence in exergame training compared to conventional training which, according to the authors, could be explained by the low level of social interaction – an assumption supported by further studies (51, 53). Similarly, in the current study, a large majority of both groups of end-users feared a lack of social contacts when training with the Senso Flex. This factor turned out to be a very decisive and a major reason for many OA and HP to agree to the idea of the COCARE-system as a supplement to conventional therapy rather than a replacement. To counteract the loss of social contact, Oesch et al. (52) proposed exercising with others and collecting points which could enhance motivation and adherence. This is in accordance with the opinion of OA who required the integration of cooperative and competitive games – an aspect which should be considered when designing future exergames. Another point to consider when designing ICTs is that communication should remain as much as possible on a personal level instead of replacing the therapists' feedback with a chatbot or similar technologies.

Moreover, some OA criticized the imbalance between the cognitive and physical demands of the games. However, it must be taken into consideration that the older participant's perceived themselves as physically healthy. Besides, on average, they appeared to be well-informed about various aspects of physical and cognitive functions which became evident when they presented detailed ideas and high expectations of what an effective training should include, respectively which functions it should aim at. This was also demonstrated when they rated "scientific foundation" as a highly important factor for a telerehabilitation program – even more important than "entertainment." This was somewhat contrasting the view of HP that did not deem an evidence-base as likewise important. Therefore, the development and scientific evaluation of further games to establish a solid evidence-base for effectiveness seems crucial to win physically healthy and well-educated OA as primary end-users. Especially games targeting a higher level of endurance and strength, or the integration of upper body movements should be considered.

4.3. Potential users

Despite this, in general, there were disagreements and uncertainties in both groups regarding the appropriate target group of the Senso Flex. As indicated above, according to many participants, the COCARE-system's main users will be patients in late rehabilitation, however, some also recognized its potential as a tool for prevention, offering, in addition, a welcomed diversion in everyday life. In contrast, people with cognitive limitations were disregarded as potential users which is not in line with previous research showing exergames as well as telerehabilitation are feasible and effective treatment approaches for people with mild cognitive impairment (MCI) (54–56) or dementia (57–59). However, the combination of telerehabilitation and exergames in older people with cognitive impairment has not yet been analyzed sufficiently. Thus, the participants' doubts should not be ignored and, consequently, a definition of the COCARE system's target group(s) is necessary before working on further developments.

4.4. Differences between groups of end-users and sites

As listed above, HP most often agree with OA regarding important needs and requirements – especially regarding social factors and guidance. Besides, they agree that OA have limited experience and abilities regarding new technologies. However, it became evident that HP tended to underestimate older people's interest in and experience with technology. This is most likely based on ageism which is even occurring among physiotherapists (60). Furthermore, another explanation might lie in their occupation which regularly confronts them with older people having cognitive and/or physical disabilities, whereas the older participants of the current study were, as described, on average rather healthy. So, in fact, most OA would be willing to conduct such a home-based training with technological devices.

Furthermore, surprisingly, HP did not assign similarly great importance to the factor "scientific foundation," whereas they rate "entertainment" significantly higher. Previous research (61–64) investigated physiotherapists' reasons for their selection of treatment methods and found that "most reported interventions are supported by evidence, interventions with unclear or no evidence of effect were also used to a high extent."

(61). Instead, they relied on their initial education, other therapists, and on gained experience. This could also be regarded as another explanation for their pessimism toward older people's interest in exergame-based training as this most likely was not part of their education. Moreover, it could explain the site differences. Among the healthcare-professionals in Switzerland the number of young professionals was higher than in Italy at FDG or in Cyprus at Materia and, therefore, they were even more influenced by their education. This might explain why they found "scientific foundation" the least important compared to therapists of the other two sites since evidence-based physiotherapy implementation is associated with many barriers by physiotherapists (65). Eventually, this indicates a need to integrate the theory of ICTs for the use in physiotherapeutic treatments in the curriculum of therapists.

Accordingly, the fact that HP regarded entertainment as a much more important factor might be based on their experience teaching them that enjoyment is vital for the adherence of OA to their therapy. This again might be a reason why HP mentioned more freedom in exergames as another important developmental step, whereby OA focused more on adaptations with respect to age and physical and cognitive demands.

4.5. Limitations

Although this study provides important insights about needs and requirements of OA toward healthcare technologies in general and especially toward the COCARE system, it is important to acknowledge some limitations. Due to organization issues and COVID-19 restrictions, only few of the focus groups' participants tried out the Senso and Senso Flex and only a small selection of games could be shown. The rest of the participants stood close by and observed. This might have caused a limited reliability of their evaluation of difficulty of the games. Furthermore, as described above, it must be considered that the older participants were physically and cognitively in good condition compared to peers and also their exposure to and use of technologies is higher than the average in this age group. This is confirmed by previous surveys: according to Eurostat and the Swiss Federal Office for Statistics, in 2021, about 61% of OA in EU (Cyprus 58%, Italy 45%) (66), and about 73% in Switzerland used the internet - especially for sending emails (67), whereas the percentage of OA regularly using the internet was significantly higher (82%) in our study. One explanation for this finding might be their high level of education (47). In any case, these differences lead to a reduced representativeness of the study sample. However, the numbers of older adults being familiar with the internet and technologies is increasing (68) and likewise the generalizability of the presented results.

5. Conclusions

Unlike the predictions of HP, the OA showed an interest in technologies for the improvement of health and in using the COCARE system as a tool for telerehabilitation. However, some adaptions like a simplified installation of and navigation through the system were required. Furthermore, the importance of social factors was strongly emphasized by both groups of end-users. Based on these results, the COCARE-system is about to be adapted and, as a next step within the UCD-approach, the adapted version will be investigated again analyzing it's usability and acceptability. The information gained in this study is part of an iterative approach to develop a complex health intervention (24) and warrants further iterative cycles of development with stakeholder input and system adaptations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the ETH Zurich. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JS: conceptualization, methodology, data curation, software, formal analysis, and writing—original draft. EG: conceptualization, methodology, supervision, and writing—original draft. EB: methodology. IC, MF, SM, FR, and CS: methodology, data curation, and writing—review and editing. All authors revised the manuscript and approved the version submitted for publication and agree to be accountable for all aspects of the work.

Funding

This work was funded by the European Union and the involved National Funding Authorities (Innosuisse-the Swiss Innovation Agency, Italian Ministry of Health (fondi di Ricerca Corrente), and Cyprus Research and Innovation Foundation) as part of the AAL Association Joint Programme under Grant number:

aal-2020-7-145-CP. Open access funding provided by ETH Zurich.

Conflict of interest

EB was a co-founder of Dividat, the spin-off company that created and developed the COCARE-system used in this study. However, no revenue was paid (or promised to be paid) directly to EB or his institution. SM was employed by company Materia Group.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Kirst M, Im J, Burns T, Baker GR, Goldhar J, O'Campo P, et al. What works in implementation of integrated care programs for older adults with complex needs? *A realist review Int J Qual Heal Care.* (2017) 29:612–24. doi: 10.1093/intqhc/mzx095

2. Metz DH. Mobility of older people and their quality of life. *Transp Policy.* (2000) 7:149–152. doi: 10.1016/S0967-070X(00)00004-4

3. Rantakokko M, Portegijs E, Viljanen A, Iwarsson S, Kauppinen M, Rantanen T. Changes in life-space mobility and quality of life among community-dwelling older people: a 2-year follow-up study. *Qual Life Res.* (2016). doi: 10.1007/s11136-015-1137-x

4. Lutz W, Sanderson W, Scherbov S. The coming acceleration of global population ageing. *Nature.* (2008) 451:716–9. doi: 10.1038/nature06516

5. Goodwin N, Dixon A, Anderson G, Wodchis W. *Providing Integrated Care for Older People With Complex Needs: Lessons From Seven International Case Studies.* London: The King's Fund (2014).

6. Ahmed M, Marín M, Bouça-Machado R, How D, Judica E, Tropea P, et al. Investigating users' and other stakeholders' needs in the development of a personalized integrated care platform (PROCare4Life) for older people with dementia or parkinson disease: protocol for a mixed methods study. *JMIR Res Protoc.* (2021). doi: 10.2196/preprints.22463

7. Eurostat Ageing Europe. *Looking at the Lives of Older People in the EU.* Publications Office of the European Union. Luxbembourg (2020).

8. Tillou A, Kelley-Quon L, Burruss S, Morley E, Cryer H, Cohen M, et al. Long-term postinjury functional recovery: outcomes of geriatric consultation. *JAMA Surg.* (2014) 149:83–9. doi: 10.1001/jamasurg.2013.4244

9. Sixsmith A, Mihailidis A, Simeonov D. Aging and technology: taking the research into the real world. *Public Policy Aging Rep.* (2017) 27:74–8. doi: 10.1093/ppar/prx007

10. Sixsmith A. Technology and the challenge of aging. In: Sixsmith A, Gutman G (eds) *Technol Act Aging.* New York: Springer, pp 7–26. (2013). doi: 10.1007/978-1-4419-8348-0_2

11. van Boekel LC, Wouters EJM, Grimberg BM, Boumans J, van der Meer NJM, Luijkx KG. Perspectives of stakeholders on technology use in the care of community-living older adults with dementia. *Healthcare.* (2019). doi: 10.3390/healthcare7020073

12. Altilio R, Liparulo L, Panella M, Proietti A, Paoloni M. Multimedia and gaming technologies for telerehabilitation of motor disabilities [Leading Edge]. *IEEE Technol Soc Mag.* (2015) 34:23–30. doi: 10.1109/MTS.2015.2494279

13. Omboni S, McManus RJ, Bosworth HB, et al. Evidence and recommendations on the use of telemedicine for the management of arterial hypertension: An international expert position paper. *Hypertension.* (2020) 3:1368–83. doi: 10.1161/HYPERTENSIONAHA.120.15873

14. Nawaz A, Skjæret N, Helbostad JL, Vereijken B, Boulton E, Svanaes D. Usability and acceptability of balance exergames in older adults: a scoping review. *Health Informatics J.* (2016) 22:911–31. doi: 10.1177/1460458215598638

15. Adcock M, Sonder F, Schättin A, Gennaro F, De Bruin ED, A. usability study of a multicomponent video game-based training for older adults. *Eur Rev Aging Phys Act.* (2020) 17:1–15. doi: 10.1186/s11556-019-0233-2

16. Altorfer P, Adcock M, de Bruin ED, Graf F, Giannouli E. Feasibility of cognitive-motor exergames in geriatric inpatient rehabilitation: a pilot randomized controlled study. *Front Aging Neurosci.* (2021). doi: 10.3389/fnagi.2021.739948

17. Morat M, Bakker J, Hammes V, Morat T, Giannouli E, Zijlstra W, et al. Effects of stepping exergames under stable versus unstable conditions on balance and strength in healthy community-dwelling older adults: A three-armed randomized controlled trial. *Exp Gerontol.* (2019) 127:110719. doi: 10.1016/j.exger.2019.110719

18. Rendon AA, Lohman EB, Thorpe D, Johnson EG, Medina E, Bradley B. The effect of virtual reality gaming on dynamic balance in older adults. *Age Ageing.* (2012) 41:549–52. doi: 10.1093/ageing/afs053

19. Wüest S, Borghese NA, Pirovano M, Mainetti R, Van De Langenberg R, De Bruin ED. Usability and effects of an exergame-based balance training program. *Games Health J.* (2014) 3:106–14. doi: 10.1089/g4h.2013.0093

20. Adcock M, Thalmann M, Schättin A, Gennaro F, de Bruin ED. A pilot study of an in-home multicomponent exergame training for older adults: feasibility, usability and pre-post evaluation. *Front Aging Neurosci.* (2019) 11:1–17. doi: 10.3389/fnagi.2019.00304

21. Maillot P, Perrot A, Hartley A. Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. *Psychol Aging.* (2012) 27:589–600. doi: 10.1037/a0026268

22. Adcock M, Fankhauser M, Post J, Lutz K, Zizlsperger L, Luft AR, et al. Effects of an in-home multicomponent exergame training on physical functions, cognition, and brain volume of older adults: a randomized controlled trial. *Front Med.* (2020). doi: 10.3389/fmed.2019.00321

23. Dabbs ADV, Myers BA, Mc Curry KR, Dunbar-Jacob J, Hawkins RP, Begey A, et al. User-centered design and interactive health technologies for patientsi. *CIN - Comput Informatics Nurs.* (2009) 27:175–83. doi: 10.1097/NCN.0b013e31819f7c7c

24. O'Cathain A, Croot L, Duncan E, Rousseau N, Sworn K, Turner KM, et al. Guidance on how to develop complex interventions to improve health and healthcare. *BMJ Open.* (2019) 9:1–9. doi: 10.1136/bmjopen-2019-029954

25. Skivington K, Matthews L, Simpson SA, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ.* (2021) 374:2020–1. doi: 10.1136/bmj.n2061

26. Charness N, Boot WR. Aging and information technology use: potential and barriers. *Curr Dir Psychol Sci.* (2009) 18:253–8. doi: 10.1111/j.1467-8721.2009.01647.x

27. Kitzinger J. Introducing focus groups. *BMJ.* (1995) 311:299–302. doi: 10.1136/bmj.311.7000.299

28. Mayring P, Fenzel T. Qualitative inhaltsanalyse. Handb Methoden der empririschen. *Sozialforsch.* (2019). doi: 10.1007/978-3-658-21308-4_42

29. Fenzl T, Mayring P. QCAmap: eine interaktive Webapplikatin für qualitative inhaltsanalyse. *Zeitschrift für Soziologie der Erziehung und Sozial ZSE.* (2017) 37:333–40. doi: 10.23668/psycharchives.11259

30. Arthanat S, Vroman KG, Lysack C, Grizzetti J. Multi-stakeholder perspectives on information communication technology training for older adults: implications for teaching and learning. *Disabil Rehabil Assist Technol.* (2019) 14:453–61. doi: 10.1080/17483107.2018.1493752

31. Shatil E. Does combined cognitive training and physical activity training enhance cognitive abilities more than either alone? A four-condition randomized controlled trial among healthy older adults. *Front Aging Neurosci.* (2013) 5:1–12. doi: 10.3389/fnagi.2013.00008

32. Soares VN, Yoshida HM, Magna TS, Sampaio RAC, Fernandes PT. Comparison of exergames versus conventional exercises on the cognitive skills of older adults: a systematic review with meta-analysis. *Arch Gerontol Geriatr.* (2021) 3:4485. doi: 10.1016/j.archger.2021.104485

33. Kappen DL, Mirza-Babaei P, Nacke LE, Mirza-Babei P, Nacke LE. Older adults' physical activity and exergames: a systematic review. *Int J Hum Comput Interact.* (2019) 35:140–67. doi: 10.1080/10447318.2018.1441253

34. Swanenburg J, Wild K, Straumann D, Bruin ED de. Exergaming in a moving virtual world to train vestibular functions and gait; a proof-of-concept-study with older adults. *Front Physiol.* (2018) 9:1–9. doi: 10.3389/fphys.2018.00988

35. Uzor S, Baillie L. Investigating the long-term use of exergames in the home with elderly fallers. *Conf Hum Factors Comput Syst – Proc.* (2014) 3:2813–22. doi: 10.1145/2556288.2557160

36. Franco JR, Jacobs K, Inzerillo C, Kluzik J. The effect of the Nintendo Wii Fit and exercise in improving balance and quality of life in community dwelling elders. *Technol Heal Care.* (2012) 20:95–115. doi: 10.3233/THC-2011-0661

37. Rosenberg D, Depp CA, Vahia I V, Reichstadt J, Palmer BW, Kerr J, et al. Exergames for subsyndromal depression in older adults: a pilot study of a novel intervention. *Am J Geriatr Psychiatry.* (2010) 18:221–6. doi: 10.1097/JGP.0b013e3181c534b5

38. Lee B, Chen Y, Hewitt L. Age differences in constraints encountered by seniors in their use of computers and the internet. *Comput Human Behav.* (2011) 27:1231–7. doi: 10.1016/j.chb.2011.01.003

39. Peek STM, Wouters EJM, Luijkx KG, Vrijhoef HJM. What it Takes to successfully implement technology for aging in place: focus groups with stakeholders. *J Med Internet Res.* (2016). doi: 10.2196/jmir.5253

40. Charness N, Boot WR. Technology, gaming, and social networking. *Handb Psychol Aging Eighth Ed.* (2016). doi: 10.1016/B978-0-12-411469-2.00020-0

41. Arthanat S, Vroman KG, Lysack C, A. home-based individualized information communication technology training program for older adults: a demonstration of effectiveness and value. *Disabil Rehabil Assist Technol.* (2016) 11:316–24. doi: 10.3109/17483107.2014.974219

42. McLaughlin AC, Gandy M, Allaire JC, Whitlock LA. Putting fun into aging - overcoming usability and motivational issues in video games for older adults. *Ergon Des.* (2012) 20:13–20. doi: 10.1177/1064804611435654

43. Chatterjee S, Price A. Healthy living with persuasive technologies: framework, issues, and challenges. *J Am Med Informatics Assoc.* (2009) 16:171–8. doi: 10.1197/jamia.M2859

44. Shapira N, Barak A, Gal I. Promoting older adults' well-being through Internet training and use. *Aging Ment Heal.* (2007) 11:477–84. doi: 10.1080/13607860601086546

45. Nguyen TTH, Tapanainen T, Obi T. A review of information and communication technology (ICT) training for elderly people - Toward recommendations for developing countries. In: *PACIS 2014 Proceedings*. Chengdu (2014). Available online at: http://aisel.aisnet.org/pacis2014/267

46. Berkowsky RW, Cotton SR, Yost EA, Winstead VP. Attitudes towards and limitations to ICT use in assisted and independent living communities: findings from a specially-designed technological intervention. *Educ Gerontol.* (2013) 39:797–811. doi: 10.1080/03601277.2012.734162

47. Vroman KG, Arthanat S. Lysack C. "Who over 65 is online?" Older adults' dispositions toward information communication technology. *Comput Human Behav.* (2015) 43:156–66. doi: 10.1016/j.chb.2014.10.018

48. Pfister PB, Knols RH, de Bie RA, de Bruin ED. Feasibility of a blended therapy approach in the treatment of patients with inflammatory myopathies. *Arch Physiother.* (2021) 11:1–16. doi: 10.1186/s40945-021-00108-z

49. Zemp DD, Baschung Pfister P, Knols RH, Quadri P, Bianchi G, Giunzioni D, et al. A blended e-health intervention for improving functional capacity in elderly patients on haemodialysis: a feasibility study. *Front Digit Heal.* (2022) 3:4932. doi: 10.3389/fdgth.2022.1054932

50. Yap YY, Tan SH, Choon SW. Elderly's intention to use technologies: a systematic literature review. *Heliyon.* (2022) 8:e08765. doi: 10.1016/j.heliyon.2022.e08765

51. Meekes W, Stanmore EK. Motivational determinants of exergame participation for older people in assisted living facilities: mixed-methods study. *J Med Internet Res.* (2017) 19:e238. doi: 10.2196/jmir.6841

52. Oesch P, Kool J, Fernandez-Luque L, Brox E, Evertsen G, Civit A, et al. Exergames versus self-regulated exercises with instruction leaflets to improve adherence during geriatric rehabilitation: a randomized controlled trial. *BMC Geriatr.* (2017) 17:1–9. doi: 10.1186/s12877-017-0467-7

53. Brox E, Luque LF, Evertsen GJ, Hernandez JEGExergames for elderly: Social exergames to persuade seniors to increase physical activity. In: 2011 5th Int. Conf. Pervasive Comput. Technol. Healthc. Work. PervasiveHealth 2011. (2011). pp 546–549. doi: 10.4108/icst.pervasivehealth.2011.246049

54. Zhao Y, Feng H, Wu X, Du Y, Yang X, Hu M, et al. Effectiveness of exergaming in improving cognitive and physical function in people with mild cognitive impairment or dementia: systematic review. *JMIR Serious Games.* (2020) 8:1–13. doi: 10.2196/16841

55. Cotelli M, Manenti R, Brambilla M, Gobbi E, Ferrari C, Binetti G, et al. Cognitive telerehabilitation in mild cognitive impairment, Alzheimer's disease and frontotemporal dementia: A systematic review. *J Telemed Telecare.* (2019) 25:67–79. doi: 10.1177/1357633X17740390

56. Manenti R, Gobbi E, Baglio F. Effectiveness of an innovative cognitive treatment and telerehabilitation on subjects with mild cognitive impairment: a multicenter, randomized, active-controlled study. *Front Aging Neurosci.* (2020). doi: 10.3389/fnagi.2020.585988

57. Swinnen N, Vandenbulcke M, de Bruin ED, Akkerman R, Stubbs B, Vancampfort D. Exergaming for people with major neurocognitive disorder: a qualitative study. *Disabil Rehabil.* (2020) 3:1–9. doi: 10.1080/09638288.2020.1822934

58. Swinnen N, Vandenbulcke M, de Bruin ED, Akkerman R, Stubbs B, Firth J, et al. The efficacy of exergaming in people with major neurocognitive disorder residing in long-term care facilities: a pilot randomized controlled trial. *Alzheimer's Res Ther.* (2021) 13:1–13. doi: 10.1186/s13195-021-00806-7

59. Swinnen N, de Bruin ED, Dumoulin C, Thalmann M, Guimarães V, De Jong J, et al. The VITAAL stepping exergame prototype for older adults with major neurocognitive disorder: a usability study. *Front Aging Neurosci.* (2021) 13:1–13. doi: 10.3389/fnagi.2021.701319

60. Frey-Widmer C, Goncalves Mantellini G, Bennett J, Höpflinger F. Does ageism exist in swiss physiotherapy? An empirical survey among physical therapists. *WCPT Congr.* (2015). doi: 10.1016/j.physio.2015.03.2687

61. Bernhardsson S, Öberg B, Johansson K, Nilsen P, Larsson MEH. Clinical practice in line with evidence? A survey among primary care physiotherapists in western. *Sweden J Eval Clin Pract.* (2015) 21:1169–77. doi: 10.1111/jep.12380

62. Condon C, McGrane N, Mockler D, Stokes E. Ability of physiotherapists to undertake evidence-based practice steps: a scoping review. *Physiother.* (2016) 102:10–9. doi: 10.1016/j.physio.2015.06.003

63. Al-Enezi L, May S. Why Do Physiotherapists Do What They Do? *A Study of Kuwaiti Physiotherapists Physiother Res Int.* (2017) 22:1–8. doi: 10.1002/pri.1640

64. Turner P, Whitfield TW. Physiotherapists' use of evidence based practice: a cross-national study. *Physiother Res Int.* (1997) 2:17–29. doi: 10.1002/pri.76

65. Mota da. Silva T, da Cunha Menezes Costa L, Garcia AN, Costa LOP. What do physical therapists think about evidence-based practice? A systematic review. *Man Ther.* (2015) 20:388–401. doi: 10.1016/j.math.2014.10.009

66. Eurostat. (2021) How popular is internet use among older people? Available online at: https://ec.europa.eu/eurostat/de/web/products-eurostat-news/-/edn-20210517-1

67. Schweizerische Eidgenossenschaft: Bundesamt für Statisik. (2021) Einzelpersonen und Online-Aktivitäten. Available online at: https://www.bfs.admin.ch/bfs/de/home/aktuell/neue-veroeffentlichungen.assetdetail.20144266.html

68. Zickuhr K, Madden M. *Older Adults and Internet Use*. Washington: Pew Research Center (2012).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 January 2023
DOI 10.3389/fpubh.2022.1075204

OPEN ACCESS

EDITED BY
Ronald W. Berkowsky,
California State University, Channel Islands, United States

REVIEWED BY
Yiming Zhao,
Wuhan University, China
Xi Han,
Guangdong University of Finance and Economics, China

*CORRESPONDENCE
Yuxiang Chris Zhao
✉ yxzhao@vip.163.com

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 20 October 2022
ACCEPTED 28 December 2022
PUBLISHED 24 January 2023

CITATION
Wang X and Zhao YC (2023) Understanding older adults' intention to use patient-accessible electronic health records: Based on the affordance lens.
Front. Public Health 10:1075204.
doi: 10.3389/fpubh.2022.1075204

Understanding older adults' intention to use patient-accessible electronic health records: Based on the affordance lens

Xindi Wang and Yuxiang Chris Zhao*

School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China

Background: Given the aging population and the rapid development of the digital society, concerns about promoting older adults' health skills are increasing. Patient-accessible electronic health records (PAEHRs) are implemented globally for aging health safeguards. The demand for using health-related information communication technologies (ICTs) among older adults and the factors that promote their usage intention of PAEHRs need to be studied.

Methods: Drawing upon affordance theory, we constructed a research model that integrates four affordance types, aggregation, interactivity, collaboration, and communication, to identify the effects of affordances and attachment to platforms and doctors that contribute to older adults' usage intention on PAEHRs. Online survey data from 498 older adults (above 60 years) were collected and analyzed using partial least square-structural equation modeling.

Results: Our findings demonstrated how PAEHR's affordances facilitate older adults' attachment to platforms and doctors. We found that aggregation ($\gamma = 0.417$, $P < 0.001$) and interactivity ($\gamma = 0.397$, $P < 0.001$) can positively influence older adults' attachment to the PAEHR platform, and collaboration ($\gamma = 0.407$, $P < 0.001$) affordance can positively influence older adults' attachment to doctors on the PAEHR platform. Furthermore, seniors' attachment to the platform ($\gamma = 0.598$, $P < 0.001$) and attachment to the doctor ($\gamma = 0.156$, $P < 0.01$) can both positively influence their usage intention, and attachment to the platform had a positive relationship with attachment to doctors ($\gamma = 0.230$, $P < 0.001$) on the PAEHR.

Conclusion: This study enriched the understanding of elders' attachment to doctors on PAEHRs and contributed to the literature on health-related ICT usage targets of older adults. Our findings also shed light on inspiring operators of health-related ICTs to formulate appropriate strategies for aging-friendly design to guide older adults to adopt health-related ICTs in their everyday health information practices.

KEYWORDS

older adults, patient-accessible electronic health records, attachment theory, affordance lens, usage intention

Introduction

Health care organizations are faced with supporting clinical decision-making, empowering consumers, and advancing science through information technology. Given the aging population and concerns about promoting the personal health skills of older adults, patient-accessible electronic health records (PAEHRs) are implemented globally to address aging problems, including doctor–patient relationships and health management (1). However, due to the narrow channel of health knowledge popularization and its limited target population, the scope of the audience for health education has not been extended to elder consumers. Human-computer

interaction (HCI) research on aging has highlighted the possibilities for technology to promote older adults' health and wellbeing (2). Wiljer et al. (3) showed that most renowned experts at the PAEHR workshop agreed that accessing the EHR is a patient's fundamental right. Nevertheless, there was little agreement on exactly how access should be provided.

While many older adults resist digital technology (4), they are also critical adopters of health-related ICTs. With the aging and digitalization of society, the field of information behavior has gradually begun to focus on the needs of older adults' population to use health-related information systems (5, 6). For example, Faiola (7) verified the important role of mHealth in empowering the elders to participate in health care and decision-making. Hoque (8) identified that performance expectations, effort expectations, and social influence are significant influencing factors that promote the adoption of mHealth by older adults based on the UTAUT model. To promote the adoption of health-related ICTs among older adults, Pan (9) suggested that mHealth should reduce older adults' use costs and help them benefit from social, informational, and emotional gratification. Considering that elders' attachment to PAEHRs is not only pertinent to their relationship with doctors but also relates to platforms' technological features, the concept of "affordances" from ecological psychology can explain their sustained engagement with health-related ICTs. Affordances are the possibilities of goal-directed actions that an object provides to a goal-oriented actor (10). Many researchers have adopted the concept of affordance to investigate the actualization of EHR among health care organizations. For example, Strong et al. (11) recognize affordance theory as a lens through which to study the possibilities afforded to the medical group for accomplishing their goals through an EHR system. Vos et al. (12) examined how the collaborative affordances of an EHR are actualized in its use by health care professionals and pointed out that the optimal actualization of EHRs' collaborative affordances in hospitals requires organizational, technical, and behavioral adaptations. Burton-Jones and Volkoff (13) investigated effective use in the context of community-care EHR systems and how a network of affordances supports the achievement of organizational goals.

Recently, research on PAEHR targeted the viewpoints of patients and health care professionals (14). Some of them focused on health care professionals' perceived effects of PAEHR 6 years after launch (15, 16), but most research concentrated on patients' perceptions of health-related engagement and empowerment (17). Burke Redmond et al. (18) configured a subset of a web-based multimedia patient-accessible electronic health record for patient and family access and suggested that the electronic health record could become a useful tool for health information exchange. Moll and Rexhepi (19) investigated patients in Sweden for the long-term effects of PAEHRs on their communication with health care professionals and their involvement in the care process. Rexhepi et al. (20, 21) provided an in-depth understanding of cancer patients' attitudes and experiences with online medical records and indicated that more patients in the near future might prefer to receive bad news through PAEHR, which can reduce anxiety instead of causing negative emotions. Nurgalieva et al. (22) explored patients' perspectives on sharing their health data through PAEHR and surprisingly found that older patients and patients with lower educational levels share more frequently. Eriksson-Backa et al. (23) studied older adults' experiences of using the PAEHRs' associated portal and other electronic health services and found that improving security, usability and additional information and functions might increase their effective use.

To date, previous studies have provided inadequate insights into PAEHR usage intention among older adults and have also been limited in terms of users' attachment to doctors and platforms relating to PAEHRs. These two gaps point to a critical need for a theory-informed analytical understanding of how elder individuals' perceptions of PAEHRs' function affect their usage intention from the affordance lens. The first objective of our study was to identify the antecedents of older adults' intention to use PAEHRs by considering attachment theory and affordance perspectives, developing a research model to illustrate how the affordances of PAEHRs can facilitate elders' attachment to doctors and platforms and the influencing mechanism of attachment on usage intention. The second objective of our study was to explore the possible existence of relationships between the older adult's perception of PAEHRs' affordance, elders' attachment to the platform due to feature-rich integration and interaction with PAEHRs, and elders' attachment to doctors due to communication and collaboration between them. Based on affordance theory and attachment theory, we embarked on an empirical study of PAEHR usage intention among the older adult population. In particular, this study addressed three research questions:

RQ1—How could PAEHRs' affordance influence older adults' attachment to doctors and platforms?
RQ2—How could older adults' attachment to doctors and platforms influence their usage intention of PAEHRs?
RQ3—How does older adults' attachment to platforms' technological features affect their attachment to doctors on PAEHRs?

Research model and hypothesis development

Attachment and usage intention

Organizational scholars have defined attachment as the psychological state of the employee's relationship with their organization. In the field of ICT, it can be defined as an attachment to online group members and the online platform they were using (24). Older adults can form an attachment to a particular object (25). The attachment to a unique ICT such as PAEHRs, or rather the platform that can provide actions has stimulated the enthusiasm of older adults. Especially when people receive positive feedback in the process of interacting with PAEHRs (for example, making medical decisions or learning health-related knowledge), they tend to generate positive emotions such as confidence and trust, which will encourage them to use PAEHRs more actively. Thus, we hypothesized the following:

H1: Object attachment to the platform of PAEHRs positively influences the usage intention of older adults.

Elders' relationship with doctors on PAEHRs can also be a factor influencing their intention of health management (26). We thought the effect of older adults' emotional attachment reflects an affective bond between patients and doctors on EHR usage intention. Patients'

emotional attachment to doctors drives their usage intention, as they revisit the doctors on the platform (27). Elders' emotional attachment has a mediating role in driving their routinized use of social media (28). In the context of patient-accessible electronic health records, we hypothesized the following:

H2: Emotional attachment to doctors on PAEHRs positively influences the usage intention of older adults.

In the context of PAEHRs, we also discuss the effect of older adults' attachment to a platform on their attachment to doctors who provide health care services on it. Currently, it is necessary to rely on ICTs to communicate with doctors for health-related purposes (29). Attachment to the platform drives people to manage their health and enhances patient–doctor emotional bonds on PAEHRs. The patients who used personal health records reported more positive feedback, such as maintaining contact with their doctors (30). The stronger people's dependence on PAEHRs, the more eager they are to engage with their health issues, thereby influencing users' attachment to doctors through communication and collaboration on the platform. Thus, we hypothesized the following:

H3: Older adults' object attachment to the platform of PAEHRs positively influences their emotional attachment to doctors.

Affordances and attachment

The affordances that provide user-object interactions have been informed design decisions for facilitating users' object attachment (25), which implies that EHR affordance should be taken into account as a key factor that influences people's attachment to the platform. Drawing upon affordance theory, we constructed a research model that integrates aggregation affordance, interactivity affordance, collaboration affordance, and communication affordance to test how these affordances affect elders' attachment to the EHR platform. The aggregation affordance and interactivity affordance are proposed from the perspective of the platforms' technological features.

The aggregation affordance of PAEHRs refers to integrating other assistive functions in addition to the electronic medical record. Aggregation affordance provides users with multiple function combinations to complete the task according to their wishes (31), which affords users access to multiple functions within a single application. According to the efficient integration of required functions, which can be operated by users, the PAEHR with aggregation affordances can motivate people to enhance their socialization and meaningful life (32). Thus, we hypothesized the following:

H4: Aggregation affordance positively influences older adults' attachment to the platform of PAEHRs.

PAEHRs' interactivity affordance enables users to know what the PAEHR is and how it works (33), including accessing, reviewing (medical advice), and editing (height, weight, or blood pressure) individual electronic health records or blocking certain medical records from access by other medical staff. With greater interactivity enabled through platforms, the PAEHR provides chances for individuals to master their own abilities or those given by affordances. The elders can become increasingly habitually dependent on these apps for recording or reviewing health records. Thus, we hypothesized the following:

H5: Interactivity affordance positively influences older adults' attachment to the platform of PAEHRs.

Collaboration and communication affordances are proposed from the perspective of the doctor–patient relationship. The collaboration affordance enables users to work together with doctors through PAEHR's coordination features to achieve their goals (34). Wallberg et al. (35) found sound evidence that the majority of patients preferred a collaborative role in treatment decisions, and some of them preferred a passive form of collaboration in which the doctor made the final treatment decision. Doctor–patient collaboration is positively linked to greater fulfillment of patient expectations (36), which might lead elders to form a strong emotional attachment to doctors who can show a cooperative relationship with them. Thus, we hypothesized the following:

H6: Collaboration affordance positively influences older adults' attachment to doctors on PAEHRs.

Integrating communication about health information within health care systems empowers customers with the accessibility of professionals' assistance, which is a vital part of patient treatment (37). The communication affordance allows users to send messages to doctors or contact health care medical staff electronically and ask questions about medical records (33). The great quality of doctor–patient communication increases the trust between doctors and patients (38) and constructs a harmonious physician–patient relationship, which leads to elders' compliance and satisfaction with doctors. Thus, we hypothesized the following:

H7: Communication affordance positively influences older adults' attachment to doctors on PAEHRs.

The research model is presented in Figure 1 and is based on the attachment theory, affordance, and usage intention literature. We aim to examine the effect of PAEHRs' affordance (i.e., aggregation affordance, interactivity affordance, collaboration affordance, and communication affordance) on older adults' perceived attachment (i.e., attachment to platform and attachment to doctors) and their usage intention. We also posited that older adults' attachment to platform routes contributes to their attachment to doctors on PAEHRs, which further influences usage intention.

Methods

Measures

All construct items in this study were adapted from existing studies. Each item was measured using a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). There were two stages of questionnaire formation. Initially, we invited six elder consumers with health-oriented experience in mobile applications from the aging community to participate in the initial questionnaire.

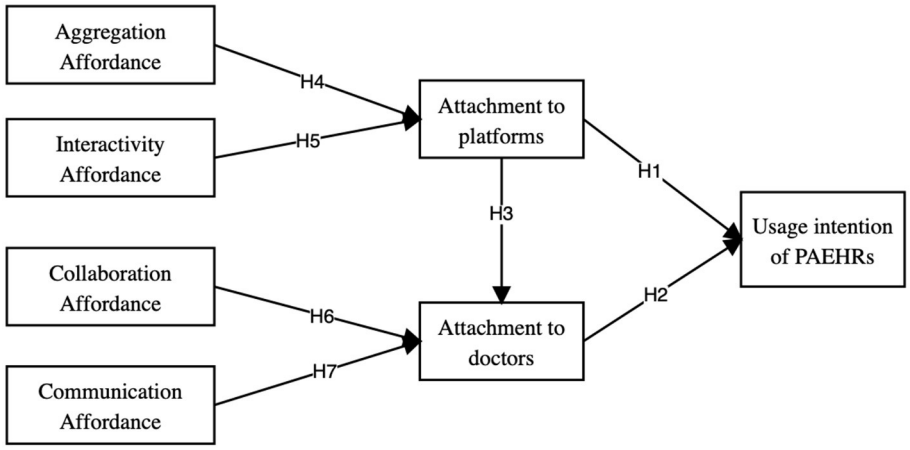


FIGURE 1
Research model.

We revised the questionnaire and obtained the final version based on their feedback. The construct items and references are detailed in Table 1.

Data collection and sample

To examine the proposed research model, we conducted an online survey focused on older adult users over 60 in China and adopted the snowball sampling approach for data collection. People over 60 years of age were selected as potential respondents in the current study for the following reasons. First, according to previous studies, people over 60 are defined as older adults (29). This age group is also usually considered in studies related to health care services among older adults (42). Second, chronic disease prevalence exists among people over age 60; thus, this population segment could have more potential needs and concerns for personal health management.

Finally, a total of 498 questionnaires were collected. Table 2 summarizes the demographic information of the 498 participants, 48.2% were males and 51.8% were females. The age of the participants mostly ranged from 60 to 65. In total, 92.6% thought they were in good health (chose "Excellent," "Very well," and "Good" in the health status option). Two participants reported that their health status was very poor. We set up a multiple-choice question and found that "Recording basic health information (height, weight, blood pressure, blood lipids, etc.)" were selected most frequently as the main contact activity on PAEHRs.

Results

In this study, structural equation modeling (SEM) was adopted to test the proposed hypotheses. We utilized partial least squares (PLS) to test the proposed model, which is a suitable method for the validation of exploratory studies and relatively complicated models (43). SmartPLS 3.3.3 was employed to test both the measurement and structural models. The statistical significance levels of the structural model path coefficients were verified using the bootstrapping technique.

The measurement model

The reliability and validity of the research model were evaluated through multiple data analyses. Reliability is a test of the consistency or stability of survey data. The value of Cronbach's alpha (α) and the composite reliability (CR) were used to examine the internal consistency of the conceptual model constructs. Cronbach's alpha values exceeded the recommended level of 0.7, indicating acceptable reliability. The CR values exceeded the recommended level of 0.8, indicating good reliability (44).

Furthermore, the average variance extracted (AVE) was used to measure the convergent and discriminant validity of the research model. First, the AVE values of all constructs exceed the 0.5 thresholds, suggesting qualified convergence validity and demonstrating that items can effectively show the corresponding constructs (45). The reliability and convergence validity results are detailed in Table 3. Moreover, the diagonal of Table 4 is the square root of AVE, and its values were all higher than the correlation of inner constructs, confirming that the measurement model has good discriminant validity. Our results also showed (see Table 5) that item loadings on their construct were higher than the cross-loadings on any other construct, and all item loadings were larger than the required value of 0.7. These results thus also suggest that convergent validity and discriminant validity are satisfied (46). Finally, we conducted Harman's single-factor test on the ten constructs in the research model. The results showed that the most covariance explained by one factor is 39.236%, indicating that common method biases are unlikely threats to our results (47).

The structural model

The test of the structural model included the examination of path coefficients and the corresponding significance levels. Figure 2 presents the results of the PLS analysis. The hypothesis testing results are listed in Table 6. We also adopted the bootstrapping technique that can directly test the influence of the independent variable on the dependent variable. The results show that the positive effects of attachment to PAEHRs' platform and doctors

TABLE 1 Research items and references.

Constructs	Items	Source
Aggregation affordance	AA1: I would like to review all my health records (i.e., blood pressure, blood glucose) on the PAEHR. AA2: I expect the PAEHR to integrate multiple functions (i.e., appointment registration, online consultation). AA3: I expect the PAEHR to integrate my physical examination reports, medical advice, and other information from different medical institutions.	(31, 32)
Interactivity affordance	IA1: I expect to fully access several sections of the PAEHR system (i.e., health content, medical records). IA2: I would like to record my basic personal information (i.e., height, weight, exercise history, sleep duration) on the PAEHR. IA3: I expect to choose what I want to browse on the PAEHR.	(33, 39)
Collaboration affordance	COL1: I look forward to treating my doctor as a friend and working with them to solve health problems. COL2: I look forward to treating my doctor as a partner and working with them to make health-related plans (i.e., diet plan, exercise plan). COL3: I hope to make efforts for my treatment and recovery by deep thinking with a doctor.	(36, 40)
Communication affordance	COM1: I look forward to discussing health issues with doctors on PAEHRs. COM2: I look forward to being able to ask doctors about health problems on PAEHRs. COM3: I hope that when I am in doubt during my treatment, I can ask my doctor for advice through PAEHRs.	(33, 38)
Attachment to platform	AP1: I think it is important to record my health information (i.e., blood pressure, blood lipids, sleep quality) on PAEHRs. AP2: I think it is important to keep an electronic health record of my medical history, prescriptions, or physical reports. AP3: I'm interested in using PAEHRs.	(30, 41)
Attachment to doctors	AD1: I want to get along well with doctors on PAEHRs. AD2: I look forward to getting closer to doctors on PAEHRs. AD3: Doctors' words have an impact on my thoughts.	(24, 27)
Usage intention of PAEHRs	UI1: I will use PAEHRs to record personal health information. UI2: I will upload my medical prescriptions and other health contents to the PAEHR. UI3: I will keep consultation notes in PAEHRs' electronic health record.	(30, 31)

TABLE 2 Demographic information of participants ($N = 498$).

Measure	Items	Frequency	Percentage (%)
Gender	Male	240	48.2
	Female	258	51.8
Age	60–65	256	51.4
	66–70	145	29.1
	71–75	68	13.7
	76–80	21	4.2
	Over 81	8	1.6
Health status	Excellent	52	10.4
	Very well	213	42.8
	Good	196	39.4
	Poor	35	7.0
	Very poor	2	0.4
Main activities on PAEHRs (multiple choices)	Recording basic health information (height, weight, blood pressure, blood lipids, etc.)	423	84.9
	Uploading/accessing health data (heart rate, sleep time) from smart devices such as smart bracelets	242	48.6
	Recording exercise duration and caloric expenditure	172	34.5
	Uploading/reviewing medical reports, physical examination reports	328	65.9
	Reviewing previous medical records	286	57.4
	Consulting doctors online (sending messages, instant communication)	189	38.0
	Others	16	3.2

on older adults' usage intention are significant, supporting H1 and H2. Attachment to platforms significantly influences attachment to doctors, indicating that H3 is supported. Aggregation affordance and interactivity affordance significantly influence older adults' attachment to the PAEHR platform, and collaboration affordance significantly influences attachment to doctors, indicating that H4, H5, and H6 are supported. The results also suggest that the influences of communication affordance on attachment to doctors are not statistically significant. Hence, H7 is not supported.

We use a quantitative survey method to validate some hypotheses for the empirical study. In total, six of seven hypotheses were supported. In sum, these significant links indicate that PAEHRs' affordance and elders' usage intention of PARHEs have the relationships specified in the model.

Discussion

This study investigated how older adults' attachment to platforms and doctors affects their usage intention of PAEHRs based on the view of affordance. For older adults, our findings show that their attachment to the platform and doctors of the PAEHR positively influences usage intention. Furthermore, older adults' objective attachment to the platform significantly influenced their emotional

TABLE 3 Reliability and convergent validity.

Construct	Composite reliability	AVE	Cronbach's alpha
AA	0.839	0.636	0.717
IA	0.838	0.633	0.710
COL	0.845	0.646	0.726
COM	0.863	0.677	0.763
AP	0.869	0.688	0.773
AD	0.843	0.642	0.722
UI	0.851	0.656	0.737

TABLE 4 Discriminant validity.

Construct	AA	IA	COL	COM	AP	AD	UI
AA	**0.798**						
IA	0.689	**0.796**					
COL	0.637	0.643	**0.804**				
COM	0.597	0.572	0.637	**0.823**			
AP	0.691	0.684	0.617	0.649	**0.829**		
AD	0.561	0.608	0.644	0.558	0.578	**0.801**	
UI	0.585	0.639	0.574	0.628	0.688	0.502	**0.810**

TABLE 5 Loadings and cross loadings.

	AA	IA	COL	COM	AP	AD	UI
AA1	**0.850**	0.575	0.551	0.496	0.653	0.484	0.482
AA2	**0.778**	0.520	0.494	0.446	0.506	0.436	0.437
AA3	**0.761**	0.555	0.474	0.491	0.468	0.419	0.487
IA1	0.536	**0.792**	0.493	0.446	0.525	0.461	0.474
IA2	0.543	**0.808**	0.523	0.463	0.570	0.489	0.471
IA3	0.565	**0.786**	0.517	0.455	0.537	0.501	0.584
COL1	0.474	0.460	**0.786**	0.488	0.455	0.511	0.407
COL2	0.494	0.534	**0.819**	0.507	0.490	0.538	0.484
COL3	0.570	0.556	**0.806**	0.542	0.544	0.503	0.493
COM1	0.472	0.474	0.552	**0.829**	0.515	0.512	0.497
COM2	0.519	0.460	0.502	**0.827**	0.522	0.447	0.546
COM3	0.485	0.478	0.515	**0.813**	0.573	0.407	0.509
AP1	0.630	0.576	0.505	0.490	**0.842**	0.472	0.495
AP2	0.625	0.596	0.552	0.536	**0.842**	0.512	0.531
AP3	0.463	0.530	0.478	0.587	**0.804**	0.453	0.685
AD1	0.486	0.525	0.561	0.505	0.520	**0.825**	0.420
AD2	0.497	0.529	0.567	0.500	0.488	**0.845**	0.425
AD3	0.348	0.392	0.399	0.307	0.364	**0.729**	0.355
UI1	0.466	0.578	0.478	0.384	0.450	0.426	**0.721**
UI2	0.476	0.507	0.489	0.553	0.624	0.422	**0.851**
UI3	0.486	0.489	0.436	0.571	0.583	0.380	**0.851**

attachment to doctors on the PAEHR. Specifically, affordance about the aggregation and interactivity of PAEHRs is positively related to elders' attachment to the platform, and affordance about user-doctor collaboration is positively related to elders' attachment to doctors, while communication affordance has no significant effect on older adults' attachment to doctors.

Facilitators from the perspective of attachment to platform

Drawing upon the affordance lens, we found that older adults' attachment to platforms and doctors can significantly improve their willingness to use PAEHRs. First, this study reveals that the aggregation affordance and interactivity affordance of PAEHRs are contributing factors for motivating older adults' attachment to the platforms. Specifically, with aggregation affordance, the PAEHRs' platform can integrate auxiliary functions in addition to electronic medical records, such as online consultation or health information seeking. The effect of integrated features can affect users' behaviors in the sociotechnical environment (48). Aggregation affordance provides older adults more options to use full-featured PAEHRs by combining different functions to achieve their health-related goals, which can contribute to their attachment to the platform. For example, the elders can enjoy a one-stop shop on PAEHRs, which is a blend of vicarious experience and direct communication with a professional physician for consultation. Depending on their condition, elder patients can choose whether to search for further health information, consult online, or go to an offline brick-and-mortar medical facility for further treatment based on the initial diagnosis provided by the online physicians.

Meanwhile, interactivity affordance allows users to interact with other actors or the environment where they operate through their actions (49). PAEHR's interactivity affordance affords older adults accessibility to their medical records and the permission to control personal preferences, update their health records or share their health-related opinions with their health care providers on the platform. ICT-enabled geriatric patient-friendly interactive experiences can largely enhance the attachment of older adults to PAEHRs, thus further promoting the positive use of health-related ICTs among older adults.

In addition, our results showed that older adults' attachment to the platform of PAEHRs has a positive relationship with their attachment to doctors and their usage intention of PAEHRs. Currently, people are increasingly inseparable from information technology, where it is difficult to distinguish which abilities are their own and which are endowed by ICTs. The functionally integrated PAEHR attracting users to communicate or collaborate with doctors on the platform is related to elders' attachment to the platform and causes their attachment to the doctor on the platform.

Moreover, the results also showed that attachment to the platform and attachment to doctors could both influence older adults' usage intention of PAEHRs, and attachment to the platform had a much more significant influence than attachment to doctors. This finding means that the PAEHR platform integrating functional and accessible features is the most critical factor that assures older adults have the ability to engage in activities on PAEHRs for health management.

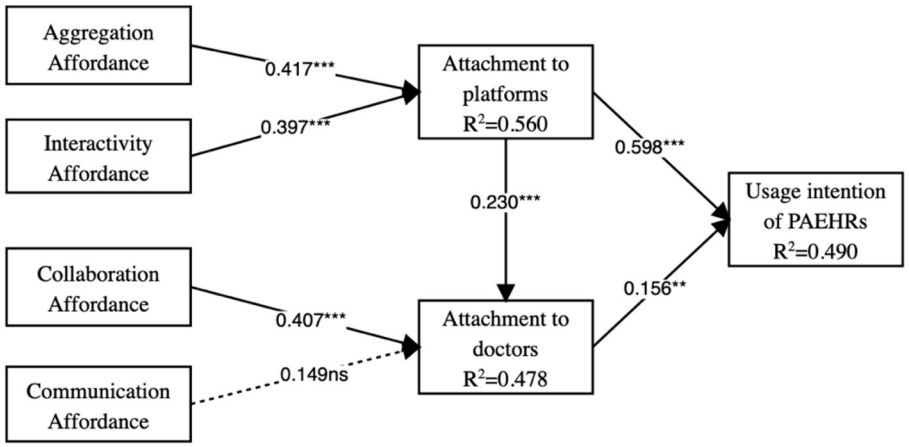


FIGURE 2
Structural equation model with standardized coefficients. **$p < 0.01$, ***$p < 0.001$, ns, nonsignificant. Nonsignificant paths are presented by a dashed line.

TABLE 6 Results of hypothesis testing.

Hypothesis	Paths	Path coefficients	*t*-value	*p*-value	Hypothesis validation
H1	AP→UI	0.598	13.981	0	Supported
H2	AD→UI	0.156	3.145	0.002	Supported
H3	AP→AD	0.230	4.306	0	Supported
H4	AA→AP	0.417	8.804	0	Supported
H5	IA→AP	0.397	7.717	0	Supported
H6	COL→AD	0.407	6.063	0	Supported
H7	COM→AD	0.149	1.911	0.056	Not supported

Facilitators from the perspective of attachment to doctors

Although PAEHRs' platform aggregates essential parts that attract older adults to use, some behavioral influence doctors might have is also critical for older adults' usage intention. We found that collaboration affordance positively influences older adults' attachment to doctors on the PAEHR, while communication affordance did not relate to this kind of attachment. Previous research has proven that communication is a success factor that can construct a harmonious doctor–patient relationship (50). As some studies have shown, doctors' communication and interpersonal skills are essential in health care (51). A good doctor–patient relationship contributes to patients' self-confidence and has a positive influence on therapeutic qualities (52). In the usage context of PAEHRs, users' attachment to doctors is dependent more on the ICT-based skills of patient-centered communication. We speculate that the reason this construct was not significant in this study may be related to the small percentage of older adults in our sample who had online consultations with their physicians (38%). Compared to other types of affordances, such as vicarious interactions, the number of elder patients who have direct communication with their physicians on PAEHRs is still a minority.

Furthermore, previous studies have reported that collaborative aspects were an essential factor influencing the patient–doctor relationship (37). This study also found that collaboration with doctors on the PAEHRs makes older adults feel attached to doctors. Consistent with this argument, prior work found that the patient's collaboration with health care providers promotes mHealth app use for the elders and empowers them with sustainable healthy lifestyle behaviors (7). According to the positive impact of collaboration affordance, cooperating with doctors on the PAEHRs platform helps elder individuals build dependency on the state of self-efficacy with the doctors' support. In particular, the treatments of geriatric diseases, especially chronic pain, are pressing problems for patients and their physicians, requiring older adults' long-term involvement in cooperation with doctors to solve their health problems. Through collaboration with doctors, the relationship between doctors and patients is also promoted, which generates users' attachment to doctors on the PAEHR platform.

This study has several theoretical implications. First, this study is unique in identifying the antecedents of older adults' attachment to doctors and platforms from the affordance lens. Second, this study established the connection between elders' involvement in health issues and attachment to the platform and doctors on PAEHRs, contributing to the literature on attachment theory in health-related ICTs. Our findings are useful for informing the development of optimal designs for elders-oriented applications to bridge the digital gap between older adults' endorsements and new forms of health-related ICTs.

Our research model of older adults' usage intention on PAEHRs has several practical implications. First, it offered healthcare

organizations ideas on attracting older adults to engage in health management and improve health skills. Our research also called on doctors participating in online diagnosis and treatment to pay attention to their communication skills with patients. Second, we reminded health-related system designers to develop an accessible PAEHRs platform that aggregates various functions to support older adults in seeking health information, reading health-related articles, and sharing health opinions. Third, elder individuals' attachment to the platform can contribute to their attachment to doctors whom they can consult on health issues or collaborate on a medical plan. This result reminded PAEHRs' system design professionals that building an elders-oriented platform is the foundation on which supporting the collaboration between doctors and patients is worth being comprehensively considered.

Conclusion

Elders' use of PAEHRs is an effective means of engaging and managing their health issues while also promoting the solution of aging problems. Our results revealed the inherent influencing mechanism of the affordance of PAEHRs on their attachment to doctors and platforms. In summary, designing the PAEHR more suitable for elder individuals, professionals need to focus leave space for patients' involvement in medical decision-making with their health care providers (14), which may also increase doctors' communication skills and patient compliance. Furthermore, PAEHRs should not only be equipped with electronic medical records and other assistive health-related functions to support collaboration between users and doctors but also guide doctors on the platform to pay attention to communication skills when cooperating with users, especially focusing on patient-centered communication, which can contribute to elders' attachment to doctors, thus promoting the usage intention of PAEHRs.

This research has limitations. First, we only focused on older adults who have experience using health-related apps, without considering elder individuals who cannot use mobile phones. Second, questionnaires were obtained online through the self-report of elders, which may lead to their recall bias. Third, the research questionnaire only investigated elder individuals in the form of text, which may not be conducive to their understanding. Although PAEHR applications have been globally implemented, there are many other health-related ICTs for elder individuals. Future research will include a wider range of users among the senior population, and researchers can study the elders-oriented design of other types of health-oriented products.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

XW conceived and designed the study, collected the data, did the data analysis, and wrote the first draft. YZ revised and edited the manuscript and supervised the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by Research on the Construction of Data Resources Framework for the Smart Aging in Healthy China Initiatives supported by the Key Projects of the National Social Science Foundation of China under Grant (No. 22&ZD327). This research was also supported by Postgraduate Research and Practice Innovation Program of Jiangsu Province (No. KYCX22_0550).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Mamra A, Sibghatullah AS, Ananta GP, Alazzam MB, Ahmed YH, Doheir M. Theories and factors applied in investigating the user acceptance towards personal health records: review study. *Int J Healthc Manag.* (2017) 10:89–96. doi: 10.1080/20479700.2017.1289439

2. Shapira N, Azy B, Iddo G. Promoting older adults' wellbeing through Internet training and use. *Aging Ment Health.* (2007) 11:477–84. doi: 10.1080/13607860601086546

3. Wiljer D, Urowitz S, Apatu E, DeLenardo C, Eysenbach G, Harth T, et al. Patient accessible electronic health records: exploring recommendations for successful implementation strategies. *J Med Internet Res.* (2008) 10:e1061. doi: 10.2196/jmir.1061

4. Barros Pena B, Clarke RE, Holmquist LE, Vines J. Circumspect users: Older adults as critical adopters and resistors of technology. In: *Proceedings of the CHI Conference on Human Factors in Computing Systems.* Yokohama (2021). p. 1–14.

5. Zhang X, Xu X, Cheng J. WeChatting for health: what motivates older adult engagement with health information. *Healthcare.* (2021) 9:751. doi: 10.3390/healthcare9060751

6. Wilson J, Heinsch M, Betts D, Booth D, Kay-Lambkin F. Barriers and facilitators to the use of e-health by older adults: a scoping review. *BMC Public Health.* (2021) 21:1–12. doi: 10.1186/s12889-021-11623-w

7. Faiola A, Papautsky EL, Isola M. Empowering the aging with mobile health: a mHealth framework for supporting sustainable healthy lifestyle behavior. *Curr Probl Cardiol.* (2019) 44:232–66. doi: 10.1016/j.cpcardiol.2018.06.003

8. Hoque R, Sorwar G. Understanding factors influencing the adoption of mHealth by the elderly: an extension of the UTAUT model. *Int J Med Inform.* (2017) 101:75–84. doi: 10.1016/j.ijmedinf.2017.02.002

9. Pan J, Dong H. mHealth adoption among older chinese adults: a conceptual model with design suggestions. *Int J Hum Comput Interact*. (2022). doi: 10.1080/10447318.2022.2066247. [Epub ahead of print].

10. Zhao Y C, Zhang Y, Tang J, Song S. Affordances for information practices: theorizing engagement among people, technology, and sociocultural environments. *J Doc.* (2020) 77:229–50. doi: 10.1108/JD-05-2020-0078

11. Strong DM, Volkoff O, Johnson SA, Pelletier LR, Tulu B, Bar-On I, et al. A theory of organization-EHR affordance actualization. *J Assoc Inf Syst.* (2014) 15:2. doi: 10.17705/1jais.00353

12. Vos JF, Boonstra A, Kooistra A, Seelen M, van Offenbeek M. The influence of electronic health record use on collaboration among medical specialties. *BMC Health Serv Res*. (2020) 20:1–11. doi: 10.1186/s12913-020-05542-6

13. Burton-Jones A, Volkoff O. How can we develop contextualized theories of effective use? A demonstration in the context of community-care electronic health records. *Inf Syst Res.* (2017) 28:468–89. doi: 10.1287/isre.2017.0702

14. Cijvat CD, Cornet R, Hägglund M. Factors influencing development and implementation of patients' access to electronic health records—a comparative study of Sweden and the Netherlands. *Front Public Health.* (2021) 9:621210. doi: 10.3389/fpubh.2021.621210

15. Moll J, Cajander Å. Oncology health-care professionals' perceived effects of patient accessible electronic health records 6 years after launch: a survey study at a major university hospital in Sweden. *Health Inf J.* (2020) 26:1392–403. doi: 10.1177/1460458219881007

16. Wass S, Vimarlund V. Same, same but different: Perceptions of patients' online access to electronic health records among healthcare professionals. *Health Inf J.* (2019) 25:1538–48. doi: 10.1177/1460458218779101

17. Huvila I, Cajander Å, Moll J, Enwald H, Eriksson-Backa K, Rexhepi H. Technological and informational frames: explaining age-related variation in the use of patient accessible electronic health records as technology and information. *Inf Technol People.* (2021) 35:1–22. doi: 10.1108/ITP-08-2020-0566

18. Burke Redmond P, Rossi Anthony F, Wilner Bryan R, Hannan Robert L, Zabinsky Jennifer A, White Jeffrey A. Transforming patient and family access to medical information: utilisation patterns of a patient-accessible electronic health record. *Cardiol Young.* (2010) 20:477–84. doi: 10.1017/S1047951110000363

19. Moll J, Rexhepi H. The effect of patient accessible electronic health records on communication and involvement in care - a national patient survey in Sweden. *Divers Equal Health Care.* (2021) 18:232–40. doi: 10.3233/SHTI200323

20. Rexhepi H, Moll J, Huvila I, Åhlfeldt RM. Do you want to receive bad news through your patient accessible electronic health record? A national survey on receiving bad news in an era of digital health. *Health Inf J.* (2021) 27:1–11. doi: 10.1177/14604582211035817

21. Rexhepi H, Åhlfeldt RM, Cajander Å, Huvila I. Cancer patients' attitudes and experiences of online access to their electronic medical records: a qualitative study. *Health Inf J.* (2018) 24:115–24. doi: 10.1177/1460458216658778

22. Nurgalieva L, Cajander Å, Moll J, Åhlfeldt RM, Huvila I, Marchese M. 'I do not share it with others. No, it's for me, it's my care': On sharing of patient accessible electronic health records. *Health Inf J.* (2020) 26:2554–67. doi: 10.1177/1460458220912559

23. Eriksson-Backa K, Hirvonen N, Enwald H, Huvila I. Enablers for and barriers to using My Kanta–a focus group study of older adults' perceptions of the National Electronic Health Record in Finland. *Inf Health Soc Care.* (2021) 46:399–411. doi: 10.1080/17538157.2021.1902331

24. Ren Y, Harper FM, Drenner S, Terveen L, Kiesler S, Riedl J, et al. Building member attachment in online communities: Applying theories of group identity and interpersonal bonds. *MIS Q.* (2012) 36:841–64. doi: 10.2307/41703483

25. Baxter WL, Aurisicchio M, Childs PR. A psychological ownership approach to designing object attachment. *J Eng Des.* (2015) 26:140–56. doi: 10.1080/09544828.2015.1030371

26. Náfrádi L, Kostova Z, Nakamoto K, Schulz PJ. The doctor-patient relationship and patient resilience in chronic pain: a qualitative approach to patients' perspectives. *Chronic Illn.* (2018) 14:256–70. doi: 10.1177/1742395317739961

27. Wu T, Deng Z, Chen Z, Zhang D, Wu X, Wang R. Predictors of patients' loyalty toward doctors on web-based health communities: cross-sectional study. *J Med Internet Res.* (2019) 21:e14484. doi: 10.2196/14484

28. Zheng S, Gu J. Effect of media richness on older adults' routinized use of social media in mobile applications. *Mob Inf Syst.* (2022) 2022:8836431. doi: 10.1155/2022/8836431

29. Zhao YC, Zhao M, Song S. Online health information seeking behaviors among older adults: systematic scoping review. *J Med Internet Res.* (2022) 24:e34790. doi: 10.2196/34790

30. Taha J, Czaja S J, Sharit J, Morrow DG. Factors affecting usage of a personal health record (PHR) to manage health. *Psychol Aging.* (2013) 28:1124–39. doi: 10.1037/a0033911

31. Majedi A. Consumer adoption of personal health records. (PhD Thesis). University of Ottawa, Ottawa, ON, Canada (2014).

32. Kaptelinin V, Nardi B. Affordances in HCI: toward a mediated action perspective. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. Association for Computing Machinery, New York, NY, USA. (2012). p. 967–76.

33. Karahanna E, Xu SX, Xu Y, Zhang NA. The needs- affordances- features perspective for the use of social media. *MIS Q.* (2018) 42:737–56. doi: 10.25300/MISQ/2018/11492

34. Lee CT, Vanderwater C, Pickrell W, Wong JC. The association among cancer patients' collaboration with their healthcare providers, self-management and wellbeing during radiotherapy: an observational, cross-sectional survey. *Eur J Cancer Care.* (2020) 29:e13308. doi: 10.1111/ecc.13308

35. Wallberg HM, Marianne N, Christina B, Lesley FD, Nils WB. Information needs and preferences for participation in treatment decisions among Swedish breast cancer patients. *Acta Oncol.* (2000) 39:467–76. doi: 10.1080/0284186007500 13375

36. Jahng KH, Martin LR, Golin CE, DiMatteo MR. Preferences for medical collaboration: patient-physician congruence and patient outcomes. *Patient Educ Couns.* (2005) 57:308–14. doi: 10.1016/j.pec.2004.08.006

37. Alsos OA, Das A, Svanæs D. Mobile health IT: the effect of user interface and form factor on doctor-patient communication. *Int J Med Inform.* (2012) 81:12–28. doi: 10.1016/j.ijmedinf.2011.09.004

38. Montanaro E, Artusi CA, Zibetti M, Lopiano L. Complex therapies for advanced Parkinson's disease: what is the role of doctor-patient communication? *Neurol Sci.* (2019) 40:2357–64. doi: 10.1007/s10072-019-03982-5

39. Du HS, Xiaobo K, Christian W. Inducing individuals to engage in a gamified platform for environmental conservation. *Ind Manag Data Syst.* (2020) 120:692–713. doi: 10.1108/IMDS-09-2019-0517

40. Paylor J, Christopher M. The possibilities and limits of "co-producing" research. *Front Sociol.* (2019) 4:23. doi: 10.3389/fsoc.2019.00023

41. Xiaofei Z, Guo X, Ho SY, Lai KH, Vogel D. Effects of emotional attachment on mobile health-monitoring service usage: an affect transfer perspective. *Inf Manage.* (2021) 58:103312. doi: 10.1016/j.im.2020.103312

42. Jorge SP, David NV, Alba GC, Germán VR, Antonio CJ. Health economic evaluation of exercise interventions in people over 60 years old: a systematic review. *Exp Gerontol.* (2022) 161:111713. doi: 10.1016/j.exger.2022.111713

43. Chin WW, Marcolin BL, Newsted PR. A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Inf Syst Res.* (2003) 14:189–217. doi: 10.1287/isre.14.2.189.16018

44. Bagozzi R, Yi Y. On the Evaluation of structural equation models. *J Acad Mark Scie.* (1998) 16:74–94. doi: 10.1007/BF02723327

45. Straub D, Boudreau MC, Gefen D. Validation guidelines for IS positivist research. *Commun Assoc Inf Syst.* (2004) 13:24. doi: 10.17705/1CAIS.01324

46. Gefen D, Straub D. A practical guide to factorial validity using PLS-Graph: tutorial and annotated example. *Commun Assoc Inf Syst.* (2005) 16:91–109. doi: 10.17705/1CAIS.01605

47. Podsakoff PM, Organ DW. Self-reports in organizational research: problems and prospects. *J Manage.* (1986) 12:531–44. doi: 10.1177/014920638601200408

48. Liao Z, Yang J, Fu C, Zhang G, CLUENET enabling automatic video aggregation in social media networks. In: *International Conference on Multimedia Modeling.* Berlin, Heidelberg: Springer. (2011). p. 274–84.

49. Nardon L, Kathryn A. Valuing virtual worlds: The role of categorization in technology assessment. *J Assoc Inf Syst.* (2012) 13:772–96. doi: 10.17705/1jais.00311

50. Haluza D, David J. ICT and the future of health care: aspects of doctor-patient communication. *Int J Technol Assess Health Care.* (2014) 30:298–305. doi: 10.1017/S0266462314000294

51. Iordăchescu DA, Golu FT, Paica CI, Gorbănescu A, Panaitescu AM, Gică C, et al. The Relationship between the Infertility Specialist and the Patient during the COVID-19 Pandemic. *Healthcare*. (2021) 9:1649. doi: 10.3390/healthcare91 21649

52. Skea Z, Harry V, Bhattacharya S, Entwistle V, Williams B, MacLennan G, et al. Women's perceptions of decision-making about hysterectomy. *BJOG.* (2004) 111:133–42. doi: 10.1046/j.1471-0528.2003.00027.x

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 27 January 2023
DOI 10.3389/fpubh.2023.1057689

OPEN ACCESS

EDITED BY
Ronald W. Berkowsky,
California State University Channel Islands, United States

REVIEWED BY
Alexander S.,
University of Zurich, Switzerland
Loredana Ivan,
National School of Political Studies and Public Administration, Romania

*CORRESPONDENCE
Gabriela Mustata Wilson
✉ gabriela.wilson@uta.edu

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 29 September 2022
ACCEPTED 09 January 2023
PUBLISHED 27 January 2023

CITATION
Cevallos N, Ramadhani WA, Lindgren J, Bell B, Martinez-Cosio M, Harvey TE, Nanda U and Mustata Wilson G (2023) (St)aging in place: Information and communication technologies for a health-centered agile dwelling unit. *Front. Public Health* 11:1057689. doi: 10.3389/fpubh.2023.1057689

(St)aging in place: Information and communication technologies for a health-centered agile dwelling unit

Nicole Cevallos[1], Widya A. Ramadhani[2,3], Julia Lindgren[4], Bradley Bell[4], Maria Martinez-Cosio[4], Thomas E. Harvey[3], Upali Nanda[3,5] and Gabriela Mustata Wilson[1]*

[1]Multi-Interprofessional Center for Health Informatics, The University of Texas at Arlington, Arlington, TX, United States, [2]School of Architecture, University of Illinois Urbana-Champaign, Champaign, IL, United States, [3]Center for Advanced Design Research and Evaluation, Dallas, TX, United States, [4]College of Architecture, Planning, and Public Affairs, The University of Texas at Arlington, Arlington, TX, United States, [5]HKS Architects, Dallas, TX, United States

As the number of older adults is growing rapidly in the U.S., the need for personalized, innovative, and sustainable Information and Communication Technologies (ICTs) solutions is critical to support individuals' social, emotional, and physical health. Such technology can significantly help older adults' ability to live independently in their homes despite the challenges the aging process may present, referred to as aging or staging in place. In this study, we explored ways to integrate ICTs into Agile Dwelling Units (AgDUs) through affordable, innovative, technology-enabled tools and practices that can be adapted to respond to individual's needs while supporting independent, secure, and engaged healthy living. The technology-enabled and human-centered AgDUs organically transform in response to users' needs. This approach offers a viable solution for older adults at different stages throughout their lifespan to transition into an intimate, technologically-enhanced living environment while allowing for (1) customization to user's needs; (2) cost optimization and maintenance; and (3) accessibility that minimizes gaps in compliance from a provider and user perspectives. Integrating ICTs in AgDUs to support health monitoring and management could reduce forthcoming pressure on the healthcare system and care providers to accommodate the needs of older adults. This approach is described through a collaborative multidisciplinary lens that highlights a partnership between academia, industry experts, and key stakeholders to advance healthy living and extend lifespan through design-build and technology integration. The main goal of this approach is to increase access to health services and optimize healthcare costs.

KEYWORDS

staging in place, aging in place, agile dwelling unit, information and communication technologies, older adult

Introduction

According to the World Health Organization (WHO), the proportion of the world's population over 60 years will nearly double from 12 to 22% from 2015 and 2050. By 2020, people aged 60 years and older have outnumbered children younger than 5 years. In addition, by 2050, 80% of older people will be living in low- and middle-income countries (1). This exponential growth in the older adult population is expected to create higher demand for care and health services and raise concerns about the adaptability of current environments to respond to this group's diverse needs. Undoubtedly, the demand for care is greater than the health services availability (2). Therefore, over the last few years, the older adult population's dependence on ICTs has risen to try and address this gap (3). Health technology is particularly critical for health monitoring and management for the older population. Health-centered digitalized technology

lessens the burden on the growing aging population from how fast and frequently real-time data is updated, stored, and transmitted to a health portal where healthcare professionals can gather accurate patient progress (4). Some examples of health technologies can vary in functionality, such as wearable sensors, computerized cognitive tests, vital monitoring vitals biosensors, and automatic assistive bed lighting. The use of ICTs for supporting older adults' health is not exclusive to tasks directly related to disease treatment or medication management in clinical settings (5). ICTs, specifically Health ICTs, offer the possibility to help older adults in their residential settings with various everyday activities from digitalized technologies that store observed and analyzed data objectively from behaviors of movement all the way to progress of injuries with the use of internet, health applications, and remote monitoring devices, etc. (6). Such increased demand for ICTs to support older adults indicates the need for innovations and developments of ICTs that are designed to allow for independent living, along with a strategic and effective integration of technologies in residential units (7). In this study, we explored ways to integrate ICTs into Agile Dwelling Units (AgDU), a micro-dwelling unit specifically designed with older users in mind to support them in living an independent, secure, and engaged healthy life. AgDUs should at least be equipped with internet access and ideally connected to a health information system with user's primary healthcare. AgDUs may be any size, provided that the proposed total square footage is less than that of the primary unit and that local government requirements are satisfied (8, 9).

The study was conducted by a multidisciplinary team of experts, faculties, and students from the field of health technology, human factors, architecture, and urban planning. There were two phases: (1) research to identify the gaps and challenges in designing technology-integrated dwelling units for aging in place and (2) develop a prototype of agile dwelling units for aging in place. This article is focused on presenting the findings from phase one, which involved literature research, interviews, and roundtable discussions with experts. Eight interviews and two roundtable discussions were conducted remotely between October to December 2021. At least two researchers were involved in each session, one as a facilitator and the other as a note-taker. The meeting was conducted using Microsoft Teams and recorded for transcription and analysis. Participants were experts from research centers, non-profit organizations, design firms, universities, and corporations from various disciplines, such as computer science, public health, architecture, urban planning, nursing, health information technology, and digital technology. They were asked to share their expertise and provide perspectives in their relevant discipline. for better ICTs development that recognizes the need for older adult users' integration in the residential units to support successful (st)aging in place through an Agile Dwelling Unit (AgDU). For a sustainable long-term solution for the aging population as population growth is changing, AgDUs can help stabilize the healthcare system burdens, housing economy concerns, and lifestyle burdens as a result of aging.

The state of ICT for aging in place

To age in place successfully, older adults must be able to live safely, independently, and comfortably in their area of residence while also participating in the community (10, 11). Researchers suggest that maintaining independence, including allowing aging adults to engage in various day-to-day activities, is important for healthy aging in place (12). As we age, we may need social and technical support to adapt to age-related changes and other factors that may interfere with our ability to perform daily activities independently. To understand the role of ICTs and the existing gaps and challenges, the research team conducted peer-reviewed literature research, discovery interviews, and roundtable discussions with experts from various fields, including medical professionals, academic scholars, and industry experts in Technology from Computer Science, Digital Health, Nursing, Health care, Smart Living, and Health Informatics.

Literature shows the increasing trend of ICT development as the economic growth from investments, price trends, and ICTs product revenues have overall positive outcomes (13, 14). However, there are still considerable concerns regarding the accessibility of ICTs for older adults, especially considering the complexity of technology functions and operations. A recent case study shows a lack of ICT skills while overreporting user competencies toward ICTs, which are inaccurate (15). A study conducted in Macedonia, Attica, Central Greece, and areas of Peloponnese had 300 participants aged 65–85 who were interviewed and surveyed. The study aimed to see how familiar elderly individuals were with modern technology. Overall, the study results showed that women, on average, had more exposure to smart appliances and health technology, such as refrigerators, electric stoves, and daily home appliances, while men used more TVs and ATMs more (16). Another qualitative research study in Hong Kong included 50 aging participants (ages 60 and older) surveyed on their negative outlooks on technology. Different technologies were categorized based on barriers experienced from a "personal" (i.e., related to health and functional capacities), "technological" (i.e., related to cost and complexity), and "environmental," i.e., associated with the surrounding environment) perspective (17). Results suggested that individuals do not use technology due to lack of training, digital competency, economic factors, and that the devices are not user-friendly for this aging population. Lack of consideration for involving older adult users' characteristics and needs can impede the access, adoption, compliance, and continued use of ICTs.

Furthermore, interviews and roundtable discussions with industry experts in senior living and health technology highlighted the lack of ICT integration into residential units, especially for aging-in-place support. For instance, the Birkeland Current and Sovrinti company has developed and studied the movement of residents of senior living facilities using sensors and devices in Real Time Location System (RTLS). They collected total activity in a facility per day, time in or out of the home and associated durations, and room utilization (18). This technology has the potential as a preventative measure for community-dwelling older adults who may be in the early stages of dementia or are at risk of falling, but it has not been implemented yet. Using ICTs in residential units to support aging in place has much potential. Still, it needs to be designed to be reliable, easy to use, and adaptable to accommodate the changing needs of individuals.

Lifelong approach to designing for older adults: Introducing (St)aging in place

Designing ICTs to support aging individuals must anticipate changes throughout the aging process. Such changes can be biological, physiological, environmental, psychological, behavioral, and social (19). These changes are noticeable when they impact older adults' health or ability to engage in various everyday activities. When age-related changes significantly affect older adults' independence to do basic daily activities, they need continued support at home, or they may need to move to other residential settings that provide care and support for them. However, the latter choice is less preferred, as most older adults want to stay in their current home and community for as long as possible (20).

When considering ways to accommodate older adults' changing needs, one should consider that aging in place is a dynamic adaptation process. Designing residential units or ICTs should focus on accommodating users with different needs and capacities. The development of the AgDU project presented in this article reconceptualizes the aging-in-place concept, which focuses on life during old age to the **(st)aging in place concept** that emphasizes the changing capacities of individuals throughout the life course as individuals experience aging (21). Integrating the stage concept instead of the age concept means implementing a multigenerational perspective focusing on a longer life- and health span (22). People in the same age group do not necessarily have the same physical, emotional, and cognitive characteristics and needs. Therefore, the staging perspective can capture different stages in life, making the design relevant for older adults and other age groups with various health statuses, capacities, and needs.

Designing residential units with technology in mind

The (st)aging in place idea was further conceptualized into an Agile Dwelling Unit (AgDU) that is agile and adaptable to accommodate various health needs and users' challenges (23). This is a development of an existing residential typology called accessory dwelling units (ADU) that has grown in popularity as sources of secondary income, residences for aging relatives, and even primary residences for those seeking a minimalistic lifestyle. There are many benefits to building and residing in an accessory dwelling unit, such as increasing residential density, flexibility in site location, and the simplicity of spaces without loss of function. However, in the current accessory dwelling unit design and construction trend, these units are often rigid in terms of use and forms. This project explored the innovative solutions to the auxiliary dwelling unit and how they can be translated into an AgDU prototype by integrating ICTs, especially health technologies. In a nutshell, we define **AgDUs** as affordable, innovative, technology-enabled dwelling units that can be adapted to individual needs while supporting independent, secure, and engaged healthy living.

Regarding the spectrum of user interaction, the study performed by Demiris (24) organized ICTs into *active* and *passive* technology. When considering ICTs in relationship to residential units, the research team categorized ICTs based on the relation with the residential units: *attached* and *detached* technology.

- *Attached* technology comprises devices that are a part of a home infrastructure (usually built-in) and are not intended to travel outside the home. This includes lighting sensors, security cameras, digital home assistance, and smart home technology.
- *Detached* technology are devices that are not a part of the housing infrastructure and can become mobile such as mobile devices, tablets, and wearables.
- *Active* technology refers to devices that require the individual to operate and directly interact with the technology (24). For example, turning on and off the lights in a room *vs.* an automated light system where the individual does not have to operate a switch for the lights to function.
- *Passive* technology refers to devices that do not require an individual to operate directly (24). This technology is good for monitoring health and activity, which can be useful in determining users' declining physical or cognitive health. For example, using smart home sensors for detecting falls, tracking physical movements, and detecting heat for cooking. All these sensors do not require direct interaction, such as turning the sensor manually.

Table 1 illustrates the category and examples of ICTs that belong to the intersection of those categorizations. From the user's perspective of interacting with technology, these technologies are categorized as *active* and *passive*. *Active* technology needs direct interaction with the users, whereas *passive* technology is not operated directly by users. Concerning the physical environment, ICTs can be connected to parts of the building or be mobile or worn. Across the two categorizations, ICTs can be situated in four groups: *active-attached*, *active-detached*, *passive-attached*, and *passive-detached* technology. This matrix is intended to guide the identification and selection of ICTs that can be incorporated into residential units. The next step is to examine which technology is suitable for supporting older adults to (st)age in place regardless of their health status, physical limitation, health and technology/digital literacy, and desire.

Discussion

Designing residential units with technology in mind offers viable solutions for older adults with various health conditions and physical capacities to maintain their independence when (st)aging

TABLE 1 St(aging)-in-place ICT Matrix.

	Attached (Part of the home infrastructure and not mare to travel outside the home)	Detached (Not built into the infrastructure of the home)
Active	Ring doorbell Smart lights system	Pill dispenser Smartwatch
Passive	Fall detection sensor Real-time location sensor	Vital sign monitor

The matrix represents technology choices based on the relationship between the user, the built environment, and the behavioral needs.

in place. The categorization of ICTs for (st)aging in place allows designers, providers, and users to map the types of technology that can be integrated into the residential units. Identifying technology needs to be followed by strategies to support successful technology adoption and continued use by older adults and other residents (if any) in the residential units. Literature research, interviews, and roundtable discussions with experts have demonstrated the need for non-invasive, ubiquitous, non-interactive, and simplified functional ICTs to support the everyday life of older adults, including health management and monitoring. This research aims to identify the most effective health ICTs for the aging population. Informed by the findings, the research team proposes three strategies for a successful transition to technology-integrated residential units for (st) aging in place:

Strategy 1: Customizability of ICTs to users' needs

A life-long approach should prepare for the ever-changing health and capacities of users. The physical environment and integrated technology should be customized to the user's needs, abilities, and desires. For instance, customizable displays of household appliances (i.e., font and icon size, notification volume, and methods to input commands) allow older adults with different capacities to operate those appliances for housekeeping activities. Moreover, it is important to remember that customizing technology should involve needs assessment based on users' demographics, digital, and health literacy. This type of customizability is aligned to the findings suggested by Ferati et al. (25), where the sustainability of technology long term uses "Systems Thinking" and "Designing Thinking" to identify several challenges in design solutions (25). Systems thinking allows more for holistic methodology and encompasses the understanding of inter-relationships such as aging and the use of technology. Design thinking encompasses challenging the current status over human ergonomics and technology integration. A 'personalized aging' approach allows users to modify the infrastructure to match their needs and desires across the life stages.

Strategy 2: Cost optimization and maintenance

ICTs are costly, especially when designing AgDU with multiple forms of technology. What makes ICTs expensive involves three aspects: the initial purchase, maintenance of the ICTs through continuous financial investments or services that come with ICT products, and the need to change the technology. Finding strategies to best implement training goes hand in hand with what services are being provided and the type of ICT used. For example, remote monitoring devices linked to an app, such as a biomarker that sends vital signs or trackable steps to the application, have been used after a patient has been discharged. In the long term, this can reduce patients being readmitted to the hospital and reduce costs that could be avoided with more real-time data tracking. This would increase more accurate, productive, optimal medical consultations and decrease unnecessary doctor and medical referrals to see other specialists. Due to COVID-19, tracking certain factors of an individual's health using real-time data is developing into the main health-centric feature changing how health services and medical consultations are done (26). Similarly, a mHealth intervention of 1,617 individuals with diabetes mellitus. The study proposes cost optimization through diabetes and insulin management through smartphone devices. The systems would include clinician consultations frequently, usage, messaging, mobile applications, and addressed low-income patients (27). Results showed cost reductions from avoided unnecessary visits to the hospital, self-monitoring, are cost-effective, and promote lifestyle changes that reduce costs long term, such as healthy dieting (27).

Strategy 3: Accessibility to minimize gaps in compliance

During the roundtable, digital technology experts emphasized ontraining and educating the user about how to use the technology and its functionalities. Users will have higher levels of compliance when they are exposed to training, personalized sessions (online or in-person), and reward systems added for apps or technologies that needs sustainable self-reporting from the users (28). Additionally, when placing different ICTs in a residential unit, it is important to consider the visibility, proximity to related activity, and the ease of access so that users are indirectly reminded to continue using them appropriately.

The three strategies align with the theoretical model of Maslow's Hierarchy of needs. The use of a device can become a habit, and the use of the device can be out of preference or necessity. Human factors and ergonomics are used to identify the health necessities that technology can provide. Maslow's model is a model that determines the order in which the needs of a human are being met. There are five stages of needs: physiological needs, safety, love and belonging, esteem, and self-actualization (29). The first stage is the physiological needs of a human; food, water, and shelter. This project aims to provide all these needs, but most importantly, health under the category's Physiological needs, Safety and Security using technology (29). For physiological need, such as physical mobility, cognitive support, and maintaining or reducing symptoms of chronic diseases of an individual, several attached technology systems cover multiple needs for aging in place.

AgDUs provide physiological needs through the support of health ICTs for all physical or cognitive health-related behaviors highlighted in Figure 1. For example, Cognitive computerized testing can be used as a tactical format to manage dementia, wearable sensors for evaluating walking abilities or sleeping disorders, and environmental sensors to assess the risk of falls (30).

Another instance of physiological need that AgDU can provide is sustainable and affordable shelter, especially when an older adult may develop a chronic disease that does not allow for work in their later stages of life. An experience such as a fall can potentially go from walking to relying on a wheelchair. The AgDU's modality would comply with wheelchair accessibility needs by designing a first floor, wide, smooth flooring. Safety and security needs are also considered from having a sustainable residential environment being affordable of Maslow's model. These three

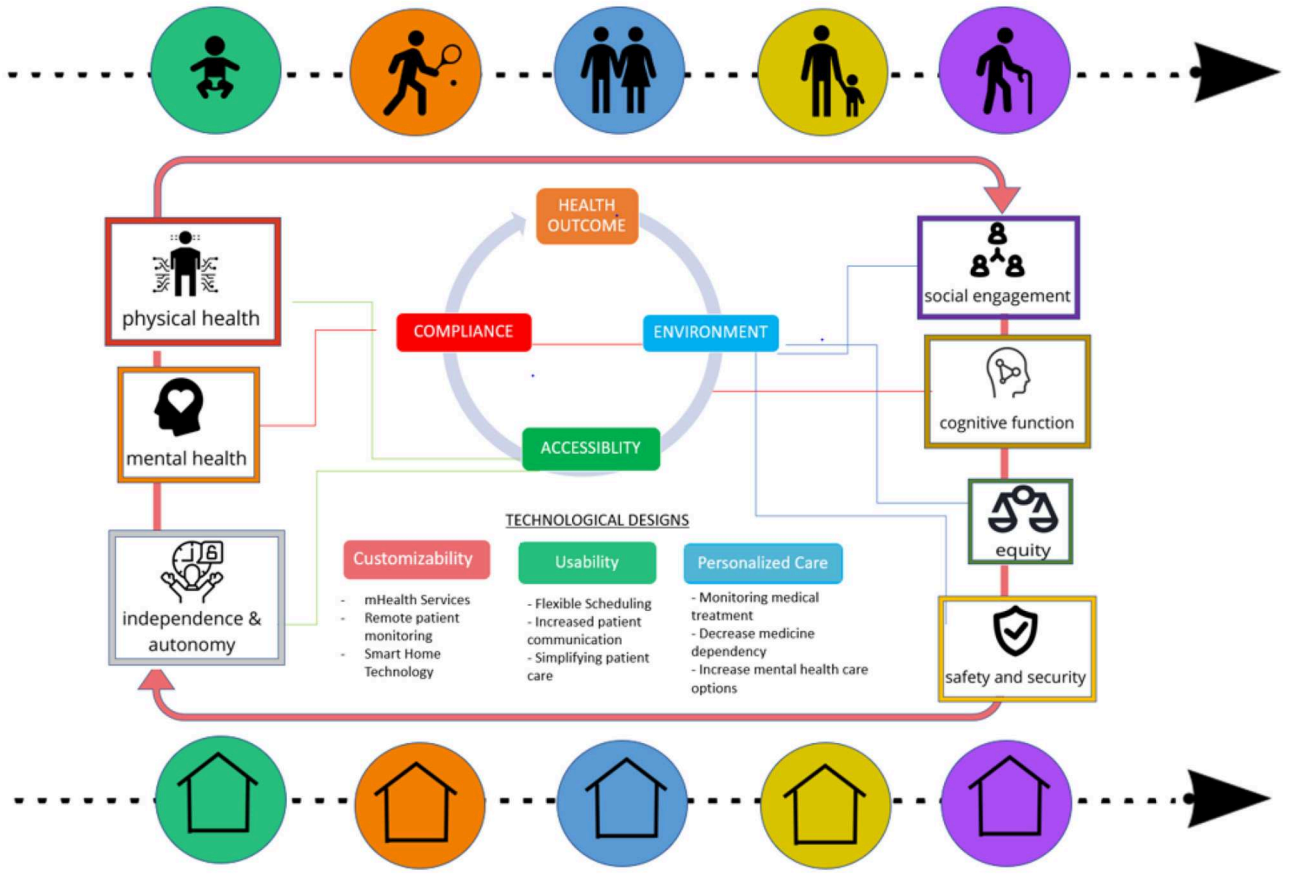


FIGURE 1
St(aging)-in-place ICT strategy diagram. The (st)aging in place concept highlights the home environment's capability to respond to the needs of the individual throughout different life stages in a single residence. The diagram depicts how technological designs support environment, accessibility, and compliance factors.

strategies are highlighted in Figure 1. The three strategies are categorized as compliance, accessibility, and environment. Within each category are design factors, customizability, usability, and personalized care, with a few examples of how the design factors support the three strategies mentioned above. The three strategies and the three design factors are designated to one another in a color-coordinated fashion. The pictures show aspects of health such as physical health, mental health, cognitive function, etc., which need to be considered when integrating various ICTs to achieve better health outcomes while minimizing the burdens on the healthcare system — i.e., compliance, accessibility, and the environment.

As mentioned in the "St(aging)-in-Place" section, the concept comes from the reconceptualization of "aging in place" with the notion of continuous accommodations in the residential space of an aging individual's needs. As the residential environment changes, health ICTs are supposed to be a support and part of the accommodations as needed among older adults. This concept is highlighted in Figure 1 (i.e., both arrows with circles on top and the bottom of the diagram shows a period over time of "stages" in life changing with a same residential environment to indicate that an aging individual does not need to move away from their home to satisfy whatever needs are required to sustain independent living).

Conclusion

In recent years innovation in Information Technology (ICT) has increased overall. Even so, there is a need to improve ICT design for older adults and the services provided for using ICTs to enhance digital competency and digital literacy among older adult users, specifically for health technological design. Residential units designed with the integration of ICTs in mind offer a viable solution for older adults to stage in place. With the variety of health conditions, physical capacities, and availability of social support, a technology-integrated residential unit like AgDU can facilitate users in adapting to the changes throughout their life course. Collaboration between users, architects, healthcare, and technology providers is needed to ensure successful integration into the residential units and care plans while providing reliable support for the users for successful technology adoption and

continued use to support their health and wellbeing. This study is an early ideation stage of an AgDU. While several early prototypes have been designed and developed by the University of Texas at Arlington students, there is a need to expand the coalition project to study and test the AgDU concept in the community. Involving government agencies and industry partners is a critical next step to further developing AgDU design strategies, development, and deployment.

Additionally, further research is needed to explore the integration of ICTs beyond the physical and digital spaces. This would allow for coordinated care efforts among older adults, caregivers, healthcare providers, and other supporting services contributing to the staging in place. Overall, studies and metrics offer significant promise for the future of aging through ICT skills improvements and design in the built environment.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

UN was employed by HKS Architects.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. World Health Organization. *Ageing and health.* (2021). Available online at: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health (accessed September 27, 2022).

2. National Cancer Policy Forum, I. of M. *Supply and Demand in the Health Care Workforce - Ensuring Quality Cancer Care through the oncology workforce - NCBI... Ensuring Quality Cancer Care through the Oncology Workforce: Sustaining Care in the 21st Century.* (2009). Availabel online at: https://www.ncbi.nlm.nih.gov/books/NBK215249/ (accessed September 16, 2022).

3. Marston HR, Genoe R, Freeman S, Kulczycki C, Musselwhite C. Older adults' perceptions of ICT: Main findings from the technology in later life (till) study. In: *Healthcare* (Basel, Switzerland). (2019). Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6787574/ (accessed September 16, 2022).

4. Seifert A, Cotten SR. Use of information and communication technologies among older adults: Usage differences, health-related impacts, and future needs. In: Rohlinger DA, Sobieraj S. editors. *The Oxford Handbook of Sociology and Digital Media.* Ney York, NY: Oxford University Press. (2021) p. 1–27. doi: 10.1093/oxfordhb/9780197510636.013.12

5. Anderson M, Perrin A. *2. barriers to adoption and attitudes towards technology*. Pew Research Center: Internet, Science and Tech. (2019). Available online at: https://www.pewresearch.org/internet/2017/05/17/barriers-to-adoption-and-attitudes-towards-technology/ (accessed September 16, 2022).

6. Peek STM, Luijkx KG, Vrijhoef HJM, et al. Understanding changes and stability in the long-term use of technologies by seniors who are aging in place: A dynamical framework. *BMC Geriatr.* (2019) 19:236. doi: 10.1186/s12877-019-1241-9

7. Peek STM, Wouters EJM, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJM. Factors influencing acceptance of technology for aging in place: A systematic review. *Int J Med Inform.* (2014) 83:235–48. doi: 10.1016/j.ijmedinf.2014.01.004

8. AARP. *ADU Model state act and local ordinance.* (2021). Available online at: https://www.aarp.org/livable-communities/housing/info-2021/adu-model-state-act-and-local-ordinance.html (accessed January 16, 2022).

9. Hannon C. *Accessory Dwelling Units: Model State Act and Local Ordinance.* American Planning Association. (2021). Available online at: https://www.planning.org/knowledgebase/resource/9123024/ (accessed January 16, 2022).

10. Centers for Disease Control and Prevention. *Healthy Places Terminology*. (2009). Available online at: https://www.cdc.gov/healthyplaces/terminology.htm (accessed May 1, 2022).

11. Rogers WA, Ramadhani WA, Harris MT. Defining aging in place: The intersectionality of space, person, and time. *Innov. Aging.* (2020) 4:igaa036. doi: 10.1093/geroni/igaa036

12. National Institute on Aging. *Participating in activities you enjoy as you age.* (2022). Available online at: https://www.nia.nih.gov/health/aging-place-growing-older-home (accessed September 27, 2022).

13. Toader E, Firtescu B, Roman A, Anton S. Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries. *Sustainability.* (2018) 10:3750. doi: 10.3390/su10103750

14. Nguyen CP, Doytch N. *The impact of ICT patents on Economic Growth: An international evidence.* Telecommunications Policy. (2021). Available online at: https://www.sciencedirect.com/science/article/pii/S0308596121001956?casa_token=DotOww27LawAAAAA%3AG3ByZHjyB7PGivUCN0Kp-WVSMNNJ1gX8Z2LZElQltUJC9ZgpfCoBBaaqfR0J75l_OvON-Nfa7DPy (accessed September 16, 2022).

15. Palczyńska M, Rynko M. ICT skills measurement in social surveys: Can we trust self-reports? *Quality Quantity.* (2021) 55:917–43. doi: 10.1007/s11135-020-01031-4

16. Roupa Z, Nikas M, Gerasimou E, Zafeiri V, Giasyrani L, Kazitori E, et al. The use of technology by the elderly. *Health Sci J.* (2010) 4:118. Available online at: https://www.researchgate.net/publication/266448717_The_useof~technology_by_the_elderly (accessed August 24, 2022).

17. Chen K, Chan A H. Use or non-use of gerontechnology–a qualitative study. *Int J Environ Res Public Health.* (2013) 10:4645–66. doi: 10.3390/ijerph10104645

18. Birkeland Current. *NIA Study, Birkeland Current.* Available online at: https://www.birkelandcurrent.com/nia-study (accessed December 18, 2022).

19. National Institute on Aging. *The National Institute on Aging: Strategic directions for research, 2020-2025.* Department of Health and Human Services USA. (2020). Available online at: https://www.nia.nih.gov/about/aging-strategic-directions-research/understanding-dynamics-aging (accessed August 24, 2022).

20. Binette J. *2021 Home and Community Preference Survey: A National Survey of Adults Age 18-Plus.* AARP Research: Washington, DC, USA. (2021). doi: 10.26419/res.00479.001

21. CADRE Research. *Building a coalition for (st)aging in place via agile dwelling unit (AgDU).* (2022). Available online at: https://www.cadreresearch.org/agile-dwelling-unit (accessed September 27, 2022).

22. Golden S. *Stage (Not Age): How to Understand and Serve People Over 60, The Fastest Growing, Most Dynamic Market in the World.* Boston, Massachusetts: Harvard Business Review Press. (2022).

23. Ramadhani W. *Agile Dwelling Units coalition team presented at EDRA 53 Conference — CADRE.* (2022). Available online at: https://www.cadreresearch.org/blog/2022/7/7/agdu-coalition-team-presented-at-edra-53 (accessed September 21, 2022).

24. Demiris G. *The future of home health care - NCBI Bookshelf*. Innovations in Technology - The Future of Home Health Care - NCBI Bookshelf. (2015). Available online at: https://www.ncbi.nlm.nih.gov/books/NBK315926/ (accessed September 16, 2022).

25. Ferati M, Bertoni M, Dalipi F, Kurti A, Jokela P, Anderberg P, et al. Tackling the sustainability of digital aging innovations through design thinking and systems thinking perspectives. In: *Presented at the ICT for Health, Accessibility and Wellbeing: First International Conference, IHAW 2021*, Cham: Springer. (2021). p. 179–184. doi: 10.1007/978-3-030-94209-0_15

26. Talal M, Zaidan AA, Zaidan BB, Albahri AS, Alamoodi AH, Albahri OS, et al. Smart home-based IoT for real-time and secure remote health monitoring of triage and priority system using body sensors: Multi-driven systematic review. *J Med Syst*. (2019) 43:1–34. doi: 10.1007/s10916-019-1158-z

27. Shan R, Sarkar S, Martin SS. Digital health technology and mobile devices for the management of diabetes mellitus: state of the art. *Diabetologia*. (2019) 62:877–87. doi: 10.1007/s00125-019-4864-7

28. Farivar S, Abouzahra M, Ghasemaghaei M. Wearable device adoption among older adults: A mixed-methods study. *Int. J Inf Manage*. (2020) 55:102209. doi: 10.1016/j.ijinfomgt.2020.102209

29. Kenrick DT, Griskevicius V, Neuberg SL, Schaller M. Renovating the pyramid of needs: contemporary extensions built upon ancient foundations. *Perspect Psychol Sci*. (2010) 5:292–314. doi: 10.1177/1745691610369469

30. Gros A, Bensamoun D, Manera V, Fabre R, Zacconi-Cauvin A-M, Thummler S, et al. Recommendations for the Use of ICT in elderly populations with affective disorders. *Front Aging Neurosci*. (2016) 8:269. doi: 10.3389/fnagi.2016.00269

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 February 2023
DOI 10.3389/fpubh.2023.1076571

OPEN ACCESS

EDITED BY
Alexander Seifert,
University of Zurich, Switzerland

REVIEWED BY
Mario R. Jokisch,
Institute for Gerontology,
Heidelberg University, Germany
Jeehoon Kim,
Idaho State University, United States

*CORRESPONDENCE
Amy M. Schuster
✉ amschus@clemson.edu

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 21 October 2022
ACCEPTED 24 January 2023
PUBLISHED 10 February 2023

CITATION
Schuster AM, Ghaiumy Anaraky R and Cotten SR (2023) Online health information seeking and the association with anxiety among older adults. *Front. Public Health* 11:1076571. doi: 10.3389/fpubh.2023.1076571

Online health information seeking and the association with anxiety among older adults

Amy M. Schuster[1]*, Reza Ghaiumy Anaraky[2] and Shelia R. Cotten[1,3]

[1]Department of Sociology, Anthropology and Criminal Justice, Clemson University, Clemson, SC, United States, [2]Department of Technology Management and Innovation, Tandon School of Engineering, New York University, New York City, NY, United States, [3]Department of Communication, Clemson University, Clemson, SC, United States

Introduction: The Internet supplies users with endless access to a wealth of information and is generally the first source searched by U.S. adults (18 years and older) when seeking health information. Age and anxiety are associated with online health information seeking (OHIS). Older adults (65 years and older) are increasing their OHIS. Importantly, OHIS can potentially lead to improved health outcomes for older adults. The relationship between OHIS and anxiety is less clear. Studies report those with more symptoms of anxiety are more likely to be OHIS, while other studies find the reverse pattern or no association. Generalized anxiety disorder affects up to 11% of older adults and is oftentimes unrecognized and untreated.

Methods: To address the mixed findings in the literature, we analyzed six waves (2015–2020) of data from the National Health and Aging Trends Study to assess the causal relationship between anxiety and OHIS using a Random Intercept Cross-lagged Panel Model framework.

Results: We found that while anxiety symptoms lead to OHIS in the next wave, OHIS was not associated with anxiety symptoms in the next wave.

Discussion: This suggests that for this sample of older adults, OHIS does not reduce or exacerbate older adults' symptoms of anxiety.

KEYWORDS

online health information seeking, older adults, NHATS, longitudinal, anxiety

Introduction

The growth of the Internet has provided users unlimited access to an abundance of information, including health information. The Internet is typically the first source searched by U.S. adults (18 years and older) when seeking health information (1), in order to alleviate uncertainty and increase medical understanding (2). Online health information seeking (OHIS) is mainly performed to find personal health information, request personal health information (e.g., test results, appointments), or to find health information for others (3).

There has been a steady increase in the percentage of Internet using older adults who are OHIS (4), from 14.5% in 2011 to 43.6% in 2020 (5). In addition, the COVID-19 pandemic prompted a rapid increase in the number of older adults using the Internet to access health information (6, 7). Importantly, OHIS increases older adults' health information knowledge which aides them in decision-making related to health concerns (8). OHIS gives older adults a feeling of empowerment in managing their health and has been associated with increased ability to provide self-care and increased health-related quality of life (8, 9).

Older adults are heterogenous in terms of their OHIS (10). They use different devices, such as smartphones or tablets, to access health information (11). Young-old older adults (65–74 years), compared to those older, are more likely to be OHIS (4, 12, 13) and to use social media for health-related information (14). For example, 63% of community-dwelling older adults, 66–74 years old, use the Internet to search for health information; this number drops to 49% for community-dwelling older adults aged 75 years and older (15). In addition to age, gender, education, annual

income, and health status influence older adults' level of engagement with OHIS. Older adults who are female and who have more chronic health symptoms are more likely to be OHIS (16–20), whereas older adults with less than a high school education and an annual household income of <$25,000 are less likely to be OHIS (4).

Though research focusing on older adults' OHIS is increasing, less is known about how OHIS is related to well-being outcomes among older adults, such as anxiety. On average, 15% of older adults have anxiety symptoms (21) such as constant worrying, being on edge, fearful, or having a hard time concentrating. Having anxiety symptoms is not the same as having an anxiety disorder. Diagnostic criteria for anxiety disorders include having extreme, persistent worry and fear that is difficult to control and affects daily tasks, social life, and relationships (22). Up to 14% of older adults meet the diagnostic criteria for an anxiety disorder (23). Among older adults, generalized anxiety disorder (GAD) is the most common type of anxiety disorder with a prevalence rate of up to 11% (24–26). GAD is characterized by chronic, excessive feelings of dread about routine life issues, activities, or events, where the worst is anticipated, although there is little reason for this belief (27). GAD is often accompanied by physical symptoms such as being easily fatigued, unexplained pains (chest, head, muscles), trembling, sweating, cognitive decline, and feeling out of breath (27, 28). Among older adults, GAD is often unrecognized and untreated, as anxiety symptoms may be unacknowledged or ignored by the older adult or are overlooked by medical professionals who consider the physiological symptoms related to normal aging-related changes (28). Untreated anxiety disorders can decrease older adults' ability to perform daily activities, reduce their overall health, and lower their quality of life (28).

GAD is influenced by a range of social, economic, and genetic factors (29). Research has found that older adults with GAD are excessively concerned about health-related issues, finances, family problems, or the potential for disaster, and they may have problems sleeping, focusing, and relaxing (28). Interestingly, OHIS has been associated with a decrease in anxiety symptoms (3). Most of the research related to OHIS and anxiety has concentrated on health anxiety, the fear of having a critical medical condition even though they have minimal or no symptoms [see articles by Kontos et al. (19) and Berle et al. (20)], yet <10% of older adults experience health anxiety (30–33). However, the relationship between OHIS and anxiety is not well understood at this time. This could be due to studies using different research designs, samples, OHIS and anxiety measures, and analytic approaches. Coglianese et al. (3) performed a longitudinal cohort study analyzing 2 days of data for 105 Italian hospitalized pregnant women using the 40-item State-Trait Anxiety Inventory and the 3-part UIH questionnaire on online information-seeking behaviors. They reported that OHIS and anxiety had a negative association. Berle et al. (20) used a cross-sectional design and sampled 992 adults from Australia, Canada, Ireland, New Zealand, the United Kingdom, and the U.S. using the 7-item PROMIS-Emotional Distress Anxiety Short Form Scale and a 1-item OHIS measure. The found no association between anxiety symptoms and OHIS.

Five studies on the relationship between OHIS and anxiety had samples that included older adults. Cotten et al. (34) analyzed data from the National Cancer Institute's 2005 Health Information National Trends Survey with 2,929 internet using adults (18 years and older) using two measures (amount of online activities created by summing 10 OHIS activities and the 6-item K6 scale). They reported that more OHIS activities (5 or more) were significantly associated with more symptoms of distress. They posit that when individuals seek online health information, they may find varying information, some of which may be inaccurate or misleading. As individuals try to navigate this information, it may lead to uncertainty, which could increase anxiety levels and psychological distress. When individuals experience anxiety and/or distress because of their OHIS, it may lead to further OHIS in an effort to reduce uncertainty. Thus, higher anxiety might be associated with higher levels of OHIS. Conversely, if the information that is found reduces anxiety, it may reduce further OHIS. Choi and DiNitto (35) analyzed one wave (2011) of the National Health and Aging Trends Study data which uses a 2-item Generalized Anxiety Disorder scale (GAD-2) and the 4-item Internet use for health-related tasks measure. They found that higher anxiety symptoms were associated with less OHIS for older adults (65 years and older). de Looper et al. (36) employed a pre/post-test design using the 6-item State-Trait Anxiety Inventory and a 1-item OHIS measure with a sample aged 33–88 years. They reported that OHIS was not significantly related to feelings of anxiety before or after a cancer consultation. Myrick and Willoughby (37) analyzed data from the 2013 Health Information National Trends Survey (HINTS 4, Cycle 3) which used a 1-item anxiety measure and a 1-item OHIS measure and found that U.S. adults (M = 54.68 years, SD = 16.47) who reported feeling anxious all the time were significantly less likely to go online and search for health information. Seçkin (38) used a cross-sectional design with a 1-item adverse effect measure and multiple OHIS measures and reported that U.S. adults (18–93 years, M = 48.82, SD = 16.43) who used Internet health information to manage their healthcare (e.g., self-diagnose, self-treat) had more feelings of worry and anxiety. Due to variability in research designs we cannot determine if OHIS is affecting feelings of anxiety or vice versa. It is likely that feelings of anxiety could lead to OHIS and that OHIS could also lead to feelings of anxiety.

To address the gaps in the literature and the dearth of longitudinal studies examining the relationship between OHIS and GAD among older adults, this study focused on the symptoms of anxiety with a longitudinal sample consisting of only older adults (65 years and older). Though we are not testing a formal theory, we build upon work by Cotten et al. (34) who discussed potential pathways through which ICT use affects mental health. In our case, we speculate that OHIS can help older adults make informed life decisions. However, given that older adults are more likely to experience health concerns, it may be the case that finding more information online may exacerbate anxiety, particularly if they do not have medical professionals to discuss information with or if the information they find online suggests a more serious health concern. Conversely, if the information they find online assuages their worries, it may lessen anxiety. This study is guided by the research question, how do OHIS and anxiety impact each other over time? Based on the literature, we hypothesize that (1) anxiety symptoms will have a negative and longitudinal impact on OHIS and (2) OHIS will have a positive and longitudinal impact on symptoms of anxiety.

TABLE 1 Sample demographics.

	2015 ($N = 7,057$)	2016 ($N = 5,897$)	2017 ($N = 5,161$)	2018 ($N = 4,589$)	2019 ($N = 4,111$)	2020 ($N = 3,524$)
			N (%)			
Gender						
Female	4,060 (57.50)	3,406 (55.76)	2,969 (57.53)	2,650 (57.75)	2,384 (57.99)	2,042 (57.95)
Male	2,997 (42.50)	2,491 (42.24)	2,192 (42.47)	1,939 (42.25)	1,727 (42.01)	1,482 (42.05)
Race						
White	4,867 (68.97)	4,150 (70.37)	3,633 (70.39)	3,255 (70.93)	2,926 (71.17)	2,553 (72.44)
Black	1,431 (20.28)	1,177 (19.95)	1,045 (20.24)	913(19.89)	817 (19.87)	689 (19.55)
Other	759 (10.76)	570 (9.66)	483 (9.35)	421 (9.17)	368 (8.95)	282 (8.80)
Living with partner	3,489 (49.40)	2,877 (48.78)	2,475 (47.95)	2,171 (47.30)	1,915 (46.58)	1,631 (46.28)
			M (SD)			
Age	77.76 (7.62)	78.46 (7.44)	79.10 (7.20)	79.74 (6.99)	80.34 (6.79)	80.75 (6.48)
Education	4.06 (1.73)	4.08 (1.73)	4.10 (1.73)	1.73 (4.12)	4.13 (1.73)	4.18 (1.74)
Overall health	3.23 (1.05)	2.72 (1.53)	2.36 (1.68)	2.10 (1.75)	1.86 (1.75)	1.63 (1.77)
Limitations in ADLs	0.33 (0.76)	0.34 (0.78)	0.36 (0.80)	0.37 (0.81)	0.41 (0.86)	0.40 (0.86)
Anxiety	0.82 (1.27)	0.81 (1.26)	0.80 (1.28)	0.77 (1.23)	0.76 (1.22)	0.79 (1.23)
OHIS	0.84 (0.99)	0.91 (1.04)	0.95 (1.06)	0.96 (1.07)	1.06 (1.06)	1.21 (1.10)

N's vary depending on the level of missing data across the variables.

Materials and methods

Study sample

We used data from wave 5 (2015) to wave 10 (2020) of the National Health and Aging Trends Study (NHATS) which is comprised of a nationally representative sample of older adults (age 65 and above). The NHATS collects information annually through in-person interviews with older adults on their mental and physical function to investigate late in life trends. Data collection began in 2011, with a sample of 8,245 older adults; however, due to participant dropouts or death, the number of respondents decreased each year. To address this sample change, a new cohort of 4,182 participants was added in 2015, creating a total of 8,334 participants in wave 5. For this study, we included 6 waves (2015–2020) of data given: (1) the sample was updated in wave 5 (2015), and (2) the 2020 data was the last available data at the time we carried out the analysis. The baseline in our study was defined at wave 5. We excluded proxy responses and those residing in a nursing home (1,277 participants). The final sample size for this study was 7,057 older adults.

Measures

Online health information seeking

In the NHATS, older adults were asked if they use the Internet or not, *In the last month have you ever gone on the Internet or online for any reason?* Those who respond "yes" were then prompted to answer more detailed questions about their Internet use. For this study, OHIS was measured with three Internet use questions*: In the last year, have you gone on the Internet or online to: (1) contact any of your medical providers, (2) handle Medicare or other insurance matters, (3) get information about your health conditions* (35, 39–41). Response options included yes (coded as 1) or no (coded as 0) to each of these questions. We used a sum score, ranging from 0 to 3, to operationalize OHIS. A higher score reflected more OHIS. Cronbach's alpha for OHIS was 0.651.

Generalized anxiety disorder

Anxiety was assessed through the 2-item Generalized Anxiety Disorder scale (GAD-2): *Over the last month, (1) how often have you felt nervous, anxious, or on the edge? (2) how often have you been unable to stop or control worrying?* (42). The response options ranged from 0 = "not at all" to 3 = "nearly every day." To operationalize anxiety, responses were summed, ranging from 0 to 6. A higher score indicated more anxiety symptoms. The GAD-2 is a validated brief screening measure for assessing anxiety symptoms with good psychometric properties (cut off point ≥3: 86% sensitivity, 83% specificity) (42, 43). NHATs adapted the measure from a 2 week to a month time frame. Cronbach's alpha for GAD was 0.644.

Covariates

We controlled for the following sociodemographic information (age, education, gender, race, living arrangement) and health status [limitations in activities of daily living (ADLs) and self-reported health]. Age (65–107 years) was measured as a continuous variable. Education was measured with eight categories, including "no school", "1–12th grades", "high school diploma", "trade school diploma", "some college", "associate degree", "bachelor's degree", and "graduate degree." Since some levels of education did not have many observations, treating it as a categorical variable was not feasible;

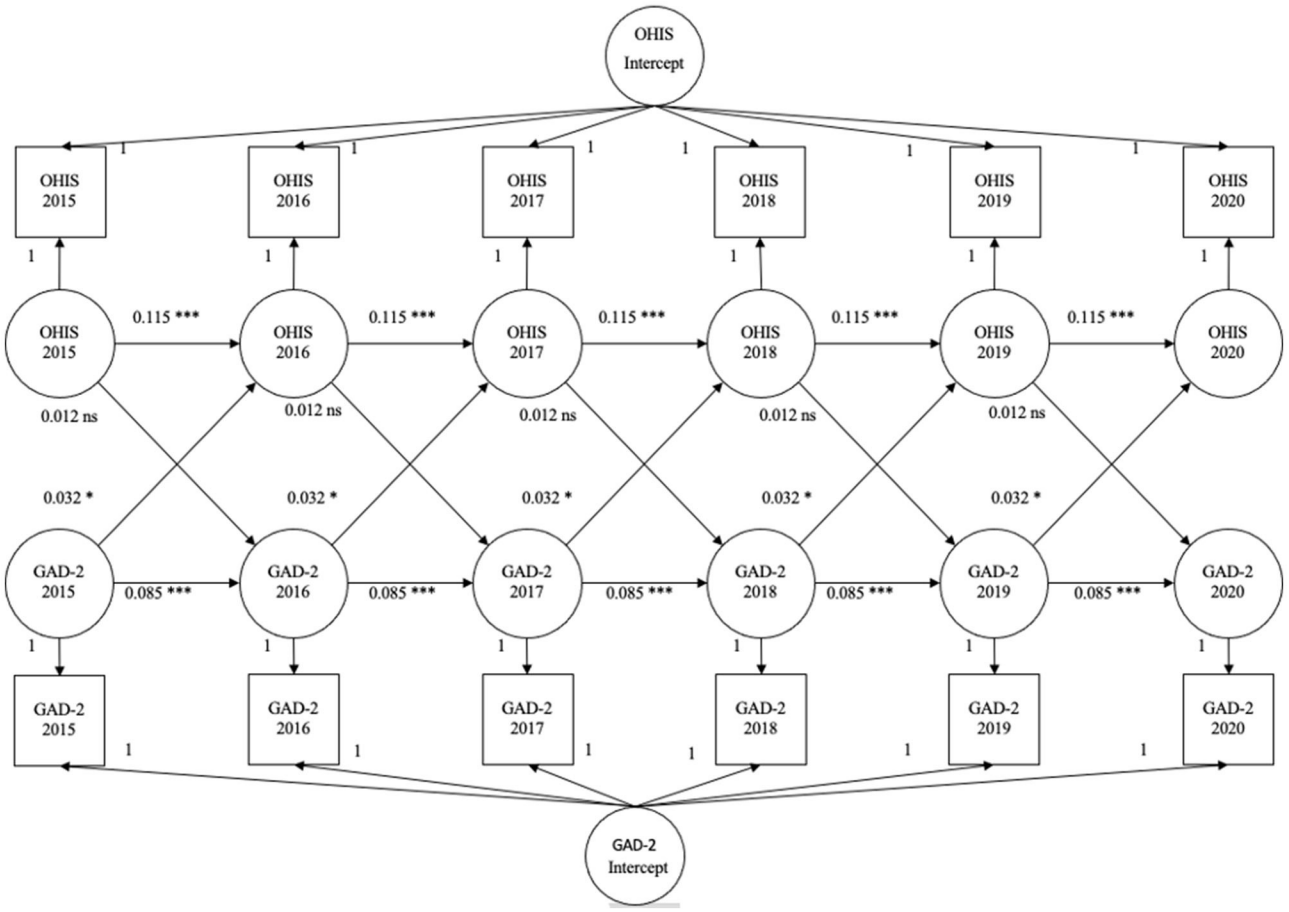


FIGURE 1
Results of RI-CLPM. *$p < 0.05$, ***$p < 0.001$, ns = not significant.

therefore, we treated it as a continuous variable. Gender [1 (male), 0 (female)], race [White (reference category), Black, Other], and living arrangement [0 living alone (never married, widowed, or divorced), 1 living with partner (living with partner or married)] were dummy coded. Race, gender, and level of education were analyzed at baseline (2015). Living arrangement was analyzed at each given wave. In the cases where the living arrangement data was missing in a given wave, we used the last existing data. Limitations in ADLs were measured through four questions measuring the extent of difficulty respondents experienced in using the toilet, eating, getting dressed, and showering or washing up by themselves and without help during the last month. The responses were recorded by a 4-item Likert scale of none, a little, some, or a lot. We used the sum score of these four measures as limitations in ADLs, ranging from 4–16. A self-reported health variable was measured by asking the following question: "Would you say that, in general, your health is excellent, very good, good, fair, or poor?" Self-reported health ranged from 1–5, with a higher score signifing better health.

Analytic strategy

We used a Random Intercept Cross-lagged Panel Model (RI-CLPM) framework to assess the causal relationship between anxiety symptoms and OHIS. The RI-CLPM includes auto-regressive and cross-lagged effects (44). Autoregressive effects allow the state of a unit to be a function of its past state. Cross-lagged effects assess whether one variable at time t can predict another variable at time $t + 1$. The RI-CLPM is a popular method for scholars to study causal relationships between two variables using longitudinal data (3, 20, 36, 37). Furthermore, we followed Hamaker et al. (44) approach by conducting both unconstrained and constrained models. In the unconstrained model, the auto-regressive and cross-lagged effects can vary from wave to wave. In the constrained model, however, model specification constrains the auto-regressive and the cross-lagged effects to be equal over time. The superior model is determined by comparing the fit indices between the unconstrained and constrained models. If the two models are not significantly different, the model is time non-invariant and we choose the constrained model (i.e., the more parsimonious model). If the unconstrained model fits significantly better than the constrained model, it means that the auto-regressive and lagged effects vary among waves. In this case, we proceeded with the unconstrained model. We used the sample weights on 2015 (the baseline year) provided by the NHATS dataset for the analysis. Although the NHATS data has sample weights for each wave, we used a wide format in the RI-CLPM analysis and were only able to use one analytic sample weight. All the analyses were

carried out in R v.4.2. We used the Lavaan package and a full-information maximum likelihood estimator to conduct the RI-CLPM analyses (45).

Results

Older adults in this study at baseline were, on average, aged 77.76 years (SD = 7.62) and were predominantly White (68.97%) and female (57.50%). Table 1 reports participants' demographic information. At baseline, OHIS was on average 0.84 (SD = 0.99) and anxiety was 0.82 (SD = 1.27).

We conducted a RI-CLPM to assess the causal relationships between anxiety and OHIS. We controlled for age, gender, race, living arrangement, education, overall health, and limitations in ADLs. First, we conducted the unconstrained model. This model fit the data good (CFI = 0.969, TLI = 0.951, RMSEA = 0.016, 90% CI: [0.015, 0.017], SRMR = 0.042, $\chi^2_{(217)} = 618.417$, $p < 0.001$) (46, 47). Next, we conducted a constrained model where the auto-regressive and the cross-lagged parameters were equal across the waves. Similar to the unconstrained model, the model fit indices suggested a good fit for the constrained model (CFI = 0.968, TLI = 0.959, RMSEA = 0.015, 90% CI: [0.014, 0.016], SRMR = 0.043, $\chi^2_{(265)} = 667.187$, $p < 0.001$) (46). We followed the criteria recommended by Chen (48) to compare the two models. The criteria suggests accepting time invariance when ΔCFI < 0.010, ΔRMSEA < 0.015, and ΔSRMR < 0.030. The comparisons of our model fit indices were far away from the cutoff points suggested by Chen and the two models are not significantly different from one another. Therefore, we could infer that the model was time invariant, and proceeded with the constrained (more parsimonious) model. We report only the constrained model.

Controlling for age, gender, race, marital status, level of education, limitations in ADLs, and self-reported health, our results suggest a cross-lagged effect of anxiety on OHIS such that a higher level of anxiety would lead to having a higher OHIS in the consequent waves ($\beta = 0.032$, $p = 0.023$). Hypothesis 1 was rejected. In addition, OHIS did not predict anxiety in the next wave ($\beta = 0.012$, $p = 0.563$). Hypothesis 2 was rejected. In addition, we found two within-person autoregressive effects. Anxiety at a given wave predicted anxiety in the next wave ($\beta = 0.085$, $p < 0.001$). Likewise, OHIS at a given wave predicted OHIS in the next wave ($\beta = 0.115$, $p < 0.001$). On average, this model accounted for 17.26 percent of the variance in anxiety and 1.45 percent of the variance in OHIS. Figure 1 shows these results. To keep Figure 1 readable, we did not include information about the control variables. Table 2 presents the results, including the control variables, and how they predict the dependent variables.

Overall, males had lower levels of anxiety compared to females ($ps < 0.001$). Males also showed higher OHIS behaviors in wave 2020 ($p < 0.05$). However, in the other waves, their OHIS was slightly higher, but not significantly different from females. Among the older adults, those who were older showed slightly lower levels of anxiety in waves 2015 and 2016 and less OHIS behaviors across all the waves ($ps < 0.001$). Living with a partner (vs. alone) led to higher levels of anxiety only in wave 2020 ($p < 0.05$) and higher OHIS in waves 2015 to 2018 ($ps < 0.01$). Black respondents reported lower anxiety than White respondents in waves 2015, 2016, 2017, and 2019 ($ps < 0.05$). Furthermore, Black respondents (in waves 2015, 2016, and 2019) and respondents of other races (in waves 2015, 2018, 2019) showed less OHIS behaviors ($ps < 0.05$). Those with a higher education reported lower levels of anxiety (in waves 2015 to 2019, $ps < 0.05$) and higher OHIS behaviors (across all the waves, $ps < 0.001$).

At the within-level, an increase in one's limitations in ADLs was associated with an increase in one's level of anxiety ($p < 0.001$) but not any difference in OHIS behaviors ($p > 0.05$). Furthermore, a deterioration in one's overall perceived health led to having higher levels of anxiety ($p < 0.001$), but not any difference in OHIS behaviors ($p > 0.05$).

Discussion

This study advances research on the relationship between OHIS and anxiety in two ways. We examined the longitudinal reciprocal relationship between OHIS and anxiety, as the results regarding the relationship between OHIS and anxiety have been mixed in prior studies (3, 20, 36, 37). We also examined these relationships specifically among older adults, a group for which little is known about OHIS and anxiety (34–38).

For our main research objective, examining the causal relationship between OHIS and anxiety, our results suggest that while older adults' feelings of anxiety drive their OHIS, OHIS does not significantly affect anxiety symptoms. This could be because older adults searching online for health information can spring from their anxiety as they strive to find information regarding their own health or that of their social ties. It is likely that limitations in ADLs and perceived health status are related to these patterns given that each was related to higher levels of anxiety in our analysis. Further research is needed with more precise health indicators to better discern the nature of these relationships.

While anxiety leads to more OHIS, the reverse was not found. OHIS was not related to changes in anxiety. It may be the case that older adults' interactions with technology and the feedback they receive from it may not be able to mitigate anxiety. Yet, it also does not exacerbate anxiety. OHIS may affect other aspects of well-being (34), which were not examined in the current study. In addition, research is also needed to further investigate older adults' perceptions of the health information they find online, whether it is perceived as credible, and how they choose to use this information, which have been shown to be important for other demographic groups (18).

Future studies should explore this scenario further and investigate older adults' expectations that may not be fulfilled by the current OHIS procedures, and whether and how technology can adapt to older adults needs to better meet their expectations. In particular, technology developers should focus on providing interface designs that facilitate easy use for older adults and those who may not be as skilled in using technologies for OHIS. Being able to easily find reliable and valid online health information and to easily identify that the information is reliable and valid may help mitigate anxiety. Conversely, trouble finding this information or in knowing whether the information is reliable and valid could potentially exacerbate anxiety. Revisiting the technology design and providing a better OHIS experience for older adults can benefit them in several ways. First, an OHIS procedure tailored to older adults' needs can potentially encourage more older adults to search for online health information. In addition, while current OHIS practices do not mitigate older adults' anxiety, an older-adult-friendly OHIS procedure can potentially mitigate some of older adults' anxiety. This

10.3389/fpubh.2023.1076571

TABLE 2 The results of the RI-CLPM.

DV: Anxiety									
	2015			2016			2017		
	β	SE	p-value	β	SE	p-value	β	SE	p-value
Between-level									
Age	−0.009	0.003	<0.001	−0.006	0.003	0.032	−0.004	0.003	0.173
Gender (vs. Female)	−0.311	0.036	<0.001	−0.306	0.038	<0.001	−0.297	0.040	<0.001
Race (Black vs. White)	−0.167	0.044	<0.001	−0.145	0.046	0.002	−0.155	0.050	0.002
Race (Other vs. White)	0.023	0.062	0.716	0.004	0.067	0.955	−0.033	0.069	0.627
Education	−0.035	0.010	0.001	−0.039	0.011	<0.001	−0.033	0.011	0.004
Living with partner (vs. alone)	−0.065	0.038	0.088	−0.025	0.038	0.519	0.041	0.040	0.306
Within-level									
Limitations in ADLs	0.236	0.017	<0.001	0.236	0.017	<0.001	0.236	0.017	<0.001
Overall health	−0.231	0.011	<0.001	−0.231	0.011	<0.001	−0.231	0.011	<0.001
Anxiety (prior wave)	–	–	–	0.085	0.016	<0.001	0.085	0.016	<0.001
OHIS (prior wave)	–	–	–	0.012	0.020	0.563	0.012	0.020	0.563
	2018			2019			2020		
	β	SE	p-value	β	SE	p-value	β	SE	p-value
Between-level									
Age	−0.002	0.003	0.423	−0.005	0.003	0.125	−0.005	0.003	0.114
Gender (vs. Female)	−0.285	0.040	<0.001	−0.281	0.042	<0.001	−0.396	0.045	<0.001
Race (Black vs. White)	−0.056	0.052	0.282	−0.181	0.050	<0.001	−0.107	0.055	0.053
Race (Other vs. White)	0.054	0.072	0.450	0.016	0.072	0.818	0.042	0.078	0.594
Education	−0.025	0.011	0.028	−0.048	0.012	<0.001	−0.020	0.012	0.105
Living with partner (vs. alone)	0.022	0.041	0.593	0.002	0.043	0.958	0.093	0.046	0.043
Within-level									
Limitations in ADLs	0.236	0.017	<0.001	0.236	0.017	<0.001	0.236	0.017	<0.001
Overall health	−0.231	0.011	<0.001	−0.231	0.011	<0.001	−0.231	0.011	<0.001
Anxiety (prior wave)	0.085	0.016	<0.001	0.085	0.016	<0.001	0.085	0.016	<0.001
OHIS (prior wave)	0.012	0.020	0.563	0.012	0.020	0.563	0.012	0.020	0.563
DV: OHIS									
	2015			2016			2017		
	β	SE	p-value	β	SE	p-value	β	SE	p-value
Between-level									
Age	−0.012	0.003	<0.001	−0.017	0.004	<0.001	−0.017	0.004	<0.001
Gender (vs. Female)	0.046	0.043	0.284	0.076	0.046	0.099	−0.008	0.048	0.863
Race (Black vs. White)	−0.197	0.058	0.001	−0.169	0.068	0.013	−0.120	0.072	0.094
Race (Other vs. White)	−0.228	0.069	0.001	−0.097	0.081	0.231	0.001	0.098	0.994
Education	0.098	0.011	<0.001	0.098	0.012	<0.001	0.099	0.013	<0.001
Living with partner (vs. alone)	0.129	0.042	0.002	0.132	0.045	0.004	0.152	0.046	0.001
Within-level									
Limitations in ADLs	0.017	0.017	0.319	0.017	0.017	0.319	0.017	0.017	0.319
Overall health	−0.012	0.012	0.318	−0.012	0.012	0.318	−0.012	0.012	0.318
Anxiety (prior wave)	–	–	–	0.032	0.014	0.023	0.032	0.014	0.023
OHIS (prior wave)	–	–	–	0.115	0.020	<0.001	0.115	0.020	<0.001

(Continued)

TABLE 2 (Continued)

	2018			2019			2020		
	β	SE	p-value	β	SE	p-value	β	SE	p-value
Between-level									
Age	−0.019	0.004	<0.001	−0.021	0.004	<0.001	−0.023	0.004	<0.001
Gender (vs. female)	0.043	0.050	0.393	0.094	0.051	0.064	0.110	0.053	0.040
Race (Black vs. White)	−0.124	0.076	0.102	−0.208	0.080	0.009	−0.006	0.088	0.947
Race (Other vs. White)	−0.204	0.093	0.028	−0.272	0.096	0.005	0.096	0.116	0.410
Education	0.114	0.013	<0.001	0.095	0.014	<0.001	0.075	0.015	<0.001
Living with partner (vs. alone)	0.137	0.048	0.004	0.007	0.048	0.885	0.056	0.052	0.281
Within-level									
Limitations in ADLs	0.017	0.017	0.319	0.017	0.017	0.319	0.017	0.017	0.319
Overall health	−0.012	0.012	0.318	−0.012	0.012	0.318	−0.012	0.012	0.318
Anxiety (prior wave)	0.032	0.014	0.023	0.032	0.014	0.023	0.032	0.014	0.023
OHIS (prior wave)	0.115	0.020	<0.001	0.115	0.020	<0.001	0.115	0.020	<0.001

may indirectly improve older adults' quality of life by reducing their anxiety (28).

Among our sample of Internet using older adults, OHIS increased slightly with each wave. This result is consistent with the literature reporting a steady increase over the years of older adults who are OHIS (15). In addition, we found that across each wave, young-old older adults were more likely to be OHIS, which is also consistent with the literature (4, 16–18). Researchers also need to be cognizant of rapid changes, like COVID-19, that create new opportunities and new challenges for older adults to search for health resources *via* the Internet. During the COVID-19 pandemic, there was a rapid increase in the number of older adults who were OHIS for information and using online portals to communicate with providers (6, 49, 50), which suggests that researchers who analyze future waves of NHATS data may find additional pathways through which OHIS and anxiety are interrelated.

Limitations

There are a few limitations to note in this study. First, the NHATS dataset is comprised of self-reported responses so there is the possibility of recall bias. Second, NHATS has a dichotomized measure for the different types of Internet use in the past year which limited the depth of the OHIS measure used in this study. Interestingly, none of the previous cross-sectional studies on the relationship between OHIS and anxiety reported the same results as our study which could be related to the variability of OHIS measures used in each study. Three studies measured OHIS with 1-item but different questions (20, 36, 37). Two studies had more thorough measures that included questions related to type of health information searched and frequency of search (3, 38). This could also be due to the difference in research designs between the studies, with our study being longitudinal and focusing only on older adults. OHIS is not a linear process or a single event (51, 52). Research is needed that utilizes longitudinal data that includes more robust OHIS measures which assess the amount of use, type of use, reasons for the use, and how the health information was used. Knowing these aspects of OHIS may help to further elucidate how anxiety and OHIS are interrelated among older adults. Third, due to the timeframe change for the GAD-2 from 2-weeks to a month the reliability of the measure decreased. However, a lower Cronbach's alpha is not uncommon with a 2-item measure (53) and for NHATS measures where a timeframe has been adapted (54).

Practical implications and future directions

In conclusion, this study suggests that a causal relationship exists between anxiety and OHIS, with higher anxiety leading to more OHIS among this sample of older adults. It does not suggest, however, that OHIS is bad for older adults in terms of inducing or exacerbating anxiety. Nor does OHIS reduce anxiety. Further research using more nuanced measures of OHIS may provide further delineation of the impacts of OHIS on older adults' well-being. While this study suggests that OHIS does not affect anxiety level in older adults in this sample, further longitudinal research utilizing more robust measures of OHIS are clearly warranted.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://nhats.org/researcher/nhats.

Ethics statement

NHATS was approved by the Johns Hopkins University Institutional Review Board and all participants provided informed consent. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SC conceived the project and provided feedback on and edited the first draft. RG performed the analysis and together with AS wrote the first draft of the manuscript. All authors revised and approved the final version of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Finney Rutten LJ, Blake KD, Greenberg-Worisek AJ, Allen SV, Moser RP, Hesse BW. Online health information seeking among us adults: measuring progress toward a healthy people 2020 Objective. *Public Health Rep.* (2019) 134:617–25. doi: 10.1177/0033354919874074

2. Cotten SR, Gupta SS. Characteristics of online and offline health information seekers and factors that discriminate between them. *Soc Sci Med.* (2004) 59:1795–806. doi: 10.1016/j.socscimed.2004.02.020

3. Coglianese F, Beltrame Vriz G, Soriani N, Piras GN, Comoretto RI, Clemente L, et al. Effect of online health information seeking on anxiety in hospitalized pregnant women: Cohort study. *JMIR Med Inform.* (2020) 8:e16793. doi: 10.2196/16793

4. Hong YA, Cho J. Has the digital health divide widened? trends of health-related internet use among older adults from 2003 to 2011. *J Gerontol B Psychol Sci Soc Sci.* (2017) 73:856–65. doi: 10.1093/geronb/gbw100

5. Freedman VA, Cornman JC, Kasper JD. *Trends in Online Health Information, Adults Ages 70 and Older*. Rockville, Maryland: National Health and Aging Trends Study: Trend Dashboards (2021).

6. Zeng B, Rivadeneira NA, Wen A, Sarkar U, Khoong EC. The impact of the COVID-19 pandemic on internet use and the use of digital health tools: secondary analysis of the 2020 health information national trends survey. *J Med Internet Res.* (2022) 24:e35828. doi: 10.2196/35828

7. Drazich BF, Li Q, Perrin NA, Szanton SL, Lee JW, Huang CM, et al. The relationship between older adults' technology use, in-person engagement, and pandemic-related mental health. *Aging Ment Health.* (2023) 27:156–65. doi: 10.1080/13607863.2022.2046695

8. Seçkin G, Hughes S, Hudson C, Laljer D, Yeatts D. Chapter 8: positive impacts of online health information seeking on health perceptions and the mediational relationship with health communication and sense of empowerment. In: Hale TM, Chou WYS, Cotten SR, Khilnani A, (eds). *Studies in Media and Communications*. Bingley, United Kingdom: Emerald Publishing Limited (2018). p. 205–40.

9. Seçkin G, Hughes S, Yeatts D, Degreve T. Digital pathways to positive health perceptions: does age moderate the relationship between medical satisfaction and positive health perceptions among middle-aged and older internet users? *Innov Aging.* (2019) 3:igy039. doi: 10.1093/geroni/igy039

10. McMillan SJ, Macias W. Strengthening the safety net for online seniors: factors influencing differences in health information seeking among older internet users. *J Health Commun.* (2008) 13:778–92. doi: 10.1080/10810730802487448

11. Mertens A, Rasche P, Theis S, Bröhl C, Wille M. Use of information and communication technology in healthcare context by older adults in Germany: initial results of the tech4age long-term study. *Com.* (2017) 16:165–80. doi: 10.1515/icom-2017-0018

12. Fox S, Duggan M. *Health online 2013*. Washington, D.C.: Pew Research Center. (2013). p. 55. Available from: https://www.pewresearch.org/internet/2013/01/15/health-online-2013/ (accessed January 22, 2023).

13. Meischke H, Eisenberg M, Rowe S, Cagle A. Do older adults use the Internet for information on heart attacks? Results from a survey of seniors in King County, Washington. *Heart Lung.* (2005) 34:3–12. doi: 10.1016/j.hrtlng.2004.06.006

14. Parida V, Mostaghel R, Oghazi P. Factors for Elderly Use of Social Media for Health-Related Activities. *Psychol Mark.* (2016) 33:1134–41. doi: 10.1002/mar.20949

15. Rainie L. *Senior citizens and digital technology*. (2012). Available from: http://www.slideshare.net/PewInternet/senior-citizens-and-digital-technology (accessed on September 15, 2012).

16. Xiao Z. Internet uses for general, health-related, and smoking cessation information seeking from gender and uses and gratifications frameworks. *Int J Commun.* (2022) 16:25.

17. Goldner M, Hale TM, Cotten SR, Stern MJ, Drentea P. The Intersection of Gender and Place in Online Health Activities. *J Health Commun.* (2013) 18:1235–55. doi: 10.1080/10810730.2013.778364

18. Stern MJ, Cotten SR, Drentea P. The separate spheres of online health: gender, parenting, and online health information searching in the information age. *J Fam Issues.* (2012) 33:1324–50. doi: 10.1177/0192513X11425459

19. Kontos E, Blake KD, Chou WYS, Prestin A. Predictors of eHealth usage: insights on the digital divide from the Health Information National Trends Survey 2012. *J Med Internet Res.* (2014) 16:e172. doi: 10.2196/jmir.3117

20. Berle D, Starcevic V, Khazaal Y, Viswasam K, Hede V, McMullan RD. Relationships between online health information seeking and psychopathology. *Gen Hosp Psychiatry.* (2020) 62:96–7. doi: 10.1016/j.genhosppsych.2019.04.006

21. Mehta KM, Simonsick EM, Penninx BW, Schulz R, Rubin SM, Satterfield S, et al. Prevalence and correlates of anxiety symptoms in well-functioning older adults: findings from the health aging and body composition study. *J Am Geriatr Soc.* (2003) 51:499–504. doi: 10.1046/j.1532-5415.2003.51158.x

22. American Psychiatric Association. *Diagnostic and statistical manual of mental disorders. 5th ed.* (2013). Washington, DC: American Psychiatric Association.

23. Wolitzky-Taylor KB, Castriotta N, Lenze EJ, Stanley MA, Craske MG. Anxiety disorders in older adults: a comprehensive review. *Depress Anxiety.* (2010) 27:190–211. doi: 10.1002/da.20653

24. Boehlen FH, Herzog W, Schellberg D, Maatouk I, Schoettker B, Brenner H, et al. Gender-specific predictors of generalized anxiety disorder symptoms in older adults: Results of a large population-based study. *J Affect Disord.* (2020) 262:174–81. doi: 10.1016/j.jad.2019.10.025

25. Beekman ATF, Bremmer MA, Deeg DJH, Van Balkom AJLM, Smit JH, De Beurs E, et al. Anxiety disorders in later life: a report from the longitudinal aging study Amsterdam. *Int J Geriatr Psychiatry.* (1998) 13:717–26. doi: 10.1002/(SICI)1099-1166(1998100)13:10<717::AID-GPS857>3.0.CO;2-M

26. Zhang X, Norton J, Carrière I, Ritchie K, Chaudieu I, Ancelin ML. Generalized anxiety in community-dwelling elderly: Prevalence and clinical characteristics. *J Affect Disord.* (2015) 172:24–9. doi: 10.1016/j.jad.2014.09.036

27. Mental Health America [MHA]. *Mental Health Older Adults.* (2022). Available from: https://www.mhanational.org/anxiety-older-adults (accessed January 22, 2023).

28. American Association for Geriatric Psychiatry [AAGP]. *Anxiety and Older Adults: Overcoming Worry and Fear*. (2023). Available from: https://www.aagponline.org/index.php?src=gendocs&ref=anxiety (accessed January 22, 2023).

29. National Institute of Mental Health. *Anxiety Disorders*. National Institute of Mental Health (2022). Available online at: https://www.nimh.nih.gov/health/topics/anxiety-disorders#part_145335 (accessed January 22, 2023).

30. Boston AF, Merrick PL. Health anxiety among older people: an exploratory study of health anxiety and safety behaviors in a cohort of older adults in New Zealand. *Int Psychogeriatr.* (2010) 22:549–58. doi: 10.1017/S1041610209991712

31. Ghubach R, El-Rufaie O, Zoubeidi T, Sabri S, Yousif S, Moselhy HF. Subjective life satisfaction and mental disorders among older adults in UAE in general population. *Int J Geriatr Psychiatry*. (2010) 25:458–65. doi: 10.1002/gps.2360

32. Brown RJ, Skelly N, Chew-Graham CA. Online health research and health anxiety: A systematic review and conceptual integration. *Clin Psychol Sci Pract*. (2020) 27:e12299. doi: 10.1111/cpsp.12299

33. McMullan RD, Berle D, Arnáez S, Starcevic V. The relationships between health anxiety, online health information seeking, and cyberchondria: Systematic review and meta-analysis. *J Affect Disord*. (2019) 245:270–8. doi: 10.1016/j.jad.2018.11.037

34. Cotten SR, Goldner M, Hale TM, Drentea P. The importance of type, amount, and timing of Internet use for understanding psychological distress: Internet use and psychological distress. *Soc Sci Q*. (2011) 92:119–39. doi: 10.1111/j.1540-6237.2011.00760.x

35. Choi NG, DiNitto DM. Internet use among older adults: Association with health needs, psychological capital, and social capital. *J Med Internet Res*. (2013) 15:e97. doi: 10.2196/jmir.2333

36. de Looper M, van Weert JCM, Schouten BC, Bolle S, Belgers EHJ, Eddes EH, et al. The influence of online health information seeking before a consultation on anxiety, satisfaction, and information recall, mediated by patient participation: field study. *J Med Internet Res*. (2021) 23:e23670. doi: 10.2196/23670

37. Myrick JG, Willoughby JF. Educated but anxious: How emotional states and education levels combine to influence online health information seeking. *Health Inform J*. (2019) 25:649–60. doi: 10.1177/1460458217719561

38. Seçkin G. Expansion of Parson's sick role into cyberspace: Patient information consumerism and subjective health in a representative sample of U. *S internet users Soc Sci Med*. (2020) 247:112733. doi: 10.1016/j.socscimed.2019.112733

39. Kim J, Lee HY, Won CR, Barr T, Merighi JR. Older adults' technology use and its association with health and depressive symptoms: Findings from the 2011 National Health and Aging Trends Study. *Nurs Outlook*. (2020) 68:560–72. doi: 10.1016/j.outlook.2020.05.001

40. Lee HY, Kim J, Sharratt M. Technology use and its association with health and depressive symptoms in older cancer survivors. *Qual Life Res*. (2018) 27:467–77. doi: 10.1007/s11136-017-1734-y

41. Kim J, Lee HY, Christensen MC, Merighi JR. Technology access and use, and their associations with social engagement among older adults: do women and men differ? *J Gerontol B Psychol Sci Soc Sci*. (2017) 72:836–45. doi: 10.1093/geronb/gbw123

42. Kroenke K, Spitzer RL, Williams JBW, Monahan PO, Löwe B. Anxiety Disorders in Primary Care: Prevalence, Impairment, Comorbidity, and Detection. *Ann Intern Med*. (2007) 146:317. doi: 10.7326/0003-4819-146-5-200703060-00004

43. Kroenke K, Spitzer RL, Williams JBW. The Patient Health Questionnaire-2: Validity of a Two-Item Depression Screener. *Med Care*. (2003) 41:1284–92. doi: 10.1097/01.MLR.0000093487.78664.3C

44. Hamaker EL, Kuiper RM, Grasman RPPP, A. critique of the cross-lagged panel model. *Psychol Methods*. (2015) 20:102–16. doi: 10.1037/a0038889

45. Rosseel Y. lavaan: An R Package for Structural Equation Modeling. *J Stat Softw*. (2012) 48:2012. doi: 10.18637/jss.v048.i02

46. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct Equ Model Multidiscip J*. (1999) 6:1–55. doi: 10.1080/10705519909540118

47. Ghaiumy Anaraky R, Li Y, Knijnenburg B. Difficulties of Measuring Culture in Privacy Studies. *Proc ACM Hum-Comput Interact*. (2021) 5:1–26. doi: 10.1145/3479522

48. Chen FF. Sensitivity of Goodness of Fit Indexes to Lack of Measurement Invariance. *Struct Equ Model Multidiscip J*. (2007) 14:464–504. doi: 10.1080/10705510701301834

49. Zhang C, Liao WF, Ma YM, Liang CY. Research on older people's health information search behavior based on risk perception in social networks—A case study in China during COVID-19. *Front Public Health*. (2022) 10:946742. doi: 10.3389/fpubh.2022.946742

50. Marzo RR, Chen HWJ, Abid K, Chauhan S, Kaggwa MM, Essar MY, et al. Adapted digital health literacy and health information seeking behavior among lower income groups in Malaysia during the COVID-19 pandemic. *Front Public Health*. (2022) 10:998272. doi: 10.3389/fpubh.2022.998272

51. Jensen JD, Liu M, Carcioppolo N, John KK, Krakow M, Sun Y. Health information seeking and scanning among US adults aged 50–75 years: Testing a key postulate of the information overload model. *Health Inform J*. (2017) 23:96–108. doi: 10.1177/1460458215627290

52. Kim K, Lustria MLA, Burke D, Kwon N. Predictors of cancer information overload: findings from a national survey. *Inf Res*. (2007) 12:1–29.

53. Hulin, C., Netemeyer, R., Cudeck, R. Can a Reliability Coefficient Be Too High? *J Consum Psychol*. (2001) 10:55–8. doi: 10.1207/S15327663JCP1001&2_05

54. Simning A, Fox ML, Barnett SL, Sorensen S, Conwell Y. Depressive and Anxiety Symptoms in Older Adults With Auditory, Vision, and Dual Sensory Impairment. *J Aging Health*. (2019) 31:1353–75. doi: 10.1177/0898264318781123

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 February 2023
DOI 10.3389/fpubh.2023.1094745

OPEN ACCESS

EDITED BY
Ronald W. Berkowsky,
California State University, Channel Islands, United States

REVIEWED BY
Loredana Ivan,
National School of Political Studies and Public Administration, Romania
Jan Vanus,
VSB-Technical University of Ostrava, Czechia

*CORRESPONDENCE
Yu Luo
✉ luoyuhlgl@tmmu.edu.cn

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 10 November 2022
ACCEPTED 31 January 2023
PUBLISHED 24 February 2023

CITATION
Kong D, Liu S, Hong Y, Chen K and Luo Y (2023) Perspectives on the popularization of smart senior care to meet the demands of older adults living alone in communities of Southwest China: A qualitative study. *Front. Public Health* 11:1094745. doi: 10.3389/fpubh.2023.1094745

Perspectives on the popularization of smart senior care to meet the demands of older adults living alone in communities of Southwest China: A qualitative study

Dehui Kong, Siqi Liu, Yan Hong, Kun Chen and Yu Luo*

School of Nursing, Army Medical University (Third Military Medical University), Shapingba, Chongqing, China

Background: Older adults who live alone face challenges in daily life and in maintaining their health *status quo*. Currently, however, their growing demands cannot be satisfied with high quality; therefore, these demands expressed by elders may be settled in the form of smart senior care. Hence, the improvement in smart senior care may produce more positive meanings in promoting the health and sense of happiness among this elderly population. This study aimed to explore the perceptions of demands and satisfaction with regard to the provision of senior care services to the community-dwelling older adults who live alone in Southwest China, thus providing a reference for the popularization of smart senior care.

Methods: This study adopted a qualitative descriptive approach on demands and the popularization of smart senior care. Semi-structured and in-depth individual interviews were conducted with 15 community-dwelling older adults who lived alone in Southwest China between March and May 2021. Thematic analysis was applied to analyze the data.

Results: Through data analysis, three major themes and subcategories were generated: "necessities" (contradiction: more meticulous daily life care and higher psychological needs vs. the current lower satisfaction *status quo*; conflict: higher demands for medical and emergency care against less access at present), "feasibility" (objectively feasible: the popularization of smart devices and applications; subjectively feasible: interests in obtaining health information), and "existing obstacles" (insufficient publicity; technophobia; patterned living habits; and concerns).

Conclusions: Smart senior care may resolve the contradiction that prevails between the shortage of medical resources and the increasing demands for eldercare. Despite several obstacles that stand in the way of the popularization of smart senior care, the necessities and feasibility lay the preliminary foundation for its development and popularization. Decision-makers, communities, developers, and providers should cooperate to make smart senior care more popular and available to seniors living alone, facilitating independence while realizing aging in place by promoting healthy aging.

KEYWORDS

smart senior care, older adults, live alone, community, qualitative research

1. Introduction

With the global aging process continuing to deepen, unprecedented attention has been given to older adults as well as to the demands for senior care. The process of population aging is faster in China than in most of the higher-income countries (1). Until 2020, the population of China aged 65 years and above accounted for 13.5% of the total population (2). This proportion is projected to increase to 26.1% by 2050 (3), which is marked as a super-aged society (4). With the expansion of life expectancy, life events, including changes in living arrangements, divorce and widowhood, and a large migration of the population to big cities, have increased the number of older adults living alone (5). In Western countries and some Asian countries such as China and Japan, the proportion of senior citizens living alone has increased (6). Compared with their counterparts living with families, those living alone are busy with several daily household chores (7) and are prone to develop chronic diseases (8). Research showed that older adults living alone were more likely to suffer from social isolation, to feel lonely, to develop depressive symptoms (9), and to receive less social support (10). Due to the lack of a companion, those elders who are living alone lack the encouragement to maintain a healthy lifestyle. In case of an emergency such as a sudden illness, they cannot have timely access to medical care (11), and the consequences may be fatal, resulting in higher medical costs and more meticulous care (12). In China, in the future, the number of senior citizens living alone will further increase, and more attention should be given to the vulnerable population (13). Being the primary place where the older adults live, the community plays a significant role in providing support. However, a survey in China noted that there was a low percentage of fulfilled needs, with services provided by communities being insufficient (14), among which regular visits by professionals, referrals, and first-aid, physical examination, and education were the most sought after needs in medical demand (15). Moreover, it has been indicated that, in the United States of America, Singapore, and China, senior citizens were more willing to take care of themselves at home or in the community, bringing a better quality of life, a sense of belonging, and security, thereby achieving social value (16–18).

Innovations and rapid advances in technology reformed modern medicine and health care for older adults (19). Smart senior care is a systematic, intelligent development of the conventional eldercare industry combining modern technology, aiming to enhance the living conditions and meet the needs of older adults in health management, safety and security, emergency aid, entertainment, and learning *via* technological services and products (20, 21). With the integration of information and technology such as big data, the Internet of Things, cloud computing, electronic health care, and mobile Internet, smart senior care is able to collect human signs and provide home care and interventions, realizing information interconnection among home, community, and medical institutions (22, 23). According to previous studies, smart senior care plays diverse roles in different scenarios with various devices. First, smartphone applications are used to obtain services. For instance, iFall and Smartfall are two Android apps for older adults which can send signals and alerts (24) as well as detect falls (25). iWander monitors the wandering elders with Alzheimer's diseases (26). More broadly, smart home technology is used for supporting older adults with dementia (27). Some smart home technologies can even control the environment such as giving injections of drugs such as insulin *via* actuators (28). Third, the application of artificial intelligence makes it possible for robots to attend to older adults with rehabilitation needs (29, 30). Fourth, the use of wearable sensors make remote monitoring possible, with functions of measuring vital signs in real-time, sending alerts in emergency circumstances (31), and intervening in a planned way in those circumstances (32).

As mobile devices and networks get popularized, the scope of application of smart senior care has become wider and wider, and the utilization rate has gradually increased. Studies revealed that older adults are usually positive toward gerontechnology, but they also raise questions and express their concerns on the ethics and technology adopted, such as autonomy, privacy and data protection, data accuracy and reliability, and other considerations such as biological effects and standardization of the devices and applications (33, 34). However, smart senior care still provides a new idea and option for senior care with the potential to promote safety and independence for the elders through discovering and preventing accidents, alerting, and locating (35). Through the monitoring of daily activities, abnormal behaviors such as falls, and cognitive anomalies, the wellbeing of the solo-living senior citizens can be guaranteed to a greater extent (36). Continuous monitoring is crucial for those living alone, which allows for the provision of the unremitting health status of older adults (37), realizing early detection and diagnosis of diseases, and can improve the quality of life and reduce the waste of medical resources (38). Moreover, the combination of interprofessional teams and smart senior care enables primary care physicians, nurses, specialists, and other professionals to discuss together to handle elderly patients with multimorbidity without transferring them (39), while avoiding multiple outpatient appointments as well as preventing the spread of inadequate and conflicting information between medical staff (40).

In response to the irreversible aging process, smart senior care may be an effective solution to promote healthy aging, which contributes to advancing the living standards and maintaining the functional ability and independence for community-dwelling older adults (22, 41). In spite of these advantages, to date, in China, the application of smart senior care is still at an early stage, with smart devices being relatively simple (42). Without satisfying and understanding the needs and expectations of older adults, smart senior care cannot be adopted undoubtedly (43). Thus, considering the demands and willingness of the elders to apply smart senior care is essential for its development (44). Accordingly, this study aimed to explore the perspectives of community-dwelling older adults who live alone with respect to demands and their satisfaction with regard to senior care by listening to the voice of the demanders so as to provide reference for the popularization of smart senior care.

2. Materials and methods

2.1. Study design

This article is a qualitative descriptive study which is widely used in the fields of medicine and health care and is also suitable for seeking information to develop suggestions or interventions

(45). The study was facilitated through semi-structured one-to-one in-depth interviews.

2.2. Settings and participants

The study was conducted from March to May 2021. A purposive sampling method was employed to select the elders living alone in two communities of the main urban area in Chongqing as the research objects. Chongqing is a municipality located in the southwest part of China. As of the year 2020, the population aged 65 years and above accounted for 17.08% of the total population, which is higher than the average level of 13.5% in China (2). Before the interview, the research proposal was delivered to the staff of the community healthcare service centers to gain their collaboration to identify potential participants through their information system, and recruitment advertisements were simultaneously distributed in the communities. Older adults who were interested in participating in the study contacted the researchers directly or *via* the community staff. The inclusion criteria of subjects included seniors (1) aged 65 years or above; (2) who are living alone; and (3) who are able to understand the contents and express their thoughts. The exclusion criteria of subjects were as follows: (1) seniors with cognitive impairment and (2) those who were unable to cooperate.

2.3. Instruments

A semi-structured interview outline was designed through literature retrieval, group discussion, and pre-interview revisions. The sequence of questions raised was adjusted according to pre-interviews, and ambiguous expressions were modified, which mostly included: (1) How is your current living condition? Are there any difficulties regarding eldercare? What services do you need most presently? (2) How do you feel about living alone? In what ways do you usually communicate with others, and who are the most frequent persons you communicate with? How does the community help you with emotional needs? (3) Have you ever used/heard of any means of smart eldercare for registration, consultation, health-related queries, drug delivery, or making an appointment for health examination or healthcare services through the Internet? If yes, please provide more details. (4) If software or a function with positioning and alarm services in emergencies is accessible, are you willing to use it and if so, why? (5) Are you willing to apply smart senior care to your needs and what are its benefits/difficulties?

2.4. Data collection

Before formal data collection, the research purpose and contents were interpreted to the community-dwelling elders living alone. Meanwhile, we explained to the elders that the interview would be recorded and promised to keep this study confidential, strictly protecting the privacy of the subjects. Written informed consent was obtained thereafter. The demographic data were obtained before formal interviews were held, which were accomplished together with the same interviewer and recorder, DK and SL. The location of the interview was left to the discretion of the interviewees to choose a place that is quiet and familiar for older adults based on meeting the environmental requirements for interviews. The whole process was recorded synchronously using a voice recorder and non-verbal information, including expressions, body gestures, and tone, was observed and recorded in time. Various methods such as explanation, clarification, and questioning were applied during the interviews, and any inducement and suggestion were avoided. Each interview lasted for 20–40 min. When the interview was completed, the opinions of the participants were collected for a follow-up improvement. The sample size was considered until the data were repeated and no new topic emerged (46). After interviewing 13 older adults living alone, the data were saturated and no new content was included. We interviewed two more older adults living alone and confirmed that the data obtained were fully saturated. Finally, the data of 15 interviewees were analyzed.

2.5. Data analysis

Data collection and analysis were carried out simultaneously, and the recorded conversations were transcribed verbatim within 24 h of the interviews. Then, the transcripts were checked with the original recordings to ensure accuracy manually. Inductive thematic analysis was used to analyze the data manually, following the procedures proposed by Braun (47, 48): (1) Two researchers, DK and SL, read through the transcripts independently to get familiar with the contents. (2) They separately retrieved information related to smart senior care and the demands and satisfaction of the participants to form initial codes. (3) The two researchers classified the primary codes into potential themes separately and gathered related quotations. (4) In face-to-face meetings, the research team reviewed and verified the themes and split, merged, or deleted some topics according to the standards of internal and external heterogeneity to generate a thematic framework. Any disagreement on themes was discussed together to reach a consensus. (5) All of the researchers participated in clarifying the contents and developing a name for each theme. (6) The analysis report was written.

3. Results

In this study, 15 community-dwelling older adults living alone were interviewed and their average age was 75.07 years (range 68–79 years). Of the participants, seven were men and eight were women (Their details are presented in Table 1). Twelve out of the 15 participants suffered from chronic diseases, among which hypertension, diabetes, and cardiovascular diseases were the most common.

Based on the perspectives to meet the demands of senior citizens living alone in communities in Southwest China, the popularization of smart senior care could be summarized into three themes: necessities, feasibility, and existing obstacles. The domains of the themes are demonstrated in Figure 1.

TABLE 1 Demographic characteristics of the participants.

Variable	Number
Age	
65–74	7
≥75	8
Gender	
Men	7
Women	8
Pre-retirement occupation	
Teacher	1
Worker	8
Civil servant	3
Engineer	1
Unemployed	2
Education	
Primary school	6
Junior high	4
Senior high	2
College and above	3
Number of children	
0	1
1	5
2	6
3	3
Monthly income (CNY)	
0–2999	2
3000–3999	10
≥4000	3
Time living alone (year)	
<1	2
1–5	8
≥6	5

3.1. Necessities

The participants expressed their needs in daily life and psychological aspects as well as in medical and emergency care, but they hardly received any related services.

3.1.1. Contradiction: More meticulous daily life care and higher psychological needs vs. the current lower satisfaction status quo

The elders living alone reported a high demand for daily care services, but few services were provided to them presently, and the difficulties faced in rendering elderly care were concentrated. *P12: "It would be better if there was a canteen for us seniors. We could eat there and then go back home to rest." P13: "My wife was in hospital for 10 days due to cardiovascular diseases and spent more than 100,000 yuan in a short time last year. When older adults are ill, the biggest difficulty is the financial problem." P14: "I'm afraid of inability to take care of myself, completely bedridden one day. By then what can I do?"*

The elders living alone were reluctant to place the full burden of care on their children who were also shouldering the burden of both work and family. They required supplemental care to compensate for home care. *P13: "Seniors at our age often have only one child. The only child of the family lives separately who also must raise children, and they cannot spare more time and energy to take care of the older generation. So, there are more older adults who need help and care. Once sick, it is hard to know if one is alive, what the physical condition is. It is even difficult to seek help."*

Loneliness was common, and social interaction with peers was prominent. Among the interviewees, seven complained of being "lonely" and three mentioned "being used to it." *P3: "The circle is smaller, and friends are fewer. Basically, there is no one with the same hobbies. People from the same work unit and at the same generation have long gone if older than me, and I don't know the ones younger than me because I retired earlier." P13: "After my wife left, I was not used to it for a long time. She had lived with me for decades, and it's too lonely to live alone. There is no companion around. I'm the only one eating at the dining table, only one bowl and one pair of chopsticks from morning till night. I've been living alone for almost a year. It's getting better now."*

Social interactions with peers, such as former colleagues, neighbors, and friends, were of great significance to senior citizens living alone. *P1: "As long as the neighbors don't see me in one day, they will call and ask me where I am. We, several teachers often get together and play, cards for example."*

3.1.2. Conflict: Higher demands for medical and emergency care against less access at present

In this study, the elders living alone expressed strong demands for medical and emergency care, whereas present services are limited and insufficient. *P11: "Recently, the community staff came but only had a look. They took at most a simple device like blood pressure meter which I had already bought."* Some participants also questioned the medical skills of community physicians, and they thought whether to accept the services or not depended on disease conditions. *P13: "It is likely to visit the community physician for some common illnesses, but not for severe diseases."*

All the participants considered the software that could realize a one-click alarm in the case of emergency as necessary, which could save lives at a critical moment, and expressed their willingness to use it in future. *P10: "It is necessary. Since I live alone, if I get sick at night suddenly, it would be a big trouble. I am on the 7th floor, by then I can't go downstairs. So, I need this."* As for medical alarm systems such as the fall or immobility alarm, most seniors said it was useful "just in case." *P2: "This is still necessary. It is useful in emergency and just in case." P8: "It should be used. Gao jiahu was in*

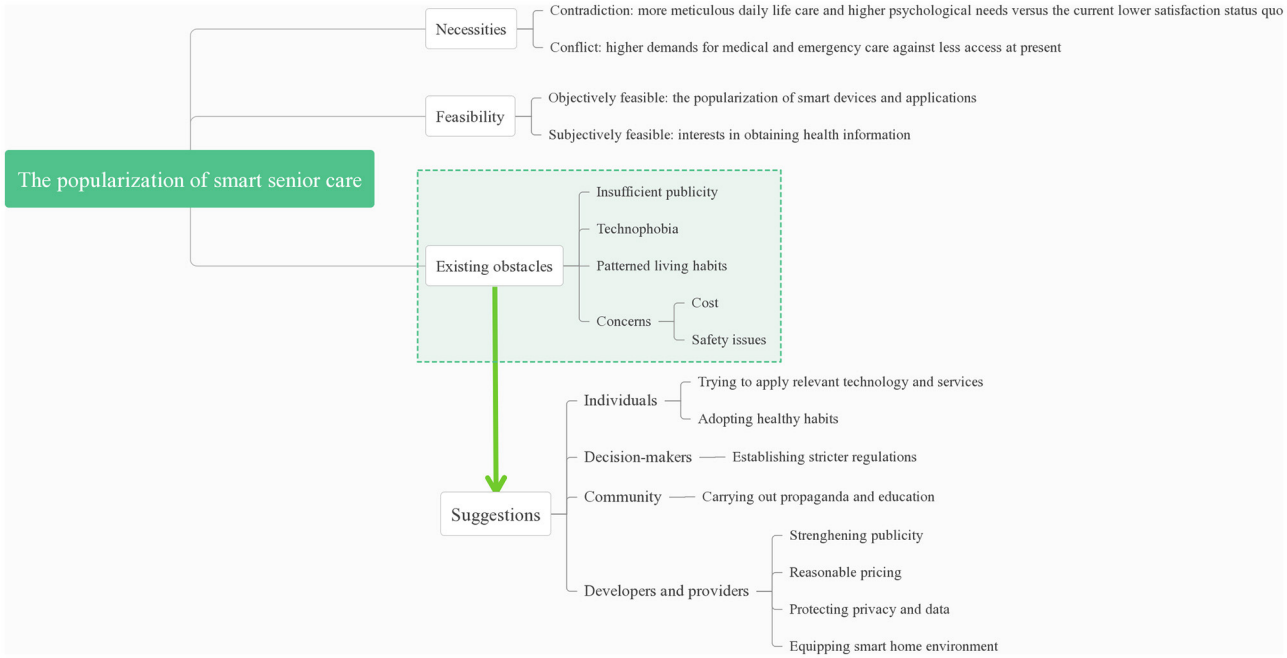


FIGURE 1
Domains of the themes and suggestions on the popularization of smart senior care.

our group of the factory. After his death, all the maggots crawled out, and no one was at home. So, after my wife passed away, neighbors asked me to come down to show up every day, and they could know how I was."

3.2. Feasibility

Smartphones and some applications were prevalent among older adults in this interview. The participants were not only willing to receive health-related information but were also willing to take up the initiative to inquire.

3.2.1. Objectively feasible: The popularization of smart devices and applications

Ten of the seniors living alone in this interview used smartphones, which were mostly purchased by their children. Additionally, all those who had smartphones could use applications such as WeChat for daily chats and video functions. Several of them could also use social interaction and health management functions. *P1: "I can use WeChat video and voice calls. When I go out to play with friends, I will post all photos on Moments. My previous students will definitely "like" them when they see the pictures I post." P10: "I can video chat and post photos on Moments, and I also use WeChat sports every day. For example, I will know how many steps my son and granddaughter walk in a day, whether they are busy or not. Sometimes when they walk too much, I even joke and ask where you have gone."*

3.2.2. Subjectively feasible: Interests in obtaining health information

The elders could obtain health-related information through various channels, and the majority of them expressed their willingness to receive and actively inquire about health information, especially the contents related to their health and diseases, but they had difficulty in discriminating the quality and accuracy of related information. *P4: "I am eager to know what the professors talk about, and the information related to high blood pressure." P8: "I usually search for health information with Baidu, but it should be read selectively, as some are advertising. I read books mostly because I have noticed irresponsible information posted on Baidu. A book is more responsible, since editors have reviewed and audited it after all." P15: "I read health information. I have to evaluate if it is useful and real, or for selling medicine. There are many advertisements. I doubt if it is real."*

3.3. Existing obstacles

Although the elders living alone expressed high demands yet low satisfaction, smart senior care has not been regarded as a settlement to meet their needs. We also explored the probable reasons for this contradiction.

3.3.1. Insufficient publicity

The interviewees were not aware of most services of smart senior care. When asked about online consultation, health-related queries, having an appointment for health examination, and

booking healthcare services through smartphones or the Internet, most of the participants had never used or heard of such services. In terms of online registration, most of the participants had merely heard of the related information from offspring who had registered online for them. *P8: "I don't know how to register online to see a doctor. But not long before my granddaughter registered online for me when I went to Xinqiao hospital."* As regards online drug delivery, only one participant had ordered medicines online by herself, while the son of another participant had ordered medicines for her through the Internet. *P11: "I often get medicines online. My son buys them for me."*

3.3.2. Technophobia

Most of the seniors included in the present study were motivated to learn the functions of a smartphone they needed and were interested in, but still they were able to use only a limited number of applications. *P7: "I use a smartphone for investing in stocks. I'm willing to learn useful functions if I like it, but I need someone to teach me."*

However, most of the participants were intimidated by the relatively complex functions of smartphones and applications. They refused to use a smartphone for fear of being cheated and thought that it was cumbersome and complicated. *P2: "I don't use WeChat since seniors are afraid of being fooled. Simple functions are OK. I know it's very troublesome to chat on a cell phone through WeChat, TicTok, etc. I don't even think about it or browse it." P15: "I use a cell phone for seniors. My child suggested replacing a smartphone for me, but there are too many new functions and I'm not able to use it. I am too lazy to learn."*

3.3.3. Patterned living habits

Older adults living alone had some unhealthy living habits. Even if they were aware that these habits were harmful to their health, making changes to their diet pattern was still difficult for them, such as excessive salt intake and eating leftovers. *P13: "Salt intake usually exceeds the limit, and 5 g salt a day is just too little. To prepare only two or three dishes in one meal will exceed the limit. When less salt is added to the dishes, it is not tasty, with no appetite at all. The physicians also told us that salt consumption couldn't exceed 5g, but no one can do it." P14: "I know it's not healthy reheating leftovers, but there are usually too many, and it's wasteful to dump the dishes."*

3.3.4. Concerns

Cost was the topmost consideration as regards whether to accept related services or not. *P11: "It is useful, but cost money. We must save money for hospitalization and surgery. For example, when one is hospitalized and told he has cancer, he must spend money at that time. So, I should be more careful at this point."*

Another consideration concentrated on safety issues. First, as regards online payment, senior citizens living alone were less agreeable to make payments online. *P12: "I can use WeChat payment, but I don't use it frequently. I don't think it's safe enough and it might have kinds of hidden trouble." P13: "I use cash. I'm afraid of making mistakes, because I'm at an old age, and sometimes I may make a mistake on a decimal point. I can't even figure out what's wrong with the payment."*

Second, referring to online drug delivery, which is better known, the elders had a skeptical or negative attitude, worrying about the security aspect. *P1: "I have never bought drugs online. I don't believe it. I think it is better to prescribe medicine in a hospital. I am afraid to buy fake medicine." P11: "I am worried to be cheated, fearing that the medicine is advertised to be good but fail to achieve the desired effect. I like it (buying medicine online). But I am afraid of being fooled. If the medicine is to be sold online, it should be reviewed repeatedly and gain approval and we will be at ease when taking medicine."*

4. Discussion

The contradiction between the shortage of experienced staff and the growing demands for eldercare is becoming increasingly prominent. It is difficult to fully rely on manpower to provide care services for older adults (28, 44). Smart eldercare services may assist community-dwelling older adults who live alone in many ways. Physically, the fulfillment of their willingness to age in place requires support in daily life (49). This is consistent with other studies at home and abroad that receiving daily life care helps to improve the quality of life, thus increasing satisfaction (50–52). However, participants in this interview are unwilling to put all care burden on their offspring since they do not want to seem burdensome, similar to the surveys referring to the refusal to be troublesome and loss of control (53, 54) but promoting the use of technology (55). Consequently, smart senior care is of vital importance as an alternative or supplement to family care for solo-living older adults. Psychologically, despite the elders living alone often feeling lonely, there is a lack of community attention to their mental health, which is often overshadowed by physical health (56). Our interview coincides with previous studies that online social interaction with peers plays an essential role in the interpersonal relationships of older adults living alone, increasing their social involvement and enhancing their sense of happiness (57, 58).

In addition, older adults living alone require continuous and immediate medical support, and some dangerous conditions leading to deterioration in their health can be avoided through real-time monitoring (28, 59). The need for medical care of senior citizens living alone is higher, whereas corresponding services provided by the community are basic and limited. It was reported that Chinese older adults needed health monitoring, drug delivery, and home visits (60). Additionally, the emergency care demands of the elders living alone are particularly significant. Unlike some other countries (36, 61), present-day China lacks long-term telecare such as remote consultation and one-click alarm calls for help (62). With the development of science and technology, smart senior care is expected to provide medical services and emergency rescue measures, filling the gap in family care, thus creating a safe and secure environment for older adults who live alone (63).

The feasibility of the popularization of smart senior care consists of two aspects. First, with the spread of the Internet, an increasing number of senior citizens were involved in the wave of science and technology in China (13). The Statistical Report on China's Internet Development pointed out that the percentage

of middle-aged and elderly netizens with Internet access in China has grown at the fastest pace. As of June 2021, the number of Internet users aged 60 years and above exceeded 100 million, accounting for 12.2% of the total Internet users, with an increase in 1.9% compared with the same period of 2020 (64). Moreover, the COVID-19 pandemic motivated senior citizens to use smart devices, similar to their Chinese counterparts, senior citizens in the USA used computers more frequently than prior to the epidemic, owing to various reasons such as more reliance on telemedicine (65). Furthermore, a growing number of health management applications are available online as well (66). Second, our study reveals that older adults who live alone are actively interested in receiving and obtaining health-related information, in line with an Australian study which found that most of the older adults took interest in accessing websites on healthy aging (67). A study also showed that nearly half of the Chinese seniors surfed online daily and showed more interest in health-related information, with Internet access becoming the most likely way to fetch health-related information (59). In the process, senior citizens also had questions on information quality, which put forward higher requirements for the authority and reliability of health information on the Internet. The initiative of the elders to pose health-related queries has become another motivation for the popularization of smart senior care (68), which makes it possible to enter into the community and the life of senior citizens living alone.

However, there are still barriers against the popularization of smart senior care. The first affecting factor is related to insufficient publicity, bringing about the incuriosity of older adults in the first place. Except for drug delivery and online registration, the interviewees never heard of services related to smart senior care, not to mention practical utilization. Low awareness will inevitably bring low usage. In addition, as Smith B et al. pointed out, although more access to health information is available now than ever before, large amounts of information without adequate explanation and guidance could lead to confusion (69). Therefore, a proper advertising with clear instructions is prerequisite. The second affecting factor pertains to the fact that, as a technologically "marginalized" group, older adults are still relatively unfamiliar with smartphone applications (61). Similarly, an American survey reported that older adults needed more time to learn how to use such technologies than the younger (70). Even the elders with relevant experiences still had difficulty in carrying out basic operations (71). Due to their negative attitudes toward intelligent products and functions as well as the limited information received, older adults believe that they are incapable of handling technological products, resulting in "technophobia" and unwillingness to learn the applications, thereby generating a vicious circle (72). The third affecting factor mentions that, although older adults have multiple accesses to health information, such information does not fully convert into healthy behaviors. Even being aware of the fact that certain behaviors are unhealthy, it is hard for older adults to alter them sometimes because these habits formed over a long term and there was no assistance from cohabitants. A Canadian survey with more than 75% of the participants living alone also revealed that unhealthy eating habits were associated with low health literacy and economic status (73). Consequently, when it comes to the solo-living seniors, smart senior care is likely to take an active part in sending continuous reminders and instructions to them. The fourth affecting factor is related to concerns. The primary concern is cost, which is rooted in the traditional concept of "economy" in China. If the service is not cost-effective, the elders would rather spend money on items that are more necessary in accordance with a survey in the UK (66). Another concern is associated with security issues, which were also reported in a previous study (63, 70). Considering limited guidance to help the elders, coupled with their lack of knowledge about details in smart eldercare services (74), it is rational to worry about "being cheated."

To remove the obstacles, we can formulate propositions in four aspects. As for decision-makers, stricter regulations for smart senior care services can help alleviate the worries of senior users. Additionally, if smart senior care could be covered by health insurance, older adults are more likely to adopt such services (34), especially for the solo-living. From the communities' side, propaganda and education ought to be carried out routinely to advance the digital health literacy of older adults who live alone with no one nearby to teach them. Developers and providers have to consider the fact that, only by strengthening the publicity of smart senior care can the awareness of the solo-living elders be increased. Figuring out a rational way to advertise is an indispensable option. In addition, the price of the services should be affordable for senior citizens, with the security aspect taken into consideration. Additionally, when it comes to ethical issues, more attention should be paid to privacy and data protection to ensure the autonomy and dignity of older adults, such as restraining information sharing, introducing data ownership policies, and facilitating control over technology by older adults themselves (34, 75). Moreover, home environment with alarm systems, sensors and actuators, activity recognition, monitoring and communicating systems, and Internet connection should be taken into consideration during the construction of buildings and renovation of houses (76). For the elders living alone, adopting healthy habits, discarding their prejudice, and attempting to apply relevant technology and services are likely to be the first steps.

5. Conclusion

This study investigated the senior care needs of community-dwelling older adults living alone and their perspectives on smart senior care. At present, the *status quo* of unmet needs for daily life care, psychological, medical, and especially emergency care motivates the application of smart senior care in this solo-living group. In recent years, the popularity of smart devices and software has made it possible for older adults to access technology and related services. In addition, their initiative to obtain and query health-related information lays the foundation for the popularization of smart senior care. However, older adults still have some concerns over smart senior care, which are becoming the existing obstacles to its promotion. In this regard, joint efforts should be made to address the barriers. Older adults who live alone ought to break down the stereotypes of technology and adopt healthy habits. Decision-makers, communities, developers, and providers should coordinate to make smart senior care more well known and accessible, offer related services to older adults, particularly to those living alone, realizing aging in place, thereby

responding to international calls for healthy aging. The results of this study will also provide reference for the popularization and development of smart senior care.

5.1. Strengths and limitations

The number of older adults living alone has witnessed a rapid surge in China (77). This study highlighted the elders living alone, as few previous research studies reported, to call on public attention to this population. Moreover, limited qualitative research has been conducted on demands and the popularization of smart senior care. Conversations can get closer to the real feelings and the inner voice of older adults. We also hope that, in this way, the elders can participate in the planning of eldercare as co-designers instead of being passive recipients.

This study also has a few limitations. First, the sample size of this study was limited and was mainly taken from the central urban areas of Chongqing. The results may not be generalized to the national level. Furthermore, given cultural differences, the reasons for older adults living alone in China may be different from those living in Western countries. In China and other Asian countries, living with children is still the first choice for most of the older adults, while living alone is often the last resort for them. Instead, most senior citizens in Western countries believe that living alone gives them more independence and can protect their personal privacy (78), which is more of an individual's active choice.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Institutional Review Board of Army Military Medical University/Third Military Medical University (approval number 2021-13-01). The patients/participants provided their written informed consent to participate in this study.

Author contributions

DK: study design, data collection, interpretation and analysis, and manuscript drafting. SL: data collection, interpretation and analysis, and manuscript drafting and revision. YH: study coordination, data analysis, and manuscript revision. KC: study design, data analysis, and manuscript revision. YL: guarantor of integrity of the entire study, study design, and manuscript revision. All authors read and approved the final version of the manuscript.

Funding

The research received funding from the National Social Science Fund of China (Grant no. 19XRK001). The funding sources were independent and did not influence the study design, data collection and analysis, publishing decisions, or manuscript preparation.

Acknowledgments

The authors sincerely thank all the participants. Furthermore, the authors also thank the Shuangbei Community Health Care Service Station and the Tianxingqiao Community Health Care Service Center for their assistance in the study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Ye P, Jin Y, Er Y, Duan L, Palagyi A, Fang L, et al. A scoping review of national policies for healthy ageing in mainland china from 2016 to 2020. *Lancet Reg Health West Pac.* (2021) 12:100168. doi: 10.1016/j.lanwpc.2021.100168

2. Statistics NBO. *Bulletin of the Seventh National Census.* (2021). Available online at: http://www.stats.gov.cn/ztjc/zdtjgz/zgrkpc/dqcrkpc/ggl/202105/t20210519_1817698.html (accessed August 21, 2022).

3. Fang EF, Xie C, Schenkel JA, Wu C, Long Q, Cui H, et al. A research agenda for ageing in China in the 21st century (2nd edition): Focusing on basic and translational research, long-term care, policy and social networks. *Ageing Res Rev.* (2020) 64:101174. doi: 10.1016/j.arr.2020.101174

4. Chen R, Xu P, Song P, Wang M, He J. China has faster pace than Japan in population aging in next 25 years. *Biosci Trends.* (2019) 13:287–91. doi: 10.5582/bst.2019.01213

5. Wang J, Pei Y, Zhong R, Wu B. Outpatient visits among older adults living alone in china: does health insurance and city of residence matter? *Int J Environ Res Public Health.* (2020) 17:256. doi: 10.3390/ijerph17124256

6. Lee SM, Edmonston B. Living alone among older adults in Canada and the U.S. *Healthcare*. (2019) 7:68. doi: 10.3390/healthcare7020068

7. Tsai LT, Rantakokko M, Portegijs E, Viljanen A, Saajanaho M, Eronen J, et al. Environmental mobility barriers and walking for errands among older people who live alone vs. with others. *BMC Public Health.* (2013) 13:1054. doi: 10.1186/1471-2458-13-1054

8. Nam EJ, Lee JE. Mediating effects of social support on depression and suicidal ideation in older Korean adults with hypertension who live alone. *J Nurs Res.* (2019) 27:e20. doi: 10.1097/jnr.0000000000000292

9. Gu L, Yu M, Xu D, Wang Q, Wang W. Depression in community-dwelling older adults living alone in china: association of social support network and functional ability. *Res Gerontol Nurs.* (2020) 13:82–90. doi: 10.3928/19404921-20190930-03

10. Kim J, Lee JE. Social support and health-related quality of life among elderly individuals living alone in South Korea: a cross-sectional study. *J Nurs Res.* (2018) 26:316–23. doi: 10.1097/jnr.0000000000000241

11. Abell JG, Steptoe A. Living alone and mortality: more complicated than it seems. *Eur Heart J Qual Care Clin Outcomes.* (2019) 5:187–8. doi: 10.1093/ehjqcco/qcz014

12. Koivunen K, Sillanpaa E, von Bonsdorff M, Sakari R, Pynnonen K, Rantanen T. Living alone vs. living with someone as a predictor of mortality after a bone fracture in older age. *Aging Clin Exp Res.* (2020) 32:1697–705. doi: 10.1007/s40520-020-01511-5

13. Song L, Ge Y, Zhang X. The relationship between wechat use by chinese urban older adults living alone and their subjective well-being: the mediation role of intergenerational support and social activity. *Psychol Res Behav Manag.* (2021) 14:1543–54. doi: 10.2147/PRBM.S330827

14. Meng D, Xu G, Davidson PM. Perceived unmet needs for community-based long-term care services among urban older adults: a cross sectional study. *Geriatr Nurs.* (2021) 42:740–7. doi: 10.1016/j.gerinurse.2021.03.013

15. Li S, Zhang J, Liu Y, Wang AP, Qiu G. Survey of the demand for care services for older people and the training needs of their care workers: a cross-sectional study in Northeast China. *BMC Nurs.* (2022) 21:25. doi: 10.1186/s12912-022-00809-1

16. Malhotra R, Bautista MAC, Muller AM, Aw S, Koh GCH, Theng YL, et al. The aging of a young nation: population aging in Singapore. *Gerontologist.* (2019) 59:401–10. doi: 10.1093/geront/gny160

17. Lu N, Xu S, Zhou Q. Social capital and preferences for aging in place among older adults living in rural Northeast China. *Int J Environ Res Public Health.* (2020) 17:85. doi: 10.3390/ijerph17145085

18. Quinlan C, McKibbin C, Cuffney C, Brownson R, Brownson C, Clark J, et al. Barriers to aging in place for rural, institutionalized older adults: a qualitative exploration. *Clin Gerontol.* (2020) 45:1–13. doi: 10.1080/07317115.2020.1820651

19. Sapci AH, Sapci HA. Innovative assisted living tools, remote monitoring technologies, artificial intelligence-driven solutions, and robotic systems for aging societies: systematic review. *JMIR Aging.* (2019) 2:e15429. doi: 10.2196/15429

20. Fu L, Pei T, Yang J, Han J. How smart senior care can achieve value co-creation: evidence from China. *Front Public Health.* (2022) 10:973439. doi: 10.3389/fpubh.2022.973439

21. Jy W. *Shanghai: Aging In The Digital Age.* (2022) Available online at: https://chinareportasean.com/2022/03/17/shanghai-aging-in-the-digital-age/ (accessed March 17, 2022).

22. Huang Q, Li Y, Wu X, Ge S, Qu Z, Wang A, et al. The willingness and influencing factors to choose smart senior care among old adults in China. *BMC Geriatr.* (2022) 22:967. doi: 10.1186/s12877-022-03691-3

23. Meng Q, Hong Z, Li Z, Hu X, Shi W, Wang J, et al. Opportunities and challenges for Chinese elderly care industry in smart environment based on occupants' needs and preferences. *Front Psychol.* (2020) 11:1029. doi: 10.3389/fpsyg.2020.01029

24. Anthony Berauk VL, Murugiah MK, Soh YC, Chuan Sheng Y, Wong TW, Ming LC. Mobile health applications for caring of older people: review and comparison. *Ther Innov Regul Sci.* (2018) 52:374–82. doi: 10.1177/2168479017725556

25. Mauldin TR, Canby ME, Metsis V, Ngu AHH, Rivera CC. SmartFall: a smartwatch-based fall detection system using deep learning. *Sensors (Basel).* (2018) 18. doi: 10.3390/s18103363

26. Anderson K, Burford O, Emmerton L. Mobile health apps to facilitate self-care: a qualitative study of user experiences. *PLoS ONE.* (2016) 11:e0156164. doi: 10.1371/journal.pone.0156164

27. Moyle W, Murfield J, Lion K. The effectiveness of smart home technologies to support the health outcomes of community-dwelling older adults living with dementia: a scoping review. *Int J Med Inform.* (2021) 153:104513. doi: 10.1016/j.ijmedinf.2021.104513

28. Majumder S, Aghayi E, Noferesti M, Memarzadeh-Tehran H, Mondal T, Pang Z, et al. Smart homes for elderly healthcare-recent advances and research challenges. *Sensors.* (2017) 17:496. doi: 10.3390/s17112496

29. Moucheboeuf G, Griffier R, Gasq D, Glize B, Bouyer L, Dehail P, et al. Effects of robotic gait training after stroke: a meta-analysis. *Ann Phys Rehabil Med.* (2020) 63:518–34. doi: 10.1016/j.rehab.2020.02.008

30. Koutentakis D, Pilozzi A, Huang X. Designing socially assistive robots for alzheimer's disease and related dementia patients and their caregivers: where we are and where we are headed. *Healthcare.* (2020) 8:73. doi: 10.3390/healthcare8020073

31. Mardini MT, Iraqi Y, Agoulmine N, A. Survey of healthcare monitoring systems for chronically ill patients and elderly. *J Med Syst.* (2019) 43:50. doi: 10.1007/s10916-019-1165-0

32. Calvillo-Arbizu J, Naranjo-Hernandez D, Barbarov-Rostan G, Talaminos-Barroso A, Roa-Romero LM, Reina-Tosina J. A sensor-based mhealth platform for remote monitoring and intervention of frailty patients at home. *Int J Environ Res Public Health.* (2021) 18:730. doi: 10.3390/ijerph182111730

33. Kong D, Fu J, Hong Y, Liu S, Luo Y. The application and prospect of mobile health (mHealth) in health service for older people living alone in community: a narrative review. *Iran J Public Health.* (2022) 51:724–32. doi: 10.18502/ijph.v51i4.9233

34. Pirzada P, Wilde A, Doherty GH, Harris-Birtill D. Ethics and acceptance of smart homes for older adults. *Inform Health Soc Care.* (2022) 47:10–37. doi: 10.1080/17538157.2021.1923500

35. Karlsen C, Moe CE, Haraldstad K, Thygesen E. Caring by telecare? A hermeneutic study of experiences among older adults and their family caregivers. *J Clin Nurs.* (2019) 28:1300–13. doi: 10.1111/jocn.14744

36. Kim D, Bian H, Chang CK, Dong L, Margrett J. In-home monitoring technology for aging in place: scoping review. *Interact J Med Res.* (2022) 11:e39005. doi: 10.2196/39005

37. Kumari P, Mathew L, Syal P. Increasing trend of wearables and multimodal interface for human activity monitoring: a review. *Biosens Bioelectron.* (2017) 90:298–307. doi: 10.1016/j.bios.2016.12.001

38. Majumder S, Deen MJ. Smartphone Sensors for Health Monitoring and Diagnosis. *Sensors.* (2019) 19:164. doi: 10.3390/s19092164

39. Pariser P, Pham TT, Brown JB, Stewart M, Charles J. Connecting people with multimorbidity to interprofessional teams using telemedicine. *Ann Fam Med.* (2019) 17:S57–62. doi: 10.1370/afm.2379

40. Boeckxstaens P, Brown JB, Reichert SM, Smith CNC, Stewart M, Fortin M. Perspectives of specialists and family physicians in interprofessional teams in caring for patients with multimorbidity: a qualitative study. *CMAJ Open.* (2020) 8:E251–6. doi: 10.9778/cmajo.20190222

41. Valenzuela PL, Morales JS, Santos-Lozano A, Serra-Rexach JA, Izquierdo M, Lucia A. mHealth and aging. *J Am Med Dir Assoc.* (2018) 19:810–1. doi: 10.1016/j.jamda.2018.06.002

42. Hung J. Policy development on upskilling/reskilling older population care staff in China. *Int J Environ Res Public Health.* (2022) 19. doi: 10.3390/ijerph19159440

43. Peek ST, Wouters EJ, Luijkx KG, Vrijhoef HJ. What it takes to successfully implement technology for aging in place: focus groups with stakeholders. *J Med Internet Res.* (2016) 18:e98. doi: 10.2196/jmir.5253

44. Zhang Q, Li M, Wu Y. Smart home for elderly care: development and challenges in China. *BMC Geriatr.* (2020) 20:318. doi: 10.1186/s12877-020-01737-y

45. Kim H, Sefcik JS, Bradway C. Characteristics of qualitative descriptive studies: a systematic review. *Res Nurs Health.* (2017) 40:23–42. doi: 10.1002/nur.21768

46. Saunders B, Sim J, Kingstone T, Baker S, Waterfield J, Bartlam B, et al. Saturation in qualitative research: exploring its conceptualization and operationalization. *Qual Quant.* (2018) 52:1893–907. doi: 10.1007/s11135-017-0574-8

47. Vaismoradi M, Turunen H, Bondas T. Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nurs Health Sci.* (2013) 15:398–405. doi: 10.1111/nhs.12048

48. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* (2006) 3:77–101. doi: 10.1191/1478088706qp063oa

49. Melchiorre MG, D'Amen B, Quattrini S, Lamura G, Socci M. Caring for frail older people living alone in Italy: future housing solutions and responsibilities of family and public services, a qualitative study. *Int J Environ Res Public Health.* (2022) 19:413. doi: 10.3390/ijerph19127413

50. Oliveira DC, Oliveira CM, Lima-Costa MF, Alexandre TDS. Difficulty in performing activities of daily living and the need for help in older adults: evidence on social distancing models from the ELSI-COVID-19 initiative. *Cad Saude Publica.* (2020) 36:e00213520. doi: 10.1590/0102-311x00213520

51. Talarska D, Tobis S, Kotkowiak M, Strugala M, Stanislawska J, Wieczorowska-Tobis K. Determinants of quality of life and the need for support for the elderly with good physical and mental functioning. *Med Sci Monit.* (2018) 24:1604–13. doi: 10.12659/MSM.907032

52. Hu B, Chou YC. Care poverty among older adults in east asia: a comparison of unmet care needs between China and Taiwan. *Arch Gerontol Geriatr.* (2022) 102:104738. doi: 10.1016/j.archger.2022.104738

53. Lindquist LA, Ramirez-Zohfeld V, Forcucci C, Sunkara P, Cameron KA. Overcoming reluctance to accept home-based support from an older adult perspective. *J Am Geriatr Soc.* (2018) 66:1796–9. doi: 10.1111/jgs.15526

54. Robinson KN, Menne HL, Gaeta R. Use of informal support as a predictor of home- and community-based services utilization. *J Gerontol B Psychol Sci Soc Sci.* (2021) 76:133–40. doi: 10.1093/geronb/gbaa046

55. Peek ST, Luijkx KG, Rijnaard MD, Nieboer ME, van der Voort CS, Aarts S, et al. Older adults' reasons for using technology while aging in place. *Gerontology.* (2016) 62:226–37. doi: 10.1159/000430949

56. Pitrou I, Berbiche D, Vasiliadis HM. Mental health and satisfaction with primary care services in older adults: a study from the patient perspective on four dimensions of care. *Fam Pract.* (2020) 37:459–64. doi: 10.1093/fampra/cmaa019

57. Hong Y, Fu J, Kong D, Liu S, Zhong Z, Tan J, et al. Benefits and barriers: a qualitative study on online social participation among widowed older adults in Southwest China. *BMC Geriatr.* (2021) 21:450. doi: 10.1186/s12877-021-02381-w

58. Fu J, Cheng Z, Liu S, Hu Z, Zhong Z, Luo Y. Development and validation of peer relationship scale for Chinese community-dwelling elderly. *Psychol Res Behav Manag.* (2021) 14:889–903. doi: 10.2147/PRBM.S311352

59. Sun X, Yan W, Zhou H, Wang Z, Zhang X, Huang S, et al. Internet use and need for digital health technology among the elderly: a cross-sectional survey in China. *BMC Public Health.* (2020) 20:1386. doi: 10.1186/s12889-020-09448-0

60. Li J, Dai Y, Wang CC, Sun J. Assessment of environmental demands of age-friendly communities from perspectives of different residential groups: a case of Wuhan, China. *Int J Environ Res Public Health.* (2022) 19:120. doi: 10.3390/ijerph19159120

61. Kong L, Woods O. Smart eldercare in Singapore: negotiating agency and apathy at the margins. *J Aging Stud.* (2018) 47:1–9. doi: 10.1016/j.jaging.2018.08.001

62. Wu Y, Liu Y, Su Z, Sun S, Liu C, Ding W, et al. Demands for telenursing-based long-term care among disabled older adults in Qingdao, China: a cross-sectional study. *Patient Prefer Adherence.* (2021) 15:1981–90. doi: 10.2147/PPA.S326413

63. Sundgren S, Stolt M, Suhonen R. Ethical issues related to the use of gerontechnology in older people care: a scoping review. *Nurs Ethics.* (2020) 27:88–103. doi: 10.1177/0969733019845132

64. Center CINI. The 48th Statistical Report on Internet Development in China. (2021). Available online at: https://www.cnnic.net.cn/hlwfzyj/hlwxzbg/hlwtjbg/202109/P020210915523670981527.pdf (accessed September 17, 2022).

65. Leese MI, Bernstein JPK, Dorociak KE, Mattek N, Wu CY, Beattie Z, et al. Older adults' daily activity and mood changes detected during the COVID-19 pandemic using remote unobtrusive monitoring technologies. *Innov Aging.* (2021) 5:igab032. doi: 10.1093/geroni/igab032

66. Andrews JA, Brown LJ, Hawley MS, Astell AJ. Older adults' perspectives on using digital technology to maintain good mental health: interactive group study. *J Med Internet Res.* (2019) 21:e11694. doi: 10.2196/11694

67. LaMonica HM, English A, Hickie IB, Ip J, Ireland C, West S, et al. Examining internet and ehealth practices and preferences: survey study of australian older adults with subjective memory complaints, mild cognitive impairment, or dementia. *J Med Internet Res.* (2017) 19:e358. doi: 10.2196/jmir.7981

68. Zhao YC, Zhao M, Song S. Online health information seeking behaviors among older adults: systematic scoping review. *J Med Internet Res.* (2022) 24:e34790. doi: 10.2196/34790

69. Smith B, Magnani JW. New technologies, new disparities: the intersection of electronic health and digital health literacy. *Int J Cardiol.* (2019) 292:280–2. doi: 10.1016/j.ijcard.2019.05.066

70. Li C, Neugroschl J, Zhu CW, Aloysi A, Schimming CA, Cai D, et al. Design considerations for mobile health applications targeting older adults. *J Alzheimers Dis.* (2021) 79:1–8. doi: 10.3233/JAD-200485

71. Kim S, Yao W, Du X. Exploring older adults' adoption and use of a tablet computer during COVID-19: longitudinal qualitative study. *JMIR Aging.* (2022) 5:e32957. doi: 10.2196/32957

72. Di Giacomo D, Guerra F, Perilli E, Ranieri J. Technophobia as emerging risk factor in aging: Investigation on computer anxiety dimension. *Health Psychol Res.* (2020) 8:8207. doi: 10.4081/hpr.2020.8207

73. Pirrie M, Harrison L, Angeles R, Marzanek F, Ziesmann A, Agarwal G. Poverty and food insecurity of older adults living in social housing in Ontario: a cross-sectional study. *BMC Public Health.* (2020) 20:1320. doi: 10.1186/s12889-020-09437-3

74. Jo TH, Ma JH, Cha SH. Elderly perception on the internet of things-based integrated smart-home system. *Sensors.* (2021) 21:284. doi: 10.3390/s21041284

75. Chan A, Cohen R, Robinson KM, Bhardwaj D, Gregson G, Jutai JW, et al. Evidence and user considerations of home health monitoring for older adults: scoping review. *JMIR Aging.* (2022) 5:e40079. doi: 10.2196/40079

76. Sanchez-Comas A, Synnes K, Hallberg J. Hardware for recognition of human activities: a review of smart home and AAL related technologies. *Sensors.* (2020) 20:227. doi: 10.3390/s20154227

77. Lagergren M, Kurube N. Comparing long-term care recipients in urban and rural municipalities in Japan and Sweden. *J Aging Soc Policy.* (2014) 26:281–94. doi: 10.1080/08959420.2014.900283

78. Gu D, Feng Q, Yeung WJ. Reciprocal dynamics of solo-living and health among older adults in contemporary China. *J Gerontol B Psychol Sci Soc Sci.* (2019) 74:1441–52. doi: 10.1093/geronb/gby140

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 April 2023
DOI 10.3389/fpubh.2023.1125834

OPEN ACCESS

EDITED BY
Alexander Seifert,
University of Zurich,
Switzerland

REVIEWED BY
Mei Lan Fang,
University of Dundee,
United Kingdom
Alberto Zanutto,
University of Macerata,
Italy

*CORRESPONDENCE
Catharina M. van Leersum
✉ c.m.vanleersum@utwente.nl

SPECIALTY SECTION
This article was submitted to Aging and Public Health, a section of the journal Frontiers in Public Health

RECEIVED 16 December 2022
ACCEPTED 15 March 2023
PUBLISHED 14 April 2023

CITATION
van Leersum CM, Konrad KE, Siebrand E, Malik ZB, den Ouden MEM and Bults M (2023) Engaging older adults with a migration background to explore the usage of digital technologies in coping with dementia. *Front. Public Health* 11:1125834. doi: 10.3389/fpubh.2023.1125834

Engaging older adults with a migration background to explore the usage of digital technologies in coping with dementia

Catharina M. van Leersum[1]*, Kornelia E. Konrad[1], Egbert Siebrand[2], Zohrah B. Malik[3], Marjolein E. M. den Ouden[3] and Marloes Bults[3]

[1]Science, Technology, and Policy Studies, Faculty of Behavioural, Management, and Social Sciences, University of Twente, Enschede, Netherlands, [2]Ethics and Technology Research Group, Saxion University of Applied Science, Deventer, Netherlands, [3]Technology, Health and Care Research Group, Saxion University of Applied Science, Enschede, Netherlands

Background: Coping with dementia can imply particular challenges for people with a migration background due to diversity in their life course, personal characteristics, and living environment. Some of the services available for people with dementia include digital technologies for care, providing health services, and maintaining or increasing participation, independence, and safety. This study aimed to explore the role of digital technology in coping with dementia in the lives of older adults with a migration background, and the possibilities to engage and collaborate with older adults.

Methods: This study combined a qualitative interview-based approach with citizen science principles in the design and execution of a project studying the use of Anne4Care.

Results and discussion: Participants valued that technology should provide health benefits and fit into aspects of their daily lives. Anne4Care was considered helpful in staying independent and connecting to loved ones in their country of birth. The participants needed to learn new competencies to work with the device, and not all had the material prerequisites, such as an internet connection. Still, this learning process was considered purposeful in their life, and the virtual assistant could be integrated into care and daily practices. The involvement of the older adults with dementia as co-researchers made them feel valuable and as equal partners during this research. An important prerequisite for the involvement of older adults with a migration background was existing relations with carers and care organizations.

Conclusion: Digital care technologies to cope with dementia can become a valuable part of care practices in the lives of older adults with a migration background. Involving older adults in the development of technology, acknowledging their expertise and needs, and working together in short iterations to adapt the technology for their specific needs and situations were experienced as valuable by the researchers, older adults, and care professionals.

KEYWORDS

older adults, digital technology, technologies for care, citizen science, dementia, migrants, independent living aid products

1. Introduction

Dementia is a global problem introducing a major social and emotional burden for people with dementia, their relatives, and health authorities (1). Coping with dementia tends to imply particular challenges for people with a migration background due to diversity in their life course, personal characteristics, dietary patterns, physical activity, and living environment (2). Kenning et al. (1) found in a meta-synthesis of qualitative studies on accessing dementia care by ethnic minorities that these older adults often lacked knowledge about their disease and symptoms, and care services often lacked cultural awareness and diversity. Other issues are less familiarity with available care services and lower health literacy—someone's ability to find, understand, and use the information to promote and maintain good health (1, 3). This is partly due to language barriers and a lack of culturally sensitive care. The language barrier often goes along with deterioration, cognitive decline, and lower levels of health literacy (2).

Caring for people with dementia at home is a good option, but the need to improve access to dementia services for people with a migration background is increasing (4). With this comes a need to provide culturally sensitive care. Culturally sensitive care was described by immigrant South Asian residents in United Kingdom nursing homes as "care that respects individuality, creates mutual understanding, caters for spiritual need, and maintains dignity" (5). In a scoping review by Fang et al. (6), culturally and spiritually sensitive care was found crucial to support individuals coping with aging. They define a cultural group in terms of shared stories, beliefs, values, myths, and practices shaped by history and geography, and a spiritual group in terms of religious, spiritual, and faith-based beliefs and practices. One way to achieve culturally and spiritually sensitive care is education and skill development of care professionals with regard to diverse cultural and spiritual groups (7). Furthermore, a Dutch study showed the importance of ethnic community health workers when providing culturally sensitive care (8). Health workers from the same ethnic community share the language but, above all, are trusted and respected by the community. They act as key figures and providers of services, tackling some of the barriers migrants experience to accessing healthcare (8) (Figure 1).

Overall, with the current diverse population of people with dementia and a migration background in the Netherlands, there is a need to broaden and adapt services to meet diverse needs. Currently, more and more digital technologies for care are being introduced to older adults aimed at facilitating common tasks and activities. However, how these are received by older adults with a migration background is hardly known. The remainder of the article starts by describing the range of available digital technologies for older adults with dementia and reviewing findings on their use by older adults. Then, we introduced Anne4Care as an example technology and introduce our use of a social practices approach and citizen science as a particular approach to engage with older adults. After this introduction, we explain our methods in more detail, then the qualitative findings are presented, leading to the discussion and conclusion.

Abbreviations: Anne4Care, anne for care; COVID-19, coronavirus; IMEAN, consultancy and care organization for older adults with a migration background; PVA, Personal Virtual Assistant; TOPFIT Citizenlab, research and innovation program to use citizen science and improve health and wellbeing of citizens.

1.1. Digital technologies for older adults with dementia

Part of the services available for people with dementia includes digital technologies that are aimed at providing services to maintain or increase participation, activity, the feeling of independence, and safety (9). The number of available digital technologies for care is increasing rapidly and varies in form and functionality, such as eating aids, digital locks, smart home sensors, shower robots, safety bracelets, virtual doctor visits, or incontinence detection sensor technology (9, 10). Digital technologies assist older adults by providing instructions in daily or health-related tasks and life, monitoring health behavior, or providing companionship (11). These technologies have been presented as an essential means to tackle the increased demand for healthcare (10, 12), and digitalization could be one of the approaches to alleviate the challenges of the aging population and improve quality of life (13). However, older adults with a migration background tend to access and use new technologies later compared to native older adults (14, 15). One of the reasons is a low proficiency in the language in the country of residence (16). Overall, little is known about the use of digital technologies by older adults with a migration background (17, 18).

With regard to people with dementia in general, several experiments engaged people with early-stage dementia in research or development of technologies. Zamir et al. (19) showed that the use of video-calling in care environments could reduce feelings of loneliness when the family is unable to visit regularly. Technologies with virtual agents can strengthen the self-management of people with dementia and their self-care, participation, and independence (20). Stara et al. (21) explored the use of Personal Virtual Assistant (PVA) Anne4Care (see Box 1). They concluded that the use of these screen-based applications allows for natural interactions between humans and computers. Other studies have shown that exercises could be provided with the use of animated conversational agents (22), virtual agents give the user a sense of companionship (23), and people with dementia seem to naturally engage with these virtual agents (24). However, people with a migrant background make less use of the Internet or technology for health purposes and were not included as key stakeholders in development or research processes (16, 18).

BOX 1 Anne4Care.

Anne4Care is a VPA that includes video-calling, a personal agenda, medication reminders, reading the news, and games. It is a technological device created to support users with cognitive impairments in many aspects of their daily life. Hence, it enables them to live more actively and independently and lowers the burden on formal and informal caregivers (21). The device Anne4Care is available in different languages, such as Dutch and English. Currently, the company is developing a Turkish version of the same device and saw the embedding of Anne4Care in homes of older adults with a migration background as an opportunity to test and improve the latest version.

The COVID-19 pandemic caused more loneliness among older adults. Caregivers who were involved in this project searched for creative solutions to decrease feelings of loneliness among their clients and raised some ideas, such as introducing video-call technologies in the homes. Especially for these older adults, who were not able to visit family in their birth countries, easy access to video-call technologies appeared to be a good solution. People could benefit by using video calls to strengthen social relationships, overcome difficulties with the local language, and foster independence (18).

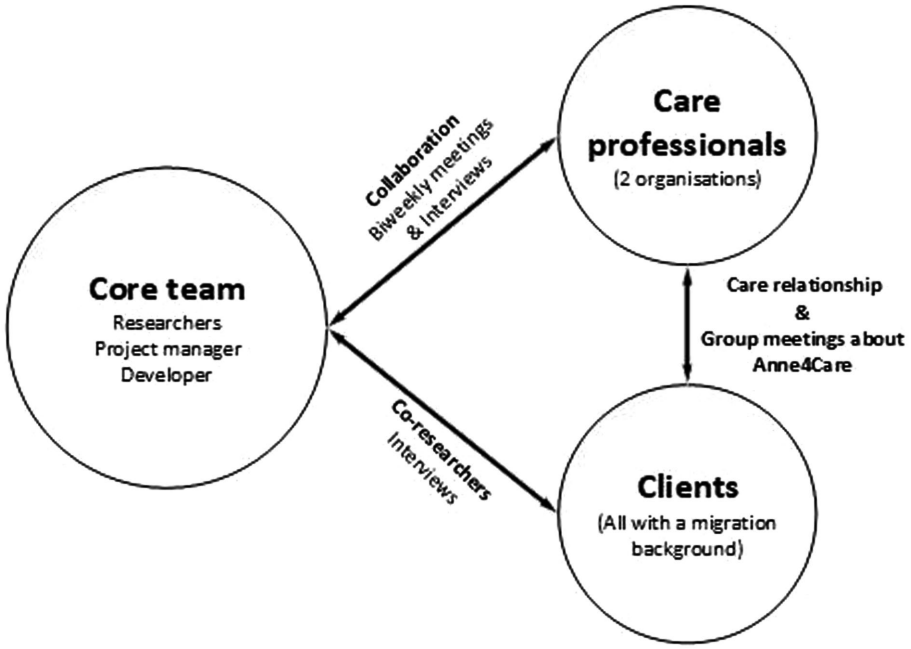


FIGURE 1
Overview of stakeholder groups and interactions.

1.2. Approach: Social practices and citizen science

In our study, we aimed at an approach that allowed us to closely involve users in our research and to be sensitive to their particular experiences, lifeworlds, and needs (2, 18). In line with Shaw et al. (25), we chose a social practice orientation and combined it with the application of citizen science principles.

Wider use of technologies, such as Anne4Care, often proved more difficult than anticipated (25). To be used productively, technologies need to be embedded within the daily practices of their users and their wider socio-technical networks, accounting for situated knowledge, personal habits, and collective routines (25). Even if the technology is already in use by one stakeholder group, practices and socio-technical networks might be different for another stakeholder group. In this research, it was important to adapt the technology to the personal needs of older adults. It needs to fit with their daily practices but might influence these practices and those of others related to older adults as partners and carers as well. Social Practice theory argues that new technologies may change current practices, with practices being constituted by material elements, such as objects, tools, technologies, and infrastructures, by competencies, such as knowledge, practical know-how, and embodied skills, and by meanings, such as cultural conventions, expectations, and socially shared meanings (26, 27). All these elements are essential for a practice to "work" and to become part of people's daily lives and social networks.

Citizen science, or the use of scientific principles and methods by non-professional scientists, may be a powerful method to improve public participation in research as well as to improve the implementation of technologies (28). Citizen science principles require close collaboration with the intended users, involving them actively in the capacity of co-researchers rather than mere research subjects. This close collaboration of researchers with co-researchers is meant to enable an alignment of the technology with the needs of the users and their practices (25, 29). Close involvement throughout the research process allows citizens to influence and improve both the design and execution of research and to prevent important aspects from being neglected or omitted, for example, aspects that are related to having a migration background and that researchers may not be aware of.

In some development processes of video-call interventions, older adults have been involved. However, in most development processes, younger adults who are not retired, do not receive care, show no signs of dementia, and have a certain level of technology literacy are usually included (30). As Fischer et al. (31) argue, the full potential of including older adults in the development of technologies is still to be exploited. This may be one of the reasons why innovative technologies struggle to meet expectations and get the attention of the aging population (31).

We did not come across any studies investigating the use of technology or involving older adults with a migration background in the development processes of digital technologies for care. Most studies include the majority population. Therefore, it remains unclear how these older adults experience being involved in the development of technologies (18). This study aimed to explore (1) the role of digital care technology in the lives of older adults with a migration background in an early stage of dementia and (2) ways to engage and collaborate with these older adults in the development of technology. Against this aim, Anne4Care served as a case example and we drew on citizen science principles to assess the perceived value of the application for the users and study the use practices and the needs of these older adults. Furthermore, the methods and value of the used citizen science approach were evaluated.

2. Methods

2.1. Design

To assess the specific value of Anne4Care for the envisaged user group, a wide variety of aspects of living with dementia and having a migration background must be reflected in the design and execution of the study. This was achieved by the intensive involvement of older adults and their carers from the early design of the study to analyzing the results and presenting the conclusion. Hence, persons with a migration background in an early stage of dementia participated as co-researchers. There were several stages in this study where researchers and co-researchers collaborated intensively. First, one care professional was consulted regularly during the design of the research. Her contribution was essential to making the final design of this research and understanding how we can collaborate with older adults with a migration background. For example, how much time they could contribute to the research process and how. Second, the topic list that was used in the semi-structured interviews was evaluated and updated by the co-researchers. The co-researchers had a final word considering the formulation of certain questions and interesting topics. Third, the coding matrix used to analyze the interviews was evaluated and updated by one co-researcher. This co-researcher made the matrix complete and specific to their experiences and daily life. Fourth, the conclusion was drawn and presented in close collaboration with co-researchers and researchers. During one presentation, the care professional, a researcher, and a co-researcher presented the findings together to a general audience.

These former steps needed to meet certain conditions. These conditions were drawn from the experience that citizen science has a strong social aspect in which values such as respect and equality play an important role. For example, a good relationship is paramount for collaboration and both co-researchers' and researchers' input and adaptations are mutually respected. It also means that care professionals monitor the health status of co-researchers and put research actions on hold if necessary. Finally, having an eye for reciprocity as giving credits but also in the sense that collaboration can have both indirect (e.g., better technology as the outcome of the study) and direct health benefits since being a co-researcher brings new social contacts, new mental challenges, and purposes into their lives.

2.2. Setting

This research was part of the TOPFIT Citizenlab program, a research and innovation program in which citizens, healthcare professionals, and companies join forces with researchers to develop and implement technology for health. Furthermore, this program investigates the applicability, results, and contribution of citizen science methodologies in different settings. The present study involved clients with a migration background who visited the activity program of a healthcare organization. Two organizations (IMEAN and Alifa) were involved, both situated in the Twente region of the Netherlands. These organizations provide care to clients with a migration background with cognitive impairments. IMEAN solely provides care to male older adults and Alifa provides care to both male and female older adults. Most clients visit these care organizations two times a week to participate in activities. Three care professionals participated in this study, who all took care of the clients and spoke their native language. This was important to create a safe and trustful environment for the clients and give them a voice when they were troubled with conversating in the Dutch language. The Anne4Care device was installed in the homes of the clients/co-researchers. None of them were familiar with or made use of comparable technology. The team of researchers closely collaborated with the care professionals and Anne4Care company during the design phase. Decisions regarding the procedure of recruitment, obtaining informed consent, data collection, and analysis were made jointly. The recruitment was performed by the care professionals.

Before recruitment and data collection, ethical approval was obtained from the University of Applied Sciences Saxion Ethical Advice Committee (reference number SEAC-2020-005). The co-researchers were personally informed about the study before the start of the test period with Anne4Care. They gave written consent and were informed about their right to withdraw at any moment. Data were anonymized, confidentiality was maintained, and the data will be retained for 10 years.

2.3. Stakeholders

There are three main stakeholder groups within this project: A core team consisting of five researchers, a project manager of Citizenlab, and a developer of Anne4Care; a group of three care professionals involved in two different organizations; and a group of 13 clients with a migration background. The core team had biweekly meetings in which one of the care professionals was always present, and the care professionals were all involved during the interviews. All clients were involved as co-researchers, and as compensation for their participation in this research, they could use the Anne4Care technology for free. The co-researchers had an established care relationship with the care professionals and participated jointly in organized group meetings about Anne4Care. In addition, the co-researchers were in contact with the core team during interviews. The older adults did not receive any training in research activities to become co-researchers. In collaboration with the care professional and the older adults, we discussed who would be capable and who felt comfortable performing which task. All co-researchers received training and assistance to use the Anne4Care technology. The basics of the technology were explained by their care professionals and they could reach out to a help desk for questions.

2.4. Informed consent procedure

The informed consent procedure was an important activity for establishing relationships and trust between the researchers and co-researchers. The language barrier and level of literacy needed to be taken into consideration with older adults. During an introductory meeting, the researchers visited IMEAN to meet two care professionals and five clients. The professionals working with the clients had a key role as mediators. They already knew their clients very well and speak their language. They were constantly monitoring the situation and translating the informed consent statements into Turkish. They also translated the questions of the clients to the researchers. The informed consent form was explained,

TABLE 1 Three steps of data collection, method, number of included co-researchers, and purpose of each step.

Data collection	Method	Co-researchers	Purpose
First interviews	Semi-structured interview	13 co-researchers	1. Understand the lives and care needs of the co-researchers 2. Explore their expectations regarding Anne4Care 3. Discuss previous experiences with care and technologies
Second interviews	Semi-structured interview	8 co-researchers	1. Explore the experiences with and suggested adjustments of Anne4Care 2. Discuss their experiences with the current and ideas for future roles as a co-researcher
Interviews with care professionals	Semi-structured interview	4 care professionals	1. Explore their role and experiences as a professional in the use and implementation of Anne4Care 2. Discuss their experiences in working together with the co-researchers

stressing that there was no pressure to participate and that they could decide to leave the study at any moment. We found this meeting extremely important because it laid the foundations of a relationship with the clients who became our co-researchers, while at the same time stressing the importance of citizen science and their role as co-researcher.

After evaluating this first meeting with the care professionals, they suggested working on a video explaining the study and the steps of informed consent. This tool supported care professionals in explaining the project to new clients. A video was created in the Turkish language. It was shown during two informative evenings at Alifa and was received well by the clients. It helped evoke questions from clients and address the concerns of some of the participants. Working closely with the care professionals meant that we regularly spoke with them regarding the atmosphere and feelings in the client group. This strengthened our relationship with the clients, as we could address the topics of interest during the interviews. To provide a few examples, there were fears about Anne "listening in" to conversations at home or worries about the cost of electricity. Other considerations of the clients included the follow-up when the study would end. Will they be allowed to keep Anne4Care? These issues were uncovered during the first meetings and were further discussed during conversations between the researchers and co-researchers.

2.5. Data collection

Since Anne4Care was introduced as a response to the COVID-19 pandemic, the data collection took place during the pandemic. Data were collected between September 2020 and November 2021. The semi-structured in-depth interviews took place at the care organization or at the home of the co-researchers. The location was chosen according to the preference of the co-researcher. During the interviews, a care professional was always present. In some cases, they assisted in the role of interpreter. Even though the researchers did not understand the co-researcher when they talked in the Turkish language, we experienced that the co-researcher made contact with and talked toward the researcher who asked the question. Co-researchers were invited for two interviews. The first interview was planned shortly after the introduction of Anne4Care in their home, and a second interview 4 months later. Five researchers conducted the interviews. The follow-up interviews were conducted by the same researcher(s) (Table 1).

A total of 13 first interviews were conducted with all involved co-researchers. The interviews lasted between 30 and 60 min. The topic guide was developed in collaboration with one co-researcher and the care professionals. The first interview aimed to start the collaboration between researchers and co-researchers and get further acquainted with each other. The discussed topics included (1) the lives and care needs of the co-researchers, (2) their expectations regarding Anne4Care, and (3) previous experiences with care and technologies (Supplementary material 1).

A total of 8 s interviews were conducted with the same co-researchers who participated in the first interviews. Five of the co-researchers were not interviewed two times by the researchers due to COVID-19 illness. These interviews lasted between 20 and 45 min. The care professionals had a conversation with the five missing co-researchers, and the outcome of these conversations was shared with the researchers. The topics discussed during the second interviews included (1) the experiences with and suggested adjustments of Anne4Care and (2) their experience with the current and ideas for future roles as a co-researcher (Supplementary material 1).

Before, during, and after the interviews, the care professionals regularly organized meetings with all co-researchers. The co-researchers were asked to bring their Anne4Care. During the meetings, they shared experiences and were able to help each other with difficulties. The care professionals were present to help as well. Afterward, they shared their experiences with the core team.

Four semi-structured interviews were conducted with the care professionals. These interviews took place at the care organization and lasted for 60 min. These interviews aimed to talk about their role and experiences as professionals in the use and implementation of Anne4Care and working together with the co-researchers (Supplementary material 2).

2.6. Data analysis

All interviews were audio recorded and transcribed verbatim. The transcripts were made in English and Dutch. All Turkish spoken words were translated by an interpreter during the interviews. Due to our close collaboration with the care professionals, we have good reasons to assume that the translations were sufficiently accurate. Only the translations were part of the transcripts. Content analysis was performed on all transcripts. Inductive coding was applied to observe and combine various aspects into overarching themes (32). During the first step, open coding was used to identify relevant themes. The concepts of migration background, technology for care, and culturally sensitive care were taken in relation to the themes determined with the inductive coding process. Three researchers performed the analysis of two transcripts and compared the coding. A coding matrix was developed comprising these themes. Thereafter,

TABLE 2 Demographic characteristics of co-researchers (*N*=13).

Co-researcher	Gender	Age	Nationality
1	Man	65 years	Turkish
2	Man	82 years	Turkish
3	Man	83 years	Turkish
4	Man	65 years	British
5	Woman	71 years	Turkish
6	Man	80 years	Turkish
7	Man	52 years	Turkish
8	Man	59 years	Turkish
9	Man	77 years	Turkish
10	Woman	65 years	Turkish
11	Man	73 years	Turkish
12	Man	83 years	Turkish
13	Woman	70 years	Turkish

one transcript was anonymized and coded together with a co-researcher. The coding matrix of the researchers was presented, and the co-researcher suggested many additional themes, such as unawareness of the older adult regarding the risks when the technology would fail, dependency on technology or care in general, and disappointment when the technology did not answer to expectations. This led to the final coding matrix, which was used by one researcher to continue the data coding (32). The co-researcher was only involved in coding one transcript due to the cognitive load and concentration that the analysis asks of the co-researcher. The researchers discussed the coding at biweekly meetings. Translation of quotes from the transcripts to English took place in preparation for the findings. Software package NVivo11 was used for the data coding.

3. Findings

First, we present an overview of the co-researchers and a case description of one co-researcher. Then, the findings are presented and structured along the materials, competencies, and meanings involved in the use of Anne4Care by our co-researchers. Furthermore, we highlight how the practices of others in the network of the co-researchers were affected. Thereafter, the implications of being a co-researcher are further explored.

3.1. Co-researchers

A total of 13 co-researchers collaborated in this project. Since IMEAN solely provides care to male older adults, we recruited a higher number of male co-researchers; 10 of the 13 co-researchers were men, and their ages varied from 52 to 83 years. One had British nationality, but all others had Turkish nationality (Table 2). A case description of one co-researcher is presented in Box 2 to show an example of the living context of the co-researchers who were involved in this research.

BOX 2 Case description of co-researcher EE.

Mrs. EE is 70 years old and born in Turkey. Thirty years ago, she arrived in the Netherlands together with her husband, and they live in the Eastern part of the country. Mrs. EE does not have many friends in the neighborhood and does not have much contact with neighbors. This problem increased due to the COVID-19 pandemic because it was more difficult to visit each other, prepare dinner together, or visit the mosque. There are no relatives in the Netherlands to assist with care or daily activities. Mrs. EE has heart failure and diabetes, and deteriorating auditive and visual capacities. Furthermore, she has an early stage of dementia and visits daycare for 2 days a week. On the other days, she is at home where she does some housekeeping tasks and uses a scoot mobile for outdoor activities, such as grocery shopping.

Anne4Care was introduced in the home of both Mrs. EE and her husband. They each received their own tablet to use Anne4Care. Mrs. EE was already using different technologies such as a mobile phone and laptop, especially to search for information on the Internet or to play games. Anne4Care was introduced at first only to be used for reminders of medication and appointments. She did not use the video conference possibility. After a couple of months, the functionalities of games and listening to the radio were added. These additional functionalities were welcomed and used often. Furthermore, the reminder option was valuable for Mrs. EE because she uses many different medications, and alerts were set to remind her of prayer times. Finally, reminders were introduced for the preparation of dinners including recipes and to turn off the gas after preparing dinner.

3.2. Technology in the lives of older adults

To understand the role of technology in the lives of older adults, the interviews focused on the perspective of the co-researchers on technology, the use of technology in general, and more specifically the experiences with Anne4Care. In this section, we inquired into how technology could become part of the daily lives and particular practices of the co-researchers. Following the social practice approach, in our analysis of the findings, we paid particular attention to how meanings, material elements, and competencies influenced and featured in the ways Anne4Care was approached by the older adults, how they used it, and the needs they voiced. Furthermore, we considered not only individual practices but also how they affected relations with others, in particular family members and carers.

3.2.1. Meanings and expectations

Most co-researchers preferred to use Anne4Care throughout the day as it gave them a purpose and was valuable to assist with health-related tasks. Anne became a part of their home and routine. In the morning, Anne started their day by saying "good morning." This was a warm welcome and gave the feeling there was someone else at home. They also felt comfortable with the avatar of Anne4Care being present in their home. Although the avatar was a blond woman, it was not considered important to change toward, for example, a Turkish woman. Also, the name had a positive cultural meaning according to the co-researchers with a Turkish background, because the word "Anne" means mother in the Turkish language.

Most co-researchers were benevolent to work with Anne4Care, welcomed technology in their life, and preferred to have virtual assistance at home. They were interested in Anne4Care because it is a device communicating with them in their native language. The co-researchers stated to use technology as it makes their lives easier, for example, by allowing them to communicate with family and

friends in their home country, helping them to cope with memory loss, or supporting them with the Dutch language. Furthermore, technology should provide health benefits. The co-researchers considered this as particularly important for them, as their family often lives in a different country and could not support them with health problems or health tasks in their daily lives. Some of these tasks in which Anne4Care could assist is the provision of reminders for medication. However, it could also be used for different, culturally important practices that are relevant for structuring their day, such as reminders for daily prayers.

> *"Our older generation thinks about certain things differently than the younger generation. They have different interests to use technology. People from my age, we are interested in the health benefits and how we are supported to reach these."*—KK.

Half of the co-researchers thought Anne4Care was an entertainment or learning device. There were already some puzzles and games, but the co-researchers pointed out that more advanced puzzles or games are needed to provide more challenges. These challenges are discussed as valuable to cope with dementia and possibly decelerate mental deterioration. Furthermore, language games were discussed as an addition to facilitating knowledge of the Dutch language. The functionalities such as games and puzzles as well as reading a newspaper, listening to the radio, and even managing the agenda were meaningful activities.

> *"It is so much fun to work with Anne. For example, when I have a new appointment, I would like to know how to add this to the agenda. Anne keeps me occupied, active, and at the same time more independent."*—MM.

In addition to the positive ideas about technology, there are some concerns based on privacy issues. Some co-researchers disclosed that they just do not like the internet. They have no idea what could be possible with these modern technologies and who could have access. Some mentioned that people from their generation are a bit slow in accepting something new and have a negative attitude toward technological development in general.

> *"They turned Anne off during the nights. I asked why they switched it off and he told me that they were afraid someone could watch through the device. Sometimes we just want to go on too fast, but the technology frightens them, and they must get used to it."*—Professional A.

3.2.2. Materials and infrastructure

Most co-researchers paid little attention to the multiplicity of technologies they already used. As an exception, one co-researcher was interested in technology during his entire life. He had a collection of older and newer photo and video devices, which assisted him in staying connected with Turkey. A small number had technologies including alarm devices, a flashing doorbell, and a robot vacuum cleaner. The couple who possessed the robot vacuum initially did not expect to use the robot but were eventually satisfied with the result and the easiness of use. Although most co-researchers did not feel very knowledgeable about technology, they had expectations of technology in general as well as of Anne4Care specifically. Considering Anne4Care, most expected to take the device outside their homes also. However, Anne4Care stopped working when plugged into the electricity socket or when it lost an internet connection. This implied that the device could be used at home but not outside, and, for example, medication reminders were not provided when leaving the house. The co-researchers argued that this made the device more useful for housebound people. To support their daily and health practices under varying circumstances, it should be possible to take the device outside.

> *"It would be good if they introduce a mobile app that interrogates the same personal details which I could use when I'm out, and then they can remind me to take my medicines when I'm not at home. Now it would only really work for somebody who's housebound."—DD.*

In the case of older adults with a migration background, financial resources are often minimal, which makes it more difficult to purchase the technology. Furthermore, the co-researchers had no idea where others could buy such a device and in which stores it could be purchased, and they wondered about the costs when the project would end. Regarding finances, the professionals compared it to the transition from a landline phone to an internet-based smartphone. This was established due to the possibility to call their family and friend in their country of birth free of charge. Thus, Anne4Care would be more likely to be taken up, if it could replace their smartphone and should not include additional costs. Some co-researchers were concerned about the electricity bills because the device needs to be plugged in all day.

> *"The idea to spend money or save money is deeply embedded in these older adults. Saving as much as possible is especially important because they need it for tickets to visit family and friends. Therefore, purchasing innovative technologies, paying the electricity bills,* etc. *is a huge problem for them."*—professional A.

Another suggestion, connected to finances, was made by the care professionals. To improve the care they could provide, there should be an application in Anne4Care to assist with financial and administrative tasks. This kind of assistance would add more value to the device for some of the co-researchers because it gives them a deeper understanding of their financial situation and possibly more independence.

3.2.3. Competences, learning, and support

The professionals argued that the introduction of Anne4Care in the homes of older adults needs time, attention, and understanding of their situation and cultural background. The care professionals strive toward a smooth introduction of technologies such as Anne4Care to improve independent living. In the future, introducing the technology in an early phase seemed necessary due to the beginning of dementia and the time the appropriation process takes. According to the professionals, this would be possible if they introduce it to each of their new clients. However, it may also be that, in an earlier phase of dementia, the clients could have more difficulties seeing the value of the device. The embedding of technology introduces new practices of support in addition to the current care practices. For example, additional help could be provided by the care organization, but assistance should also

be provided at home. The questions of how this support is arranged and who will have which task need to be determined.

> *"At the start of the project, the coordination was done by someone else and I was not involved in the decision to start using this technology. The moment we started to introduce Anne to the clients in our organisation, that was the moment I got involved. I consider this as a well-aligned process. Then the introduction at the homes of our clients went through different phases, and with some it took more time than with others. The phases for example included setting-up the device, get started, explanation of different functions, and testing the device together. At every home visit, we need to send some time with the device to make it part of our clients daily practice and our care practice."*—Professional CC.

According to the care professionals, the involvement of a care professional they trust was critical to introduce technology into the lives of older adults with a migration background. Initially, most co-researchers had some hesitation and the care professionals as well as other co-researcher who were already involved in the project had to convince them to use Anne4Care. However, once they got familiar with the device and embedded it into their daily routines, they did not want to miss it anymore, as it gave them purpose in their daily activities and helped with staying more independent in health tasks.

All co-researchers were eager to participate and use Anne4Care. However, a remark made by most of them was that they needed assistance to use technology in general. Many needed help to use their smartphone, for example, to send a message or translate a Dutch message. They lacked the appropriate knowledge and familiarity with digital technologies. They came to the Netherlands to work in sectors where technologies did not play an important role. Thus, they did not come across many new or digital technologies during their lives. To use technology such as Anne4Care, they need to learn new skills. Although learning is acknowledged as valuable for coping with dementia, learning something new is challenging, especially due to their deteriorating memory and obliviousness.

> *"We do not understand much about technology! I cannot handle it well. When we would have had the ability or need to use technology in an earlier stage that would have been easier. There is so much under development and now, storing new knowledge is a slow process."*—CC.

Although they recognize their suffering from obliviousness and necessary time to learn something new, some wanted to learn how Anne4Care operates. This provided distraction during the day and challenged them while discovering more about technology.

> *"These are all new things for me which I would like to use, but I need to know and learn how to do it, or I will not be able to use it. That would be such a pity."*—KK.

One co-researcher suggested the possibility to develop a short course on technology to help with the learning difficulties. He mentioned that repetition is an important aspect of such a course, all the more for older adults with dementia. Repetition is necessary for people with dementia to provide a more permanent understanding.

> *"They have explained this once or twice, but then you need to remember. I need someone to practice the new things in order to actively remember."*—LL.

In addition to repetition, the language barrier should be considered. For the co-researchers, it was important to collaborate with people who can overcome the language barrier and are familiar with low digital literacy. This collaboration should become part of the current care for older adults. Next to a course, the co-researchers emphasized the usefulness of the joint meetings at the care organization, which allowed them to share knowledge and help each other to work with Anne4Care. These meetings were experienced as fun and worthwhile. It gave the co-researchers the possibility to ask questions and use the technology. This option of collaboration can be integrated into current care. Furthermore, the co-researchers argued that it is important to ensure that they can communicate in their native language, all the more for older adults with dementia, as second language skills may suffer. The addition of an employee at the Anne4Care service desk who spoke their language was noted as meaningful by all co-researchers. If they came across difficulties in using the device, they could reach out to this employer and receive immediate help without the interference of an interpreter.

3.3. Family and care relationships

The introduction of a technology such as Anne4Care in the lives and homes of people implied that people in their surroundings are faced with it as well. One co-researcher disclosed that he had regular discussions with his partner before Anne4Care was introduced. His partner had the task to remind him to take medication, and then, there was a device at which he did not become angry. This improved their relationship and lowered the care burden of the partner. In addition, all care professionals acknowledge that the tasks of informal caregivers are lowered, especially due to the reminders provided by the device. However, another partner had more trouble with Anne4Care because she had to do additional tasks to make the device work rather than being relieved from them. The partner not only had to learn how to use Anne4Care but also keep the device up-to-date, which took a lot of time.

> *"We spent probably a whole Thursday afternoon trying to figure out how to make it work. Also, now my partner must put the medicines in manually and type all these difficult medical words. Oh, a lots of medical words, brand names, she has to add all and the frequency per day and what time of day it needs to be taken. And do that all manually does not take work away from her, but it puts work on top. Also, to put my appointments from the diary, I have a paper diary, and she must go through and copy all of these and put them in."*—DD.

Another discussion with the professionals concerned the possibility to provide more personalized care. More personalized care could improve their relationship with the clients. Anne4Care provides the opportunity to adjust care to different disabilities and help with personal needs, such as reminders for daily prayers or turning off the gas after cooking activities. The care professionals knew about the lower ability to remember to turn off the gas of one

co-researcher. To stay at home, the first advice was to stop cooking meals, which was not the most healthy solution for this co-researcher due to diabetes. With the possibility to add all kinds of reminders in the device, the co-researcher could live longer in her home and make her own healthy meals at home by receiving recipes, shopping lists, and reminders to cook and turn off the gas. In addition, in the example below, the care professional came across the difficulties her client had with household chores due to reduced arm strength.

> *"With the use of Anne at the home, we get more insight into the lives of our clients. For example, this man seemed to function very well, but with the use of Anne we encountered a disability with which he could have some assistance from us. You see how we can also ignore some care needs."*—Professional B.

3.4. Being a co-researcher

After the extensive informed consent meetings, some clients were more open and directly willing to participate while others were more reluctant. They mutually talked about the technology and the research and some convinced others to participate. In the end, all clients present during the meeting became our co-researchers. The name of the co-researcher gave them a feeling of pride and being part of a development process. They all knew that Anne4Care was still in a developmental phase and did not expect that everything was working optimally.

> *"I know Anne still needs to be improved, it is in the development phase. Yes, there are some things that are not working as they should, but that is why I am involved. I will test it at home to face all ailments and provide important feedback to adjust Anne where needed."*—HH.

Most mentioned the group meetings during which they shared their experiences and knowledge and learned from each other.

> *"We share the needed adjustments for the device, but also what we expect will be discussed. Everyone is free to share personal needs and everything can be brought onto the table. Where one of us would like to have a different interface for the medication, someone else needs an alarm button."*—BB.

These group meetings made everyone feel valuable and being part of the research project. Giving their opinion made them feel more important and of influence on the final development. For older adults, this social component in the project was particularly important. Practicing together increased their motivation to learn and use the technology. One of the co-researchers also compared the home situation where her husband had to learn to use Anne4Care on his own or together with his wife with the group meetings where he is with other men. She claims that he is more motivated when he is around other men.

All co-researchers want to recommend Anne4Care to others, and a small group would even be part of promoting activities. They have ideas concerning where to find older adults with a migration background and how to engage them in meetings about modern technologies. However, they mentioned some barriers such as fewer social connections due to COVID-19, low digital literacy, and unknown availability and costs of the technology.

> *"I would like to recommend this to others, share my knowledge in a group. However, I expect most of them to say 'I cannot even write or read'… Yes, most of them are analphabetic and do not have had any education. Others would be hesitating because they expect a lot of challenges while learning this innovative technology, they would claim to have too little brain capacity. Still, I would very much like to recommend it."*—EE.

4. Discussion

This study aimed to explore the role of digital technology in coping with dementia in the lives of older adults with a migration background and to explore possibilities to engage and collaborate with older adults, as our co-researchers. Considering the first research question, digital technologies for care may help older people with dementia to stay independent and connect to loved ones in their country of birth. The technology should fit into their lives, contain adjustable language settings, and can be used both inside and outside their homes. Important while collaborating with co-researchers, regarding the second research question, is acknowledging their expertise and needs and working together in short iterations to adapt the technology to their specific needs and situations. The group sessions in which the co-researchers shared findings and worked together with others with a similar background and the same language were experienced as very valuable. The following sections will discuss four topics in more detail, all revolving around the relations between the four core "entities" in our study: co-researchers, researchers, care professionals, and technology: (1) how to reach older adults with a migration background to experiment with the use of digital technology, (2) how to build a relationship with them to assist them in using technology and to collaborate with them in research, (3) the value of the engagement and collaboration across the research process and the need to adjust the engagement preferences and capabilities of the co-researchers, and (4) the role of technology in their lives. The discussion ends with the strengths and limitations of this research, an overall conclusion highlighting the main insight, and recommendations for practice and future research.

4.1. Reaching older adults with a migration background

Based on our research, we identified several challenges regarding the development and implementation of digital technologies for coping with dementia for older adults with a migration background. Regarding our research questions, there are several challenges we will further discuss. One of these challenges in healthcare and social work is to reach people with a migration background. In our conversations with older adults, it became clear that, for making them aware of care technologies, providing culturally sensitive care, or collaborating with them in the development or implementation of the technologies, it is necessary to reach these older adults directly. However, they also

stressed that most older adults with a migration background do not want to use digital technology or make use of a health service. Health services often have difficulties reaching people with a migration background, also because little culturally sensitive care is provided and understood (4). Some of our co-researchers had negative experiences with previous healthcare organizations and preferred specialized care organizations such as those involved in our study.

To reach older adults with a migration background to experiment with technology, different suggestions were given by the co-researchers. The most important suggestions were the support of the older adults among each other or support through specialized care organizations. The involved care professionals and researchers experienced that reaching older adults willing to experiment with the technologies was challenging. Some studies described that people with a higher social status are more likely to be early adopters of new technologies and people with a lower social position adopt technology later (33). Most older adults with whom we collaborated did not identify themselves as early adopters of technology and would not have experimented with the technology if the care professional did not approach them.

4.2. Building a relationship

In addition to involving a specialized, trustworthy organization, as a second element, our findings showed the importance of the relationship between older adults with a migration background and their care professionals. This was important for getting interested in and accepting the new technology for care into their lives. Due to unfamiliarity with technology, a relationship of trust with a care professional was crucial in combination with culturally sensitive care. The position of the care professional was important to convince older adults to use technology. She understood culturally sensitive care, had the same nationality, spoke their language, and had a relationship of trust with the co-researchers. In the early stage of this study, the researchers and care professionals had extensive discussions with older adults. These discussions revealed barriers and worries for this specific group of older adults, such as anxiety, language, the added value of technology, and cost of electricity use, and helped to create a climate of trust.

In addition to the relationship with the care professional, the same applies to the relationship with the researcher. Researchers must take time to introduce themselves, build trust, and work together with the co-researchers. Acknowledging and valuing the expertise of co-researchers gave them a feeling of pride. Other studies also showed that trust in researchers has a significant role in enhancing cooperation with co-researchers (34). Incorporating the views and needs of vulnerable populations is the first step (34), and an active role as a co-researcher is the next.

4.3. Collaboration with the co-researchers

Third, the continuous, collaborative involvement of the co-researchers across different steps of the research proved very valuable both for the research process as well as the adoption and integration of the technology into user practices. It appeared, however, also important to allow for some flexibility in how individual co-researchers were involved. The collaboration with co-researchers revealed various needs and desires toward future developments of Anne4Care. The co-researchers in our study made a lot of suggestions to improve the technologies to make them fit in their lives, such as having an alarm button. The problems they experienced were necessary to improve the device and make it more useful. Another device, "skype on wheels" (19), had a low engagement among older adults after implementation in the homes due to multiple barriers, which could have been overcome with a collaborative process (19).

The question of how to engage and collaborate was also discussed with the older adults during the interviews. One suggestion was to collaborate in reaching out to other older adults with a migration background. In this study, they received the role of a co-researcher and had the option to support others in getting to know about the technologies for care or even assist in using them. They have the knowledge of where to find the target population and how to approach or talk about digital technology. While a citizen science approach strives for a high level of engagement, we allowed the co-researchers to engage in different degrees and divide tasks, depending on what individuals felt desirable and feasible for themselves. Most of the co-researchers felt capable of at least testing the device and collaborating in the workshops and interviews to discuss their experiences and needs for adjustments to the device. Only a small group was involved in discussing the topics for the interview guide and one co-researcher was involved in analyzing the data. While it would have been valuable to include more co-researchers during the analysis, it also became clear that research interests needed to be balanced against the risk of overburdening the co-researchers.

4.4. Technology in the lives of older adults

The last point is connected to our first research question and elaborated on how to relate to technology for care and embed it in the lives of older adults. According to the co-researchers, it was rather easy to fit the technology into their home and home routine; this was also observed by the researchers and care professionals involved in this study. The fact that it was a tablet, a physical object, made it an artifact with which people started to talk in their native language. This affectionate reaction is achieved with such artifacts, rather than with apps (35). Apparently, including an avatar that invoked culturally positive meanings facilitated the creation of such an affectionate relationship as well. When a new artifact is implemented, it co-shapes daily practices, the actions people take, and the relationship among the user, the artifact, and the surrounding (36–38). The older adults experienced a connection with the technologies brought into their homes, and they even started to trust the technology. On the one hand, they interacted, talked, and reacted to the technology, and on the other hand, they felt a connection and the artifact became an element in their routines and practices. However, before this connection is possible, older adults need to open themselves to using technologies for care.

As Kouvonen et al. (18) argue, older adults with a migration background and ill health experience more barriers to using technology than those with better health. They argued that the technology should be adaptable to those with specific cultural needs to facilitate adoption. The care professionals in our study also argued that it is important to invest time in providing support, especially with the introduction of technology. They invested a lot of time to explain the technology and collaborate with the older adults when they used the technology for the first time. Older adults need to perceive that they can and why they should use digital technologies for care. For

this, it appears necessary to assess life and health-related differences to identify which particular technology older adults could and would use and which might differ between native and migrant older adults (39–41). Similar to the division of tasks during the experimentation of digital technologies, also the eventual use of these technologies will differ from one to another. Mitchell et al. (16) also underlined that the use of specific applications is not similar across older adults with different nationalities, which could even cause health disparities.

4.5. Strengths and limitations

The involvement of older adults with a migration background in an early stage of dementia as co-researchers is considered a strength of this study. However, those with a moderate stage of dementia may have different experiences. Our collaboration strategy allows matching the ideas and needs of the co-researchers with the technology under development (42). In addition, the researchers worked closely together with care professionals to get an in-depth and multi-stakeholder perspective on the development and (first) use of technology. The involvement of the care professionals was also clear in the group meetings they organized at the organizations. Although an interview lasts only for a short time, being part of a research project is the start of sharing stories and building new collaborations (43). This also was the outcome of the collaboration between co-researchers and researchers within the involved care organizations. Close collaboration with care professionals was also of paramount importance since we were dealing with a group of easily overburdened people.

When interpreting the results, the following points must be considered. First, most co-researchers were men with a Turkish background. In addition to that, female co-researchers appeared to be more open toward technology, and the analysis did not show major differences between their male counterparts and the small number of female co-researchers. It is unknown whether the findings are also applicable to older adults with different migration backgrounds. In this study, the device Anne4Care was introduced in the two care organizations IMEAN and Alifa. In these organizations, there were mainly male older adults with a Turkish background, and it was therefore not possible to include co-researchers with a different migration background. Further research should also include care organizations for female older adults. Second, the device Anne4Care could have influenced and directed the findings due to experiences with this specific device. However, the device gave grips to the understanding of technology, and as O'Reilly-de Brún et al. (34) also described, implementing the device enabled the researchers to reach these older adults and enhance a meaningful contribution.

5. Conclusion

Technologies to cope with dementia can become part of the care practices and lives of older adults with a migration background. However, older adults need assistance from care professionals to understand the added value of technology and learn how to use it. The co-researchers need additional competencies to work with digital technologies, but the learning process to use technologies is also considered purposeful in their daily life. Furthermore, not all co-researchers had the materials, such as an internet connection or financial resources, to use the device, and the current care practice needs to adapt to the technology. Technology assists with independency, participation, and activities in daily life. To keep using technology, it should provide health benefits, have the option to use it inside and outside the home, fit in their care and lives, and include language settings.

The involvement of the older adults with dementia as co-researchers made them feel valuable and equal partners during the research project. Involving older adults in the development of technology, acknowledging their expertise and needs, and working together in short iterations to adapt the technology to their specific needs and situations were experienced as valuable by the researchers, older adults, and care professionals. In addition, it became clear that the formation of relations between the involved groups, as well as the technology, was an important element in the process.

Probable goals for future research could include a similar study with more co-researchers as well as co-researchers with different demographics, such as a moderate state of dementia, more female older adults, and different migration backgrounds. This could be reached through the investigation of technologies for care in more and different care organizations. Furthermore, this research showed needed changes in care practices. A recommendation for care organizations is to be aware of new developments in technologies, be aware of the need and possibility to provide culturally sensitive care with these technologies, and consider the needed pathway of introducing and support in using the technology. This study provided some first insight into these pathways, but more in-depth understanding and research to design strategies are required.

During the execution of this research, we took a citizen science approach to investigate the engagement and collaboration of older adults with a migration background. At the same time, we focussed on the social practices of these older adults with technology. In this research and during conversations with the co-researchers, we have obtained knowledge and were able to discuss some important elements in the engagement and collaboration, but a more in-depth understanding would provide additional answers to our second research question. Further understanding could be obtained, for example, by varying the research process.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the University of Applied Sciences Saxion Ethical Advice Committee (reference number SEAC-2020-005). The patients/participants provided their written informed consent to participate in this study.

Author contributions

CL, ES, ZM, and MB conducted the interviews, read, and compared the findings. At biweekly meetings between the project

team and a care professional, peer debriefing took place. ES had a close collaboration with the co-researcher during the analysis. All authors contributed to the design, preparation of the study, writing the manuscript and approved the latest version of the manuscript.

Funding

This study was powered by the Twente Regional Deal and received financial support from the Central Government's Regional Budget, the Province of Overijssel, the Region of Twente, and the Twente Board. The funders had no role in study design, data collection and analysis, the decision to publish, or preparation of the manuscript.

Acknowledgments

The authors would like to thank the company Anne4Care which made the device available for the research, and the care professionals and co-researchers for collaborating with us in every research phase and giving valuable insight.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1125834/full#supplementary-material

References

1. Kenning C, Daker-White G, Blakemore A, Panagioti M, Waheed W. Barriers and facilitators in accessing dementia care by ethnic minority groups: A meta-synthesis of qualitative studies. *BMC Psychiatry*. (2017) 17:316. doi: 10.1186/s12888-017-1474-0

2. Kristiansen M, Razum O, Tezcan-Guntekin H, Krasnik A. Aging and health among migrants in a European perspective. *Public Health Rev*. (2016) 37:20. doi: 10.1186/s40985-016-0036-1

3. Duran-Kirac G, Uysal-Bozkir O, Uittenbroek R, Van Hout H, Broese Van Groenou MI. Accessibility of health care experienced by persons with dementia from ethnic minority groups and formal and informal caregivers: A scoping review of European literature. *Dementia*. (2022) 21:677–700. doi: 10.1177/14713012211055307

4. Mukadam N, Cooper C, Livingston G. Improving access to dementia services for people from minority ethnic groups. *Curr Opin Psychiatry*. (2013) 26:409–14. doi: 10.1097/YCO.0b013e32835ee668

5. Clegg A. Older south Asian patient and carer perceptions of culturally sensitive care in a community hospital setting. *J Clin Nurs*. (2003) 12:283–90. doi: 10.1046/j.1365-2702.2003.00724.x

6. Fang ML, Sixsmith J, Sinclair S, Horst G. A knowledge synthesis of culturally- and spiritually-sensitive end-of-life care: Findings from a scoping review. *BMC Geriatr*. (2016) 16:1–14. doi: 10.1186/s12877-016-0282-6

7. Hossain MZ, Khan HTA. Barriers to access and ways to improve dementia services for a minority ethnic group in England. *J Eval Clin Pract*. (2020) 26:1629–37. doi: 10.1111/jep.13361

8. Verhagen I, Ros WJ, Steunenberg B, De Wit NJ. Culturally sensitive care for elderly immigrants through ethnic community health workers: Design and development of a community based intervention programme in the Netherlands. *BMC Public Health*. (2013) 13:1–8. doi: 10.1186/1471-2458-13-227

9. Frennert S. Hitting a moving target: Digital transformation and welfare technology in Swedish municipal eldercare. *Disabil Rehabil Assist Technol*. (2021) 16:103–11. doi: 10.1080/17483107.2019.1642393

10. Wickstrom G, Regner Å, Micko L. *Vision eHealth 2025*. Stockholm: Ministry of Health and Social Affairs (2016).

11. Vercelli A, Rainero I, Ciferri L, Boido M, Pirri F. Robots in elderly care. *DigiCult Sci. J. Digit. Cult*. (2017) 2:37–50.

12. Blix M, Jeansson J. *Telemedicine and the welfare state: The Swedish experience*. Stockholm: Research Institute of Industrial Economics (2018).

13. Peine A, Faulkner A, Jaeger B, Moors E. Science, technology and the 'grand challenge' of ageing-understanding the socio-material constitution of later life. *Technol Forecast Soc Chang*. (2015) 93:1–9. doi: 10.1016/j.techfore.2014.11.010

14. Dimaggio P, Hargittai E, Celeste C, Shafer S. Digital inequality: From unequal access to differentiated use In: K Neckerman, editor. *Social inequality*. New York, NY: Russell Sage Foundation (2004).

15. Ramos G, Chavira DA. Use of technology to provide mental health care for racial and ethnic minorities: Evidence, promise, and challenges. *Cogn Behav Pract*. (2022) 29:15–40. doi: 10.1016/j.cbpra.2019.10.004

16. Mitchell UA, Chebli PG, Ruggiero L, Muramatsu N. The digital divide in health-related technology use: The significance of race/ethnicity. *Gerontologist*. (2019) 59:6–14. doi: 10.1093/geront/gny138

17. Chen X, Östlund B, Frennert S. *Digital inclusion or digital divide for older immigrants? A scoping review*. Cham: Springer (2020).

18. Kouvonen A, Kemppainen T, Taipale S, Olakivi A, Wrede S, Kemppainen L. Health and self-perceived barriers to internet use among older migrants: A population-based study. *BMC Public Health*. (2022) 22:574. doi: 10.1186/s12889-022-12874-x

19. Zamir S, Hennessy CH, Taylor AH, Jones RB. Video-calls to reduce loneliness and social isolation within care environments for older people: An implementation study using collaborative action research. *BMC Geriatr*. (2018) 18:62. doi: 10.1186/s12877-018-0746-y

20. Biermann H, Offermann-Van Heek J, Himmel S, Ziefle M. Ambient assisted living as support for aging in place: Quantitative Users' acceptance study on ultrasonic whistles. *JMIR Aging*. (2018) 1:e11825. doi: 10.2196/11825

21. Stara V, De Jong M, Felici E, Bolliger D, Birrer E, Von Dollen V, et al. The design adaptation of the virtual assistant Anne for moderate dementia patients and their formal caregivers in protected environment tests. *Adv Hum Fact Ergonomi Healthcare Med Dev*. (2020) 957:270–9. doi: 10.1007/978-3-030-20451-8_27

22. Bickmore TW, Caruso L, Clough-Gorr K. *Acceptance and usability of a relational agent interface by urban older adults*, Portland, Oregon, USA: ACM (2015).

23. Vardoulakis LP, Ring L, Barry B, Sidner CL, Bickmore T. *Designing relational agents as long term social companions for older adults*. Heidelberg: Springer (2012).

24. Carrasco E, Epelde G, Moreno A, Ortiz A, Garcia I, Buiza C, et al. *Natural interaction between avatars and persons with Alzheimer's disease*. Berlin: Heidelberg, Springer (2008).

25. Shaw J, Shaw S, Wherton J, Hughes G, Greenhalgh T. Studying scale-up and spread as social practice: Theoretical introduction and empirical case study. *J Med Internet Res*. (2017) 19:e244. doi: 10.2196/jmir.7482

26. Blue S, Shove E, Carmona C, Kelly MP. Theories of practice and public health: Understanding (un)healthy practices. *Crit Public Health*. (2016) 26:36–50. doi: 10.1080/09581596.2014.980396

27. Watson M, Pantzar M, and Shove E. The dynamics of social practice: Everyday life and how it changes. *The dynamics of social practice*. (2012), 1–208.

28. Wiggins A, Wilbanks J. The rise of citizen science in health and biomedical research. *Am J Bioeth*. (2019) 19:3–14. doi: 10.1080/15265161.2019.1619859

29. Alami A. (2016). Why do information technology projects fail? International Conference on Enterprise Information Systems/International Conference on Project Management/International Conference on Health and Social Care Information Systems and Technologies, Melbourne, Australia: Centeris/Projman/Hcist 2016, 62–71.

30. Chen YR, Schulz PJ. The effect of information communication technology interventions on reducing social isolation in the elderly: A systematic review. *J Med Internet Res*. (2016) 18:e18. doi: 10.2196/jmir.4596

31. Fischer B, Ostlund B, Peine A. Design multiple: How different configurations of participation matter in design practice. *Des Stud*. (2021) 74:101016. doi: 10.1016/j.destud.2021.101016

32. Elo S, Kyngas H. The qualitative content analysis process. *J Adv Nurs*. (2008) 62:107–15. doi: 10.1111/j.1365-2648.2007.04569.x

33. Wejnert B. Integrating models of diffusion of innovations: A conceptual framework. *Annu Rev Sociol*. (2002) 28:297–326. doi: 10.1146/annurev.soc.28.110601.141051

34. O'Reilly-De Brun M, Macfarlane A, De Brun T, Okonkwo E, Bokanga JSB, Silva MMD, et al. Involving migrants in the development of guidelines for communication in cross-cultural general practice consultations: A participatory learning and action research project. *BMJ Open*. (2015) 5:e007092. doi: 10.1136/bmjopen-2014-007092

35. Soraa RA, Nyvoll PS, Gronvik KB, Serrano JA. Children's perceptions of social robots: A study of the robots pepper, Av1 and Tessa at Norwegian research fairs. *AI Soc*. (2021) 36:205–16. doi: 10.1007/s00146-020-00998-w

36. Contesse M, Duncan J, Legun K, Klerkx L. Unravelling non-human agency in sustainability transitions. *Technol Forecast Soc Chang*. (2021) 166:120634. doi: 10.1016/j.techfore.2021.120634

37. Lafton T. Digital literacy practices and pedagogical moments: Human and non-human intertwining in early childhood education. *Contemp Issues Early Child*. (2015) 16:142–52. doi: 10.1177/1463949115585657

38. Leino H, Karppi I, Jokinen A. It's all about the birds! Non-human actors' situational power in creating conditions for human engagement. *Plan Theory*. (2017) 16:133–49. doi: 10.1177/1473095215617985

39. Arcaya MC, Figueroa JF. Emerging trends could exacerbate health inequities in the United States. *Health Aff*. (2017) 36:992–8. doi: 10.1377/hlthaff.2017.0011

40. Gilmour JA. Reducing disparities in the access and use of internet health information. A discussion paper. *Int J Nurs Stud*. (2007) 44:1270–8. doi: 10.1016/j.ijnurstu.2006.05.007

41. Weiss D, Eikemo TA. Technological innovations and the rise of social inequalities in health. *Scand J Public Health*. (2017) 45:714–9. doi: 10.1177/1403494817711371

42. Meiland F, Innes A, Mountain G, Robinson L, Van Der Roest H, Garcia-Casal JA, et al. Technologies to support community-dwelling persons with dementia: A position paper on issues regarding development, usability, effectiveness and cost-effectiveness, deployment, and ethics. *Jmir Rehabil Assist Technol*. (2017) 4:e1. doi: 10.2196/rehab.6376

43. Star SL. This is not a boundary object: Reflections on the origin of a concept. *Sci Technol Hum Values*. (2010) 35:601–17. doi: 10.1177/0162243910377624

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 April 2023
DOI 10.3389/fpubh.2023.1088863

OPEN ACCESS

EDITED BY
Timothy M. Hale,
University of Illinois at Urbana-Champaign,
United States

REVIEWED BY
Seong Man Park,
Dankook University,
Republic of Korea
Elizabeth Yost,
Washington College,
United States

*CORRESPONDENCE
Zhi Hu
✉ aywghz@ahmu.edu.cn
Ruoling Chen
✉ r.chen@wlv.ac.uk
Zhongliang Bai
✉ baizhongliang@ahmu.edu.cn

SPECIALTY SECTION
This article was submitted to
Aging and Public Health,
a section of the journal
Frontiers in Public Health

RECEIVED 03 November 2022
ACCEPTED 07 March 2023
PUBLISHED 14 April 2023

CITATION
Cao C, Cao W, Zheng X, Ji K, Wu Y, Hu Z, Chen R and Bai Z (2023) Association of social capital with self-perceived eHealth literacy among community-dwelling older people: Age and gender differences.
Front. Public Health 11:1088863.
doi: 10.3389/fpubh.2023.1088863

Association of social capital with self-perceived eHealth literacy among community-dwelling older people: Age and gender differences

Chenglin Cao[1], Wenwen Cao[1], Xin Zheng[1], Kai Ji[1], Yunwei Wu[1], Zhi Hu[1]*, Ruoling Chen[2]* and Zhongliang Bai[1,2]*

[1]Department of Health Services Management, School of Health Services Management, Anhui Medical University, Hefei, China, [2]Faculty of Education, Health and Wellbeing, University of Wolverhampton, Wolverhampton, United Kingdom

Background: Studies have confirmed that social factors, including social capital and eHealth literacy, are important in later life. Currently, few studies are available for determining the relationship between social capital and eHealth literacy, and whether such a relationship exists among older people and there are age and gender differences in the relationship remain unclear. Consequently, this study aimed to investigate the association between social capital and eHealth literacy, specifically examing its variations in age and gender.

Methods: A cross-sectional study of 4,257 residents aged ≥ 60 years and dwelling in the community was conducted across four cities in China. A structured questionnaire was used to collect data on general characteristics, socioeconomic status, social capital, and eHealth literacy. Generalized linear models were employed to assess these associations.

Results: There were 4,218 respondents (age 71.9±7.2 years; 64.8% women). Overall, social participation, social connection, trust, cohesion, and reciprocity were all statistically associated with eHealth literacy ($p<0.05$), while such an association was not observed for social support ($p>0.05$). Specifically, a higher level of social participation was associated with better eHealth literacy scores among participants aged 70–79 years ($p<0.001$), and a higher level of social connection was associated with better eHealth literacy scores for those aged 60–69 and 70–79 years ($p<0.001$). Meanwhile, no gender differences in the associations were found.

Conclusion: There is an association between social capital and eHealth literacy in older men and women. The association varis with age. The findings provide a reference for developing targeted measures to improve self-perceived eHealth literacy among older people. It is essential for achieving active and healthy aging and developing the knowledge and understanding of relevant theories, concepts, and evidence within the field of health and social capital.

KEYWORDS

healthy aging, social capital, older adults, eHealth literacy, cross-sectional

Introduction

The rapid process of population aging, with an increasing demand for medical and health management, has a huge impact on economic and social development worldwide (1). China, as the largest developing country, has also confronted this challenge to satisfy the health needs of older adults and the goal of healthy aging (2).

Recently, an increasing number of studies have identified that social factors are beneficial for health promotion and wellness in old age, among which increasing attention has been paid to social capital (3–5). Social capital is a multi-faceted concept that includes multiple dimensions, each of which describes a phenomenon about social relations at the individual and societal levels and consists of structural social capital and cognitive social capital (6, 7). Structural social capital (social participation, social connection, and social support) usually refers to what is involved in or done through social relationships, emphasizing the concept of action and measuring individual participation in public affairs (8). Cognitive social capital (trust, cohesion, and reciprocity) generally refers to things perceived through ideas, emphasizing concepts at the cognitive level and focusing on the perception of the trustworthiness of social environment (9). More importantly, the significance of social capital in achieving better health outcomes and status has been proven in later life (10, 11). For example, older people with a higher level of social participation and social support are liable to create better self-rated health and functional capabilities (12). The positive effect of some dimensions of social capital on the daily activities of older people has been demonstrated. Likewise, social capital interventions could reduce frailty and promote the development of health-promoting lifestyles among older people (13).

Individuals are increasingly expected to conduct appropriate self-care and self-management through e-medical services and digital devices (14); therefore, eHealth literacy is a dynamic process, defined as the ability of individuals to search, access, understand, evaluate, and use specific health information from electronic sources to make appropriate health decisions (15). eHealth literacy has attracted increasing interest nowadays (16). The relevance of eHealth literacy has been observed in many studies. For example, studies have found that health inequities can be reduced by improving eHealth literacy among socially vulnerable groups (17). During COVID-19 pandemic isolation period, eHealth literacy has been found to provide disease knowledge and publicize and educate on disease prevention behaviors (18, 19). Currently, factors such as advanced age, females, lower educational achievements, and living in remote areas are linked to poor eHealth literacy (20–22).

A previous study confirmed that eHealth literacy mediates the correlation between structural social capital and health behaviors (23). Social capital can be structured *via* not only face-to-face communication but also online connection and virtual socializing (24). In addition, the role of social connection has been observed when there have been challenges in obtaining health information and services from the Internet daily. In other words, individuals will turn to their social relations for help as well as to enhance social interaction and the need for eHealth literacy (25). A previous study also confirmed that a high level of health literacy can enhance the intention to find health information on the Internet (26). Therefore, exploring the relationship between social capital and eHealth literacy has important public health significance.

Moreover, variations in different age ranges and gender groups regarding eHealth literacy have been previously confirmed (27, 28). For example, one study revealed that older people have lower eHealth literacy than their younger counterparts (27). Meanwhile, older females were less likely to know how to find useful health resources on the Internet and have fewer skills to assess health resources, with a relative lack of eHealth literacy (28). Furthermore, when social capital acts positively on health, both age and gender variations have been previously reported (29–31). For instance, a previous study reported that the relationship between social capital and loneliness differs by age group. Specifically, trust was associated with loneliness in all age groups, whereas social participation was associated with loneliness only at younger ages (32). Similarly, social participation was negatively associated with depression in older males only (29). In addition, the relationship between social capital and individual health was found to be influenced by both gender and age, in which a lack of reciprocity was negatively associated with health in males but not in younger females (31).

The relevance of social capital and eHealth literacy in health promotion and education has been widely examined and recognized. However, whether social capital is associated with eHealth literacy requires further exploration. In light of this, in the current study, we associated social capital with eHealth literacy among community-dwelling older people in China, paying special attention to examine age and gender differences in the association. Consequently, these findings will be of great public health significance and help improve eHealth literacy, thus facilitating the process of healthy aging.

Materials and methods

Participants and data collection

Between November and December 2020, to recruit eligible participants, we designed cross-sectional research characterized by stratified and multi-stage. Our sampling process can be described as follows:

First, the participants were selected from four cities in the Yangtze River Delta region in China; Jinshan of Shanghai, Huzhou of Zhejiang Province, Changzhou of Jiangsu Province, and Huainan of Anhui Province. Second, each county-level region was randomly selected from four survey areas. After that, from each county-level region, two urban communities (streets) and two rural communities (townships) were randomly selected as urban and rural communities, amounting to 16 communities. Third, we randomly selected 24 communities from above mentioned 16 communities as sampling areas in this study (Additional File 1).

According to the study design, participants aged 60 and older who were absent from deaf/mute or dementia/cognitive impairment and willing to participate in our investigation were eligible for the interview. Before commencing the investigation, we verbally explained the aims and procedures of this study to each participant, after which informed consent was obtained. In total, 4,257 respondents were surveyed and 4,218 (99.08%) were eligible for analysis. The Ethics Committee of Anhui Medical University approved the study protocol (No. 20150297). Details regarding the participants and data collection can be found elsewhere (33).

Evaluation of the independent variable

Based on our previous studies (3, 4, 34), we used a tool comprising 26 items to assess social capital, the main independent variable. Each dimension was calculated as the sum of its associated items, namely social participation (range 4–20), social support (range 4–20), social connection (range 5–25), trust (range 4–20), cohesion (range 5–25), and reciprocity (range 4–20). Participants who had higher scores suggested a better social capital degree. According to Cronbach's alpha (Cronbach's $\alpha = 0.870$), it can be demonstrated that the internal consistency of this sample is good. The full text of this measurement tool can be found in Additional File 2.

Evaluation of the dependent variable

This study measured self-perceived eHealth literacy using a simplified five-point Likert Chinese version of eHEALS (35). This scale consists of three dimensions and eight items, including the application ability test of network health information and services (items 1–5), judgment ability test (items 6 and 7), and decision-making ability test (item 8). Participants were asked to choose from 1 to 5, ranging from strongly disagree to strongly agree, respectively. We calculated the eHealth literacy score by adding the scores of the eight items together, with higher scores indicating better eHealth literacy (36). Good internal consistency was also observed in this sample according to the value of Cronbach's alpha (Cronbach's $\alpha = 0.992$). A detailed description of this measurement can be reviewed in Additional File 2.

Evaluation of related variables

This study included age (years), gender, body mass index (BMI, kg/m^2), residency (including urban or rural), living status (including living alone or not living alone), marital status (married or single), educational attainment (consisting of primary school or below, junior school, high school, and college or above), smoking status (smoking-quitter, smoker, or non-smoker), and drinking status (drinking-quitter, drinker, or non-drinker). Information on income sources (salary, family provision, subsidy, and others), medical insurance, and endowment insurance were also collected. To compare with previous studies (23, 33, 37, 38), we grouped these variables for data analysis. To achieve statistical power, the participants were divided into three groups.

Statistical procedure

In the first step, we used mean ± standard deviation and numbers and percentages to express continuous and categorical variables, respectively. In the second step, we explored the linear relationships between independent and dependent variables using Pearson's r correlation analysis. In the third step, we calculated the standard error and associated 95% confidence interval (95% CI) using generalized linear models (GLM). The fitted GLM can be expressed as follows:

$$Y \approx \alpha + \beta_1 Social\ capital\ dimensions + \beta_2 Confounders_1 + \cdots + \beta_n Confounders_n$$

In this equation, Y is the eHealth literacy score, α is the intercept, β_1 is the corresponding coefficient of social capital dimensions, $\beta_2 \ldots \beta_n$ indicates the coefficients of the covariates included in the regression models. During the data analysis, we checked and excluded collinearity among the analyzed variables according to the variance inflation factor (VIF) results (VIF greater than 10 indicates the presence of collinearity). In this study, SPSS 22.0 was used for all data analyses, and statistical significance was set at $p < 0.05$.

Results

General information on participants

As revealed in Table 1, 4,218 participants (age 71.9 ± 7.2 years), namely 1,484 males (35.2%) and 2,734 females (64.8%), were included. Of them, rural residents accounted for 45.1, and 86.5% of the participants did not live alone. Regarding marital status, most respondents were married or cohabited (78.8%). Regarding educational attainment, more than half of the participants (61.0%) attended primary school or below. Participants who did not smoke or drink accounted for 79.0 and 80.3%, respectively. In addition, most participants were covered by a basic medical insurance system for urban employees (44.6%) and basic endowment insurance for the urban working group (46.2%).

Correlations analysis of social capital with eHealth literacy

The Pearson's r correlation results are presented in Table 2. Positive and significant correlations were observed ($p < 0.05$). The correlation coefficients are as follows: social participation ($r = 0.150$), social support ($r = 0.039$), social connection ($r = 0.143$), trust ($r = 0.115$), cohesion ($r = 0.139$), and reciprocity ($r = 0.194$).

Regression results of social capital and eHealth literacy

GLM results are presented in Tables 3–5. Table 3 displays that after controlling for confounders, attenuated but positive effects of social capital were observed ($p < 0.05$), except for social support ($p > 0.05$). Specifically, among all participants, for each unit increase in social capital as to social participation, social connection, trust, cohesion, and reciprocity, eHealth literacy scores increased by 0.15, 0.27, 0.37, 0.36, and 0.34, respectively.

In Table 4, we found that age differences existed when social capital was linked to eHealth literacy in different age groups. Specifically, trust, cohesion, and reciprocity were positively and significantly linked to eHealth literacy among participants from the three age groups ($p < 0.05$). Meanwhile, social connection was positively and significantly linked to eHealth literacy for participants aged 60–69 and 70–79 years ($p < 0.001$). Finally, social participation

10.3389/fpubh.2023.1088863

TABLE 1 Descriptive analysis results of participants' characteristics (*N*=4,218).

Variables	Variable categories	
Age (years)		71.9 ± 7.2
Gender	Male	1,484 (35.2)
	Female	2,734 (64.8)
BMI (kg/m^2)		23.78 ± 3.50
Residence	Urban	2,316 (54.9)
	Rural	1902 (45.1)
Living status	Living alone	568 (13.5)
	Living with others	3,650 (86.5)
Marital status	Married	3,325 (78.8)
	single	893 (21.2)
Education	Primary school and below	2,571 (61.0)
	Junior school	937 (22.2)
	High school	538 (12.8)
	College and above	172 (4.1)
Smoking status	Smoking-quitter	307 (7.3)
	Smoker	579 (13.7)
	Non-smoker	3,332 (79.0)
Drinking status	Drinking-quitter	190 (4.5)
	Drinker	642 (15.2)
	Non-drinker	3,386 (80.3)
Income	Pension	2,344 (55.6)
	Salary	390 (9.2)
	Family provision	844 (20.0)
	Subsidy	460 (10.9)
	Others	180 (4.3)
Medical insurance	None	79 (1.9)
	Basic medical insurance system for urban employees	1881 (44.6)
	Basic medical insurance for urban residents	849 (20.1)
	New rural basic medical insurance for rural residents	1,399 (33.2)
	Commercial medical insurance	7 (0.2)
	Others	3 (0.1)
Endowment insurance	None	538 (12.8)
	Basic endowment insurance for the urban working group	1947 (46.2)
	Pension insurance for flexible employees	13 (0.3)
	Social endowment insurance for non-working urban residents	591 (14.0)
	New rural social endowment insurance for rural residents	1,110 (26.3)
	Commercial endowment insurance	19 (0.5)
Social capital	Social participation	9.16 ± 4.20
	Social support	13.81 ± 4.50
	Social connection	20.63 ± 3.85
	Trust	17.57 ± 3.00
	Cohesion	21.59 ± 3.51
	Reciprocity	15.69 ± 4.00
eHealth literacy		12.57 ± 10.00

Continuous variables are presented as range and mean ± standard deviation, categorical variables are presented as number (%).

TABLE 2 Correlation of included variables and eHealth literacy.

Variables	1	2	3	4	5	6	7
1. Social participation	1						
2. Social support	0.219**	1					
3. Social connection	0.067**	0.302**	1				
4. Trust	−0.041**	0.177**	0.625**	1			
5. Cohesion	0.049**	0.173**	0.523**	0.588**	1		
6. Reciprocity	0.068**	0.219**	0.392**	0.428**	0.411**	1	
7. eHealth literacy	0.150**	0.039*	0.143**	0.115**	0.139**	0.194**	1

*P<0.05, **P<0.01.

TABLE 3 The relationship between social capital and eHealth literacy using GLM (all participants).

Social capital dimensions	Unadjusted		Adjusted	
	B (SE)	95% CI	*B* (SE)	95% CI
Social participation	0.36 (0.04)***	0.28–0.43	0.15 (0.04)***	0.07–0.22
Social support	0.09 (0.03)**	0.02–0.15	0.04 (0.03)	−0.02-0.10
Social connection	0.37 (0.04)***	0.29–0.45	0.27 (0.04)***	0.19–0.34
Trust	0.38 (0.05)***	0.28–0.48	0.37 (0.05)***	0.28–0.47
Cohesion	0.40 (0.04)***	0.31–0.48	0.36 (0.04)***	0.28–0.44
Reciprocity	0.48 (0.04)***	0.41–0.56	0.34 (0.04)***	0.27–0.41

Adjusted by age, gender, BMI, residency, living status, marital status, education, smoking, and drinking status, income, medical insurance, endowment insurance. B, regression coefficient; SE, standard error; 95% CI, confidence interval of 95%.
P < 0.01,*P < 0.001.

was only linked to eHealth literacy among participants aged 70–79 years after adjustment ($p < 0.001$).

However, no statistically significant gender differences were identified (Table 5). In stratified analysis by gender, the social capital associated with eHealth literacy scores was the same among male and female respondents, while this association was stronger in females than in males.

Discussion

This study examined the relationship between social capital and eHealth literacy in four cities in the Yangtze River Delta region, China. Overall, the significant positive association of social capital dimensions with eHealth literacy scores was identified based on our data analyses. In other words, community-dwelling older people with higher social capital concerning social participation, social connection, trust, cohesion, and reciprocity reported a better eHealth literacy status. In addition, age differences were observed when linking social capital to eHealth literacy, whereas such differences did not exist when considering gender.

Similar to previous studies, we observed that after adjustment for confounding factors in the total population, a higher level of eHealth literacy could be found when high-ranking social capital scores concerning social connection, social participation, trust, cohesion, and reciprocity appeared (23–25). For example, the role of social participation, social support, and social connection on eHealth literacy has been proven in a previous study (23). Social connection can enhance social interaction and supplement eHealth literacy (25). Moreover, evidence has documented that higher cognitive social capital grades (trust, cohesion, and reciprocity) are conducive to obtaining redundant information in a network; therefore, acquiring knowledge and higher health awareness could eventually enhance eHealth literacy (8, 39). However, such findings were inconclusive, and no positive correlation between cognitive social capital and eHealth literacy was obtained in a previous study (23), which is inconsistent with our findings. To understand this, it is highly likely that different tools were used to assess social capital. Specifically, in the above-mentioned study, the subscale consisted of trust, cohesion, and reciprocity, a total of 11 items, and was used to assess cognitive social capital (23), indicating that more research is needed in the future.

Previous studies have depicted that perceived social support and informational social support contribute to the acquisition of eHealth knowledge and growth of eHealth literacy (40, 41), different from our findings. This may be because of the different scales for measuring social support. For example, a multidimensional scale consisting of 12 items was used to measure perceived social support, which measured two sources of support (family and friends) (40). Informational social support includes four sub-concepts: emotional support, informational support that provides information that can be used to address personal problems, material support (monetary or material help), and evaluative support (acknowledgment or respect) (41). This study used four items to assess social capital (mental and material support).

Moreover, age differences were observed when social capital was associated with eHealth literacy based on our analyses. In particular, social capital regarding trust, cohesion, and reciprocity was positively and significantly linked to eHealth literacy scores among participants of all ages in this study. One possible explanation for this finding could be that high levels of trust, reciprocity, and cohesion are positively correlated with optimism among older people, making them believe in electronic programs and online information, which may make them more likely to accept eHealth information (42). Meanwhile, a previous study demonstrated the importance of the quality of trust, cohesion, and reciprocity in determining the subjective well-being and self-assessed health status of older people in later life, increasing the availability of healthy social support resources (43, 44). In addition, self-rated health was associated with eHealth literacy, which may imply that older people with better health literacy provide more possibilities for further improving eHealth literacy (45).

TABLE 4 The relationship between social capital and eHealth literacy among different age groups.

Social capital dimensions	60–69years		70–79years		≥80years	
	B (SE)	95% CI	*B* (SE)	95% CI	*B* (SE)	95% CI
Social participation	0.06 (0.06)	−0.06-0.18	1.58 (0.06)***	0.19–0.41	0.02 (0.08)	−0.13–0.17
Social support	0.02 (0.05)	−0.06-0.18	0.07 (0.05)	−0.02-0.17	0.06 (0.07)	−0.07–0.19
Social connection	0.30 (0.06)***	0.18–0.43	0.30 (0.05)***	0.20–0.41	0.13 (0.07)	−0.02–0.27
Trust	0.45 (0.08)***	0.29–0.61	0.42 (0.07)***	0.28–0.56	0.21 (0.10)*	0.02–0.40
Cohesion	0.44 (0.07)***	0.30–0.58	0.38 (0.06)***	0.26–0.50	0.23 (0.08)**	0.06–0.39
Reciprocity	0.46 (0.07)***	0.33–0.59	0.34 (0.05)***	0.24–0.44	0.19 (0.06)**	0.07–0.32

Adjusted by, BMI, gender, residency, living status, marital status, education, smoking, and drinking status, income, medical insurance, endowment insurance. B, regression coefficient; SE, standard error; 95% CI, confidence interval of 95%.
*$P < 0.05$,**$P < 0.01$,***$P < 0.001$.

TABLE 5 The relationship between social capital and eHealth literacy among different genders.

Social capital dimensions	Male		Female	
	B (SE)	95% CI	*B* (SE)	95% CI
Social participation	0.14 (0.06)*	0.02–0.26	0.15 (0.05)**	0.06–0.24
Social support	0.00 (0.05)	−0.11–0.11	0.06 (0.04)	−0.01-0.14
Social connection	0.16 (0.07)*	0.03–0.29	0.34 (0.05)***	0.25–0.43
Trust	0.33 (0.08)***	0.16–0.50	0.39 (0.06)***	0.28–0.51
Cohesion	0.32 (0.07)***	0.18–0.45	0.39 (0.05)***	0.29–0.49
Reciprocity	0.41 (0.06)***	0.28–0.54	0.31 (0.04)***	0.23–0.39

Adjusted by age, BMI, residence, living status, marital status, education, smoking, and drinking status, income, medical insurance, endowment insurance. B, regression coefficient; SE, standard error; 95% CI, confidence interval of 95%. *$P < 0.05$, **$P < 0.01$,***$P < 0.001$.

In addition, social capital concerning social connection was positively and significantly linked to eHealth literacy scores, especially among participants aged 60–69 and 70–79 years. This echoed a study finding that a higher level of social connection could improve cognitive function and memory and that better cognitive ability may lead to increased access to the Internet and adequate health literacy, which may help older people better seek eHealth help (46).

More interestingly, our study found that social participation, a social capital dimension, was only linked to eHealth literacy among participants aged 70–79 years, which is similar to results in a previous study from Ghana (47) indicating that active participation in association activities can enhance health promotion choices by promoting access to important health-related information.

Based on our study results, gender differences did not exist. This is incompatible with the findings in previous studies (28), noting that older female immigrants were less capable of accessing the Internet to find useful health resources than their male counterparts and had fewer skills with which to access health resources, thereby resulting in a relative lack of eHealth literacy. Meanwhile, males were found to have a higher level of eHealth literacy than females among college students in a previous study (48).

Similar conclusions have been previously reached. A study on left-behind older adults in rural China demonstrated that, in comparison with older males, the role of social capital in mental health preservation was more significant for older females (49). A possible reason for this result is that females have a high degree of social trust, prefer to make friends, and are more likely to seek support from others and mobilize support resources (especially emotional support). Therefore, females have a higher network density; accordingly, some social capital indicators have a more significant protective effect on females (49, 50).

These mixed association models could inform programs to promote the eHealth literacy of older people from a social capital perspective. Moreover, when linking social capital to eHealth literacy, age and gender should be fully considered. Therefore, based on our findings, the following suggestions can be provided: First, we recommend that older people be encouraged and supported in their efforts to participate in social activities, with special attention given to the role of family members. Children and relatives should be encouraged to strengthen social support for older people and improve accessibility to electronic devices to collect and discern health information. Second, with the opportunity to vigorously promote the policy of building age-friendly communities in China (51), the community should effectively undertake health management measures and enhance interpersonal communication and mutual learning among older people to facilitate the exchange of health information, increase social participation, and encourage older people to abide by reciprocal norms and increase their sense of trust. Third, enterprises and primary healthcare institutions should attach importance to a sense of social responsibility. Electronic products should be designed to be suitable for older people or provide electronic health services. Finally, the government should provide policy support to reduce this digital divide. For example, financial subsidies should be provided, and Internet coverage should be improved. However, relevant social organizations should be coordinated and organized to offer multimedia tutorial courses to improve eHealth literacy, such as nursing homes and universities for older people (52), which is in line with the Chinese government's strategic policy of actively promoting smart healthcare (53).

Nevertheless, we acknowledge that this study has a few limitations. First, a cross-sectional study was used, which might limit the conclusion of the causal relationship between social capital and eHealth literacy. Further research should use longitudinal data and a randomized controlled trial design. On the other hand, data on social capital were only obtained by individual-level measurement, and whether community-level social capital has the same relationship with eHealth literacy needs further explored. Such an examination may help widen the application of social capital. Despite the aforementioned

limitations, we believe that using a large representative sample with a good response rate and the employment of valid and reliable measurement tools to collect data could be interpreted as the strengths of this study.

Conclusion

In conclusion, a correlation between social capital and eHealth literacy was identified based on our data analyses among older people living in a community setting. Specifically, older people with high levels of social connection, social participation, trust, reciprocity, and cohesion are more likely to prefer eHealth literacy in later life. Furthermore, this association varies with age. Our research could inform the development of personalized strategies from a social capital perspective to improve eHealth literacy among older people, which is essential for achieving active and healthy aging.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Anhui Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CC contributed to the design and writing of the article. WC, XZ, KJ, and YW contributed to data analyses. ZH, RC, and ZB contributed to funding acquisition, quality control, and data processing and revised the manuscript. All authors have read and approved the final version of the manuscript.

Funding

This work was supported by the China Scholarship Council (no. 202209095002), National Natural Science Foundation of China (no. 71573002), Special Research Project in Science and Technology Department of Anhui Province (no. 202106f01050045), Key Project of Social Science in Education Department of Anhui Province (no. SK2021A0164), Research Fund of Anhui Medical University (no. 2021xkjT049), and Open Program of Health Policy Research Center of Anhui Medical University (no. 2022wszc19).

Acknowledgments

We wish to express our sincere gratitude to all participants for their participation, collaboration, and support.

Conflict of interest

The authors declare that the research was conducted without commercial or financial relationships that could be construed as potential conflicts of interest.

Publisher's note

References

1. Chen LK. Urbanization and population aging: converging trends of demographic transitions in modern world. *Arch Gerontol Geriatr*. (2022) 101:104709. doi: 10.1016/j.archger.2022.104709

2. Man W, Wang S, Yang H. Exploring the spatial-temporal distribution and evolution of population aging and social-economic indicators in China. *BMC Public Health*. (2021) 21:966. doi: 10.1186/s12889-021-11032-z

3. Bai Z, Xu Z, Xu X, Qin X, Hu W, Hu Z. Association between social capital and depression among older people: evidence from Anhui Province, China. *BMC Public Health*. (2020) 20:1560. doi: 10.1186/s12889-020-09657-7

4. Bai Z, Wang Z, Shao T, Qin X, Hu Z. Association between social capital and loneliness among older adults: a cross-sectional study in Anhui Province China. *BMC Geriatr*. (2021) 21:26. doi: 10.1186/s12877-020-01973-2

5. Chen Y, Hicks A, While AE. Loneliness and social support of older people in China: a systematic literature review. *Health Soc Care Community*. (2014) 22:113–23. doi: 10.1111/hsc.12051

6. Westphaln KK, Fry-Bowers EK, Georges JM. Social capital: a concept analysis. *ANS Adv Nurs Sci*. (2020) 43:E80–e111. doi: 10.1097/ans.0000000000000296

7. Coleman JS. Social capital in the creation of human capital. *Am J Sociol*. (1988) 94:S95–S120. doi: 10.1086/228943

8. Amegbor PM, Braimah JA, Adjaye-Gbewonyo D, Rosenberg MW, Sabel CE. Effect of cognitive and structural social capital on depression among older adults in Ghana: a multilevel cross-sectional analysis. *Arch Gerontol Geriatr*. (2020) 89:104045. doi: 10.1016/j.archger.2020.104045

9. Lu N, Peng C, Jiang N, Lou VWQ. Cognitive social capital and formal volunteering among older adults in urban China: does gender matter? *J Appl Gerontol*. (2020) 39:404–12. doi: 10.1177/0733464818765279

10. Nyqvist F, Forsman AK, Giuntoli G, Cattan M. Social capital as a resource for mental well-being in older people: a systematic review. *Aging Ment Health*. (2013) 17:394–410. doi: 10.1080/13607863.2012.742490

11. Jiang N, Wu B, Lu N, Dong T. Neighborhood-based social capital and cognitive function among older adults in five low- and middle-income countries: evidence from the World Health Organization study on global ageing and adult health. *Int J Geriatr Psychiatry*. (2020) 35:365–75. doi: 10.1002/gps.5239

12. Lu N, Xu S, Zhang J. Community social capital, family social capital, and self-rated health among older rural Chinese adults: empirical evidence from rural northeastern China. *Int J Environ Res Public Health*. (2021) 18:5516. doi: 10.3390/ijerph18115516

13. Hu S, Jin C, Li S. Association between social capital and frailty and the mediating effect of health-promoting lifestyles in Chinese older adults: a cross-sectional study. *BMC Geriatr*. (2022) 22:175. doi: 10.1186/s12877-022-02815-z

14. Smith B, Magnani JW. New technologies, new disparities: the intersection of electronic health and digital health literacy. *Int J Cardiol*. (2019) 292:280–2. doi: 10.1016/j.ijcard.2019.05.066

15. Fernandes LG, Saragiotto BT. Clinimetrics: Ehealth literacy scale. *J Physiother*. (2021) 67:67. doi: 10.1016/j.jphys.2020.07.004

16. Kim H, Xie B. Health literacy in the Ehealth era: a systematic review of the literature. *Patient Educ Couns*. (2017) 100:1073–82. doi: 10.1016/j.pec.2017.01.015

17. Cheng C, Beauchamp A, Elsworth GR, Osborne RH. Applying the electronic health literacy lens: systematic review of electronic health interventions targeted at socially disadvantaged groups. *J Med Internet Res*. (2020) 22:e18476. doi: 10.2196/18476

18. Li X, Liu Q. Social media use, Ehealth literacy, disease knowledge, and preventive behaviors in the Covid-19 pandemic: cross-sectional study on Chinese netizens. *J Med Internet Res*. (2020) 22:e19684. doi: 10.2196/19684

19. Yang BX, Xia L, Huang R, Chen P, Luo D, Liu Q, et al. Relationship between Ehealth literacy and psychological status during Covid-19 pandemic: a survey of Chinese residents. *J Nurs Manag*. (2021) 29:805–12. doi: 10.1111/jonm.13221

20. Baur C. An analysis of factors underlying E-health disparities Cambridge quarterly of healthcare ethics: CQ. *Int J Healthc Ethics Comm*. (2008) 17:417–28. doi: 10.1017/s0963180108080547

21. Kontos E, Blake KD, Chou WY, Prestin A. Predictors of Ehealth usage: insights on the digital divide from the health information National Trends Survey 2012. *J Med Internet Res*. (2014) 16:e172. doi: 10.2196/jmir.3117

22. Choi NG, Dinitto DM. The digital divide among low-income homebound older adults: internet use patterns, Ehealth literacy, and attitudes toward computer/internet use. *J Med Internet Res*. (2013) 15:e93. doi: 10.2196/jmir.2645

23. Cui GH, Li SJ, Yin YT, Chen LJ, Li JQ, Liang FY, et al. The relationship among social capital, Ehealth literacy and health Behaviours in Chinese elderly people: a cross-sectional study. *BMC Public Health*. (2021) 21:45. doi: 10.1186/s12889-020-10037-4

24. Paige SR, Stellefson M, Chaney BH, Chaney JD, Alber JM, Chappell C, et al. Examining the relationship between online social capital and Ehealth literacy: implications for Instagram use for chronic disease prevention among college students. *Am J Health Educ*. (2017) 48:264–77. doi: 10.1080/19325037.2017.1316693

25. Hayat TZ, Brainin E, Neter E. With some help from my network: supplementing Ehealth literacy with social ties. *J Med Internet Res*. (2017) 19:e98. doi: 10.2196/jmir.6472

26. Kim YC, Lim JY, Park K. Effects of health literacy and social capital on health information behavior. *J Health Commun*. (2015) 20:1084–94. doi: 10.1080/10810730.2015.1018636

27. Hoogland AI, Mansfield J, Lafranchise EA, Bulls HW, Johnstone PA, Jim HSL. Ehealth literacy in older adults with cancer. *J Geriatr Oncol*. (2020) 11:1020–2. doi: 10.1016/j.jgo.2019.12.015

28. Zibrik LKS, Bangar N, Stacy E, Novak Lauscher H, Ho K. Patient and community centered Ehealth: exploring Ehealth barriers and facilitators for chronic disease self-management within British Columbia's immigrant Chinese and Punjabi seniors. *Health Policy Techn*. (2015) 4:348–56. doi: 10.1016/j.hlpt.2015.08.002

29. Souto EP, Moreno AB, Chor D, Melo ECP, Barreto SM, Nunes MA, et al. Social capital and depressive episodes: gender differences in the Elsa-Brasil cohort. *Front Public Health*. (2021) 9:657700. doi: 10.3389/fpubh.2021.657700

30. Gundewar A, Chin NP. Social capital, gender, and health: An ethnographic analysis of women in a Mumbai slum. *Glob Health Promot*. (2020) 27:42–9. doi: 10.1177/1757975920909114

31. Gu J, Zhu R. Social capital and self-rated health: empirical evidence from China. *Int J Environ Res Public Health*. (2020) 23:9108. doi: 10.3390/ijerph17239108

32. Nyqvist F, Victor CR, Forsman AK, Cattan M. The association between social capital and loneliness in different age groups: a population-based study in Western Finland. *BMC Public Health*. (2016) 16:542. doi: 10.1186/s12889-016-3248-x

33. Cao W, Cao C, Zheng X, Ji K, Liang Q, Wu Y, et al. Factors associated with medication adherence among community-dwelling older people with frailty and pre-frailty in China. *Int J Environ Res Public Health*. (2022) 19:6001. doi: 10.3390/ijerph192316001

34. Bai Z, Yang J, Wang Z, Cao W, Cao C, Hu Z, et al. Association between social capital and self-rated health among community-dwelling older adults. *Front Public Health*. (2022) 10:6485. doi: 10.3389/fpubh.2022.916485

35. Ma Z, Wu M. The psychometric properties of the Chinese Ehealth literacy scale (C-Eheals) in a Chinese rural population: cross-sectional validation study. *J Med Internet Res*. (2019) 21:e15720. doi: 10.2196/15720

36. Chang A, Schulz PJ. The measurements and an elaborated understanding of Chinese Ehealth literacy (C-Eheals) in chronic patients in China. *Int J Environ Res Public Health*. (2018) 15:1553. doi: 10.3390/ijerph15071553

37. Li S, Cui G, Yin Y, Wang S, Liu X, Chen L. Health-promoting behaviors mediate the relationship between Ehealth literacy and health-related quality of life among Chinese older adults: a cross-sectional study. *Qual Life Res*. (2021) 30:2235–43. doi: 10.1007/s11136-021-02797-2

38. Peng M, Liu X. Health literacy level and its influencing factors among residents aged 45~69 years in Gansu Province. *Chin Rural Health Serv Admin*. (2020) 40:278–83. [In Chinese]

39. Li Z, Xu X. Analysis of network structure and doctor behaviors in E-health communities from a social-capital perspective. *Int J Environ Res Public Health*. (2020) , :1136. doi: 10.3390/ijerph17041136

40. Wong AKC, Bayuo J, Wong FKY. Investigating predictors of self-care behavior among homebound older adults: the role of self-efficacy, Ehealth literacy, and perceived social support. *J Nurs Schol*. (2022) 54:278–85. doi: 10.1111/jnu.12730

41. Choi M. Association of Ehealth use, literacy, informational social support, and health-promoting behaviors: mediation of health self-efficacy. *Int J Environ Res Public Health*. (2020) 17:7890. doi: 10.3390/ijerph17217890

42. Takemura Y, Sato K, Kondo K, Kondo N. Characteristics associated with optimistic or pessimistic perception about the probability of contracting Covid-19: a cross-sectional study of Japanese older adults. *SSM*. (2022) 19:101186. doi: 10.1016/j.ssmph.2022.101186

43. Lu N, Zhang J. Social capital and self-rated health among older adults living in urban China: a mediation model. *Sustainability*. (2019) 11:5566. doi: 10.3390/su11205566

44. Nie X, Li Y, Li C, Wu J, Li L. The association between health literacy and self-rated health among residents of China aged 15–69 years. *Am J Prev Med*. (2021) 60:569–78. doi: 10.1016/j.amepre.2020.05.032

45. Holt KA, Overgaard D, Engel LV, Kayser L. Health literacy, digital literacy and Ehealth literacy in Danish nursing students at entry and graduate level: a cross sectional study. *BMC Nurs*. (2020) 19:22. doi: 10.1186/s12912-020-00418-w

46. Perry BL, McConnell WR, Peng S, Roth AR, Coleman M, Manchella M, et al. Social networks and cognitive function: An evaluation of social bridging and bonding mechanisms. *Gerontologist*. (2022) 62:865–75. doi: 10.1093/geront/gnab112

47. Amoah PA. Social participation, health literacy, and health and well-being: a cross-sectional study in Ghana. *SSM*. (2018) 4:263–70. doi: 10.1016/j.ssmph.2018.02.005

48. Cheng CS, Huang YJ, Sun CA, An C, Chang YT, Chu CM, et al. Gender-specific determinants of Ehealth literacy: results from an adolescent internet behavior survey in Taiwan. *Int J Environ Res Public Health*. (2022) 19:664. doi: 10.3390/ijerph19020664

49. Ke Y, Jiang J, Chen Y. Social capital and the health of left-behind older adults in rural China: a cross-sectional study. *BMJ Open*. (2019) 9:e030804. doi: 10.1136/bmjopen-2019-030804

50. Karhina K, Eriksson M, Ghazinour M, Ng N. What determines gender inequalities in social Capital in Ukraine? *SSM*. (2019) 8:100383. doi: 10.1016/j.ssmph.2019.100383

51. Chu Y, Zhang H. Do age-friendly community policy efforts matter in China? An analysis based on five-year developmental plan for population aging. *Int J Environ Res Public Health*. (2022) 19:3551. doi: 10.3390/ijerph192013551

52. De Main AS, Xie B, Shiroma K, Yeh T, Davis N, Han X. Assessing the effects of Ehealth tutorials on older Adults' Ehealth literacy. *J Appl Gerontol*. (2022) 41:1675–85. doi: 10.1177/07334648221088281

53. Hong YA, Zhou Z, Fang Y, Shi L. The digital divide and health disparities in China: evidence from a National Survey and policy implications. *J Med Internet Res*. (2017) 19:e317. doi: 10.2196/jmir.7786

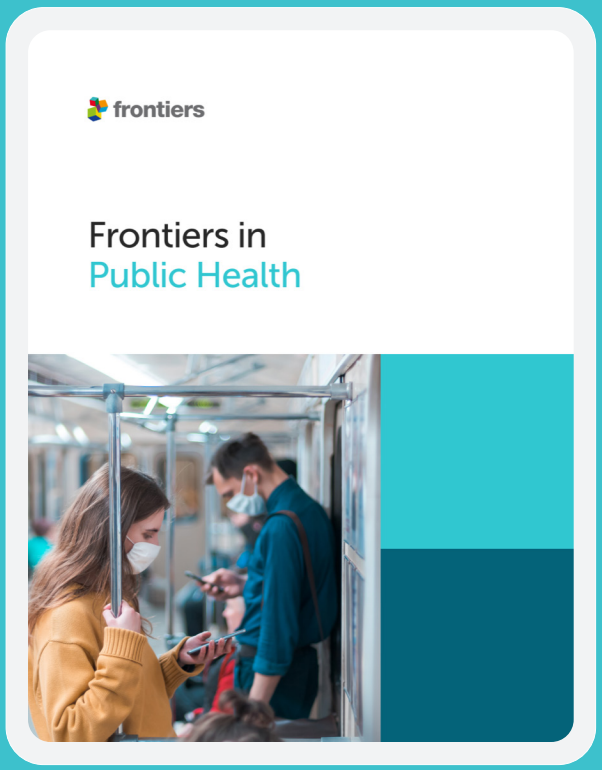
Frontiers in Public Health

Explores and addresses today's fast-moving healthcare challenges

One of the most cited journals in its field, which promotes discussion around inter-sectoral public health challenges spanning health promotion to climate change, transportation, environmental change and even species diversity.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact