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Digital divide as a determinant of health in the U.S. older adults: prevalence, trends, and risk factors

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Abstract

Background The rapid development of digital technologies has fundamentally changed the care for older adults. However, not all older adults have equal opportunities to access and use the technologies, more importantly, be able to benefit from the technologies. We aimed to explore (1) the prevalence and the trend in the prevalence of digital divide in older adults, including digital access gap, digital use gap (specifically, using digital technologies for health commutation [e-communication gap]), and self-efficacy in information seeking gap (cognitive gap); (2) sociodemographic factors related to three perspectives of digital divide; and (3) the association between digital divide and self-rated health (exploratory).

Methods Adults aged 65 years or older ($N = 5,671$, weighted mean [SD] age = 74.26 [10.09] years) from the Health Information National Trends Surveys (2017–2020) were analyzed using the weighted logistic and linear regression models.

Results There was a significant linear decrease in the adjusted prevalence of digital access gap (odds ratio [OR] = 0.86, 95% CI = 0.78, 0.94) and the e-communication gap (OR = 0.88, 95% CI = 0.82, 0.95) over time. However, there were no significant changes in cognitive gap between 2017 and 2019, and between 2018 and 2020. Overall, older adults with digital divide were more likely to be less educated, have less income, and self-identified as Hispanic people. Univariate analyses found that three perspectives of digital divide were significantly associated with poor self-rated health. Multivariate analyses adjusted for covariates (e.g., age and sex) found that the access gap but not the e-commutation gap was associated with self-rated health and that cognitive gap was only associated with self-rated health between 2018 and 2020 but not between 2017 and 2019.

Conclusions Digital divide is decreasing but remains persistent and disproportionately affects self-rated health of older adults, particularly those who are socially disadvantaged (e.g., lower education and income). Continued efforts are needed to address digital divide among them.

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Keywords Digital divide, Self-rated health, Older adults, Cognitive gap, E-communication gap, Digital access gap

Introduction

The digital revolution has changed human life, and the way humans communicate. It has also led to the transformation of healthcare delivery and practice, particularly during the COVID-19 pandemic when there was a leap in digital adoption in both healthcare systems and consumers [1]. However, digital technologies do not provide the same opportunities for every individual equally [1, 2]. People may not benefit equally from using new digital technologies depending on their preparation and capacity to use them [3]. The digital divide refers to the digital inequality between people who have access to and use digital media and those who do not [4]. It addresses disparities in digital technology access, usage, and outcomes [1], and is increasingly an important problem of society. Being a significant determinant of health disparities, the digital divide marks a difference among generations, communities, and societies due to digital inequality [5]. Moving toward a more digital-dependent world, digital access, and literacy have been recognized as "super social determinants of health" [6, 7], or digital determinants of health [8].

The term "digital divide" was first used in several newspapers in the U.S. in the mid-1990s. In the early times (1995–2003), the digital divide was more focused on physical access to information and communication technologies, such as access to the internet or relevant equipment/devices, which has been considered the first level of the digital divide. Increasingly, people recognize that the main concept of the digital divide can be the inequality of capabilities or skills (i.e., e-skills or digital literacy) and usage. One article in the Economist states, "The real reason why the poor will not have access will be evident: they lack the skills to exploit it effectively" (8/12/2001). Such a second level of the digital divide (2004–present) is also recognized as the "cognitive divide" as it relates to how people are able to "understand, learn, express, produce, share, collaborate, be creative, and innovate using technologies" [5]. The third level of the digital divide (2012-present) is focused on the outcomes or return benefits from the use of technology, such as using digital technologies for health commutation, highlighting the differences in people's ability to mobilize digital resources to achieve specific objectives [1]. This level of digital divide examines and quantifies the effect of digital technologies on productivity and economic growth [9]. Overall, the focus of the "digital divide" has been expanded to the full range of "digital inequality" in equipment, autonomy, skill, support, and scope of use, extended to the relationship between the use of digital technologies and valued individual-level outcomes, and investigated variations in rates-of-return to technology use for different subgroups within the population [9, 10].

Many factors have been reported to affect the digital divide, including sociodemographic, personal elements, social support, type of technologies, digital training, rights (e.g., civil liberties or political rights), infrastructure, and large-scale events (e.g., COVID-19) [1]. Age, gender, education, marital status, and race/ethnicity are identified to be mostly linked to the digital divide, particularly to levels 1 and 2 of the divide [1, 11]. In general, socially disadvantaged individuals—such as being older, those who are unmarried, and those with lower incomes or belonging to minority groups minority group—are more likely to be affected by the digital divide. However, the latest research suggests that the racial/ethnic digital divide at level 1 has diminished, although disparities at level 2 still persist [11]. The gender-related digital divide is also narrowing, with gender having little impact on personal and health-related internet use, while women still consistently show higher engagement on social media platforms [11]. All these findings suggest a new, promising technological landscape and call for continued effort to understand the digital divide among older adults in a rapidly evolving digital environment.

More emerging evidence about the digital divide from a health perspective is needed. Digital technologies are promising to improve health care. Telehealth and patient portals, for instance, offer a convenient way of accessing the healthcare system and facilitating effective health communication. However, health disparities due to social determinants persist or sometimes even worsen with the implementation of new technologies [12]. This is especially concerning for older adults. If digital health technologies are poorly integrated into systems of health and social care, technology itself could contribute to even greater health disparities for older adults, creating more harm than good [13, 14]. It is evident that older populations have less access to the Internet and smartphone services [15, 16]. In terms of return benefits, especially health outcomes, self-rated health is an important measure as it often captures similar information to objective health measure in predicting mortality risk among older adults [17]. Self-rated health can also provide insights into how older adults perceive and cope with their health status despite the presence of disease, and thus encouraging patient-centered care [17, 18]. Recent studies are emerging to show that access to or use of technology (e.g., internet access and usage) can affect self-rated health among older adults [19–21]. However, research addressing digital divide beyond access and use gaps, such as the cognitive gap, is limited, and none of these

studies simultaneously consider the various levels of the digital divide. Existing evidence indicates significant heterogeneity within the older adult group regarding digital adoption [22]. Some common factors that impact digital involvement include fear and anxiety about using technology, negative attitudes, and a sense of feeling too old to learn [23]. These factors highlight a significant yet under-explored barrier related to the cognitive efficacy needed for older adults to effectively use technology, specifically cognitive gap. While the digital divide and its impact on health in this population are important areas of research, studies on the digital determinants of health in general, and particularly on the cognitive gap and health among older adults, have been relatively limited.

Research questions

To better understand the digital divide among older adults, we aim to explore (1) the prevalence of digital divide in older adults, including digital access gap, digital use gap, specifically using digital technologies for health commutation (e-communication gap), and self-efficacy in information seeking gap (cognitive gap), and the trend of prevalence changes over time; (2) sociodemographic factors related to three perspectives of digital divide; and (3) the association between digital divide and self-rated health (exploratory).

Materials and methods

Data sources

This study analyzed the cross-sectional survey data from the Health Information National Trends Surveys (HINTS) collected in 2017 (HINTS 5 Cycle, N=3,285), 2018 (HINTS 5 Cycle 2, N=3,504), 2019 (HINTS 5 Cycle 3, N=5,438), and 2020 (HINTS 5 Cycle 4, N=3,865). HINTS used the complex survey design that accounts for nonresponse and sampling stratum for nationally representative estimates of adults aged 18 years +. A detailed description of HINTS survey design and response rates were described elsewhere [24]. Data are publicly available at the HINTS website (https://hints.cancer.gov/) and institutional review board approval was not applicable.

Given the focus of the current study, only older adults aged 65 years and older were included in the analysis. The final sample included 1,061 older adults from HINTS 5 Cycle 1, 1,240 from HINTS 5 Cycle 2, 1,961 from HINTS 5 Cycle 3, and 1,409 from HINTS 5 Cycle 4, yielding a total of 5,671 respondents representing national older adult populations each year. Analyses were conducted from October through July 2023.

Variables

Independent variable: digital divide. The digital divide was operationalized from three perspectives, including digital access gap, e-communication gap, and cognitive gap.

Digital access gap The digital access gap was defined by respondents' reports on whether they had (1) a tablet computer, like an iPad, Samsung Galaxy, Motorola Xoom, or Kindle Fire (0=no, 1=yes), (2) a smartphone, such as an iPhone, Android, Blackberry, or Windows phone (0=no, 1=yes), or (3) internet access (0=no, 1=yes). Specifically, internet access was measured by self-reports on "Do you ever go online to access the Internet or World Wide Web, or to send and receive e-mail? (0=no, 1=yes)" Respondents who answered "yes" to either of the 3 questions were considered to have digital access (coding the digital access gap=0), while respondents who answered "no" to all 3 questions were considered to have no digital access (coding the digital access gap=1).

E-communication gap Respondents' use of digital technologies for health communication with clinicians in the past 12 months was measured using 4 survey questions, including (1) "In the past 12 months, have you used e-mail or the Internet to communicate with a doctor or a doctor's office? (0=no, 1=yes)"; (2) "In the past 12 months, have you used your online medical record (e.g., e-mail) to securely message health care provider and staff? (0=no, 1=yes)"; (3) "Have you shared health information from either an electronic monitoring device or smartphone with a health professional within the last 12 months? (0=no, 1=yes); and (4) "Have you electronically sent your medical information to another health care provider? (0=no, 1=yes)". Respondents who answered "yes" to either of the 4 questions were considered using digital technologies for health communication with their providers (coding e-communication gap=0), while respondents who answered "no" to all 4 questions were considered not using digital technologies for health communication (e-communication gap=1).

Cognitive gap Cognitive gap was defined by respondents' self-efficacy in seeking health information. HINTS operationalized this construct slightly different across cycles. Between 2017 and 2019, self-efficacy referred to an individual's confidence in seeking general health information by asking "Overall, how confident are you that you could get advice or information about health or medical topics if you needed it?" Between 2018 and 2020, self-efficacy specifically referring to cancer information was assessed by asking "Overall, how confident are you that you could get advice or information about *cancer* if you needed it?" These questions were rated on a 5-point Likert scale from 1=not confident at all to 5=completely confident, and a high score indicated higher levels of self-efficacy. To facilitate the interpretation, we further dichotomized the Likert

scale responses into cognitive gap=1 when respondents were "not confident at all" or "a little confident" otherwise cognitive gap=0 when respondents were "somewhat confident" or "very confident" or "completely confident".

Outcome variable: self-rated health Self-rated health was measured by a single question asking "In general, would you say your health is…" with a 5-point Likert scale from 1=poor to 5=excellent, with a high score indicating better self-rated health.

Sociodemographics Sociodemographics included age (in years), sex, education, marital status, race/ethnicity, annual household income, living alone, rural residency, and health insurance. Comorbidities were measured using a sum score of 7 doctor-diagnosed chronic conditions, including cancer, diabetes, hypertension, heart condition, chronic lung disease, arthritis or rheumatism, and depression or anxiety disorder. To be noted, chronic condition arthritis or rheumatism was not assessed in 2020 (i.e., HINTS 5 CYCLE 4).

Statistical analysis

To obtain unbiased estimates from the complex HINTS survey design, HINTS final weights were incorporated to compute the point estimates, and replicate weights were used to compute the standard errors (SE) using the jackknife replication method recommended by the HINTS analytic guidelines [24]. Specifically, *for research question 1*, we used univariate analyses such as the Chi-square test and ANOVA as appropriate to describe the prevalence of digital divide across different survey cycles. To identify trends in the prevalence of digital divide over time, we used logistic regression models with the survey year as the categorical predictor (reference=2017 year) and adjusted for age, sex, and race/ethnicity. To confirm the trend analysis, we also treated the survey year as a continuous predictor to test linear and quadratic trends. The quadratic trend was insignificant and therefore not reported in the results. *For research question 2*, we used weighted multiple logistic and linear regression models to examine how the sociodemographic factors were associated with the digital divide using the same jackknife replication method. Finally, since the exploratory nature of *research question 3*, we used both univariate and multivariate models to explore the associations between the digital divide and self-rated health. All the analyses of the digital access gap and e-communication gap were performed on the combined data of 2017–2020; the analyses of the cognitive gap were performed on two separate combined datasets (i.e., 2017–2019 and 2018–2020, respectively) to account for the differences in the measure of this variable mentioned above. Stata software (version 17; StataCorp) was used for all statistical analyses. The level of significance was 0.05.

Table 1 Sample characteristics (*N*=5,671)

Categorical variables	Weighted %
Sex (female)	54.77
Education (some college or higher)	59.65
Married or partnered	56.75
Race/ethnicity	
White people	67.49
African American	7.07
Hispanic people	7.31
Other	3.79
Annual household income (≥$50,00)	38.19
Live alone	29.39
Rural residency	16.53
Health insurance	97.12
Continuous variables	Weighted mean (SD)
Age (years)	74.26 (7.46)
Comorbidities	1.93 (1.80)
Self-rated health	3.24 (1.28)

Note. SD=standard deviation. All the results were weighted. Coding schemes for categorical variables were: sex (0=male, 1=female), education (0=high school graduate or less, 1=college graduate or more), marital status (0=not married, 1=married or partnered), race/ethnicity (0=White people, 1=African American, 2=Hispanic people, 3=other), annual household income (0=less than US $50,000, 1=≥US $50,000), living alone (0=no, 1=yes), rural residency (0=no, 1=yes), and health insurance (0=had no health insurance, 1=had health insurance)

Results

Sample characteristics

Table 1 displays the characteristics of study respondents across 4 cycles (2017–2020). A total of 5,671 (19.3%) older adults aged 65 years or older (weighted mean [SD] age=74.26 [10.09] years) were included in the study. Of whom 54.8% were females, 59.7% had some college or higher education, 56.8% were married or lived as married, 67.5% were White people, and 38.2% had over $50,00 annual household income, with a mean of 3.24 (SD=1.28) self-rated health and 1.93 (SD=1.80) comorbid conditions.

Prevalence and trends in the prevalence of digital divide among older adults

Table 2 and Supplementary Table 1 describe the prevalence and trends in the prevalence of digital divide among older adults over four years. Overall, the unadjusted prevalence of older adults without access to electronic devices decreased from 28.8% in 2017, 27.7% in 2018, 22.3% in 2019, and then stabilized at 23.2% in 2020 (see Table 2). There was a significant linear decrease in the adjusted prevalence of digital access gap over time (odds ratio [OR]=0.86, 95% CI=0.78, 0.94, Supplementary Table 1). A similar pattern was also found for the prevalence and trends in the prevalence of the e-communication gap (OR=0.88, 95% CI=0.82, 0.95, Supplementary

Table 2 The unadjusted prevalence of digital access gap, e-commutation gap, and cognitive gap between 2017 and 2020 ($N=5,671$)

	2017	2018	2019	2020	*p*
	% (SE)	% (SE)	% (SE)	% (SE)	
Digital access gap[#]	28.83 (1.75)	27.67 (1.96)	22.29 (1.40)	23.17 (1.38)	0.001
E-communication gap[#]	63.87 (1.91)	61.75 (1.83)	56.90 (1.59)	57.30 (1.86)	0.002
Cognitive gap					
Self-efficacy in seeking health information[##]	5.48 (1.14)	NA	6.84 (0.71)	NA	0.426
Self-efficacy in seeking cancer health information[###]	NA	7.90 (0.92)	NA	5.90 (1.03)	0.349

Note. [#]Statistics were derived from 2017 to 2020 (4 survey cycles; $N=5,671$); [##]statistics were derived from years of 2017 and 2019 (2 survey cycles; $n=3,022$); [###]statistics were derived from years of 2018 and 2020 (2 survey cycles; $n=2,649$)

SE=Jackknife standard errors; NA=not available

Table 1). Specifically, the unadjusted prevalence of the e-communication gap decreased from 63.9% in 2017, 61.8% in 2018, 56.9% in 2019, and then slightly increased to 57.3% in 2020 (see Table 2). The decreased e-communication gap was in a linear trend over time (OR=0.88, 95% CI=0.82, 0.95, Supplementary Table 1). However, there were no significant changes in cognitive gap between 2017 and 2019, and between 2018 and 2020 (see Table 2 and supplementary Table 1).

Sociodemographic factors associated with digital divide among older adults

As shown in Table 3, factors associated with digital access gap were age (OR=1.09, 95% CI=1.07, 1.11), sex (OR=0.55, 95% CI=0.41, 0.74), education (OR=0.23, 95% CI=0.18, 0.31), marital status (OR=0.48, 95% CI=0.30, 0.78), race/ethnicity (e.g., for Hispanic people OR=1.82, 95% CI=1.13, 2.93 and for African American OR=1.49, 95% CI=1.01, 2.21), annual household income (OR=0.29, 95% CI=0.20, 0.43), and comorbidities (OR=0.90, 95% CI=0.82, 0.99). Similarly, factors associated with the e-communication gap were age (OR=1.03, 95% CI=1.01, 1.05), education (OR=0.49, 95% CI=0.39, 0.63), marital status (OR=0.74, 95% CI=0.55, 0.98), race/ethnicity (e.g., Hispanic people OR=2.11, 95% CI=1.48, 3.03), annual household income (OR=0.44, 95% CI=0.34, 0.56), rural residency (OR=1.48, 95% CI=1.13, 1.95), and comorbidities (OR=0.82, 95% CI=0.76, 0.88). Overall, older adults who had access to and used digital technologies for health were those with higher education and household income but were less likely to be older or self-identified as Hispanic people.

In addition, older adults with cognitive gaps in seeking health information were those who had reported lower education and self-identified as Hispanic people between 2017 and 2019. Nevertheless, these factors were not associated with the cognitive gap between 2018 and 2020.

Associations between digital divide and self-rated health and comorbidities

Table 4 presents the results of univariate and multivariate analyses on the associations between the digital divide and self-rated health. In the univariate models, three perspectives of digital divide including digital access gap (Mean=2.98, 95% CI=2.91, 3.06), e-communication gap (mean=3.20, 95% CI=3.15, 3.25), and cognitive gap of self-efficacy in seeking health information (mean=2.92, 95% CI=2.65, 3.18 for the years between 2017 and 2019; and mean=2.81, 95% CI=2.58, 3.04 for the years between 2018 and 2020, respectively) were significantly associated with self-rated health.

In the multivariate models, the digital access gap (β=-0.14, 95% CI=-0.25, -0.02, Model 1 in Table 4) but not the e-commutation gap (β=-0.07, 95% CI=-0.16, 0.02, Model 2 in Table 4) was associated with self-rated health across the years (2017–2020). In addition, the cognitive gap was only associated with self-rated health between 2018 and 2020 (β=-0.29, 95% CI=-0.51, -0.07) but not between 2017 and 2019 (β=-0.20, 95% CI=-0.41, -0.01) after the sociodemographic factors were adjusted for (e.g., age, sex, and comorbidities).

Discussion

We described the prevalence and trend in the prevalence of digital divide in terms of digital access gap, e-communication gap, and cognitive gap, specifically self-efficacy in seeking health information, explored the sociodemographic factors associated with digital divide, and examined the association between three perspectives of digital divide and self-rated health among the U.S. older adults. Several key findings have emerged from the current study.

The digital divide in older adults

First, we found that the digital divide still persists among U.S. older adults, although there is an increasing trend in accessing and using digital technologies for health across the study years. This finding suggests that despite the increasing availability of digital technologies, the likelihood of a digital divide in accessing and using these technologies among older adults still remains high. For example, in our sample, we found that about one-quarter of older adults (ranging from 23 to 29%) reported a lack of digital access and the majority of them (ranging from 57 to 64%) reported non-use of digital technologies for health communication. This prevalence is similar to that of internet use among older adults reported by prior research [24–26].

Table 3 Sociodemographic factors related to digital access gap, e-commutation gap, and cognitive gap

	Digital access gap[#]			**E-communication gap**[#]		
	OR	**95% CI**	***P***	**OR**	**95% CI**	***P***
Age (years)	1.09	1.07, 1.11	< 0.001	1.03	1.01, 1.05	0.001
Sex (female)	0.55	0.41, 0.74	< 0.001	0.99	0.81, 1.21	0.935
Education (some college or higher)	0.23	0.18, 0.31	< 0.001	0.49	0.39, 0.63	< 0.001
Married or partnered	0.48	0.30, 0.78	0.004	0.74	0.55, 0.98	0.034
Race/ethnicity						
White people	Ref	Ref	Ref	Ref	Ref	Ref
African American	1.49	1.01, 2.21	0.047	1.04	0.76, 1.42	0.822
Hispanic people	1.82	1.13, 2.93	0.015	2.11	1.48, 3.03	< 0.001
Other	1.41	0.79, 2.53	0.243	1.13	0.75, 1.69	0.556
Annual household income (≥$50,000)	0.29	0.20, 0.43	< 0.001	0.44	0.34, 0.56	< 0.001
Live alone	1.01	0.63, 1.61	0.976	0.88	0.64, 1.21	0.416
Rural residency	1.12	0.75, 1.66	0.588	1.48	1.13, 1.95	0.005
Health insurance	1.14	0.39, 3.37	0.813	0.51	0.18, 1.44	0.202
Comorbidities	0.90	0.82, 0.99	0.036	0.82	0.76, 0.88	< 0.001
	Cognitive gap (2017, 2019)[##] Self-efficacy in seeking health information			**Cognitive gap (2018, 2020)**[###] Self-efficacy in seeking **cancer** health information		
	OR	95% CI	*P*	OR	95% CI	*P*
Age (years)	1.01	0.96, 1.05	0.791	1.00	0.96, 1.05	0.825
Sex (female)	0.71	0.45, 1.13	0.150	1.00	0.56, 1.78	0.987
Education (some college or higher)	0.49	0.28, 0.86	**0.014**	0.73	0.41, 1.31	0.289
Married or partnered	0.89	0.44, 1.79	0.740	0.77	0.30, 1.98	0.587
Race/ethnicity						
White people	Ref			Ref		
African American	0.92	0.45, 1.88	0.814	0.95	0.45, 2.00	0.885
Hispanic people	4.61	2.28, 9.34	< 0.001	1.95	0.99, 3.81	0.052
Other	2.81	1.17, 6.77	0.021	0.98	0.31, 3.14	0.975
Annual household income (≥$50,000)	0.54	0.26, 1.10	0.088	0.78	0.43, 1.40	0.399
Live alone	1.41	0.75, 2.68	0.283	0.83	0.30, 2.31	0.714
Rural residency	0.80	0.36, 1.76	0.573	1.08	0.47, 2.45	0.856
Health insurance	1.51	0.11, 20.67	0.756	0.25	0.01, 5.20	0.367
Comorbidities	1.23	0.95, 1.58	0.116	1.11	0.90, 1.38	0.317

Note. OR = Odds ratio

[#]Statistics were derived from 2017 to 2020 (4 survey cycles; $N = 5,671$); [##]statistics were derived from years of 2017 and 2019 (2 survey cycles; $n = 3,022$); [###]statistics were derived from years of 2018 and 2020 (2 survey cycles; $n = 2,649$)

Table 4 The association between digital divide and self-rated health among U.S. older adults

	Self-rated health		
	Mean	**95% CI**	***P***
Univariate results			
Digital access gap[#]			< 0.001
Yes	2.98	2.91, 3.06	
No	3.33	3.29, 3.37	
E-communication gap[#]			0.005
Yes	3.20	3.15, 3.25	
No	3.32	3.26, 3.38	
Cognitive gap			
Self-efficacy in seeking health information[##]			0.010
Yes	2.92	2.65, 3.18	
No	3.28	3.22, 3.34	
Self-efficacy in seeking cancer health information[###]			< 0.001
Yes	2.81	2.58, 3.04	
No	3.27	3.22, 3.32	
Multivariate results	β	95% CI	P
Digital access gap[#]	-0.14	-0.25, -0.02	0.019
E-communication gap[#]	-0.07	-0.16, 0.02	0.145
Cognitive gap			
Self-efficacy in seeking health information[##]	-0.20	-0.41, -0.01	0.056
Self-efficacy in seeking cancer health information[###]	-0.29	-0.51, -0.07	0.010

Note. [#]Statistics were derived from 2017 to 2020 (4 survey cycles); [##]statistics were derived from years of 2017 and 2019 (2 survey cycles); [###]statistics were derived from years of 2018 and 2020 (2 survey cycles). Multivariate models controlled for age, sex, education, marital status, race/ethnicity, annual household income, live alone, rural residency, health insurance, and number of comorbidities

We also found that older adults with a digital divide are more likely to be older, less educated, lower income, unmarried or unpartnered status, rural residency, and racial/ethnic minorities, all of which suggest a more vulnerable group. This finding is also similar to those reported by prior studies [27, 28] on various forms of digital technologies such as the internet [29], eHealth [30], mobile health applications [31], social media [32], and personal health record [33], although the literature has seldom considered all three perspectives of digital divide simultaneously. However, we did not find an association between living alone and the three levels of the digital divide in our study. This finding contradicts prior research [34], which suggests that older adults who co-reside with children or grandchildren may experience a smaller digital divide, as family support is believed to be key in developing digital skills and information literacy for older adults [35]. While living alone was not significant in our analysis, this does not imply that it has no impact on the digital divide. Other factors, such as marital status, may interact with living arrangements, complicating this association and requiring further study. Consistent with the latest research, our results also found that women, previously considered vulnerable groups, actually have a smaller digital access gap [11]. This may be attributed to previous finding that women are more likely to rely on the internet for social relationships and emotional support [11].

Overall, our findings, along with other studies, indicate that although the general adoption rate of digital technology among older adults has increased recently [2], especially after the COVID-19 pandemic, the overall profile of users has not fundamentally changed over time. Such an unchanged profile may suggest that older adults as "digital immigrants" are still under-represented and underserved than that of the general population in digital health care. Two main reasons may explain this under-representation and under-servicing of older adults. One is that the design of digital technologies is not well suitable or inclusive to older adults [26, 36, 37], which might discourage their use, and another is that data from older adults are not adequately represented in the digital applications that might make them more likely to be excluded from digital technologies [2, 26, 38]. All the findings suggest that digital care for older adults is a promising start but is better now to take on a hybrid format that combines digital and in-person modalities for better support of older adults [39].

Digital divide and health disparities

The digital divide is still an ongoing global challenge for older adults [40], in particular for those with lower socioeconomic status and racial and ethnic minority groups. There is a new call for a shift in the focus from the level 1 digital access gap and the level 2 use gap of the digital divide to a focus on the return outcomes [1]. In line with previous studies, we found a significant association between the digital access gap and self-rated health [21, 41]. However, when examining the digital use gap, Zhou et al. observed that internet use improves older adults' health by facilitating access to health information [21]. In contrast, our multivariate analysis did not find a significant relationship between the e-communication gap and health status, possibly due to differences in measurement. Zhou et al.'s study used a broader measure to assess the importance of internet in accessing information, whereas our study focused specifically on e-health communication between older adults and healthcare providers [21]. Our results confirm the current digital divide literature [1, 40], showing that gaps in access to and use of digital technologies are prevalent and further extend them to gap-related health consequences, highlighting that these gaps are associated with poor self-rated health status, although the multivariate analysis revealed slightly different results (i.e., e-communication gap is not related to health status). Our results along with prior research

indicate that older adults regardless of whether economically developed or underdeveloped are very often digitally excluded [42]. Digital exclusions are particularly problematic for older adults given that those who are digitally excluded are often socially excluded [26, 42, 43], which has shown to be associated with various physical and mental health consequences [26, 40, 44]. Evidence also supports that older adults who are in poor health are more likely to be digitally excluded since disability can make technologies more challenging to use [45], and older adults can further develop disability if they are digitally excluded and are not able to stay connected to others [46, 47]. Therefore, older adults can not only suffer from digital exclusion but also social exclusion, both of which may, in turn, contribute to worse health outcomes [48]. Consequently, the digital divide and health disparities can coexist and can further reinforce each other to create an additional layer of inequality in health for older adults, especially those who are socially disadvantaged (e.g., lower education and income). With the recent rapid development of digital technologies, expanding them into patient-centered care is increasingly important and can significantly impact the quality of care for older adults [2, 49]. On one hand, equitable access to digital technologies can provide everyone, everywhere with high-quality care, and thus powerfully narrow the health disparities. On the other hand, if these tools are not equitably provided or used, these technologies can rather complicate existing disparities instead [2]. Our results suggest a new form of health disparities in the context of digital technologies and reinforce the concept of the digital divide as a social determinant of health that might disproportionately impact older adults. As such, careful consideration is required to ensure that existing disparities are not exacerbated and to ensure that no older adults, particularly those the most vulnerable mentioned above are left behind in digital applications [2, 27].

Low cognitive gap

Interestingly, we found that the prevalence of older adults with cognitive gap are relatively low and stable over time (ranging from 5.5% in 2017 to 5.9% in 2020), suggesting that older adults may experience less difficulty in seeking digital health information than expected. This is a new finding of our study. In the digital divide research, cognitive gap in general and digital efficacy in particular are not well studied. Similar to attitude, motivation, or risk perception, efficacy is deemed an important personal element that might be linked to the digital divide but has not been extensively tested [36, 50]. In health behavior research, self-efficacy is a well-known factor affecting the health and health behaviors of older adults [51]. In digital technology research, a very recent study shows that self-efficacy can not only directly affect the use behavior but can also affect the use intention further leading to the use behavior [52]. Although older adults are not the primary users of technologies, they show great interest in using these technologies and recognize the health-related benefits of using them [53, 54]. To increase the benefits of technologies among older adults, it is necessary for them to not only feel interested or recognize the usefulness of the technologies but also see themselves as being able to use them [3]. Older adults with high levels of efficacy tend to attribute technology-related difficulties to their capacities rather than to technology characteristics [52]. This attribution pattern might reflect the key features of digital literacy or the complex interplay of digital literacy and digital efficacy which play a significant role in determining the use of technologies and use-related health benefits for older adults who often have complex health needs [55, 56].

Comparing the within-group difference in efficacy among older adults, Jokisch et al. [52] study further suggests that efficacy is more important to older adults in advanced age than those in early old age. The possible reasons are that as compared to older adults in early old age, those in advanced old age may shift their focus of use experiences from technology itself towards subjective capabilities [52]. Another possible explanation is that peer support or role models as the main resources for older adults to build efficacy are often less available as people age, which leads to low digital efficacy [52]. However, our analysis did not show such an age effect on the cognitive gap. This finding is somewhat contrary to prior research where older adults reported difficulties in learning and keeping up with technologies due to age-related declines in memory and learning abilities [46, 57]. A possible reason for the difference between our findings and prior findings is that understanding how to locate health information can be different from being able to use this information if older adults lack skills or efficacy in understanding or appraising the quality of information. Although individuals may report high efficacy in locating health information, understanding or appraising that information often requires a higher level of cognitive capability, which may be lower than their perceived efficacy in finding the information. Therefore, more work is needed to compare the age effect on different perspectives of digital efficacy such as efficacy in finding, appraising, and using information.

Our findings that older adults' low cognitive gap is related to better self-reported health (although analysis from the years 2017 and 2019 revealed a marginal association) highlight the exciting possibility of addressing the digital divide and the resulting health disparities. Now is the time to address this issue using novel approaches. Qualitative evidence shows that the digital divide among older adults might not simply be about one's own abilities

to use technologies, but more about resources that are available to support their use, which makes the digital divide a social issue that requires social solutions [46]. Given the recent surge in the adoption rate of technologies among older adults, and health services are increasingly and even sometimes exclusively going online [6], novel approaches focusing on not only digital access and digital use, but also digital efficacy, and even social level of digital training support is critically important.

Limitations

We recognize several limitations in our study. First, we only examined the efficacy of finding health information, which might not fully capture older adults' experiences with the digital divide, especially their experiences of understanding and using health information, which might affect the interpretation of results. Second, due to the cross-sectional design of HINTS, the causal interpretation of our exploratory research aim (i.e., the association between the digital divide and self-rated health) should be cautious. Thirdly, self-rated health may be subject to biases, as it heavily relies on individual perceptions. Caution is needed when interpreting its implications for health, particularly regarding perceptions of one's health rather than actual health status. Future research should consider more comprehensive health outcome measures, including objective measures of health, to provide a more accurate understanding of the relationship between the digital divide and health disparities among older adults. Finally, three perspectives of the digital divide were examined separately in the current analysis, it is possible that they are closely related and can mutually influence each other. More work is needed to explore the mechanisms of how they interplay with each other and how such interplays can shape health disparities among older adults.

Conclusions

Using a nationally representative sample of U.S. older adults, we identified a shrinking but persistent digital divide among them, in particular among those who are less educated, have lower income, and belong to Hispanic minorities, suggesting that these people might be particularly vulnerable to the digital divide. We also found that the digital divide is related to poor self-rated health, indicating a significant impact of the digital divide on health disparities among older adults. Our findings also highlight that a cognitive gap, specifically efficacy in finding health information is relatively a new marker of the digital divide but shows promise to address the digital divide because this gap remains relatively low across the years.

Furthermore, new technologies such as artificial intelligence and machine learning are continually advancing in healthcare to improve care delivery. However, when certain groups, such as older adults, are digitally excluded, they may be harmed by these new tools. This phenomenon has recently been described as a fourth level of digital divide, known as health data poverty or algorithm awareness [58]. Policymakers must recognize the gaps in access, cognitive challenges, and benefits from technology use, as well as this emerging level of the digital divide related to data poverty or algorithm awareness. This is especially important since older adults are often underrepresented in the health data due to the aforementioned digital divide.

Supplementary Information

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Supplementary Material 1

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Author contributions

RY and YJ: study design, data acquisition, analysis, and interpretation, preparation of the manuscript and manuscript writing; SG: data interpretation and manuscript writing. All authors read and approved the final manuscript.

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Data availability

The authors do not have permission to share data, but the data are public and can be available on the website: https://hints.cancer.gov/.

Declarations

Ethics approval and consent to participate

Ethics approval was not required because the data were publicly available and did not contain any individually identifiable information.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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