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Internet usage and the prospective risk of dementia: A population-based cohort study

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Abstract

Background: Little is known about the long-term cognitive impact of internet usage among older adults. This research characterized the association between various measures of internet usage and dementia.

Methods: We followed dementia-free adults aged 50–64.9 for a maximum of 17.1 (median = 7.9) years using the Health and Retirement Study. The association between time-to-dementia and baseline internet usage was examined using cause-specific Cox models, adjusting for delayed entry and covariates. We also examined the interaction between internet usage and education, race-ethnicity, sex, and generation. Furthermore, we examined whether the risk of dementia varies by the cumulative period of regular internet usage to see if starting or continuing usage in old age modulates subsequent risk. Finally, we examined the association between the risk of dementia and daily hours of usage. Analyses were conducted from September 2021 to November 2022.

Results: In 18,154 adults, regular internet usage was associated with approximately half the risk of dementia compared to non-regular usage, CHR (cause-specific hazard ratio) = 0.57, 95% CI = 0.46–0.71. The association was maintained after adjustments for self-selection into baseline usage (CHR = 0.54, 95% CI = 0.41–0.72) and signs of cognitive decline at the baseline (CHR = 0.62, 95% CI = 0.46–0.85). The difference in risk between regular and non-regular users did not vary by educational attainment, race-ethnicity, sex, and generation. In addition, additional periods of regular usage were associated with significantly reduced dementia risk, CHR = 0.80, 95% CI = 0.68–0.95. However, estimates for daily hours of usage suggested a U-shaped relationship with dementia incidence. The lowest risk was observed among adults with 0.1–2 h of usage, though estimates were non-significant due to small sample sizes.

Conclusions: Regular internet users experienced approximately half the risk of dementia than non-regular users. Being a regular internet user for longer periods in late adulthood was associated with delayed cognitive impairment, although further evidence is needed on potential adverse effects of excessive usage.

KEYWORDS
aging, dementia, health disparities, internet usage

INTRODUCTION

Using the internet may help extend the cognitively healthy lifespan.[1–8] Online engagement can develop and maintain cognitive reserve, i.e., resiliency against physiological damage to the brain.[1–8] Increased cognitive reserve can, in turn, compensate for brain aging and reduce the risk of dementia.[8] Accordingly, prior research on older adults shows internet users to have better overall cognitive performance, verbal reasoning, and memory than non-users.[1–7] Nonetheless, existing research consists of cross-sectional analyses and longitudinal studies with short follow-up periods,[1–7] leaving the long-term cognitive benefits of internet usage unexamined. Also, despite extensive evidence of a disproportionately high burden of dementia in people of color, individuals without higher education, and adults who experienced other socioeconomic hardships,[9–12] little is known about whether the internet has exacerbated population-level disparities in cognitive health. The internet may have widened such cognitive health disparities given prior evidence on differential internet access and proficiency in use.[13,14] However, the internet may also have helped reduce such disparities through broadening socioeconomically disadvantaged adults' access to cognitive exercises, which may be limited through offline means. In addition to social and economic status, the gap in cognitive health between internet users and non-users may vary by generation, given generational differences in the quantity and patterns of usage.[14,15]

Moreover, although adults may stop, start, or continue to use the internet in late adulthood, little is known about how such changes in usage affect cognition. Some researchers contend that the cognitive benefit of starting or continuing internet use in late adulthood is minimal, considering accelerated brain aging. Hence, prior research did not examine changes in usage over time.[1–7] However, emerging evidence shows that older adults' behavioral changes regarding various activities (e.g., exercise, cognitive training) can modulate cognitive health,[16,17] suggesting the need to examine changes in internet usage as well.

Finally, while most studies among older adults show internet usage to be associated with better cognitive health,[1–7] the impact of excessive usage on dementia risk remains unclear. Previously, excessive internet usage has been negatively associated with various neurocognitive outcomes, including reduced verbal intelligence, attention, and deficits in gray and white matter regions.[15,18,19] However, existing evidence on the adverse effects of internet usage is concentrated in younger populations whose brains are still undergoing maturation.

Key points

- Regular internet usage at baseline is associated with approximately half the risk of dementia than non-regular usage.
- Being a regular internet user for longer periods in late adulthood is associated with delayed cognitive impairment.
- We find no evidence that the internet contributed to socioeconomic disparities in the burden of dementia.

Why does this paper matter?

Moderate online engagement in old age may help sustain cognitive function.

This study characterized how internet usage is associated with the prospective risk of dementia in a nationally representative sample of US older-age adults. First, we estimated the risk of dementia associated with whether adults regularly used the internet at the baseline over a maximum of 17.1 (median = 7.9) years, which is, to our knowledge, the longest follow-up period among existing research. Given that cognitively healthier adults are likely to self-select into being a regular user, we used inverse probability of treatment weighting to control for the non-random selection into baseline usage. We also conducted subsample analyses of people without signs of cognitive change at the baseline as another means of adjusting for the risk of reverse causality. Second, we examined how the risk of dementia associated with baseline internet usage varies by educational attainment, race/ethnicity, sex, and generation. Third, we investigated the relationship between cumulative period of internet usage and the risk of dementia to examine the effects of changes in internet usage in late adulthood. Finally, we examined the risk of dementia associated with daily hours of use to examine potential adverse effects of excessive usage. Characterizing modifiable risk factors for dementia, such as internet usage, is a public health priority, given the condition's contribution to morbidity, mortality, caregiver burden, and healthcare costs.[20,21]

METHODS

Data sources

This study used the Health and Retirement Study (HRS),[22–24] an ongoing longitudinal survey of a nationally representative sample of US older-age adults.[25,26] The HRS maintains its representativeness of adults aged 50 or older by adding new, generational cohorts identified based on multistage probability sampling. Underrepresented racial groups and Florida residents were oversampled.[25,26] Recruited respondents were followed biennially until death or attrition through phone or in-person interviews.[26] The interviews asked about demographic characteristics, health, and cognitive performance, among others. See study documentation for details.[25–28]

Study population

The current study examined dementia-free, community-dwelling adults born before 1966 and aged 50 to 64.9 at the baseline who self-completed the baseline cognitive assessments. The HRS asked about internet usage biennially since the 2002 interview, and the baseline for this study was the first interview between years 2002 and 2016 with non-missing information on internet usage. Participants were followed until the 2018 interview or attrition, for a maximum of 17.1 (median = 7.9) years.

Out of 20,241 community-residing, dementia-free adults aged 50–64.9 who participated in at least one interview between 2002 and 2016, 433 individuals were excluded because they did not report internet usage between 2002 and 2016 while satisfying eligibility criteria regarding age, dementia incidence, and community residence. Out of the remaining 19,808 adults, 17 were excluded because they did not reside in the United States and 317 were excluded because they did not self-complete the baseline cognitive assessments. Out of the remaining 19,474, 1320 were excluded due to missing data on the outcome or covariates, leaving the final sample size at 18,154 adults (rate of missing data = 6.8%).

Variables

Outcome

The outcome was incident dementia, identified based on performance in the modified Telephone Interview for Cognitive Status (TICSm), administered biennially. The TICSm includes immediate and delayed word recalls (range: 0–20 points), serial 7 s (0–5 points), and backward counting (0–2 points).[29] We classified individuals who scored less than 7 out of a total score of 27 in any given wave as having incident dementia based on the Langa–Weir Classifications, a widely used method for identifying dementia in HRS participants.[30,31] The Langa–Weir Classifications were validated against dementia diagnoses using more detailed neuropsychiatric measures.[31] In participants who did not self-complete the TICSm, the Langa–Weir Classifications identify dementia cases using proxy-reported items (memory, 0–4 points; limitations in the instrumental activities of daily living, 0–5 points; interviewer-assessments of cognition, 0–2 points). Scoring a total of 6 or higher was defined as dementia (range = 0–11). This study used cognitive status data provided by Langa et al.[24]

The survival times for incident dementia cases equal the midpoint between age at the last dementia-free wave and age at the first wave with dementia.[32,33] Respondents who did not have incident dementia were censored at their age at the last available interview. Also, we treated death without dementia as a competing event. Hence, respondents who did not have dementia based on the Langa–Weir Classifications and then died without being diagnosed with dementia were censored at the age at death. Data on whether a respondent had been diagnosed with dementia before death was collected during post-death interviews with proxies. Of note, few respondents, who remained dementia-free based on the Langa–Weir Classifications until their last biennial interview, were reported to have had dementia in post-death interviews. We treated these respondents as having incident dementia, and their survival times equal the midpoint between age at the last dementia-free biennial wave and the age at death.

Exposures

The exposure was whether a person used the internet regularly at the baseline. During each biennial interview, the HRS asked, "Do you regularly use the World Wide Web, or the Internet, for sending and receiving e-mail or for any other purpose, such as making purchases, searching for information, or making travel reservations?" Participants could answer Yes or No. Based on the baseline response, we classified participants into regular internet users and non-regular users. A dichotomous classification of internet usage is in keeping with prior studies on this topic.[1–3] In addition, this study examined *cumulative internet usage in late adulthood* as an exposure, defined as the number of biennial waves where participants used the internet regularly during the first three waves.

This variable was treated as a continuous variable after finding monotonic trends from preliminary analyses treating it as a categorical variable.

In addition, we examined daily hours of internet usage. Hours of internet usage was collected as part of an off-year survey conducted in a subsample of the HRS participants in 2013. Participants were asked, “Roughly how many hours did you spend using the Internet in the past week for all the activities you just mentioned, except watching TV or movies?” where “activities” may include a wide variety of online engagement including e-mailing, social media, getting news, and shopping. We used self-reported hours to classify time spent online per day into six ordinal categories: 0 h, 0.1–2 h, 2.1–4 h, 4.1–6 h, 6.1–8 h, and more than 8 h.

We also examined whether the association between internet usage and the risk of dementia varied by educational attainment, race-ethnicity, sex, and generational cohort. Educational attainment included less than high school, high school graduate, some college, and college graduate. Race-ethnicity included Hispanic, non-Hispanic White, non-Hispanic Black, and non-Hispanic Other. Birth year-based generational cohorts included: 1931–1941, 1942–1947, 1948–1953, 1954–1959, and 1960–1965.

Covariates

Covariates included baseline TICSm score, self-reported health (excellent, very good, good, fair, poor), age, household income, marital status (married or partnered; separated, divorced, or widowed; never married), and the region of residence (Northeast, Midwest, South, West). Age was modeled using both a linear and a squared term. Baseline household income was classified based on its ratio to the poverty threshold: <1.00; 1.00–1.249; 1.25–1.999; 2.00–3.999; 4.00≤. The analyses also accounted for whether the dementia outcome was identified based on self-completed cognitive assessments (self-completed; proxy, a spouse or partner; proxy, not a spouse or partner) and whether cognitive assessment data were imputed (imputed; not imputed).

Statistical analysis

We first assessed the crude risk of dementia associated with baseline internet usage by plotting cumulative incidence curves for baseline regular and non-regular users in the full analytic sample using a non-parametric approach.[34] The cumulative incidence function uses chronological age as the underlying timescale. It accounted for delayed entry because participants entered the study at baseline age and were required to be dementia-free. In the presence of competing risks, such as a death without dementia, cumulative incidence functions provide more accurate incidence estimates than the Kaplan–Meier estimator.[35] In addition to the full sample, we plotted the cumulative incidence of dementia by baseline internet usage in a subsample of people who remained dementia-free and had not shown signs of cognitive decline 2 years after the baseline, i.e., participants whose TICSm score from 2 years after the baseline is greater or equal to the score obtained at the baseline.

Subsequently, we used cause-specific Cox regression to estimate the difference in time-to-dementia between regular and non-regular internet users, controlling for all covariates in Table 1. In addition to the survey-weighted, non-IPTW model, we used two distinct approaches to reduce the risk of reverse causality. First, we used inverse probability of treatment weights (IPTWs) to account for non-random self-selection into baseline internet usage by balancing regular and non-regular users on the baseline TICSm score and other characteristics. Final weights were generated by multiplying survey weights with IPTWs,[36] and we estimated the average treatment effect (ATE) with non-regular users as the controls. Second, we estimated the association in a subsample without signs of cognitive decline 2 years following baseline, i.e., people whose TICSm score did not decline 2 years after the baseline.

In addition to the main effects of baseline internet usage, we examined its interactions with education, race-ethnicity, sex, and generation using separate cause-specific Cox regression models. We examined the interactive effects without and with adjustments for IPTWs. Furthermore, we conducted three sensitivity tests. Given the debate on the potential limitations of using age as the timescale in Cox models,[37] we conducted sensitivity tests using time-on-study as the timescale instead, adjusting for baseline age as a covariate. We also examined the sensitivity of results to limiting the sample to people younger than 55 and to lagging age at study entry from the baseline by 0 to 8 years in order to check for potential risks of reverse causality.

Finally, we explored variations in the prospective risk of dementia by the degree of usage. First, we examined the association between cumulative waves of regular usage in the first three waves and the risk of dementia. Here, the sample was limited to individuals who remained dementia-free and resided in the community during the first three waves of survey participation and had valid internet usage data for that period ($N = 11{,}801$). Time of entry was participant age at the last of the three waves. Second, we examined the

TABLE 1 Sample characteristics, HRS, US.[a]

	Proportion, %					
			By baseline internet use			
	Full sample (N = 18,154)		Non-regular user (N = 7821)		Regular user (N = 10,333)	
Characteristics	%	N	%	N	%	N
Outcome						
Censored without dementia	87.48	15,344	76.03	5814	93.71	9530
Dementia Incidence	4.68	1183	10.45	959	1.54	224
Death without dementia	7.84	1627	13.52	1048	4.75	579
Baseline internet use						
Non-regular use	35.24	7821	–		–	
Regular use	64.76	10,333	–		–	
Baseline age, median [IQR]	55.17 [53.17–57.25]		55.92 [53.75–59.5]		54.75 [52.83–56.42]	
Baseline TICSm score, median [IQR]	17 [14–19]		15 [13–18]		18 [16–20]	
Gender						
Male	47.36	7758	49.44	3400	46.23	4358
Female	52.64	10,396	50.56	4421	53.77	5975
Race-ethnicity						
Non-Hispanic White	72.89	10,543	59.18	3542	80.35	7001
Non-Hispanic Black	11.61	3984	18.06	2189	8.10	1795
Hispanic	10.20	2794	18.05	1777	5.93	1017
Non-Hispanic other	5.30	833	4.72	313	5.62	520
Generational cohort						
1931–1941	9.16	2952	15.67	1872	5.61	1080
1942–1947	17.88	2855	24.88	1458	14.07	1397
1948–1953	26.12	4271	28.43	1898	24.86	2373
1954–1959	25.49	4577	19.11	1644	28.97	2933
1960–1965	21.35	3499	11.91	949	26.49	2550
Educational attainment						
No high school diploma	11.23	2840	26.32	2434	3.01	406
High school graduate	30.77	5850	42.27	3164	24.51	2686
Some college	28.78	5073	22.21	1612	32.36	3461
College graduate	29.22	4391	9.20	611	40.12	3780
Marital status						
Married/partnered	72.08	12,602	64.36	4988	76.28	7614
Separated/divorced/widowed	20.70	4265	26.70	2182	17.44	2083
Never married	7.21	1287	8.94	651	6.28	636
Ratio, household income to poverty threshold						
<100%	10.23	2534	19.92	1802	4.96	732
100%–124.9%	2.88	685	5.19	469	1.62	216
125%–199.9%	8.45	1918	13.62	1174	5.63	744
200%–399.9%	23.13	4460	28.88	2203	20.00	2257
>400%	55.31	8557	32.38	2173	67.79	6384

(Continues)

TABLE 1 (Continued)

Characteristics	Proportion, %					
			By baseline internet use			
	Full sample (*N* = 18,154)		Non-regular user (*N* = 7821)		Regular user (*N* = 10,333)	
	%	*N*	%	*N*	%	*N*
Self-reported health						
Excellent	15.36	2469	9.87	715	18.35	1754
Very good	31.94	5164	22.26	1570	37.21	3594
Good	29.37	5517	30.78	2432	28.60	3085
Fair	16.67	3641	25.64	2205	11.79	1436
Poor/negative	6.65	1363	11.45	899	4.04	464
Region of residence						
Northeast	17.09	2774	15.67	1185	17.86	1589
Midwest	23.79	3818	23.20	1579	24.10	2239
South	37.84	7687	43.36	3640	34.84	4047
West	21.28	3875	17.77	1417	23.19	2458
Time on study, median [IQR]	7.92 [2.66–13.83]		8.25 [4.42–14.08]		7.75 [2.25–13.75]	
Proxy						
Proxy, spouse or partner	6.11	1153	8.59	638	4.76	515
Proxy, not spouse or partner	4.41	981	8.81	710	2.02	271
Self-reported	89.48	16,020	82.60	6473	93.22	9547
Imputation status of dementia outcome						
Not imputed	97.44	17,629	96.25	7531	98.09	10,098
Imputed	2.56	525	3.75	290	1.91	235

[a]Adjusted for survey design and weighted to approximate the US population.

association between daily hours of internet usage and the risk of dementia. Here, the sample was limited to individuals who remained dementia-free until 2012 based on the TICSm because the information on daily hours of usage was obtained in 2013 (N = 4070). Time of entry was participant age when they completed the off-year survey on daily hours of usage in 2013. These associations were examined using separate cause-specific Cox regression models with and without IPTW adjustments. All Cox regression models in this study used chronological age as the underlying timescale while accounting for delayed entry.

We graphically assessed the proportionality of relative hazard associated with internet usage in Cox models using Schoenfeld residuals. All analyses were adjusted for survey design and conducted in STATA/MP, v17.0 (StataCorp LP, College Station, TX). This project included the secondary analyses of already-collected, publicly available, de-identified data classified as non-human subjects research by the IRB at New York University. Analyses were conducted from September 2021 to November 2022.

RESULTS

Table 1 shows the weighted characteristics of the sample. Baseline regular internet users accounted for 64.76% and non-regular users for 35.24%. In the full sample, 20.54% showed changes in internet usage from their baseline before the end of the study, while 52.96% did not show changes in usage. The remaining 26.50% provided only one wave of data before being censored, or dementia incidence, and whether they changed internet usage could not be observed. Among baseline regular internet users, 13.19% of adults reported not using the internet regularly for at least one of the subsequent waves, while 34.05% of baseline non-regular users reported using the internet regularly during at least one of the following waves. Furthermore, the overall rate of incident dementia

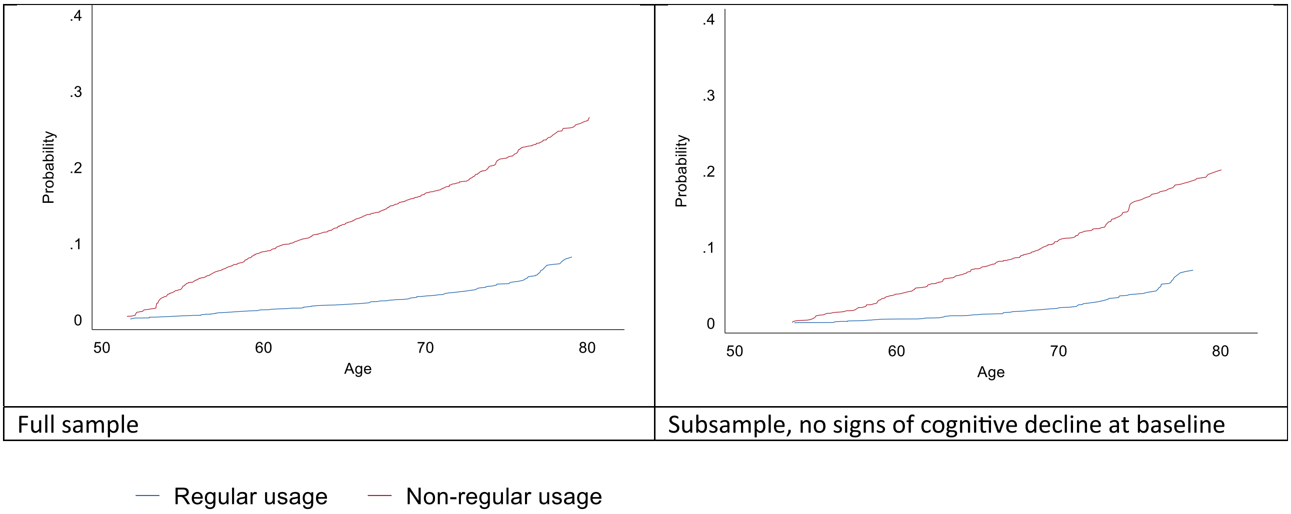

FIGURE 1 Cumulative incidence of dementia by baseline internet usage, HRS, US.

TABLE 2 Risk of dementia and baseline regular internet use, Health and Retirement Study, US.

		Adjusted risk of dementia Adjusted	
Model	**Exposure**	**CHR**	**95% CI**
Non-IPTW ($N = 18{,}154$)[a]	Non-regular	Ref	
	Regular	0.57	[0.46-0.71]
IPTW ($N = 18{,}154$)[b]	Non-regular	Ref	
	Regular	0.54	[0.41-0.72]
No cognitive decline at baseline ($N = 7457$)[c]	Non-regular	Ref	
	Regular	0.62	[0.46-0.85]

Abbreviations: 95% CI, 95% confidence interval; CHR, cause-specific hazard ratio.
[a]The model accounted for all the baseline and outcome-related characteristics shown in Table 1.
[b]The model accounted for all the baseline variables. We did not adjust for post-treatment variables (i.e., proxy-report status and imputation status of the outcome) in the models adjusting for IPTW because adjusting for post-treatment characteristics may increase the risks of bias.
[c]When the sample was limited to people without cognitive decline at baseline, no one in the youngest cohort (1960–1965) had incident dementia. Therefore, the cohort was excluded from this subsample analysis.

during the study period was 4.68%, 87.48% were censored without dementia, and 7.84% experienced a competing event, i.e., death without dementia. Baseline regular internet users had a lower prospective risk of dementia (1.54%) than non-regular users (10.45%), difference = 8.90%, 95% CI = 7.96%–9.84%. Figure 1 provides graphic descriptions of how regular users show a lower cumulative incidence of dementia than non-regular users at a given age in the full analytic sample and the sample without signs of cognitive decline.

Table 2 shows differences in time-to-dementia associated by baseline internet usage obtained from cause-specific Cox proportional hazards models with adjustments for all covariates listed in Table 1. In the non-IPTW model (weighted using survey weights only), the risk of dementia associated with regular internet usage is 0.57% of its counterpart found in non-regular users (cause-specific hazard ratio [CHR] = 0.57, 95% CI = 0.46–0.71). This association holds in the IPTW-adjusted model which accounts for non-random self-selection into baseline internet usage (CHR = 0.54, 95% CI = 0.41–0.72) and limiting the sample to adults without signs of cognitive decline at baseline (CHR = 0.62, 95% CI = 0.46–0.85). Sensitivity tests that used time-on-study as the timescale instead of age; limited the sample to people younger than 55; and used different lag times for study entry yielded estimates and conclusions comparable to the main analyses. See Figure S1 for evidence of covariate balance after the application of IPTW.

TABLE 3 Risk of dementia and baseline regular internet use within different sociodemographic categories, Health and Retirement Study, US.

	The risk of dementia			
	Non-IPTW ($N = 18{,}154$)[a]		IPTW ($N = 18{,}154$)[b]	
Demographic characteristics	**CHR**	**95% CI**	**CHR**	**95% CI**
Educational attainment[c]				
No high school diploma	0.79	[0.42–1.50]	0.65	[0.33–1.29]
High school graduate	0.52	[0.37–0.74]	0.51	[0.36–0.71]
Some college	0.63	[0.45–0.88]	0.60	[0.42–0.86]
College graduate	0.41	[0.23–0.75]	0.33	[0.16–0.67]
Race-ethnicity[c,d]				
Non-Hispanic White	0.54	[0.40–0.72]	0.64	[0.44–0.91]
Non-Hispanic Black	0.51	[0.35–0.76]	0.40	[0.20–0.79]
Hispanic	0.55	[0.29–1.04]	0.28	[0.12–0.64]
Sex[c]				
Male	0.49	[0.38–0.64]	0.55	[0.36–0.84]
Female	0.64	[0.49–0.85]	0.53	[0.38–0.75]
Generational cohort[c]				
1931–1941	0.74	[0.52–1.05]	0.51	[0.34–0.77]
1942–1947	0.75	[0.49–1.15]	0.60	[0.37–0.97]
1948–1953	0.48	[0.34–0.68]	0.51	[0.30–0.86]
1954–1959	0.44	[0.25–0.79]	0.60	[0.31–1.15]
1960–1965	0.41	[0.18–0.93]	0.46	[0.16–1.34]

Abbreviations: 95% CI, 95% confidence interval; CHR, cause-specific hazard ratio.
[a]The models accounted for all the baseline and outcome-related characteristics shown in Table 1.
[b]IPTW models accounted for all baseline variables. They did not control for post-treatment variables including imputation status and proxy-report status.
[c]All pairwise comparisons between the sociodemographic categories listed above were considered and none was statistically significant at the $p = 0.05$ level in both Non-IPTW and IPTW models.
[d]Non-Hispanic Other was included as one of the categories of race-ethnicity.

TABLE 4 Different aspects of internet usage and the risk of dementia, HRS, US.

	Risk of dementia			
	Non-IPTW[a]		IPTW[b]	
Measures of internet usage	**HR**	**95% CI**	**HR**	**95% CI**
Cumulative internet usage ($N = 11{,}801$)				
One wave of regular usage	0.79	[0.71–0.87]	0.80	[0.68–0.95]
Hours of internet use/day ($N = 4070$)[c,d]				
0 h	2.17	[0.83–5.65]	1.67	[0.62–4.48]
0.1–2 h	Ref		Ref	
2.1–4 h	1.31	[0.59–2.91]	1.44	[0.65–3.19]
4.1–6 h	1.28	[0.41–4.00]	1.77	[0.54–5.80]
6.1–8 h	2.02	[0.23–17.73]	2.21	[0.83–5.90]

[a]The models accounted for all the baseline and outcome-related characteristics shown in Table 1.
[b]IPTW models accounted for all the baseline variables. They did not adjust for post-treatment variables including imputation status and proxy-report status.
[c]The risk of dementia associated with more than 8 hours of usage could not be estimated because the group included a small number of people without dementia incidence within the study period.
[d]Instead of baseline cognitive performance, these models accounted for cognitive performance in 2012, the closest preceding cognitive assessment before the HRS asked about the hours of usage in 2013. It also controlled for baseline income using a continuous variable due to very small sample sizes of some income categories.

Table 3 shows variations in the cause-specific hazard of dementia associated with baseline internet usage within groups divided by educational attainment, race-ethnicity, sex, and generation, controlling for covariates listed in Table 1. In the non-IPTW models, the association between regular usage and the risk of dementia did not vary significantly by educational attainment, race-ethnicity, sex, or generational cohort. Within each socio-demographic axis, all pairwise comparisons between categories were examined. Variations in the association by the sociodemographic characteristics were also not significant in the IPTW adjusted models.

Finally, Table 4 shows the risk of dementia associated with cumulative internet usage and daily hours of internet usage in late adulthood. Each additional wave of regular internet usage was associated with a 21% decrease in the risk of dementia, 95% CI = 13%–29%. After an adjustment for IPTWs, this estimate decreased to 20% and remained statistically significant, 95% CI = 5%–32%. The estimated association between daily hours of usage and dementia risk showed a U-shaped relationship both before and after the IPTW adjustment, where adults with 0.1–2 h of usage appeared to experience the lowest risk and relative to whom adults with 0 h of usage had a notably higher estimated risk of dementia. In the IPTW model, the risk increased in a monotonic fashion after 2 h, with 6.1 to 8 h of usage showing the highest estimated risk. Sensitivity tests using covariates from year 2012 instead of those from the baseline also showed a preliminary indication for a U-shaped relationship. Statistical significance was not obtained for any of the estimates, perhaps, due to the much smaller sample size that was used for these analyses.

DISCUSSION

The "digital divide" refers to disparities in various realms of life between internet users and non-users.[38] Our findings show evidence of a digital divide in the cognitive health of older-age adults. Specifically, adults who regularly used the internet experienced approximately half the risk of dementia than adults who did not, adjusting for baseline cognitive function, self-selection into baseline internet usage, self-reported health, and a large number of demographic characteristics. In addition to baseline usage, we examined cumulative internet usage and found an additional wave of regular internet usage to be associated with reduced dementia risk, suggesting that changes in internet usage in late adulthood may modulate subsequent cognitive health. Thus far, research on digital divide in cognitive health has been limited to cross-sectional or longitudinal examinations with short follow-ups, and studies have only considered baseline internet usage. We fill these gaps by characterizing the relationship between the risk of dementia and baseline internet usage over a much longer period and also examining whether changes in usage are associated with subsequent cognitive performance. Taken together, these findings suggest that regularly using the internet may be associated with cognitive longevity. Nonetheless, various intervention studies have reported mixed findings[16,39,40] and further research is needed to clarify how long a person needs to be a regular user during late adulthood to experience the cognitive benefits online engagement.

Moreover, we found daily hours of online engagement to have a U-shaped association with the risk of dementia. Although we did not see statistical significance due to a small sample size, the consistent U-shaped trend offers a preliminary suggestion that excessive online engagement may have adverse cognitive effects on older adults. Previous research on the adverse consequences of internet overuse had been focused on younger populations. Future research may further consider potential underlying mechanisms. For example, excessive online engagement may lead to reduced opportunities for in-person social interactions and disengagements from the real-world in favor of virtual settings, which may in turn adversely affect cognitive health.[18,19]

Finally, we examined whether the internet has exacerbated population-level disparities in the burden of dementia, another area left unexamined by prior research. The estimated cognitive benefit associated with regular internet usage did not show statistically significant variations by race-ethnicity, educational attainment, sex, and generational cohort in models without and with adjustments for non-random self-selection into baseline usage. Therefore, we did not find evidence that the internet has exacerbated socioeconomic disparities in the burden of dementia.

This study is not without its limitations. First, the Langa–Weir Classifications may not show complete concordance with the clinical diagnoses of dementia, as noted previously.[30,31] Nonetheless, Langa–Weir is a widely used and validated method for identifying dementia in the HRS.[30,31] Future studies may consider the association between internet usage and clinical dementia diagnoses. Second, this study examined dementia-free adults at baseline, which may have biased the estimates by precluding individuals with early-onset dementia. However, early-onset dementia is very rare for people younger than 65, and we conducted subsample analyses that limited the sample to respondents without signs of cognitive decline. We found regular internet usage to be associated with reduced risks of dementia in this subsample, suggesting that any bias potentially introduced by excluding individuals with dementia at the baseline is likely to be minimal. Third, while this study focused on internet usage and prospective dementia risk and utilized multiple strategies to reduce the potential influence of reverse causality, it should be noted that cognitive health is likely to have a bidirectional relationship with internet usage.[1] Fourth, the measures of internet usage examined in this study do not distinguish between different online activities. Fifth, residual differences in baseline cognitive reserve may have biased our findings. However, we control for baseline cognitive performance along with multiple characteristics associated with cognitive reserve (i.e., income, marital status, health, and education).

CONCLUSIONS

A digital divide may exist in the cognitive health of US older-age adults. Regular internet users experienced approximately half the risk of dementia compared to non-regular users. Moreover, longer periods of regular internet usage in late adulthood were associated with lower risks of subsequent dementia incidence. Nonetheless, using the internet excessively may negatively affect the risk of dementia in older adults. Since a person's online engagement may include a wide range of activities, future research may identify different patterns of internet usage associated with the cognitively healthy lifespan while being mindful of the potential side effects of excessive usage.

AUTHOR CONTRIBUTIONS

Gawon Cho developed the research question, developed analytical plans, analyzed data, and wrote the first and multiple subsequent drafts of this manuscript. Rebecca Betensky developed analytical plans, oversaw the use of statistical methods, and contributed to writing this manuscript. Virginia Chang developed the research question, developed analytical plans, wrote multiple drafts of this manuscript, and supervised Gawon Cho's work.

CONFLICT OF INTEREST STATEMENT

Gawon Cho, Rebecca Betensky, and Virginia Chang do not have any conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Figure S1: Evidence of improved balance after applying IPTWs, HRS.

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