Does Internet use help suppress the Higher-Level Functional Capacity decline among Japanese older adults with low education? JAGES 2016–2019 Longitudinal Study

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Abstract

Background: Higher-Level Functional Capacity (HLFC) is important for independent living among older adults. Internet use has a positive impact on older adults' health, but its impact on HLFC and the difference in this impact based on educational attainment is unclear.

Objective: This longitudinal study aimed to examine whether Internet use can suppress the risk of decline in HLFC and whether this effect could be obtained even for older adults with low educational levels.

Methods: Data were obtained from the Japan Gerontological Evaluation Study (JAGES), which included 8,050 community-dwelling adults aged ?65 years from 2016 to 2019. To focus on older adults who maintained independence from 2016 to 2019, the final participants in this analysis were older adults with independent HLFC in 2016. The Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) was used to operationally define and HLFC, which consists of three subscales: instrumental activities of daily living (IADL), intellectual activity, and social role. The independent variable was defined as the frequency of Internet use in 2016; those who used the Internet more than once a month were categorized as Internet users, and the others were categorized as Internet non-users. The suppression effects of Internet use on HLFC decline were compared by stratified educational attainments of ?9 years, 10–12 years, and ?13 years. Poisson regression analysis corrected for robust standard error was used for statistical analysis to calculate the risk ratio (RR) and 95% confidence interval (CI) for HLFC decline in 2019.

Results: Adjusted for demographic and health condition risk factors, Internet use was significantly associated with suppressing the declining risk in HLFC of older adults after three years, even for those with low education. Internet users with ?9 years of educational attainment had a suppression of decline in the total score (RR[CI] 0.57 [0.43–0.76]), IADL (0.58 [0.38–0.91]), intellectual activity (0.60 [0.41–0.89]), and social role (0.74 [0.56–0.97]) compared to non-users. Similarly, those with 10–12 years had (0.78 [0.63–0.98]), (0.59 [0.39–0.90]), (0.91 [0.63–1.31]), (0.82 [0.68–0.9998]) respectively, and those with ?13 years had (0.65 [0.51–0.85]), (0.55 [0.36–0.83]), (0.64 [0.37–1.10]), and (0.83 [0.64–1.08]) respectively.

Conclusions: The study suggests that Internet use can help maintain independence of HLFC not only among older adults with high education but also among those with low education. Future policies promoting Internet utilization among older adults with low education will contribute to the reduction of functional health disparities due to educational attainment.

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levels.
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Conclusions: The study suggests that Internet use can help maintain independence of HLFC not only among older adults with high education but also among those with low education. Future policies promoting Internet utilization among older adults with low education will contribute to the reduction of functional health disparities due to educational attainment.

Keywords: Functional Capacity; instrumental activities of daily living; intellectual activity; social role; Internet; educational attainment; low education; independent living; older adults; health disparities

Introduction

Maintaining higher-level functional capacity in older adults is needed for their independent living

The World Health Organization Scientific Group on the Epidemiology of Aging has proposed that autonomy or independence in life functioning could be used as a health index for older adults [1]. In Japan, more than 70% of older adults want to continue living in familiar areas and at home; even if they need nursing care, they want to receive nursing care services at home [2]. The Ministry of Health, Labour and Welfare is currently promoting the establishment of a comprehensive community support and service provision system (The Community-based Integrated Care System) aimed at maintaining older adults' dignity and supporting their independent living in their local areas throughout their lives [3]. However, even under this system, the restriction period for daily life, which is the difference between the average life expectancy and healthy life expectancy, is 8.7 years for men and 12.1 years for women [4].

Lawton [5] proposed a seven-level hierarchical model of life functions for older adults: 1. life maintenance, 2. functional health, 3. perception and cognition, 4. physical self-maintenance, and 5.

instrumental self-maintenance, 6. effectance, and 7. social role, in ascending order of complexity. Of these, “instrumental self-maintenance (instrumental activities of daily living; IADL)” refers to the ability to maintain one's life alone at home, “effectance” refers to intellectual activity such as leisure activities and creativity, and “social role” refers to the ability to interact with people intimately in society. Physical self-maintenance (Basic Activities of Daily Living; BADL), such as eating and excretion, is important to continue living an independent life for as long as possible. An analysis of a nationally representative sample in Japan showed that most older adults living in the community had good functional capacity (IADL, intellectual activity, social role), but the capacity tended to decline with age [6] and usually deteriorated before declines in BADL [7]. In addition, other studies reported that older adults aged ≥65 years had gradual worsening of their Higher-Level Functional Capacity (HLFC) (IADL, intellectual activity, social role) after retirement [8] and that HLFC was associated with mortality and medical and long-term care costs [9, 10]. Therefore, HLFC could be a modifiable health factor for older adults to maintain independent living. Thus, preventing the loss of HLFC is critical to maintaining healthy, independent living for older adults.

It is necessary to consider the impact of educational disparities on maintaining HLFC in all older adults

The capacities of older adults are likely underpinned by the cumulative impact of health inequalities in environments skewed by factors such as gender and education level across life courses [11]. A longitudinal study in Japan reported that HLFC was significantly associated with educational attainment [6], while other studies reported that IADL was particularly poor in older adults with low education [12-15]. Therefore, to support independent living for all older adults, it is necessary to present improvement measures to suppress the decline in HLFC, including IADL, regardless of educational attainment. However, useful measures have not yet been established to determine how independent older adults can slow the decline in HLFC. Moreover, few effective improvement measures focus on the HLFC of older adults with low levels of education.

The Internet may have a positive effect on the HLFC of older adults

In Japan, the number of older adults using the Internet in the past year has increased by 10.5 points among those aged 60–69 years, by 12.7 points among those aged 70–79 years, and by 7.5 points among those aged 80 years and over compared to four years ago [16]. Information and communication technology (ICT) is spreading among older adults not only in Japan but also in other countries [17] and has been confirmed to have many health improvement effects [18-39]. Few studies have examined the relationship between Internet use and HLFC. Digital illiteracy, evaluated by lack of education, is one of the main determinants of the digital divide, especially among older individuals [40]. Thus, the Internet may be less effective for older adults with low educational attainment. However, from the viewpoint of correcting health disparities, it is necessary to confirm the existence of the Internet’s effect on preventing the loss of HLFC in older adults with low education.

Aims of the present study

To enable all older adults, regardless of their educational attainment, to maintain independent living, it is necessary to verify whether Internet use has the effect of suppressing the decline risk in HLFC and whether the effect could be obtained even for older adults with low education. To date, no study has compared the relationship between Internet use and HLFC through stratified educational attainment. This study aimed to examine whether Internet use could suppress the risk of HLFC decline even for older adults with low education, with three subscales including “IADL,” “intellectual activity,” and “social role,” by stratifying older adults aged ≥65 years by their educational attainment.

Methods

Design, Setting, and Study participants

We obtained data from the Japan Gerontological Evaluation Study (JAGES), which repeated every 3-year community-based survey and followed up with older adults in Japan [41]. We used longitudinal panel data from two surveys conducted in 2016 and 2019. The baseline survey was conducted between September 2016 and January 2017, and self-reported questionnaires were mailed to 34,571 independent community-dwelling individuals aged ≥65 years. A total of 24,313 people responded to the survey (response rate: 70.3%).

The follow-up survey was conducted between November 2019 and January 2020. Of the 24,313 baseline respondents, 8077 replied to the follow-up survey questionnaire (response rate: 33.2%). We excluded 27 responses because their age (n=26) and sex (n=1) information did not match between the baseline and follow-up surveys. The total number of intermediate participants was 8050. Furthermore, to focus on older adults who maintained their independence in 2016, the final participants in this analysis were narrowed down to older adults with independent HLFC (total score of three subscales, IADL, intellectual activity, and social role) in 2016, and those who did not meet the points of independent HLFC in 2016 were excluded; thus, our final analytic sample consisted of 4887 individuals in total score, 7270 individuals in IADL, 7144 individuals in intellectual activity, and 5970 individuals in social role. A flowchart of the participant selection process is shown in Figure 1.

Outcome variable: Higher-Level Functional Capacity (HLFC)

HLFC was evaluated using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) [7], based on the Lawton Instrumental Activities of Daily Living Scale. This 13-item index consists of three subscales of competence with yes/no responses. (1) IADL (five items: the ability to go out by train or bus, shop for daily necessities, cook, pay bills, and handle a bank/postal savings account); (2) intellectual activity (four items: the ability to complete paperwork, read newspapers, read books, or magazines, and interest in health-related articles or TV programs); and (3) social role (four items: the ability to visit friends' homes, give advice to family members or friends, visit people who have fallen ill, and start conversations with young people) (Table S1 in Multimedia Appendix 1). The validity and reliability of the index have been confirmed, and it is widely used. The score of each subscale was calculated by summing the answers (yes = 1, no = 0), with a higher score indicating better ability. The maximum total score, IADL, intellectual activity, and social role were 13, 5, 4, and 4 points, respectively. Referring to a previous report [42, 43], we defined a decline in HLFC as follows: 1) a decrease of ≥2 points in the total score, 2) a decrease of ≥1 point in the score for IADL, 3) a decrease of ≥2 points in the score for intellectual activity, and 4) a decrease of ≥2 points in the score for social role. Thus, we regarded participants with a high total score (12 or 13 points), IADL (5 points), intellectual activity (3 or 4 points), and social role (3 or 4 points) as having an intact HLFC. In this study, we regarded intact HLFC as "independent" and HLFC decline as "dependent."

Explanatory variable (1): Internet use

The frequency of Internet use in 2016 was used as the Internet use variable. The question about Internet use was as follows: Have you used the Internet or e-mails in the past year? If yes, please indicate the frequency. The response items were as follows: 1. No, 2. Yes (less than a few times a month); 3. Yes (two to three times a week); and 4. Yes (almost every day). Those who used the Internet more than once a month were categorized as Internet users, and the response "1. No" was

categorized as Internet non-users.

Explanatory variable (2): Educational attainment

Educational attainment was measured as completed years of schooling (≤9, 10–12, and ≥13 years).

Covariates

Sex, age (65–69/70–74/75–79/80–84/85+), annual household equivalized income (3-quantiles; low/middle/high), employment status (never employed, retired/not employed, and employed), marital status (married, widowed, divorced, never-married, and others), living arrangement (living with someone, living alone), self-rated health (good, poor), body mass index (<18.5/18.5–25/25–30/>30), diseases under treatment (self-reported medical conditions; hypertension, diabetes mellitus, stroke, cardiac diseases, cancer, and respiratory diseases) (no, yes), depression (no, yes) [9, 10, 44], and population density (metropolitan, urban, semi-urban, rural) were used as covariates. We used the 15-item Geriatric Depression Scale, which defines mild depression as >5 points and severe depression as >10 points. To maximize the use of depression data, we included individuals with up to two missing items in their responses. We replaced the missing values with the mean of the respondents' answers to the items. Regarding population density, for each municipality, we divided the population by the habitable land area and calculated the number of residents per km^2 per unit area. Based on the population density of the habitable area, we classified each municipality into four categories: metropolitan (≥ 4,000/km^2), urban (1,500–3,999/km^2), semi-urban (1,000–1,499/km^2), and rural (< 1,000 /km^2). Missing data were categorized into missing groups for each variable except for sex, age, and population density.

Statistical analysis

A descriptive analysis presented the characteristics of the study participants regarding Internet users and non-users, Internet use and HLFC, and educational attainment and HLFC. In addition to the missing items in the 2019 HLFC variable, missing items and other items in the educational attainment variable were excluded from the verification targets. We used Poisson regression analysis corrected for robust standard error to calculate the risk ratio (RR) and 95% confidence interval (CI) for HLFC decline in 2019. To verify the differences in educational attainment in the association between Internet use and HLFC decline, stratified analyses by educational attainment were performed. All covariates were added simultaneously, and the RR was calculated. Significance tests were conducted for each main effect and interaction. Statistical significance was set at P<.05 and was significant. Statistical analyses were conducted using Stata SE/15.0 (Stata Corp, College Station, TX, USA).

Results

Characteristics of participants

Table 1 shows the baseline characteristics of Internet users and non-users in 2016. Internet users decreased with increasing age and decreasing educational attainment. Cross-tables comparing Internet use or educational attainment and HLFC are shown in Table 2, Table 3, and Table S2 in Multimedia Appendix 1. Older adults using the Internet had a higher proportion of independence across all subscales, including total score, IADL, intellectual activity, and social role, than those not using the Internet (Table 2). The lower the educational attainment, the fewer older adults with independence in the total score and all subscales (Table 3). Moreover, of all subscales, the independence of older adults in social roles was the lowest. Additionally, the relationships tended to be similar for each answer to the TMIG-IC 13 questions (Table S3 in Multimedia Appendix 1). The baseline characteristics of participants by educational attainment in 2016 showed that the older the

participants, the more they had 9 years or less of educational attainment and the fewer they had 10–12 or 13 years or more of educational attainment (Table S4 in Multimedia Appendix 1)

Table 1. Characteristics of study participants by Internet use in 2016 (N=8050)[a]

Variables	Internet use (2016)		*P* value
	Yes (n=4336)	No (n=3190)	
Sex, n (%)			.005
Male	2116 (55.9)	1452 (38.4)	
Female	2220 (52.0)	1738 (40.7)	
Age (years), n (%)			<.001
65–69	1824 (69.9)	672 (25.8)	
70–74	1357 (58.1)	834 (35.7)	
75–79	771 (41.7)	928 (50.2)	
80–84	318 (33.9)	541 (57.7)	
85+	66 (20.6)	215 (67.2)	
Income (3-quantiles), n (%)			<.001
Q1 (Low)	990 (42.4)	1189 (50.9)	
Q2 (Middle)	1353 (61.9)	726 (33.2)	
Q3 (High)	1441 (69.2)	552 (26.5)	
Missing	552 (38.2)	723 (50.0)	
Educational attainment (years), n (%)			<.001
≤9	631 (29.8)	1288 (60.7)	
10–12	1956 (56.6)	1298 (37.6)	
≥13	1721 (72.3)	559 (23.5)	
Other	11 (36.7)	16 (53.3)	
Missing	17 (27.4)	29 (46.8)	
Employment status, n (%)			<.001
Never	171 (38.4)	244 (54.8)	
Past worker	2430 (56.6)	1643 (38.3)	
Current worker	1270 (60.7)	705 (33.7)	
Missing	465 (38.1)	598 (49.0)	
Marital status, n (%)			<.001
Married	3409 (57.1)	2227 (37.3)	
Widowed	596 (43.6)	651 (47.7)	
Separated	177 (55.0)	126 (39.1)	

Unmarried	116 (45.7)	119 (46.9)	
Others	22 (37.3)	26 (44.1)	
Missing	16 (21.6)	41 (55.4)	
Living arrangement, n (%)			<.001
Living with others	3610 (55.5)	2500 (38.5)	
Living alone	580 (49.1)	515 (43.6)	
Missing	146 (39.9)	175 (47.8)	
Self-rated health, n (%)			<.001
Good	3902 (55.7)	2661 (38.0)	
Bad	353 (41.3)	439 (51.4)	
Missing	81 (41.5)	90 (46.2)	
Body Mass Index (Kg/cm^2), n (%)			<.001
<18.5	255 (50.0)	220 (43.1)	
18.5–25	3161 (55.6)	2174 (38.3)	
25–30	803 (51.6)	639 (41.0)	
>30	80 (49.4)	73 (45.1)	
Missing	37 (26.6)	84 (60.4)	
Diseases under treatment, n (%)			.003
No	1826 (56.2)	1232 (37.9)	
Yes	2319 (52.6)	1801 (40.8)	
Missing	191 (49.6)	157 (40.5)	
Depression, n (%)			<.001
No	3541 (57.0)	2311 (37.2)	
Yes	631 (42.9)	732 (49.7)	
Missing	164 (45.1)	147 (40.4)	
Population density, n (%)			
Metropolitan	2184 (61.6)	1196 (33.7)	<.001
Urban	1286 (54.7)	910 (38.7)	
Semi-Urban	503 (48.6)	457 (44.1)	
Rural	363 (32.4)	627 (56.0)	

[a] Those with missing values for Internet use in 2016 were omitted (n=524).

Table 2. Higher-Level Functional Capacity[a] of independent and dependent individuals by Internet use in 2016

	Total score[b] n=7455			IADL[b,d] n=7853			Intellectual activity[b] n=7780			Social role[b] n=7721		
	Independent[c] (4887)	Dependent (2568)		Independent[c] (7270)	Dependent (583)		Independent[c] (7144)	Dependent (636)		Independent[c] (5970)	Dependent (1751)	
2016 Internet use	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value
Yes	2953 (68.1)	1172 (27.0)	<.001	4063 (93.7)	201 (4.6)	<.001	4019 (92.7)	225 (5.2)	<.001	3459 (79.8)	752 (17.3)	<.001
No	1644 (51.5)	1235 (38.7)		2749 (86.2)	340 (10.7)		2683 (84.1)	367 (11.5)		2147 (67.3)	884 (27.7)	
Missing	290 (55.3)	161 (30.7)		458 (87.4)	42 (8.0)		442 (84.4)	44 (8.4)		364 (69.5)	115 (21.9)	

[a] Higher-Level Functional Capacity (HLFC) comprises three subscales: IADL, Intellectual activity, and Social role. The total scores on the three subscales were also calculated.
[b] Missing values were omitted for the Total score and three subscales.
[c] Cut-off values for "independent" in Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC): "Total score 12–13/13 points", "IADL 5/5 points", "Intellectual activity 3–4/4 points", "Social role 3–4/4 points"[42,43].
[d] IADL: instrumental activities of daily living

Table 3. Higher-Level Functional Capacity[a] of independent and dependent individuals by educational attainment in 2016

2016 Educational attainment (years)	Total score[b] n=7455			IADL[b,d] n=7853			Intellectual activity[b] n=7780			Social role[b] n=7721		
	Independent[c] (4887)	Dependent (2568)		Independent[c] (7270)	Dependent (583)		Independent[c] (7144)	Dependent (636)		Independent[c] (5970)	Dependent (1751)	
	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value	n (%)	n (%)	*p* value
≤ 9	1081 (51.0)	818 (38.6)	<.001	1838 (86.7)	210 (9.9)	<.001	1734 (81.8)	282 (13.3)	<.001	1481 (69.8)	530 (25.0)	<.001
10–12	2206 (63.8)	1005 (29.1)		3172 (91.8)	207 (6.0)		3129 (90.5)	218 (6.3)		2620 (75.8)	700 (20.3)	
≥ 13	1559 (65.5)	714 (30.0)		2188 (91.9)	154 (6.5)		2215 (93.0)	124 (5.2)		1812 (76.1)	500 (21.0)	
Others	14 (46.7)	12 (40.0)		25 (83.3)	4 (13.3)		23 (76.7)	4 (13.3)		20 (66.7)	7 (23.3)	
Missing	27 (43.6)	19 (30.7)		47 (75.8)	8 (12.9)		43 (69.4)	8 (12.9)		37 (59.7)	14 (22.6)	

[a] Higher-Level Functional Capacity (HLFC) comprises three subscales: IADL, Intellectual activity, and Social role. The total scores on the three subscales were also calculated.

[b] Missing values were omitted for the Total score and three subscales.

[c] Cut-off values for "independent" in Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC): "Total score 12–13/13 points", "IADL 5/5 points", "Intellectual activity 3–4/4 points", "Social role 3–4/4 points"[42,43].

[d] IADL: instrumental activities of daily living

Table 4. Associations between Internet use in 2016[a] and suppression of Higher-Level Functional Capacity decline in 2019[b] with educational attainment

	Total score		IADL[c]		Intellectual activity		Social role	
	RR[d] (95%CI)	*P* value	RR (95%CI)	*P* value	RR (95%CI)	*P* value	RR (95%CI)	*P* value
≤ 9[e]	(n=928)		(n=1,757)		(n=1,619)		(n=1,353)	
Internet use No	Reference		Reference		Reference		Reference	
Yes	0.57 (0.43–0.76)	<.001	0.58 (0.38–0.91)	.02	0.60 (0.41–0.89)	.01	0.74 (0.56–0.97)	.03
Missing	0.95 (0.68–1.32)	.75	0.87 (0.52–1.46)	.60	0.76 (0.47–1.22)	.25	0.68 (0.47–0.98)	.04
10–12	(n=2,077)		(n=3,095)		(n=3,018)		(n=2,531)	
Internet use No	Reference		Reference		Reference		Reference	
Yes	0.78 (0.63–0.98)	.03	0.59 (0.39–0.90)	.01	0.91 (0.63–1.31)	.61	0.82 (0.68–0.9998)	.05
Missing	0.83 (0.59–1.17)	.28	0.71 (0.34–1.52)	.38	0.29 (0.07–1.24)	.10	0.71 (0.48–1.05)	.09
≥ 13	(n=1,486)		(n=2,141)		(n=2,163)		(n=1,755)	
Internet use No	Reference		Reference		Reference		Reference	
Yes	0.65 (0.51–0.85)	.001	0.55 (0.36–0.83)	.01	0.64 (0.37–1.10)	.11	0.83 (0.64–1.08)	.17
Missing	0.89 (0.50–1.58)	.69	0.62 (0.28–1.37)	.24	0.95 (0.34–2.65)	.93	1.15 (0.59–2.21)	.68

[a] Study participants were older adults with “independent” total score, IADL, intellectual activity, and social role in 2016.
[b] The missing items in the 2019 HLFC variable were excluded from the verification targets
[c] IADL: instrumental activities of daily living
[d] RR: risk ratio
[e] The missing items and other items in the educational attainment variable were excluded from the verification targets.

Results of the Poisson Regression Analysis

After dividing the independent people of each subgroup into three educational attainment groups in 2016, we compared each of them with Internet users and non-users and found that Internet users suppressed the decline in independence in the total score, IADL, intellectual activity, and social role subscales in 2019. Furthermore, especially in older adults with low levels of education, significant suppression effects were observed in the total score and all subscales (Table 4).

Compared to non-users, Internet users with ≤ 9 years of educational attainment had a suppressed decline in total score in 2019 (RR 0.57, 95% CI 0.43–0.76, P<.001) and in the IADL (RR 0.58, 95% CI 0.38–0.91, P=.02), intellectual activity (RR 0.60, 95% CI 0.41–0.89, P=.01), and social role (RR 0.74, 95% CI 0.56–0.97, P=.03) subscales. Furthermore, the 10–12-year educational attainment group also showed a reduced decline in total score (RR 0.78, 95% CI 0.63–0.98, P=.03), IADL (RR 0.59, 95% CI 0.39–0.90, P=.01), intellectual activity (RR 0.91, 95% CI 0.63–1.31, P=.61), and social role (RR 0.82, 95% CI 0.68–0.9998, P=.05). The ≥13-year educational attainment group showed a reduced decline in total score (RR 0.65, 95% CI 0.51–0.85, P=.001), IADL (RR 0.55, 95% CI 0.36–0.83, P=.01), intellectual activity (RR 0.64, 95% CI 0.37–1.10, P=.11), and social role (RR 0.83, 95% CI 0.64–1.08, P=.17) (Table 4). No interaction was found between Internet use and educational attainment (Table S5 in Multimedia Appendix 1).

Discussion

Principal Findings

The present study investigated the association between Internet use and maintaining the independence of HLFC in older adults, as well as differences in the effects of educational attainment using panel data from longitudinal surveys conducted in 2016 and 2019. In this large population-based study, Internet use in older adults was significantly associated with suppression of HLFC decline, regardless of educational attainment. Especially in older adults with low education (≤ 9 years), significant effects of suppressing the decline were observed in all subscales of HLFC, including IADL, intellectual activity, social role, and total score. These results suggest that older adults with low education levels can benefit from suppressing HLFC decline through Internet use. To our knowledge, this is the first study to investigate the association between Internet use and suppression of HLFC decline in older adults with low education by stratifying their educational attainment, which is particularly difficult to improve retrospectively.

HLFC can contribute to the independent living of older adults

Many older adults want to continue living in their familiar homes [2]. Therefore, maintaining a relatively independent HLFC, which includes traveling by train or bus, shopping, preparing meals, gathering information from various routes, and interacting with family, friends, and acquaintances, is important for promoting independent living. However, functional capacity tends to decline with age [6], which carries the risk of various health challenges [9, 10]. Therefore, maintaining and improving HLFC contributes significantly to the health of older adults, as well as the possibility of

extending independent living in their respective communities.

HLFC could get positive effects from improving IADL through Internet use

In addition to the report that the digital divide among older adults is associated with a lack of education [40], a survey in Japan also reported a digital divide where Internet use was gradually increasing among older adults, but the percentage of those with a low income using the Internet was small [16]. Similarly, the study showed that older adults with a low education or income had fewer Internet users than those with a high education or income. However, many studies have reported health-improvement effects of ICT use, including the Internet, regardless of educational attainment or income. Our results are consistent with those of previous studies showing that the use of the Internet and e-mail is likely to suppress and improve the risk of IADL decline [34, 35]. Impairment of IADL may indicate an early decline in physical and cognitive functions and may adversely affect health outcomes, incident heart failure, and mortality in older adults [45]. The related factors for IADL include social isolation [46], depression [47, 48], subjective health [47, 49], cognitive function [49], intellectual activity [50-52], social role [51, 52], community-level social capital [53], and social participation [54, 55]. Among the health improvement effects obtained using the Internet, the effects of improving social isolation and loneliness reduction [24, 27, 29, 33, 35-39], prevention and alleviation of depression [21-23, 32, 33], good subjective health [23, 33, 35], dementia risk reduction [19], good cognitive function [18, 20, 31], and social participation [28, 39] overlapped with factors related to IADL. Our results suggest that Internet use may have contributed to the suppression of HLFC decline by improving factors related to IADL, which is one of the elements of HLFC.

The effects of Internet use are closely related. For example, social isolation among Internet users is lower than that of non-users [37], and reports suggest that ICT use alleviates older adults' social isolation through four mechanisms: connecting to the outside world, gaining social support, engaging in activities of interest, and boosting self-confidence [27]. In addition, a previous study showed that non-users showed a decreasing trend in social contact, whereas Internet users maintained their social contacts at approximately the same level and alleviated loneliness [36], overlapping with the study finding that social contact and perceived social support mediated the relationship between social media communication and lower levels of loneliness [38]. Furthermore, Internet use contributes not only to the loneliness alleviation effect [24, 29, 33, 35, 36, 38, 39] but also to better self-rated health, fewer chronic illnesses, higher subjective well-being, and fewer depressive symptoms through the mediated effect of reduced loneliness [33]. In addition to the prevention and improvement of depression [21-23, 32, 33] and better self-rated health [23, 33, 35], good cognitive function [18, 20, 31] has also been reported. In addition to the effects mentioned above, good effects on well-being [25, 26, 33, 35], quality of life [22], and health literacy [30] have also been confirmed. Thus, the impact of Internet use on the daily lives of older adults may be significant.

Many older adults in Japan use the Internet to communicate with family, friends, and acquaintances and to search for interesting information [16]. Besides the fact that Internet use is "intellectual activity" itself, using it for instrumental, informational, and social purposes [39] may have further suppressed the decline in "intellectual activity" such as

"completing the paperwork," "reading newspapers," "reading books or magazines," and "being interested in health-related articles or TV programs."
Increased social participation [28] and diverse volunteer activities [39] through Internet use might have laid the groundwork for exchange relationships leading to the actions of "visiting your friends' homes," "giving advice to your family members or friends," "visiting people who have fallen ill," and "starting conversations with young people," and resulted in the suppression of social role decline.
Good intellectual activity and good social role are strongly associated with remaining independent in IADL [50, 51], and there are reports that disability in social role and intellectual activity not only likely precedes IADL disability but also significantly predicts the future onset of IADL disability [52]. In this study, it is also possible that the improvement in "intellectual activity" and "social role" through Internet use preceded and led to good IADL and contributed to the suppression of the decline in HLFC as a whole.

Internet use may have the possibility to shrink the educational inequality present in HLFC

Socioeconomic inequality was observed in terms of independence across all subscales (Table 3) (Appendix 2). This result is consistent with previous research showing educational inequality among HLFC [6]. Thus, to correct health disparities among older adults living in the community, it is necessary to take measures to maintain the HLFC of older adults, particularly those with low education; however, improving educational attainment retrospectively is almost impossible.
In this study, even at baseline, older adults using the Internet were more likely to be independent in terms of total score, IADL, intellectual activity, and social role than non-users.
Additionally, this longitudinal study showed that Internet use significantly suppressed HLFC decline in older adults, regardless of low educational attainment.
Internet use has been recognized as having the effect of promoting social participation among older adults [28]. Social participation also has the inequality that older adults with wealth or high education are more likely to participate in social activities [56], but it has the effect of reducing the risk of loneliness in not only wealthy older adults but also the least wealthy older adults and potentially acts as a buffer against health disparities [57]. In addition, although it has been reported that participation in community activities has the largest mediating effect on the relationship between education level and incident functional disability in older adults aged 65–74 years [58], this finding could explain why increased social participation through Internet use [28] mediated the relationship between educational inequality and HLFC in our study. Besides, Internet use may be seen as a proxy for continuous educational attainment, and its protective effect may not depend on "past" education levels, but rather on middle- and late-life cognitive activity represented by digital literacy [19], and there are reports that late-life cognitive activity influences subsequent cognitive health [59]. Thus, this study might show improved educational inequality in HLFC through late-life Internet use as a proxy for continuous educational attainment.

Limitations

This study had some limitations. First, since Internet usage was assessed in 2016, usage

in 2019 was not reflected. However, even past experiences of using the Internet may have contributed to suppression of HLFC decline in older adults. Thus, verification that assesses the impact of the duration of Internet use is required. Second, the purpose of Internet use was not considered. The present study verified the independent maintenance effect of HLFC through various Internet uses, including communication, collecting various information about health and medical information, searching for maps and traffic information, purchasing products and services, banking transactions, trading stocks and securities, and others. However, this inclusion might greatly contribute to verifying the effect of maintaining HLFC independence through comprehensive use of the Internet. The items mentioned above cover most purposes of Internet use by older adults. Finally, because we used data from the JAGES study, in which the participants were healthy enough to participate in the survey, our findings may have overestimated the association between Internet use and maintaining independence in HLFC among older adults.

Conclusion

In summary, the study suggests that Internet use can help maintain the independence of HLFC not only for older adults with high education but also for those with low education. Internet use suppresses the decline in HLFC such as IADL, intellectual activity, and social role, all of which are necessary for maintaining independent living in familiar communities, even for older adults with low educational attainment. Our findings serve as a reference for promoting support for the independence of older adults. In addition, using more devices/applications has been reported to be associated with fewer functional limitations, higher life satisfaction, and higher goal attainment [35]. Therefore, efforts at spreading the use of the Internet to older adults become even more crucial. In the future, it is expected that the spread of Internet utilization through policies focusing on older adults with low education will contribute to a reduction in functional health disparities due to educational attainment.

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Authors' Contributions

AT conceptualized the study and prepared the draft of the manuscript. AN, YM, TO, and KK planed and arranged acquisition of the data. AN, YM and CK prepared the data for the analyses. AT, AN, and YM performed the statistical analysis. All authors were involved in the study concept and design and acquisition, analysis, or interpretation of the data. All authors gave final approval, and agreed to be accountable for all aspects of the work.

Conflicts of Interest

None declared.

Abbreviations

BADL: Basic Activities of Daily Living
CI: Confidence Interval
HLFC: Higher-Level Functional Capacity
IADL: Instrumental Activities of Daily Living
ICT: Information and Communication Technology
JAGES: Japan Gerontological Evaluation Study
RR: Risk Ratio
TMIG-IC: Tokyo Metropolitan Institute of Gerontology Index of Competence

Multimedia Appendix 1

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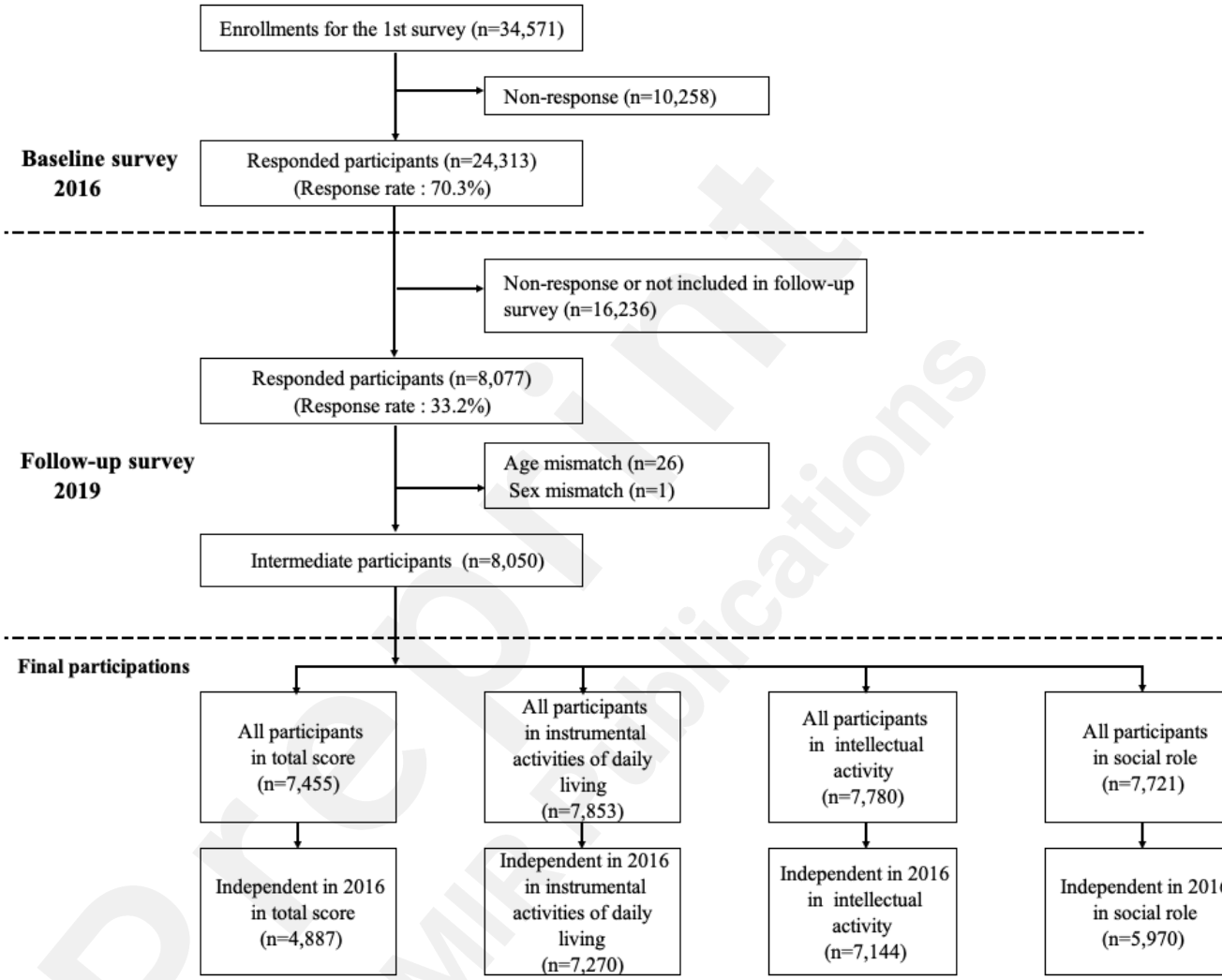
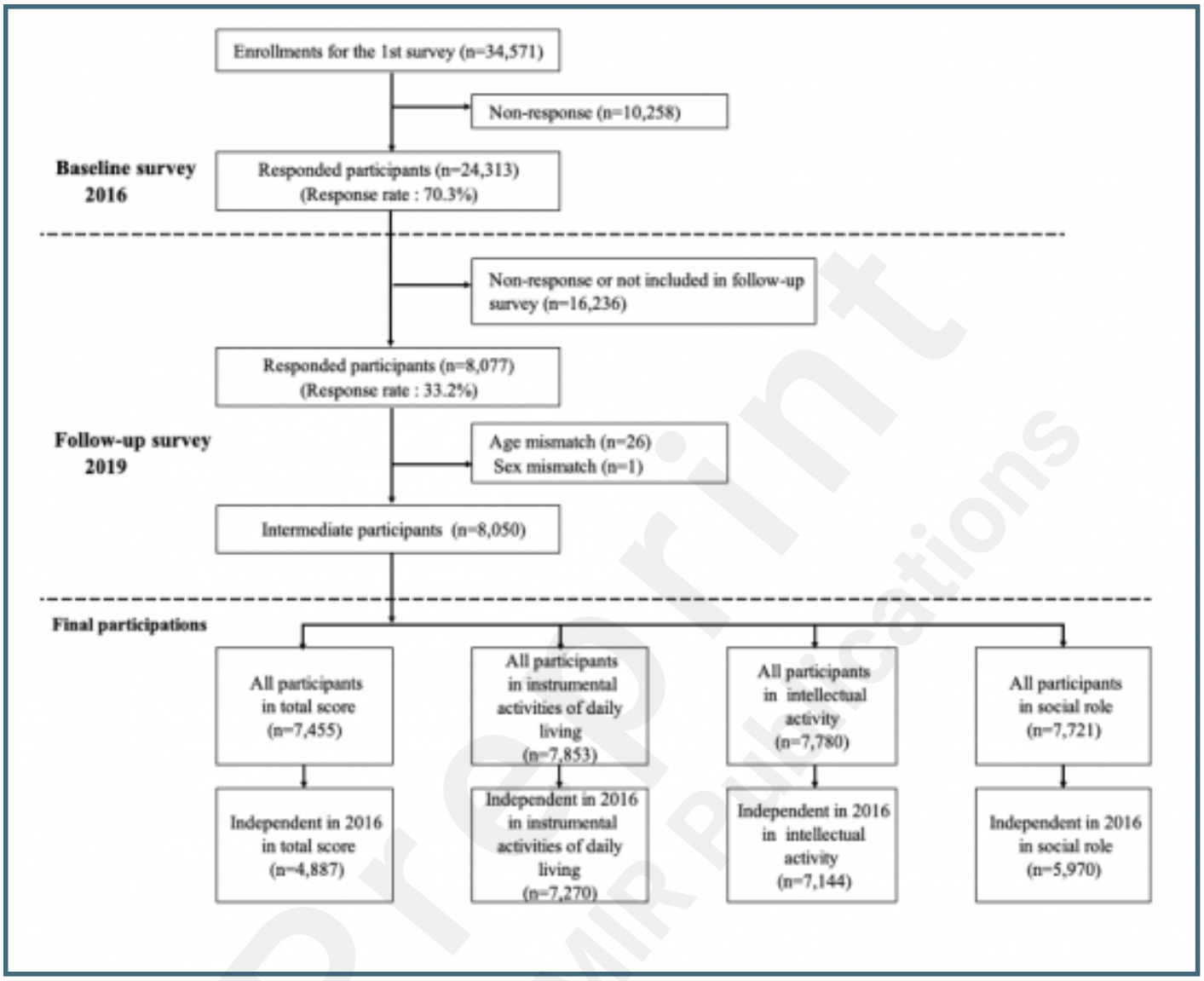
Figure 1. Participant recruitment process for the study



Supplementary Files

Figures

Participant recruitment process for the study.



Multimedia Appendixes

Questions for TMIG-IC, characteristics of the study participants, answer results of TMIG-IC by educational attainment, Characteristics of study participants by educational attainment in 2016, and interaction.
URL: http://asset.jmir.pub/assets/a91ff4a6a48e62a54cb3b5799b71d780.docx