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Computer use and cognitive decline among Japanese older adults: A prospective cohort study

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ABSTRACT

Introduction: This study aimed to examine the prospective association between computer use and cognitive decline among community-dwelling Japanese older adults, considering the characteristics of computer users.
Methods: This four-year prospective cohort study was conducted in Obu, Japan. Participants who were cognitive intact at Wave 1 (2011-2012) were followed through the study period. Cognitive decline was defined as scoring below the standard threshold in at least one of four neuropsychological tests at Wave 2 (2015-2016). The association between computer use at Wave 1 and cognitive decline was examined using logistic regression for complete samples ($n = 2010$, 52.5% female, mean 71.0 ± 4.7 years) and imputed samples ($n = 3435$, 51.8% female, mean 71.5 ± 5.3 years).
Results: The computer use group had a reduced adjusted odds ratio (aOR) of cognitive decline, after adjustment for covariates, in both the complete and imputed samples (complete samples: aOR 0.71, 95% confidence interval [CI] 0.52-0.97, $p = 0.030$; imputed samples: aOR 0.67, 95% CI 0.51-0.88, $p < 0.003$). Stratified analysis of both samples showed that computer users with ≥ 10 years' education, a GDS score of < 6, or a walking speed of $\geq$ 1.0m/s, showed reduced aOR for cognitive decline (aOR 0.61 to 0.69, $p < 0.05$). Those with < 10 years of education years, GDS scores ≥ 6 of GDS, or walking speed < 1.0m/s did not show significant association.
Conclusion: Computer use is longitudinally associated with protected cognitive function, based on computer user characteristics.

1. Introduction

Computer use for word processing, e-mail, internet use, games, and so on, has proliferated in recent decades, along with the development of computer technology. Computer-based activities aid in a number of tasks, including work, communication, and information-gathering, while also requiring knowledge of the device and technological skills, and is considered to be cognitively challenging, especially for older adults (Czaja et al., 2006; Hallgren, Nygard, & Kottorp, 2011; Nagle & Schmidt, 2012). Computers are often used for cognitive training (Bahar-Fuchs, Martyr, Goh, Sabates, & Clare, 2019), and the association between everyday computer use and cognitive health in older adults has been reported by many studies (Liapis & Harding, 2017). In a cross-sectional study, for example, frequent computer use was associated with higher executive function, especially the ability to switch between tasks (Tun & Lachman, 2010), while an imaging study showed lower daily computer use to be associated with smaller brain volume in regions integral to memory function (Silbert et al., 2016). Our previous study revealed that computer use was associated with the lowest odds ratio of cognitive impairment among six cognitive activities (reading, writing a diary or letters, solving crossword puzzles, playing board games, computer use, and maintaining housekeeping records) (Kurita et al., 2019), suggesting that computer use has a relatively high protective effect on cognitive function, compared to other cognitive activities.

Association of computer use with cognitive function is also supported by several prospective studies. A longitudinal cohort study recruiting older Australian men – one of the few longitudinal studies on the impact of computer use on cognitive function among older adults – reported that participants who used computers had a lower risk of dementia (Almeida et al., 2012). A survey conducted among older French adults examined changes in participants' amount of computer use over six

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years, measuring cognitive function only at the second wave, and reported better scores for verbal memory and executive functioning in those who had increased time spent on computer use, compared to those who decreased their computer use time (Kesse-Guyot et al., 2012). In an eight-year longitudinal study with a nationally representative sample from England, comprising participants aged 50–89 years, continuous computer use across five separate measurement points maintained higher delayed recall scores, compared to intermittent or non-use (Xavier et al., 2014). According to previous findings, including those from both cross-sectional and prospective studies, computer use in late life is likely to have a positive effect on cognitive function.

However, previous longitudinal studies had several limitations, such as the specificity of their samples (e.g., older men only), or their assessment of only a few cognitive domains, and it remains unclear whether computer use lowers risk of cognitive decline for any older adults. Further, due to the reported determinants of computer use, including demographic (e.g., age, education, and gender) and cognitive factors (Czaja et al., 2006; Kaye et al., 2014; Slegers, van Boxtel, & Jolles, 2012), the association between computer use and cognitive decline may differ according to the characteristics of older adults.

The aim of the present study was to examine the prospective association between computer use and cognitive decline, between baseline and a four-year follow-up assessment, using overall and stratified analyses.

2. Methods

2.1. Participants

The present study followed an observational four-year prospective cohort design, using the database of the National Center for Geriatrics and Gerontology-Study of Geriatric Syndromes (NCGG-SGS). The NCGG-SGS aims to establish a screening system for geriatric syndromes, and to validate evidence-based interventions for preventing these syndromes. The survey has been described in detail elsewhere (Shimada, Makizako, Doi, Lee, & Lee, 2017; Shimada et al., 2013). Community-dwelling older individuals, aged ≥ 65, years were recruited from Obu, Japan, between August 2011 and February 2012. Using the neuropsychological tests described in the next section, and 3701 participants were identified cognitively intact in the first assessment (Wave 1). Of these, 2183 respondents participated in the second examination (Wave 2), four years after baseline assessment between August 2015 and August 2016.

The data inclusion process is depicted in Figure 1. The exclusion criteria at Wave 1 were as follows: disability identified by the Japanese public long-term care insurance system (support level 1-2 and care level 1-5, n = 56); inability to perform basic activities of daily living such as eating, grooming, bathing, and climbing up and down stairs (n = 2); severe diseases, such as dementia, Parkinson's disease, or stroke (n = 148); Mini-Mental State Examination score < 21 (Perneczky et al., 2006); n = 26); and missing data (n = 34). Following the exclusion of 266 participants, 3435 participants (51.8% women, mean age 71.5 ± 5.3 years) were included at Wave 1. In addition, 1336 were excluded as did not participate in the Wave 2 assessment four years (46 to 50

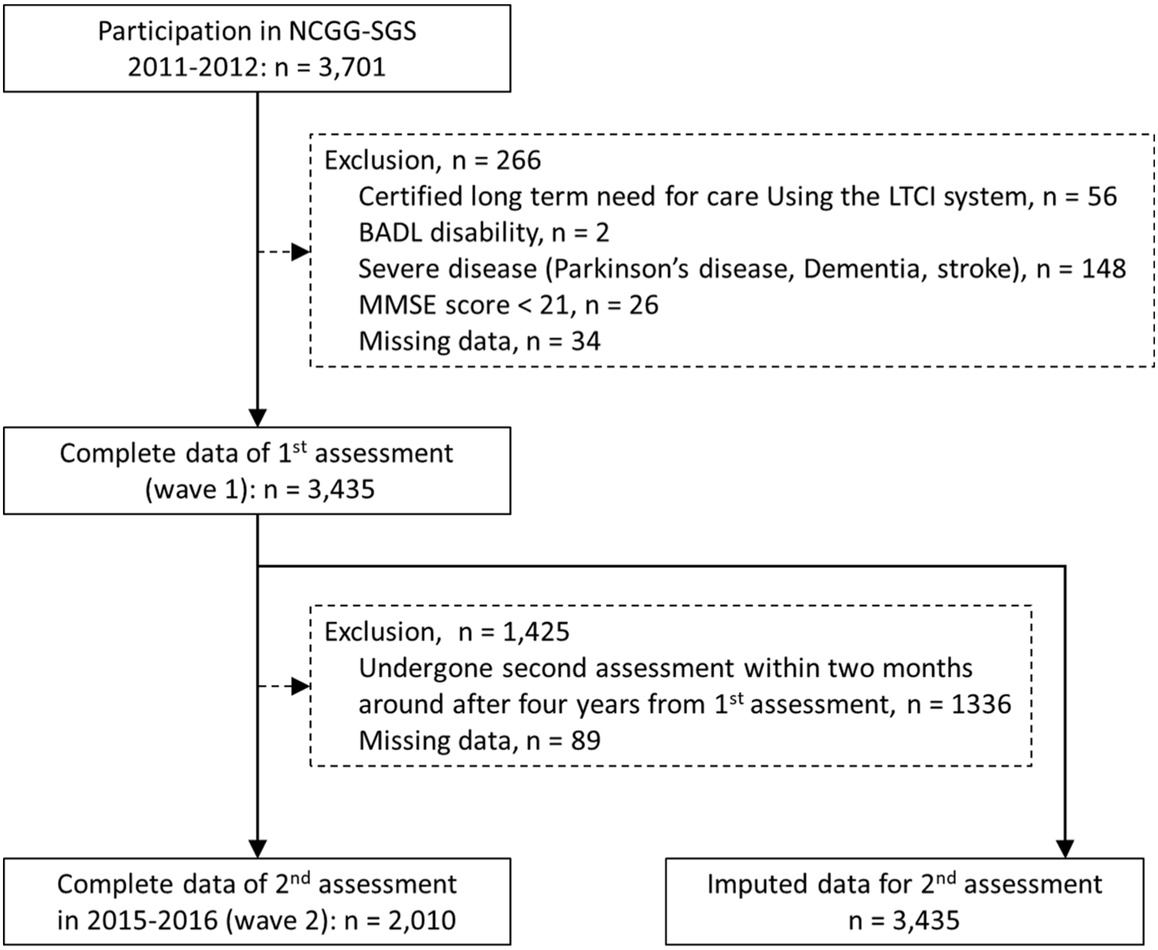

Fig. 1. Process flow for data inclusion.

months) after Wave 1, and another 89 had missing values for the neuropsychological tests scores. Ultimately, 2010 participants were included in the final data set. All participants provided informed consent prior to the study, and the study protocol was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology.

2.2. *Measurements*

2.2.1. *Cognitive decline*

The National Center for Geriatrics and Gerontology-Functional Assessment Tool (NCGG-FAT) (Makizako et al., 2013) was used to assess cognitive function. The NCGG-FAT was administered by well-trained staff to ensure that the correct test protocol was followed. Cognitive function was assessed across four cognitive domains: memory [word list memory-I (immediate recognition), word list memory-II (delayed recall)]; attention [an electronic tablet version of the Trail Making Test (TMT)-part A]; executive function (an electronic tablet version of the TMT-part B); and processing speed [an electronic tablet version of the Symbol Digit Substitution Task (SDST)]. Previous research has established an acceptable test–retest reliability and moderate to high correlation with scores of widely-used conventional neurocognitive tests among community-dwelling older adults (Makizako et al., 2013). The standardized threshold score for each test was set within 1.5 standard deviations below the age- and education-specific means derived from healthy older adults participating in other NCGG-SGS studies, but not the present study. Included samples in the present study showed more than the standardized NCGG-FAT score at wave 1; those who had one or more test scores 1.5 standard deviations lower than the standardized score at Wave 2, were classified as showing cognitive decline.

2.2.2. *Computer use*

At Wave 1, computer use was assessed through the question, “Do you use a personal computer?” Participants could answer yes or no; those who answered yes were identified as computer users. Computer use was also assessed at Wave 2, and 90.7% of 845 computer users and 89.5% of 1165 non-users at Wave 1 remained the same. As most participants’ computer use status remained constant between Wave 1 and 2, we used only the assessment of computer use at Wave 1 in our analyses.

2.2.3. *Covariates*

Sociodemographic characteristics (age, sex, and years of education), number of chronic diseases (hypertension, diabetes, hyperlipidemia, and heart disease), depressive symptoms, assessment of instrumental activities of daily living (IADL) limitations, and status of employment for paid work (yes/no), were assessed by self-report in face-to-face interviews. The number of chronic diseases was categorized as 0, 1, and ≥ 2. Depressive symptoms were assessed using the 15–item Geriatric Depression Scale (GDS), which contains 15 yes/no questions and provides a score ranging from 0 to 15 (Yesavage, 1988). IADL limitations were assessed based on the presence of one or more limitations in any of the three subitems: “using the bus or train by myself”; “buying daily necessities by myself”; and “managing my own deposits and savings at the bank by myself” (Makizako et al., 2015). Normal walking speed was measured on a 6.4m walking path, with 2.4m of measurement space in the center, and 2m spaces on either side of the center for normal walking pace during the assessment. The measurement was conducted up to five times, and the maximum speed obtained by each participant was included in the final data set.

2.3. *Statistical Analysis*

We analyzed the complete data set (n = 2010), as well as the Wave 1 data after applying exclusion criteria (n = 3435), using multiple imputation to adjust for selection bias and loss of information. Fifty imputed values compensated for missing NCGG-FAT test scores at Wave 2, yielding 50 complete data sets. The 50 complete datasets were analyzed and the results pooled for imputed sample. The main advantages of using multiple imputation over the complete samples is an increase in power to detect significant associations in a logistic regression model by using the partial information available on some subjects, and the anticipation of the likely possibility that the presence of missing scores was not completely random, but occurred among participants with similar known characteristics, and the distribution of missing values would therefore resemble that of known values (Koepsell & Monsell, 2012).

The differences in participants’ characteristics between computer user and non-user groups, in both the complete and imputed samples, were examined using the independent t-test for continuous variables, and the χ^2-test for discrete and ordinal variables. The associations between computer use and cognitive decline were examined using binomial logistic regression models, for both the complete and imputed samples. Adjusted odds ratios (aOR) and 95% confidence intervals (CI) of cognitive decline for the non-user group were calculated in fully adjusted models for all covariates. In order to examine whether the association between computer use and cognitive decline differed according to user characteristics, we stratified the overall samples by the characteristics which significantly differed between computer users and non-users, and calculated each aOR and 95% CI for cognitive decline. All analyses were conducted using SPSS version 25 (IBM, New York City, NY, USA). The level of statistical significance was set at $P < 0.05$ for all analyses.

3. Results

The characteristics of the complete (n = 2010, 52.5% female, mean age 71.0 ± 4.7 years at Wave 1) and imputed samples (n = 3435, 51.8% female, mean age 71.5 ± 5.3 years at Wave 1) are summarized in Table 1. Compared to complete samples (n = 2010), those who participated in Wave 1 (n = 1425) were significantly 1.1 years older, 10.2% less than the number of computer users, had significantly 0.4 less educational year, 0.52 higher GDS score, 0.07 m/s slower gait speed, and 4.7% more of IADL limitation (data not shown). Although both

Table 1
Characteristics of participants in the user and non-user groups.

	Complete samples (n = 2010)			Imputed samples (n = 3435)		
	User (n = 845)	Non-user (n = 1165)	p †	User (n = 1298)	Non-user (n = 2137)	p †
Age, years	69.9 ± 4.0	71.8 ± 5.1	<0.001	70.0 ± 4.3	72.4 ± 5.6	<0.001
Sex, female	280 (33.1)	775 (66.5)	<0.001	407 (31.4)	1373 (64.2)	<0.001
Education, years	12.8 ± 2.5	11.0 ± 2.2	<0.001	12.7 ± 2.5	10.8 ± 2.2	<0.001
Number of chronic diseases, 0 (n)	241 (28.5)	335 (28.8)	0.308	361 (27.8)	605 (28.3)	0.153
,1	339 (40.1)	432 (37.1)		519 (40)	788 (36.9)	
,≥2	265 (31.4)	398 (34.2)		418 (32.2)	744 (34.8)	
GDS score	2.0 ± 2.3	2.6 ± 2.4	<0.001	2.1 ± 2.2	2.9 ± 2.5	<0.001
IADL limitations, n	101 (12.0)	171 (14.7)	0.078	169 (13.0)	364 (17.0)	0.002
Employed, n	305 (36.1)	298 (25.6)	<0.001	471 (36.3)	560 (26.2)	<0.001
Gait speed, m/s	1.44 ± 0.2	1.39 ± 0.21	<0.001	1.42 ± 0.2	1.36 ± 0.22	<0.001

Values are mean ± standard deviation or n (%).
GDS, Geriatric Depression Scale; IADL, instrumental activities of daily living.
†Continuous and category variables were compared between the user and non-user groups.
using the independent t-test and $\chi2$-test, respectively.

complete and imputed samples had similar characteristics, the imputed samples had a lower proportion of computer users [complete samples: 845 (42.0%); imputed samples: 1298 (37.8%)]. As a result of multiple imputation, pooled data from 50 imputed data entries showed a higher prevalence of cognitive decline during the follow-up period than the complete data set [complete samples: 275 (13.7%); imputed samples: 655 (19.1%)]. There were significant differences in demographic characteristics between the computer user and non-user groups; computer users were younger and more educated, and the group contained more males and employed participants, and less number of IADL limitations than non-users (all $p < 0.001$). Computer users also had significantly lower GDS scores and faster gait speeds than non-users. Referring to these differences, stratified analyses were conducted by age ($<$ 75 years / $\geq$ 75 years), sex (male / female), education ($<$ 10 years / 10 years), GDS score (< 6 / ≥ 6), employment status (no / yes), IADL limitations (no / yes), and gait speed ($<$ 1.0m/s / $\geq$ 1.0m/s).

In the logistic regression model of the overall samples, the computer user group showed a reduced aOR for cognitive decline after adjustment for covariates in both the complete and imputed samples (complete samples: aOR 0.71, 95% CI 0.52-0.97, $p = 0.030$; imputed samples: aOR 0.67, 95% CI 0.51-0.88, $p = 0.003$; Table 2). In the stratified analysis, computer users with $\geq$ 10 years of education, GDS score < 6, or walking speed $\geq$ 1.0m/s, showed a reduced aOR for cognitive decline in both the complete and imputed samples (aOR 0.61:0.69, $p < 0.05$, Table 3), while those who had the opposite characteristics did not show a significant association. The other stratified factors showed a significant association between computer use and cognitive decline only for the imputed samples, related to age ($<$ 75 years), both sexes, no IADL limitations, and both employment statuses (aOR 0.61 to 0.69, $p < 0.05$, Table 3).

4. Discussion

The present study examined the association between computer use and the onset of cognitive decline, using a four-year prospective cohort design. In the overall analysis, computer use was associated with a reduced odds ratio for cognitive decline, after adjusting for all covariates. When the overall samples were stratified by participant characteristics, the significant association did not remain in those who were older, less educated, had depressive symptoms, or slow gait speed.

Our findings for the overall samples were consistent with other longitudinal studies (Kesse-Guyot et al., 2012; Xavier et al., 2014). Although previous studies used delayed recall, verbal memory and executive functioning as outcomes, our findings are a comprehensive extension of the evidence concerning the protective association of computer use with cognitive function. Continuous computer use in everyday life may contribute to preservation of cognitive function in late life, and future studies need to clarify the causal relationship. The establishment of a causal relationship will hold important implications for the retention of cognitive function, as computer use has increased in recent decades (International Telecommunication Union, 2019).

Table 2
Association between computer use and cognitive impairment using binomial logistic regression model.

	Complete samples		Imputed samples	
	aOR (95%CI)	p	aOR (95%CI)	p
Computer use (ref: non-user)	**0.71 (0.52-0.97)**	**0.030**	**0.67 (0.51-0.88)**	**0.003**
Age	**1.04 (1.02-1.07)**	**0.003**	**1.03 (1.01-1.06)**	**0.004**
Sex (ref: female)	**1.48 (1.11-1.97)**	**0.008**	**1.60 (1.27-2.01)**	**<0.001**
Education	**0.93 (0.87-0.98)**	**0.011**	**0.95 (0.91-0.996)**	**0.035**
GDS	1.03 (0.97-1.08)	0.326	1.04 (0.99-1.09)	0.083
Chronic disease (ref: 0), 1	1.09 (0.78-1.52)	0.608	1.03 (0.78-1.36)	0.846
,≥ 2	1.21 (0.86-1.69)	0.270	1.06 (0.80-1.42)	0.670
IADL limitations (ref: no)	1.03 (0.71-1.50)	0.880	1.05 (0.77-1.42)	0.770
Employed (ref: yes)	1.22 (0.89-1.68)	0.218	1.04 (0.81-1.35)	0.744
Walking speed	**0.44 (0.22-0.86)**	**0.016**	**0.40 (0.23-0.69)**	**<0.001**

aOR, Adjusted odds ratio; GDS, global depression scale; IADL, instrumental activities of daily living.

The findings from our stratified analyses differed according to participant characteristics. A longitudinal study reported that older adults with mild cognitive impairment (MCI) showed a decrease in the number of days with computer use, compared to those who were cognitively intact after computer sessions (Kaye et al., 2014). There may be similar trends of decrease in computer use time related to lower education, presence of depressive symptoms, or slow gait speed, which have been supported as factors of dementia (Beauchet et al., 2016; Livingston et al., 2017). In addition, a population-based longitudinal study examined the risk of incident MCI among computer users with and without APOEε4-carrier status; only users without APOEε4-carrier status showed significant reduced risk of MCI (Krell-Roesch et al., 2017). The time of computer use may decrease in older adults with factors of dementia; when conducting computer use interventions among older adults, therefore, the specific characteristics and needs of the target population should be considered. There were differences in results between the imputed and complete samples stratified by age ($<$ 75 years), both sexes, no IADL limitations, and both employment statuses, probably due to sampling bias and a lower prevalence of cognitive decline in the complete samples, resulting in a lower power for detecting significant associations than for imputed samples. To our knowledge, few studies have examined the association between computer use and cognitive function in any specific population.

Some questions remain, as we assessed computer use through a yes/no question only, which is a limitation of the current study. First, how computer activity inhibits cognitive decline is unknown. Some studies have examined the association between the type of computer activity and cognitive outcome. An Australian longitudinal cohort study, for example, examined the incidence of dementia and type of computer activity among older men, and reported that engaging in email, games, internet use, and word processing lowered risk of dementia (Almeida et al., 2012). A cross-sectional functional MRI study suggested conducting internet searches may engage a greater level of neural circuitry not activated while reading text pages (Small GW, 2009). In addition, a cross-sectional study found that more frequent computer users showed better cognitive performance (Tun & Lachman, 2010). More research is needed to clarify the protective mechanism of computer activity on cognitive decline. The difference of computer activity should also be examined between computer users with and without factors of dementia including lower education, presence of depressive symptoms, slow gait speed, and APOEε4-carrier status. Second, digital devices such as tablets and smartphones have increased in recent years as tools for email and internet use, instead of personal computers (International Telecommunication Union, 2019), but this study could not examine whether those who used digital devices without using computers had retained cognitive function. In a cross-sectional study, daily use of touchscreen devices (tablet computer or smartphone) only did not result in significantly better cognitive performance than in for non-daily users (Wu, Lewis, & Rigaud, 2019). As for tablets, intervention studies verified that iPad training groups showed improvements in episodic memory and processing speed (Chan, Haber, Drew, & Park, 2016; Vaportzis, Martin, & Gow, 2017). Future research should examine whether the use of digital devices, including personal computers as well as touchscreen devices, in late life has a protective effect on cognitive decline.

The strengths of the present study are its longitudinal design and large cohort, which provided access to examine the time-course

Table 3
Stratified analysis of the associations between computer use and cognitive decline using binomial logistic regression model.

	Complete samples				Imputed samples			
	n	No. of cognitive decline (%)	aOR (95%CI) [a]	p	N	No. of cognitive decline (%)	aOR (95%CI) [a]	p
Age < 75 years	1561	177 (11.3)	0.74 (0.52-1.07)	0.108	**2554**	**412 (16.1)**	**0.65 (0.48-0.87)**	**0.005**
≥ 75 years	449	95 (21.2)	0.55 (0.29-1.04)	0.068	881	243 (27.6)	0.65 (0.38-1.13)	0.124
Sex Male	955	146 (15.3)	0.70 (0.47-1.05)	0.083	**1655**	**353 (21.4)**	**0.69 (0.5-0.96)**	**0.029**
Female	1055	126 (11.9)	0.69 (0.41-1.17)	0.165	**1780**	**302 (16.9)**	**0.61 (0.39-0.96)**	**0.033**
Education < 10 years	616	94 (15.3)	0.62 (0.34-1.16)	0.134	1141	244 (21.4)	0.61 (0.36-1.03)	0.065
≥ 10 years	**1394**	**178 (12.8)**	**0.62 (0.43-0.90)**	**0.011**	**2294**	**411 (16.1)**	**0.61 (0.45-0.82)**	**<0.001**
GDS score < 6	**1799**	**237 (13.2)**	**0.69 (0.50-0.96)**	**0.029**	**3016**	**548 (18.2)**	**0.67 (0.51-0.89)**	**0.006**
≥ 6	211	35 (16.6)	0.87 (0.32-2.36)	0.789	419	108 (25.7)	0.58 (0.27-1.26)	0.170
IADL limitation No	1738	232 (13.3)	0.72 (0.51-1.01)	0.060	**2902**	**531 (18.3)**	**1.48 (1.11-1.96)**	**0.007**
Yes	272	43 (15.8)	0.63 (0.28-1.41)	0.261	533	120 (22.6)	1.48 (0.8-2.75)	0.214
Employed No	1407	207 (14.7)	0.74 (0.51-1.08)	0.115	**2404**	**484 (20.1)**	**0.68 (0.50-0.93)**	**0.015**
Yes	603	65 (10.8)	0.63 (0.35-1.13)	0.123	**1031**	**171 (16.6)**	**0.63 (0.40-0.996)**	**0.048**
Gait speed <1.0m/s	43	5 (11.6)	2.84 (0.12-69.72)	0.523	133	45 (18.5)	0.85 (0.19-3.74)	0.833
≥ 1.0m/s	**1967**	**267 (13.6)**	**0.69 (0.50-0.94)**	**0.019**	**3302**	**611 (33.4)**	**0.65 (0.5-0.85)**	**0.002**

aOR, Adjusted odds ratio; GDS, global depression scale.
Adjusting variables are age, sex, education year, GDS score, chronic disease, IADL limitations, employment status, and gait speed.

[a] Values are aOR of cognitive decline in those who use computer (ref: non-computer user).

relationship between computer use and cognitive function. There were also several limitations. First, this study did not assess the characteristics of computer use such as type of activity, the duration, and frequency. As described in the previous paragraph, some questions remain. Second, generalization of the findings in this study needs caution because the participants were not a representative sample of older adults. Participants were not randomly sampled and were sufficiently healthy to attend health checkups in their community, which may have further buffered cognitive decline. Third, the present study did not collect data of several confounding factors, such as the apolipoprotein and genotype which facilitates cognitive decline; we could not adjust for this factor in the statistical analyses.

5. Conclusion

In conclusion, our findings suggest that there is a protective longitudinal association between computer use and cognitive function, compared to non-use. However, those at risk of cognitive decline or dementia due to factors such as older age, lower education, presence of depressive symptoms, or slow gait speed, may find it difficult to maintain cognitive function through computer use. When conducting computer use interventions among older adults, there may be a need to consider the characteristics of target population.

CRediT authorship contribution statement

Satoshi Kurita: Conceptualization, Formal analysis, Writing – original draft, Funding acquisition. **Takehiko Doi:** Investigation, Writing – review & editing. **Kota Tsutsumimoto:** Investigation, Writing – review & editing. **Sho Nakakubo:** Investigation, Writing – review & editing. **Hideaki Ishii:** Writing – review & editing. **Hiroyuki Shimada:** Project administration, Methodology, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

None declared.

Contributors

Satoshi Kurita conceived the study and performed literature review, analysis and interpretation of data, and preparation of manuscript. Takehiko Doi and Kota Tsutsumimoto performed data collection and contributed to interpretation of data, and review and editing manuscript. Sho Nakakubo performed data collection and contributed to review and editing manuscript. Hideaki Ishii contributed to review and editing manuscript. Hiroyuki Shimada made a significant contribution to funding acquisition, project administration, interpretation of data, and review and editing manuscript.

Research data (data sharing and collaboration)

There are no linked research data sets for this paper. The authors do not have permission to share data.

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