

Association between Stroke and Cognitive Decline in Community Dwelling Older and Oldest People: The SONIC Study

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Abstract

Background Increasing in the older people and a decline in mortality after stroke, the rate of post-stroke cognitive decline has increased. The relationship between risk factors and post-stroke cognitive decline in dwelling old and oldest people who living in the community especially with asymptomatic stroke have to be elucidated. Therefore, the aim of this study is to investigate the association between stroke and cognitive decline during three years in community dwelling older and oldest people.

Methods This study was longitudinal study with a 3-year follow-up in urban and rural areas of Japan. The participants were 1,333 community dwelling older and oldest people (70 years old = 675, 80 years old = 589, and 90 years old = 69). Data collected included basic data (age, sex, and history of stroke), vascular risk factors (hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, and current smoking), and social factors (educational level, frequency of going outdoors, and long-term care (LTC) service used). The Japanese version of the Montreal Cognitive Assessment (MoCA-J) was used for cognitive assessment, and a decline of ≥ 2 points was defined as cognitive decline. Multiple logistic regression analysis was used to investigate the association between stroke and other risk factors with cognitive decline during a 3-year follow-up.

Results Rates of cognitive decline increased in advanced ages, equaling 33.3, 39.4, and 66.7% in those aged 70, 80, and 90 years old, respectively. The fit of the hypothesized model by multiple logistic regression showed that a history of stroke, advanced age, and greater MoCA-J score at the baseline were important risk factors, while the presence of dyslipidemia and a higher educational level were protective factors that were significantly correlated with cognitive decline during the 3-year follow-up.

Conclusions The cognitive decline after the 3-year follow-up was influenced by the history of stroke, advanced age, and greater MoCA-J score at the baseline, but protective factors were the presence of dyslipidemia and a higher educational level. Therefore, these factors are considered important and should be taken into consideration when searching for creative solutions to prevent cognitive decline after stroke in community dwelling older and oldest people.

Background

Recently, Japan has rapidly been approaching a complete aging society, among the first in the world. Therefore, the epidemiologic characteristics of stroke in older Japanese people may be good examples for other countries [1], particularly regarding oldest people. In general, the incidence of stroke increases with age, occurring in up to 69% of individuals older than 65 years and 34.4% in those older than 75 years [2]. Nevertheless, survival after stroke is a major cause of lifelong disability and places a heavy cost of care on Japan's LTC insurance system [3].

Due to an increase in the older population and a decline in mortality after stroke, the rate of post-stroke cognitive decline has increased [4, 5]. Moreover, cognitive decline can happen both immediately and long after the incidence of stroke [6]. Therefore, understanding the risk factors of cognitive decline in stroke

patients is necessary so that preventive strategies against cognitive impairment and dementia, especially in older and oldest people, can be identified. The risk factors of cognitive decline after stroke are numerous, as reported in previous studies, including: age [7–15], sex [7, 9, 10], vascular risk factors such as hypertension [7, 9, 13, 16], diabetes mellitus [10, 12–14, 17, 18], dyslipidemia [15, 19], atrial fibrillation [20–22], and current smoking [9, 16], and social factors including educational level [7, 9–11, 14, 15], frequency of going outside [23], and LTC service used [3]. The relationship between risk factors and post-stroke cognitive decline reported in previous studies may differ due to cognitive function assessment methods, but the MoCA-J is considered a useful cognitive assessment for detecting mild cognitive impairment (MCI), and its results are used to offer recommendations in a primary clinical setting and for geriatric health screening in the community. Moreover, the MoCA-J has been shown to detect cognitive decline over a 2-year period in older people with MCI and early-stage Alzheimer's disease [24].

Those 70 years old or older including the oldest people may have traditionally been overlooked in research on cognitive decline after stroke. Most of the previous studies focused on cognitive impairment and stroke in older people separately and studies in oldest people are rare [4, 16, 25]. Moreover, the effect of risk factors on cognitive decline in healthy older people after stroke who have recovered and continued living in the community is not clear. The big question is how the cognitive function will be declined by aging, especially in older people with asymptomatic stroke. Some studies have been published to compare post-stroke cognitive decline in younger and older stroke patients [20], but few of them have used community-based samples [25, 26]. There is a lack of studies that compared older and oldest people with a history of stroke to people without stroke in a community setting. In fact, aging-related cognitive decline in older and oldest people living in the community with good recovery post-stroke is seen as a new research challenge to create solutions to prevent unforeseen cognitive decline in older and oldest people without awareness post-stroke. Thus, the purpose of this study was to investigate the association between stroke and cognitive decline during three years in community dwelling older and oldest people.

Methods

Study sample

This study was a longitudinal analysis that collected data at the baseline and 3-year follow-up of a prospective cohort study called the *Septuagenarians, Octogenarians, Nonagenarians Investigation with Centenarians (SONIC)* study, a study ongoing since 2010 [27]. The participants were recruited in two regions of western and eastern Japan, and each region was composed of both urban and rural areas: Itami City, Hyogo (western urban); Asago City, Hyogo (western rural); Itabashi ward, Tokyo (eastern urban); and Nishitama county, Tokyo (eastern rural).

The inclusion criteria of this study were as follows: 1) they were free of dementia at the baseline, 2) their completed dementia data were available, and 3) the MoCA-J score was administered both at the baseline

and 3-year follow-up. Data were collected at the baseline (2010–2012) and during the 3-year MoCA-J score follow-up (2013–2015). At the baseline, a total of 2,245 participants in all age groups (69–71 years old = 1,000, 79–81 years old = 973, and 89–91 years old = 272) were included, but only 1,333 participants met the inclusion criteria and completed the 3-year follow-up (Figure 1).

Basic data

The basic data were collected on the following variables by means of self-administered questionnaires at the baseline survey including age, sex, and history of stroke.

Vascular risk factors

Blood pressure was measured by a physician and trained nurses. A sphygmomanometer was used to measure blood pressure twice with each arm in a sitting position. The average of the first and second measurements of each arm was used in the analysis. Hypertension was diagnosed according to the Japanese Society of Hypertension guideline 2019 [28], which is defined by systolic Blood Pressure (BP) \geq 140 mmHg and diastolic BP \geq 90 mmHg or the use of antihypertensive drugs at the first survey.

The blood samples were collected for subsequent analysis. The levels of fasting/casual blood glucose, low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides were determined using biochemical examinations. Diabetes mellitus was defined by fasting blood glucose \geq 126 mg/dL, casual blood glucose \geq 200 mg/dL, hemoglobin A1c \geq 6.5%, or use of antidiabetic drugs according to the Japan Diabetes Society [29]. Dyslipidemia was defined by LDL-cholesterol \geq 140 mg/dL, HDL-cholesterol $<$ 40 mg/dL, triglycerides \geq 150 mg/dL, or use of dyslipidemia drugs according to the Japan Atherosclerosis Society [30]. Finally, atrial fibrillation was determined with a self-administered questionnaire with yes/no answers.

Current smoking behavior was determined based on a self-administered questionnaire and the participants were classified in accordance with their yes/no responses.

Social factors

Data were collected on the following variables through self-administered questionnaires at the baseline survey: educational level ($<$ 10 years [junior high school or less], 10–12 years [high school], or $>$ 12 years [university or higher]), frequency of going outdoors ($<$ 1 time/week, 1 or 2 times per week, 3 or 4 times per week, 5 or 6 times per week, and every day). Finally, the participants were asked whether they had used LTC services with a mail questionnaire.

Assessment of cognitive functioning

A well-trained psychologist assessed the participants' cognitive function using the MoCA-J [24]. The MoCA-J total scores (0–30 points) were used for cognitive function assessment. A higher score indicated a higher cognitive function. Generally, the MoCA-J demonstrates greater reliability and validity in the screening of MCI in community-dwelling older people than conventional cognitive tests.

The MoCA-J scores at the 3-year follow-up subtracted from the scores at the baseline were used to define changes in the MoCA-J scores. Therefore, the participants whose MoCA-J scores decreased by ≥ 2 points were defined as those with cognitive decline, while the participants whose scores decreased by < 2 points were defined as those with maintained cognition [31, 32].

Statistical analysis

After the computation of summary statistics, the Pearson's Chi-square or Fisher's exact test for categorical variables and the independent t-test for continuous variables were employed to compare baseline characteristics between stroke and non-stroke, maintained cognition and cognitive decline groups (based on changes in MoCA-J scores), and follow-up and dropped-out groups. Cognitive decline (MoCA-J scores decreased by ≥ 2 points) was considered the outcome variable.

Logistic regression analysis was used to determine the association, expressed as an odds ratio (OR) and 95% confidence interval (CI), between risk factors and cognitive decline. Univariate logistic regression was tested for age, sex, and MoCA-J score at the baseline. In addition, multiple logistic regression was implemented in model 1 with each variable being adjusted by age, sex, and MoCA-J score at the baseline and model 2 was adjusted by all variables (age, sex, MoCA-J score at the baseline, history of stroke, hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, current smoking, educational level, frequency of going outdoors, and LTC service used). These statistical analyses were carried out with SPSS Statistics 24.0 (IBM Japan, Tokyo, Japan). Significance was set at .05.

Results

There were 2,245 participants recruited at the baseline survey and 1,333 (59.38%) met the inclusion criteria and completed the 3-year follow-up, as shown in Figure 1. Half of the participants were 70 years old (675 participants or 50.6%). Almost half of the participants were male (657 participants or 49.3%). There were 72 participants (5.4%) who had a history of stroke. Furthermore, when the participants were divided based on a history of stroke, there were significant differences between the participants who had and did not have stroke in terms of hypertension, diabetes mellitus, atrial fibrillation, frequency of going outdoors, and use of LTC services. The median MoCA-J score at the baseline was 23 (Inter quartile (IQR) = 20–26) in the stroke group and also 23 in the non-stroke group (IQR = 21–26) (Table 1). Details of each age group are shown in Additional file 1: Table S1. Moreover, only a history of stroke and MoCA-J score at the baseline in all age groups showed significant differences when a comparison was made between those with unchanged cognition and those with cognitive decline at the baseline (Additional file 2: Table S2). However, a history of stroke, sex, diabetes mellitus, current smoking, educational level, frequency of

going outdoors, LTC service used, and MoCA-J score at the baseline were significantly different when comparing the follow-up and dropped-out groups at the baseline, which may indicate some selection bias in this study (Additional file3: Table S3). Also, the percentage of stroke participants with cognitive decline increased with age, equaling 33.3, 39.4, and 66.7% in those who were 70, 80, and 90 years old, respectively. The MoCA-J score decline showed a significant difference between stroke and non-stroke groups in all ages ($P<.028$). Comparing the MoCA-J score decline between stroke and non-stroke groups in each age group (70, 80, and 90 years old), there was no significant difference. Whereas, a comparison of the MoCA-J score decline between ages (stroke vs. non-stroke) revealed a significant difference only in the non-stroke group between 70 and 80 years old ($P<.031$) (Figure 2).

Table 1. Comparison of a history of stroke as a baseline characteristic (n=1,333)

Characteristics	Total n (%)	Stroke n=72 (5.4%)	Non-stroke n=1,261 (94.6%)	P-value
Age, %				
70 years old	675 (50.6)	45.8	50.9	.395 ^a
80 years old	589 (44.2)	45.8	44.1	
90 years old	69 (5.2)	8.3	5.0	
Sex, %				
Female	676 (50.7)	40.3	51.3	.070 ^b
Male	657 (49.3)	59.7	48.7	
Hypertension, %				
Yes	969 (73.9)	87.1	73.1	.009 ^a
No	343 (26.1)	12.9	26.9	
Diabetes mellitus, %				
Yes	188 (15.1)	24.2	14.6	.034 ^a
No	1054 (84.9)	75.8	85.4	
Dyslipidemia, %				
Yes	796 (61.2)	68.1	60.8	.254 ^b
No	504 (38.8)	31.9	39.2	
Atrial fibrillation, %				
Yes	29 (2.2)	6.9	1.9	.004 ^a
No	1304 (97.8)	93.1	98.1	
Current smoking, %				
Yes	144 (11.0)	5.6	11.3	.137 ^a
No	1165 (89.0)	94.4	88.7	
Educational level, %				
< 10 years	354 (26.6)	23.9	26.8	.771 ^a
10-12 years	565 (42.5)	46.5	42.3	
> 12 years	410 (30.9)	29.6	30.9	

Characteristics	Total n (%)	Stroke n=72 (5.4%)	Non-stroke n=1,261 (94.6%)	P-value
Frequency of going outdoors, %				
< 1 time/week	79 (5.9)	5.6	12.5	.043 ^a
1-2 times/week	169 (12.7)	12.4	18.1	
3 or 4 times/week	275 (20.7)	20.7	20.8	
5 or 6 times/week	271 (20.4)	20.8	12.5	
Every day	535 (40.3)	40.5	36.1	
LTC service used, %				
Yes	52 (4.1)	8.7	3.8	.047 ^a
No	1220 (95.9)	91.3	96.2	
MoCA-J score at the baseline, median (IQR)	23 (21-26)	23 (20-26)	23 (21-26)	.242 ^b

^a P-values from Pearson's Chi-square test.

^b P-values from Fisher's exact test for categorical variables and independent t-test for continuous variable.

Multiple logistic regression by adjusting for age, sex, and MoCA-J score at the baseline showed that a history of stroke (OR = 1.88) was an independent risk factor of cognitive decline, while a higher educational level (10–12 years, OR = 0.63, > 12 years, OR = 0.55, with < 10 years as a reference) was a protective factor significantly correlated with cognitive decline at the 3-year follow-up. Moreover, after adjusting for all variables, the results revealed that a history of stroke (OR = 1.82), advanced age (80 years old, OR = 2.08; 90 years old, OR = 3.99, with 70 years old as a reference), and MoCA-J score at the baseline (OR = 1.26) were independent risk factors, whereas the presence of dyslipidemia (OR = 0.70) and a higher educational level (10–12 years, OR = 0.60, > 12 years, OR = 0.51, with < 10 years as a reference) were protective factors significantly correlated with cognitive decline at the 3-year follow-up (Table 2).

Table 2. Logistic regression model

Characteristics	Model 1		Model 2 ^c	
	Adjusted age, sex, MoCA-J scores at baseline		(All adjusted)	
	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value
Age (reference 70 years old)^a				
80 years old	1.33 (1.04- 1.70)	.025	2.08 (1.52- 2.85)	<.001
90 years old	1.42 (0.83- 2.43)	.196	3.99 (2.04- 7.79)	<.001
Sex^a	1.10 (0.87- 1.40)	.435	1.13 (0.84- 1.51)	.421
MoCA-J score at the baseline^a	1.18 (1.13- 1.23)	<.001	1.26 (1.20- 1.33)	<.001
History of stroke^b	1.88 (1.11- 3.16)	.018	1.82 (1.01- 3.30)	.047
Hypertension^b	0.98 (0.73- 1.31)	.871	1.05 (0.75- 1.45)	.792
Diabetes mellitus^b	1.37 (0.97- 1.96)	.077	1.37 (0.93- 2.00)	.108
Dyslipidemia^b	0.78 (0.60- 1.01)	.061	0.70 (0.53- 0.94)	.017
Atrial fibrillation^b	0.94 (0.40- 2.21)	.889	1.04 (0.42- 2.56)	.930
Current smoking^b	1.30 (0.86- 1.97)	.213	1.43 (0.89- 2.29)	.142
Educational level^b				

reference < 10 years)

10-12 years	0.63 (0.46- 0.87)	.005	0.60 (0.42- 0.85)	.004
> 12 years	0.55 (0.39- 0.78)	.001	0.51 (0.35- 0.75)	.001

**frequency of going outdoors^b (reference < 1
time/week)**

1-2 times/week	0.95 (0.50- 1.79)	.874	1.09 (0.54- 2.22)	.813
3 or 4 times/week	0.92 (0.51- 1.68)	.792	1.00 (0.51- 1.97)	.994
5 or 6 times/week	0.88 (0.48- 1.60)	.667	1.18 (0.60- 2.33)	.636
Every day	0.84 (0.47- 1.49)	.550	0.95 (0.50- 1.81)	.871
TC service used^b	1.19 (0.60- 2.36)	.612	1.01 (0.47- 2.15)	.985

^a univariate logistic regression analysis.

^b adjusted for age, sex, and MoCA-J score at the baseline.

^c all adjusted variables.

Discussion

The present longitudinal study demonstrated that the prevalence of stroke in community dwelling older and oldest people was 5.4%. On the other hand, the prevalence of cognitive decline after the 3-year follow-up in this survey increased in advanced ages (33.3, 39.4, and 66.7% in those who were 70, 80, and 90 years old, respectively). Previous studies reported that the prevalence of post-stroke cognitive impairment ranges widely from 20 to 80% [5, 33–35]. However, the prevalence of stroke in this study was low because post-stroke participants who had already recovered were able to participate in the investigation but those who did not fully recover were unable to take part in this study. Even though there were a small number of stroke participants, the findings shed more light on cognitive decline in older and oldest people. Moreover, our results demonstrate that participants who developed cognitive decline could be classified into two

major groups based on risk factors including a history of stroke, advanced age, and a greater MoCA-J score at the baseline and protective factors including the presence of dyslipidemia and a higher educational level.

The main finding of the present study was the association between the history of stroke and cognitive decline after the 3-year follow-up. One plausible explanation is that stroke and cognitive decline are common among older persons [36]. As this study included the oldest group of the population, the prevalence of cognitive decline after stroke may have been increased and may have had continuous effects that were evidence during the follow-up. Therefore, an advanced age was considered a risk factor of not only stroke but also cognitive decline [37]. Therefore, a combination of stroke and aging will result in a strong risk for stroke patients to develop cognitive decline. The risk of post-stroke cognitive decline in this study increased gradually by approximately one-fold with an age increase of one year, which was consistent with the study of Renjen PN, et al. [38], who found that the prevalence of cognitive decline was higher with increasing age (100% in an 80–89-year-old age group). In terms of the biological mechanism, β -amyloid deposition, one of the pathological hallmarks of Alzheimer's disease, may play a significant role in cognitive dysfunction associated with aging, and in cognitively normal older people it may be associated with gray matter atrophy and memory impairment [39]. The role of stroke pathology, besides neurodegenerative abnormalities, in the aging process, and a synergistic role for these two components, has been documented [40, 41].

Moreover, in the present study, the MoCA-J score at the baseline was considered a risk factor that could be used to predict post-stroke cognitive decline. We found that an increase in the MoCA-J score at the baseline by one point increased the risk of cognitive decline by approximately one-fold. Besides this, older people who had higher MoCA-J scores at the baseline likely developed cognitive decline. In one conventional Mini-mental Status Examination (MMSE) study, patients with a high cognitive function showed a greater reduction in MMSE than patients with a low cognitive function, which was at odds with most population studies [42]. The results of the present study suggest that stroke patients with low MoCA-J scores at the baseline were already on a trajectory of cognitive decline related to pre-existing neurodegenerative lesions or other undetermined factors triggered by the initial stroke event [43].

On the other hand, dyslipidemia was found to be a protective factor in the present study, which means that the participants who were diagnosed with dyslipidemia had a decreased risk of cognitive decline after stroke. This finding is similar to those of other large studies of older people that reported an association of high triglyceride [44] and LDL levels with better cognitive performance [45]. In contrast, a longitudinal study of 1,159 elderly Chinese individuals found associations between the elevated levels of total cholesterol and LDL- accelerated cognitive decline [46]. To elucidate current findings, it may be explained that statin use was associated with a reduced risk of dementia in participants without MCI at the baseline [47]. The pleiotropic effects of statin might favorably affect cognitive function through pro-endothelial activity, stabilization of atherosclerotic plaques, anti-inflammation, and inhibition of thrombogenesis. However, it is noteworthy that there is no established role for statin in the prevention and treatment of dementia as two large clinical trials demonstrated no cognitive improvements while a small

trial found mixed results [48].As a consequence, the effects of statin need to be further clarified in future studies.

The educational level was also a protective factor in this study, whereby a higher education level was related to an increased risk of cognitive decline after the 3-year follow-up. We deduce that cognitive functioning of stroke survivors with a higher education level was less likely to be affected because they had a larger brain reserve capacity which could compensate for brain damage [49].In contrast, a study by Wu et al. [50],which divided 206 patients who suffered from ischemic stroke into a vascular cognitive impairment (VCI) group and no-VCI group, showed that when examining MoCA scores, the number of impaired MoCA scores decreased with an increase in the educational level. In the present study, the participants who had a higher educational level at the baseline showed more cognitive decline after the 3-year follow-up. This may be explained as follows: participants with higher MoCA-J scores at the baseline and after the 3-year follow-up had a greater capacity for cognitive decline compared with those with a lower level of education and with lower MoCA-J scores at the baseline.

In the present study, several limitations have to be mentioned. Firstly, the participants could not be considered representative of the general older Japanese population. Therefore, there was a possibility of selection bias. Furthermore, the numbers of participants with a history of stroke and cognitive decline events were small. These might, to some extent, limit the external validity of the findings. Secondly, the population included only non-institutionalized community dwelling Japanese people in limited areas, and most of the study subjects were physically and mentally healthy and came to the research venue voluntarily by referring to a map. Thus, they did not suffer from dementia. Moreover, only the participants who had fully recovered from stroke were recruited in the study, and those who lived with lasting disability after stroke were excluded. Consequently, our results cannot be generalized to younger, older, or less healthy people with a history of stroke. Thirdly, the data regarding stroke history had low objective reliability because they were obtained from personal interviews. Comprehensive medical and imaging examinations to diagnose stroke may have yielded more precise and accurate results. Fourthly, this study was longitudinal in nature, so we were unable to implement a direct comparison between the participants in the study at endpoints because of subject loss during the follow-up, severe disability, or death. Moreover, the stroke ratio between follow-up and dropped-out groups was equal (1:1) and the ratio between with and without a history of stroke in the follow-up group was higher than in the dropped-out group (1:17.51 vs. 1:11.67, respectively) (Additional file 4: Table S4) and the MoCA-J score at the baseline in the follow-up group was greater than in the dropped-out group in each age group and all age groups combined, with significant differences. Thus, participants in the follow-up examination of the present study represent a relatively healthy group. This might have led to an underestimation of the true relationship between stroke and cognitive decline. Fifthly, there was no precise cut-off point for a significant decline in MoCA-J scores. Therefore, the present study specified the cut-off value for cognitive decline at the 3-year follow-up by reduction of 2 points or greater of MoCA-J scores subtracted from the scores at the baseline [31, 32].Sixthly, we used self-reported questionnaires to obtain data regarding the frequency of going outdoors as the indicator of physical activity. This may be a crude measure compared with energy expenditure. In fact, objective measures such as digital devices that automatically measure

the activity level, walking speed, and periods of activity should have been used instead. Finally, since we could not perform electrocardiography to diagnose atrial fibrillation and had to rely on personal interviews, the data obtained may have not been as accurate.

Conclusions

Several studies found various risk factors associated with cognitive decline after stroke, but this study is the first investigation involving community dwelling older and oldest people in Japan. The current study indicates that a history of stroke, advanced age, and greater MoCA-J score at the baseline were risk factors while the presence of dyslipidemia and higher educational level were protective factors during the 3-year follow-up, although the community dwelling older and oldest people tended to show both primary and secondary preventions against cognitive decline, especially those with risks of stroke and also post-stroke conditions.

Abbreviations

BP: Blood pressure; CI: Confidence interval; HDL: High-density lipoprotein; IQR: Interquartile; LDL: Low-density lipoprotein; LTC: Long-term care; MCI: Mild cognitive impairment; MMSE: Mini-mental Status Examination; MoCA-J: The Japanese version of the Montreal Cognitive Assessment; OR: Odds ratio; SONIC: The *Septuagenarians, Octogenarians, Nonagenarians Investigation with Centenarians* study; VCI: Vascular cognitive impairment

Declarations

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Authors' Contributions

Srithumsuk, Kabayama, Gondo, Ikebe, Rakugi, and Kamide: concept, designed, and developed the overall research plan. Srithumsuk, Kabayama, Masui, Akagi, Klinpuatan, Kiyoshige, Godai, Sugimoto, Akasaka,

Takami, Takeya, Yamamoto, Ogawa, Inagaki, Ishizaki, Arai, and Kamide carried out data collection. Gondo evaluated the cognitive function. Srithumsuk, Akagi, Kiyoshige, and Godai conducted analysis and interpretation of data. Sritumsuk, Kabayama, and Kamide wrote and had responsibility for the final contents of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The SONIC study was approved by the Institutional Review Board of Osaka University Graduate School of Medicine, Dentistry, and Human Sciences (Osaka, Japan) and the Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology (Tokyo, Japan). Informed consent was obtained from all study participants.

Participants have been informed of the research objectives and have given their written consent. Their anonymity has been guaranteed.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

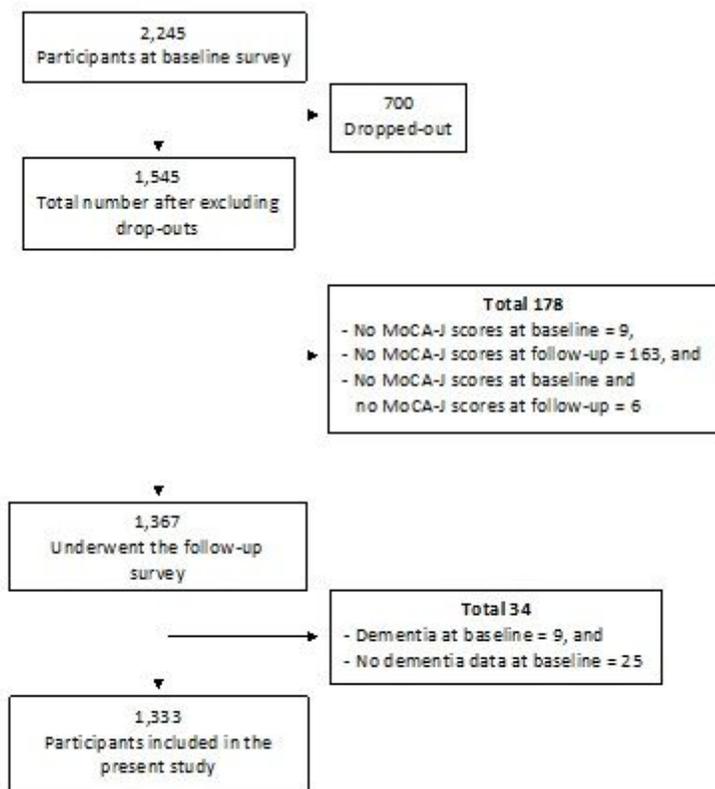


Figure 1. Participants included in the study

Figure 1

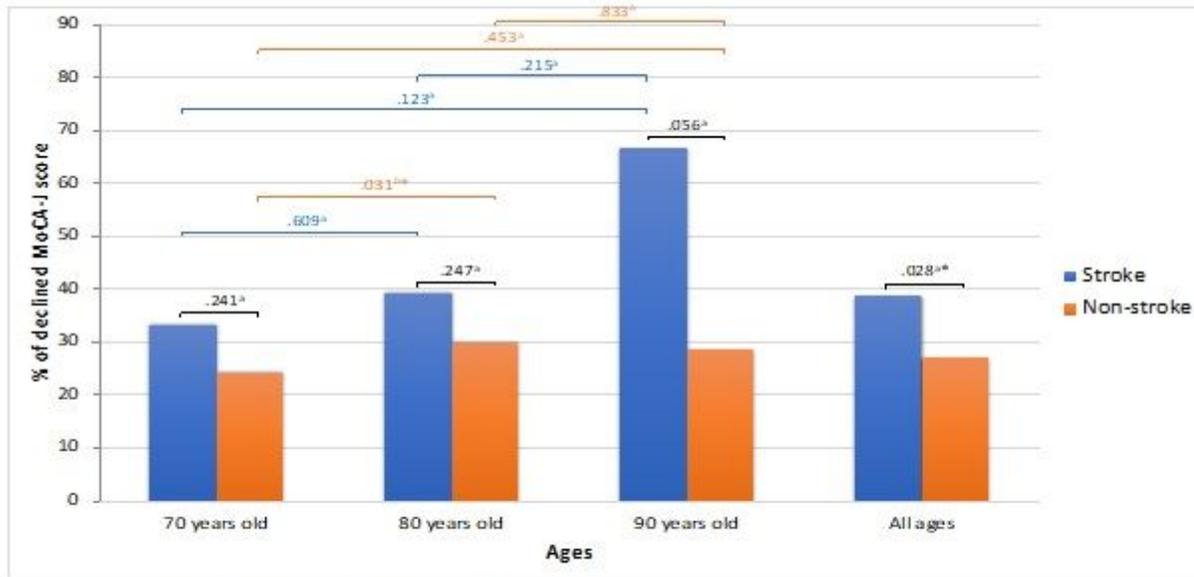


Figure 2. Percentage of declined MoCA-J scores in the stroke and non-stroke groups
^a P-values from Pearson's Chi-square test; ^b P-values from Fisher's exact test; * P-values <.05

Figure 2

Supplementary Files

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