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Disabled life expectancy with and without stroke: a 10-year Japanese prospective cohort study

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Abstract

Purpose A stroke is a debilitating condition that can cause lifelong disability, severely limiting the ability of individuals to perform daily activities. In Japan, strokes are the fourth leading cause of death; however, no previous studies have examined the influence of strokes on a disabled or disability-free life for older Japanese residents. This study aims to address this gap.

Methods The study used data from the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA) and incidence-based multistate life tables to estimate disabled and disability-free life expectancy based on the stroke status of Japanese residents aged 65 and older.

Results Japanese stroke survivors aged 65 who experienced an initial disability-free state could expect to live approximately 3 fewer total years of life, 4–5 fewer years in a disability-free state, and 1–2 more years in a disabled state compared to those without history of a stroke ($p < 0.05$). For those disabled at the beginning of the survey interval, the differences between individuals with and without stroke history were also similar to those disability-free at the beginning of the survey interval (2–4 and 5–6 fewer total and disability-free years, respectively) ($p < 0.05$). The same pattern was observed for older age groups.

Conclusion Older adults who have experienced a stroke could experience a shorter total life expectancy, shorter disability-free life expectancy, and longer disabled life expectancy than those who have not experienced a stroke. These results can inform policymakers and rehabilitation practitioners on stroke survivor long-term care needs and their post-stroke health status.

Keywords Life expectancy · Stroke · Disabled life expectancy · Disability · Mortality

Introduction

Strokes are a debilitating condition that can lead to lifelong disability, severely limiting the ability of individuals to perform daily activities. Annually, approximately 15 million people worldwide experience at least one stroke, one-third of whom are left permanently disabled [1]. In 2010, there were 5.9 million stroke-related deaths and 102.2 million disability-adjusted life years lost worldwide [2]. Since 2011, in Japan, a developed country with one of the highest life expectancies in the world, stroke has become the fourth leading cause of death after cancer, heart disease, and pneumonia [3]. It is important to note, however, that in the 1960s and 1970s, stroke was the number one cause of death in Japan, giving Japan the highest stroke mortality rates in the world. Between the 1970s and 1990s, Japan saw a rapid decline in stroke incidence and mortality. This decline tapered after the late 1990s [3–5]. Advancements in medical technology and treatments such as the tissue-plasminogen activator (t-PA) partially account for this declining trend in stroke mortality. [4] Additionally, the prevention and treatment of high blood pressure (hypertension) also significantly contributed to this sharp decline during the second half of the twentieth century [6–9]. The improved management of hypertension may have been caused by reduced rates of sodium intake and smoking among the Japanese population in addition to the increased use of antihypertensive medication. [6, 8, 10].

Despite this decline in stroke mortality, the condition is a major cause of disabilities, which greatly affect long-term care needs [11]. In Japan, the older population is growing rapidly. In 2015, people aged 65 and over accounted for 26.8% of the Japanese population, with the number projected to increase to 38.4% by 2065. [12] As strokes often occur at

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older ages [13], it is expected that they will pose a significant burden on healthcare system in Japan.

Although a stroke is an acute event, it should be treated as a chronic disease, since those who survive tend to experience long-term physical, psychological, and social challenges. Patients who have experienced a stroke face various difficulties during rehabilitation, including limited mobility, cognitive deficits, communication disorders, swallowing difficulty, depression, and anxiety [14, 15]. The concept of quality of life (QOL) is complicated [16–18]. Although having a disability does not necessarily equal lower quality of life [19, 20], long-term stroke survivors generally still report a low QOL partly due to functional impairment or depression. [21–23] However, it is important to note that not all survivors reported reduced quality of life [24]. Furthermore, stroke-induced disabilities also severely affect social participation, such as the possibility of returning to work [25, 26].

In addition, studies have shown that the risk of death following a stroke is high in older adults [27]. Previous studies have documented the mortality rate of stroke patients after 12 years to be 73–87% [28, 29]. Causes of death following a stroke have primarily been attributed to vascular complications, recurrent strokes, cardiac or aortic issues, and malignancies [30]. Stroke patients who survive life-threatening illness can experience different levels of disability, and it has been estimated that the prevalence of disability in 5-year survivors is 36–45% [31, 32]. Other research using the Barthel Index has highlighted the fact that, for the 11.84 years of total life expectancy among a cohort of stroke patients, the average number of years spent with mild, moderate, or severe disability was 0.86, 1.24 years, and 1.39 years, respectively [33].

It should also be noted that stroke can negatively impact the health of caregivers. Home-care for stroke patients is demanding and heavy-duty work. Caregivers taking care of family members who have experienced a stroke are often under-prepared for the demands of this type of caregiving. Given this challenging burden and their lack of fundamental support, family caregivers are at risk of poor mental and physical health, such as depression, illness symptoms, and chronic diseases [34, 35].

The effects of stroke are important, particularly since their treatment results in a significant economic burden, which includes the cost of hospitalization, medicine, healthcare professionals, medical treatment, and employment production losses due to stroke morbidity and mortality [36, 37]. In the United States, total stroke-related costs were estimated to be approximately $33.6 billion in 2011 [38]. Furthermore, an international comparison of stroke cost studies published in 2004 shows that, on average, 3% of total healthcare costs and 0.27% of GDP corresponded to stroke-related costs [37]. It is important to note that stroke-related costs vary greatly according to the level of difficulty individuals experience with their activities of daily living (ADLs). Stroke-related costs for patients with severe ADL difficulties are multiple times that for patients with minor or no ADL difficulties [39]. Overall, stroke-associated costs have posed a significant burden on several countries, including Japan. For example, in 2004, treatment costs for stroke patients in Japan totaled at approximately 1.2 billion dollars, which comprised about 7% of total national medical expenditures that year [4]. This, however, did not examine the caregiving burden on family members, who may be at a higher risk of poor mental and physical health [34, 35], depending on the severity of the stroke [39].

Assessing the effects of strokes on general mortality and disability is crucial to healthcare policymaking. Moreover, previous studies have examined the relationship between stroke and disability-free life expectancies in China and the United States [40, 41]. However, this work has not been conducted in Japan, a country with one of the highest life expectancies. Thus, the objective of this study was to investigate and compare total and disability-free life expectancy of elderly Japanese men and women with and without stroke histories in order to determine the impact of strokes on disability and mortality.

Data and methods

Data

The panel data were provided by the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA). Five waves of data spanning a 10-year period (1999, 2001, 2003, 2006, and 2009) were used. The sample was national representative of community-dwelling Japanese residents aged 65 + at baseline ($n = 4997$). A multistage stratified probability sampling method was used to produce an initial sample of 6700 adults aged 65 and above. Those aged 75 + were oversampled by a factor of two. In-person interviews employing structured questionnaires were conducted by trained interviewers at the homes of the respondents. The sample was refreshed in 2001 and 2003 to maintain the lowest age group (ages 65 and 66). For the purpose of data analysis clarity, this study used the panel data beginning with the 1999 baseline wave and excluded the refreshed sample. [42] Where possible, information regarding respondent death was obtained from family members as a follow-up. After removing the missing information for all the variables, there were 4859 Japanese respondents in the analysis sample. Sample weights were applied to the analyses to represent the national population of older Japanese residents aged 65 and above.

Oral consent was obtained for the first three surveys and written consent was obtained for the fourth and fifth surveys from the respondents of the Nihon University Japanese

Longitudinal Study of Aging. Due to the enforcement of Japan's 2005 Privacy Protection Law and anthropometric measurements included in the fourth and fifth surveys, permission to conduct the study was also obtained from Nihon University's Ethical Committee.

Variables

Stroke experience was measured using subjects' self-reports. For each wave, subjects were asked, "have you (subject) ever experienced or are currently experiencing cerebrovascular diseases (hemorrhage, infarction, etc.)?"

Disability was examined via two measures: activities of daily living (ADLs) and instrumental activities of daily living (IADLs). The ADL measure was based on seven activities: bathing, dressing, eating, getting in and out of bed, walking, going outside, and using the toilet. The IADL measure was also based on seven activities: preparing meals, shopping, managing money, making phone calls, doing light housework, using transportation, and taking medication. ADL disability was defined by the present study as the reporting of difficulty performing at least one ADL, while IADL disability was defined by the present study as the reporting of difficulty performing at least one IADL.

All models accounted for age and were stratified by sex. To account for potential confounders and comorbidities, socioeconomic variables were included, such as education (high school and above); health behaviors; such as whether respondents had ever smoked, drunk alcohol, and exercised [44, 45]; comorbidities, such as heart diseases [44], hypertension [44, 46], diabetes [44, 47, 48], kidney diseases [44], and respiratory diseases [44]; and Body Mass Index (BMI) [44]. For the analyses, a comorbidity index (the summed number of the five aforementioned chronic diseases) was used as a control variable.

Methods

This study used a multistate life table (MSLT) method to estimate total life expectancy (TLE), disability-free life expectancy (DFLE), and disabled life expectancy (DLE). There are two kinds of MSLTs: a population-based MSLT describing the potential life cycle events of a whole population and a status-based MSLT describing the potential life events of those in different states of health at certain ages [49]. The MSLT method takes into account situations in which (1) individuals both experience and recover from a disability, (2) individuals with different disability profiles have different mortality rates, and (3) individuals remain in the same disability state (Fig. 1). Hence, estimates of TLE, DFLE, and DLE are derived from six types of age-specific transition probabilities: movement into and out of disability, deaths from each of the health states, and maintaining health state.

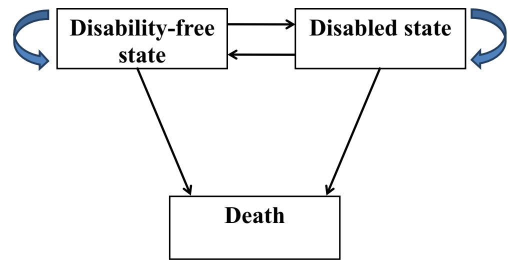

Fig. 1 Disability transitions

The incidence-based multistate life tables were estimated using a relatively new algorithm: the Stochastic Population Analysis for Complex Events (SPACE) [50]. The SPACE approach offers some advantages over traditional methods of estimating MSLTs, namely, the use of both microsimulation and the bootstrap method to estimate the sampling variability of MSLT functions. It begins by fitting a multinomial logistic regression in the following form:

$$\begin{aligned}\ln\left(\frac{p_{ij}}{p_{ii}}\right) = {} & \beta_{0ij} + \beta_{1ij} \times \text{age} + \beta_{2ij} \times \text{stroke} \\ & + \beta_{3ij} \times \text{education} + \beta_{4ij} \times \text{smoking} \\ & + \beta_{5ij} \times \text{drinking} + \beta_{6ij} \times \text{exercising} \\ & + \beta_{7ij} \times \text{number of comorbidities} \\ & + \beta_{8ij} \times \text{BMI},\end{aligned} \quad (1)$$

where p_{ij} is the transition probability from the current state i to state i ($i \neq j$); β_{0ij} is the intercept; and $\beta_{1ij} - \beta_{8ij}$ are coefficients for variables present at the beginning of the observation interval. β_{1ij} is the coefficient for age; β_{2ij} is the coefficient for self-reported stroke status; β_{3ij} is the coefficient for education (high school or above); β_{4ij} is the coefficient for smoking; β_{5ij} is the coefficient for drinking; β_{6ij} is the coefficient for exercising; β_{7ij} is the coefficient for the summed number of the five aforementioned diseases (e.g., heart disease, hypertension, diabetes, kidney disease, and respiratory disease); and β_{8ij} is the coefficient for BMI.

This study estimated transition probabilities first for the entire analytical sample and then for each bootstrap sample. There were 300 bootstrap samples, and all analyses in the study were stratified by sex. The statistical significance of differences with 95% confidence intervals of the estimates obtained from bootstrapping was also examined. SPACE provided both population-based and status-based MSLTs. This study presented the latter, since it was most relevant to the topic at-hand. For more details, please refer to Cai et al.'s article [50]. The SPACE program codes used in the study are available online (http://sites.utexas.edu/space/).

Results

Table 1 shows the descriptive information from the analyzed sample at baseline. There were 4833 older Japanese residents with no missing information regarding the analyzed variables: 56.0% were female; 39.9% had a high school education or above; 40.5% had ever smoked; 35.3% drank alcohol; 16.3% had engaged in sports or exercise recently; 8.9% had had a stroke at some point; 13.5% had had at least one ADL; and 16.0% had had at least one IADL. The mean age was 74.1; the mean BMI was 22.3; and the mean number of five chronic diseases was 0.7. The 164 cases (3.3%) were excluded from the original baseline 4997 cases due to missing information regarding the analyzed variables.

For the analysis, an analytical dataset was produced via pooling observation intervals. Each row (i.e., observation) in the data file was either an interview wave or death record, with transitions identified as between rows (observations) for each individual over time. Therefore, each individual could have multiple observations and transitions. Those with only one observation were excluded due to the lack of transition. Table 2 displays the number of transitions between ADL and IADL disability states and death-by-stroke status at the beginning of the survey. A total of 12,194 transitions were included in this study. Of these 12,194 transitions, 10,310 transitions corresponded to no stroke encounter, while 1884 corresponded to a stroke encounter. Of the 10,310 stroke-free transitions, a majority (over three-quarters) of respondents remained in the same disability state (e.g., either disability-free or disabled), almost one-tenth experienced disability incidence, 3% had recovered from their disability, and 10% were dead. Of the 1884 transitions experienced by the stroke patients, over half remained in the same disability state, 14% experienced disability incidence, approximately 5% had recovered from their disability, and 17% were dead.

Table 1 Descriptive information of the analysis sample at baseline

Variable	*N*	%
Female	2782	56.0
Education (high school and above)	1732	39.9
Ever smoker	1872	40.5
Drinking	1587	35.3
Exercising	725	16.3
Ever had stroke	474	8.9
1 + ADL	798	13.5
1 + IADL	952	16.0
	Mean	SD
Age	74.1	6.3
BMI	22.3	3.3
Number of 5 chronic diseases	0.7	0.8
Total *N*	4833	

N number; % proportion; *SD* standard deviation; chronic diseases include heart problems, hypertension, diabetes, kidney diseases, and respiratory diseases; *ADL* activities of daily living; *IADL* instrumental activities of daily living; *N* is unweighted. %, mean, and SD are weighted

Status-based estimates

Table 3 shows the status-based estimates for TLE, DFLE, and DLE as well as the ratio of DFLE to TLE in regard to the stroke status of men and women who were initially ADL disability-free. At age 65, men who had never experienced a stroke had an average TLE of 20.5 years, of which 18.7 years were disability-free and 1.8 years were disabled. On the other hand, men aged 65 who had experienced a stroke could expect, on average, to live 3.1 fewer overall years, 5.2 fewer disability-free years, and 2.1 more disabled years compared to their non-stroke experiencing counterparts ($p < 0.05$). The ratio of DFLE to TLE was larger for men with no stroke experience compared with that for men with stroke experience. In other words, those without stroke experience could, on average, expect to spend a higher proportion of their remaining years being disability-free. Similar patterns between stroke status and DFLE and TLE were observed at older ages, at which men have fewer remaining

Table 2 The number of transitions between ADL and IADL disability states and death-by-stroke status at the beginning of survey intervals

	ADL				IADL			
	Disability-free	Disabled	Dead	Total	Disability-free	Disabled	Dead	Total
No stroke								
Disability-free	7445	823	592	8860	7109	885	525	8519
Disabled	328	688	434	1450	328	962	501	1791
Total	7773	1511	1026	10,310	7437	1847	1026	10,310
With stroke								
Disability-free	795	272	94	1161	707	271	80	1058
Disabled	84	421	218	723	89	505	232	826
Total	879	693	312	1884	796	776	312	1884

ADL activities of daily living; *IADL* instrumental activities of daily living

Table 3 Status-based estimates with initial ADL disability-free state: total, disability-free, and disabled life expectancies and proportion of disability-free life expectancy for older Japanese with and without stroke, by age and sex

Age	LE (SE)				Difference (95% CI)		
	TLE (SE)	DFLE (SE)	DLE (SE)	%DF	TLE (95% CI)	DFLE (95% CI)	DLE (95% CI)
Men—without stroke					Men		
65	20.5 (0.4)	18.7 (0.4)	1.8 (0.2)	91.2	3.1 (2.0, 4.6)	5.2 (4.0, 6.8)	− 2.1 (− 3.2, − 1.1)
75	13.4 (0.3)	11.8 (0.3)	1.6 (0.2)	87.8	2.5 (1.4, 3.5)	4.2 (2.9, 5.1)	− 1.7 (− 2.5, − 0.8)
85	8.1 (0.4)	6.7 (0.3)	1.4 (0.2)	82.9	1.3 (0.6, 2.3)	2.5 (1.8, 3.2)	− 1.1 (− 1.8, − 0.5)
Men—with stroke							
65	17.4 (0.7)	13.5 (0.7)	3.9 (0.5)	77.3			
75	11.0 (0.5)	7.6 (0.5)	3.3 (0.4)	69.6			
85	6.8 (0.4)	4.3 (0.3)	2.5 (0.4)	63.0			
Women—without stroke					Women		
65	24.0 (0.4)	19.8 (0.4)	4.2 (0.3)	82.4	3.2 (0.9, 5.2)	5.0 (3.1, 6.6)	− 1.7 (− 3.0, − 0.6)
75	16.2 (0.4)	12.3 (0.3)	4.0 (0.3)	75.6	2.6 (0.6, 4.0)	3.9 (2.5, 4.8)	− 1.3 (− 2.4, − 0.3)
85	10.2 (0.4)	6.8 (0.3)	3.4 (0.3)	67.0	1.6 (0.2, 2.7)	2.4 (1.6, 3.0)	− 0.7 (− 1.8, 0.1)
Women—with stroke							
65	20.8 (1.0)	14.8 (0.8)	5.9 (0.6)	71.4			
75	13.7 (0.8)	8.4 (0.5)	5.2 (0.5)	61.7			
85	8.5 (0.6)	4.4 (0.3)	4.1 (0.5)	52.2			

ADL activities of daily living; *LE* life expectancy; *SE* standard error; *Difference* LE without stroke − LE with stroke; *CI* confidence interval; *TLE* total life expectancy; *DFLE* disability-free life expectancy; *DLE* disabled life expectancy; *%DF* percentage of DFLE over TLE. Data source: Nihon University Japanese Longitudinal Study of Aging (NUJLSOA), 1999–2009. Models control for education, smoking status, drinking status, exercise status, number of chronic diseases (heart problems, hypertension, diabetes, kidney diseases, respiratory diseases), and BMI

years of disability-free life and life in general. Women indicated similar patterns, but the difference among men who had and had not experienced a stroke was relatively greater. At age 65, women who had not experienced a stroke had a TLE of 24.0 years, of which 19.8 years were disability-free and 4.2 years were disabled. On the other hand, women who had experienced a stroke could expect to live 3.2 fewer total years, 5.0 fewer years of disability-free life, and 1.7 more years of disabled life compared to their non-stroke experiencing counterparts ($p < 0.05$). Table 4 exhibits the status-based estimates for TLE, DFLE, and DLE as well as the ratio of DFLE to TLE based on the stroke status for men and women initially IADL disability-free. Similar to the pattern shown in Table 3, individuals who had experienced a stroke could expect to live fewer total years, fewer years of disability-free life, and more years of disabled life compared to their non-stroke experiencing counterparts ($p < 0.05$).

Table 5 shows TLE, DFLE, and DLE for those who were initially ADL disabled. DFLE was significantly different ($p < 0.05$) for those with and without a stroke experience across all age groups in Japan, while TLE was significantly different ($p < 0.05$) for those with and without stroke experience aged 65 and 75. DLE was only significant for men aged 65 and 75 and women aged 65 ($p < 0.05$). Japanese residents with a stroke experience could expect to live fewer total years, fewer years of disability-free life, more years of disabled life, and experienced a smaller proportion of disability-free life compared to those without a stroke experience. These results are similar to those exhibited in Tables 3 and 4, but the difference between stroke status in regard to TLE, DFLE, and their ratio was greater among those who were initially disabled. Those in an initial disability-free state could expect to live more years and with a larger proportion of disability-free life compared to those in an initial disabled state. Furthermore, life expectancy and proportion of disability-free life were both greater for those without stroke history than for those with stroke history. Table 6 displays TLE, DFLE, and DLE for those who were initially IADL disabled. DFLE was significantly different ($p < 0.05$) for Japanese residents with and without stroke history across all age groups; TLE was significantly different ($p < 0.05$) for Japanese residents with and without stroke history for those aged 65 and 75; DLE was not significant ($p > 0.05$). These results are similar to those shown in Tables 3, 4, and 5.

Discussion

In Japan, a developed country with one of the highest life expectancies, stroke remains one of the most common causes of death [3, 51] and a leading cause of disability [4]. There have been no previous studies regarding the influence of stroke on disability-free or disabled life in older adults in

Table 4 Status-based estimates with initial IADL disability-free state: total, disability-free, and disabled life expectancies and proportion of disability-free life expectancy for older Japanese with and without stroke, by age and sex

Age	LE (SE)				Difference (95% CI)		
	TLE (SE)	DFLE (SE)	DLE (SE)	%DF	TLE (95% CI)	DFLE (95% CI)	DLE (95% CI)
Men—without stroke					Men		
65	20.5 (0.4)	18.2 (0.4)	2.3 (0.2)	88.7	3.2 (2.1, 4.7)	5.0 (4.1, 6.6)	− 1.8 (− 3.0, − 0.9)
75	13.4 (0.3)	11.2 (0.3)	2.1 (0.2)	84.0	2.4 (1.5, 3.4)	3.9 (3.1, 4.9)	− 1.5 (− 2.3, − 0.7)
85	8.1 (0.4)	6.2 (0.3)	1.9 (0.3)	76.4	1.4 (0.6, 2.2)	2.4 (1.8, 3.1)	− 1.0 (− 1.7, − 0.4)
Men—with stroke							
65	17.3 (0.7)	13.2 (0.6)	4.1 (0.5)	76.1			
75	10.9 (0.5)	7.3 (0.4)	3.6 (0.4)	66.8			
85	6.7 (0.4)	3.9 (0.2)	2.9 (0.4)	57.1			
Women—without stroke					Women		
65	24.4 (0.4)	19.3 (0.4)	5.1 (0.3)	79.2	3.0 (0.3, 4.8)	4.2 (2.2, 6.1)	− 1.2 (− 2.9, − 0.1)
75	16.4 (0.4)	11.6 (0.3)	4.8 (0.3)	70.9	2.3 (0.1, 3.8)	3.3 (1.7, 4.5)	− 0.9 (− 2.3, 0.2)
85	10.2 (0.4)	6.1 (0.3)	4.1 (0.4)	59.7	1.4 (− 0.2, 2.5)	1.9 (1.1, 2.7)	− 0.5 (− 1.7, 0.4)
Women—with stroke							
65	21.4 (1.1)	15.1 (0.9)	6.3 (0.6)	70.5			
75	14.1 (0.8)	8.4 (0.7)	5.7 (0.6)	59.4			
85	8.8 (0.7)	4.2 (0.4)	4.6 (0.6)	47.4			

IADL instrumental activities of daily living; *LE* life expectancy; *SE* standard error; *Difference* LE without stroke – LE with stroke; *CI* confidence interval; *TLE* total life expectancy; *DFLE* disability-free life expectancy; *DLE* disabled life expectancy; *%DF* percentage of DFLE over TLE. Data source: Nihon University Japanese Longitudinal Study of Aging (NUJLSOA), 1999–2009. Models control for education, smoking status, drinking status, exercise status, number of chronic diseases (heart problems, hypertension, diabetes, kidney diseases, respiratory diseases), and BMI

Table 5 Status-based estimates with initial ADL disabled state: total, disability-free, and disabled life expectancies, and proportion of disability-free life expectancy for older Japanese with and without stroke, by age and sex

Age	LE (SE)				Difference (95% CI)		
	TLE (SE)	DFLE (SE)	DLE (SE)	%DF	TLE (SE)	DFLE (SE)	DLE (SE)
Men—without stroke					Men		
65	16.7 (1.1)	12.1 (1.5)	4.6 (0.7)	72.5	2.8 (1.6, 5.9)	5.2 (4.1, 9.0)	− 2.5 (− 4.4, − 1.1)
75	10.0 (0.6)	5.5 (0.5)	4.5 (0.3)	55.0	1.8 (0.3, 3.4)	3.3 (2.0, 4.4)	− 1.5 (− 2.4, − 0.1)
85	5.2 (0.4)	1.5 (0.2)	3.6 (0.3)	29.4	0.5 (− 0.4, 1.6)	1.0 (0.6, 1.4)	− 0.5 (− 1.2, 0.4)
Men—with stroke							
65	13.9 (1.1)	6.9 (1.1)	7.1 (0.9)	49.3			
75	8.2 (0.6)	2.2 (0.3)	6.0 (0.5)	26.8			
85	4.7 (0.4)	0.5 (0.1)	4.1 (0.4)	11.7			
Women—without stroke					Women		
65	20.7 (0.9)	13.8 (1.0)	6.9 (0.6)	66.6	2.3 (1.1, 6.3)	4.6 (3.6, 8.4)	− 2.4 (− 3.9, − 0.6)
75	13.5 (0.5)	6.7 (0.5)	6.8 (0.3)	49.8	2.3 (0.6, 4.0)	3.5 (2.0, 4.5)	− 1.3 (− 2.2, 0.3)
85	7.5 (0.4)	2.1 (0.2)	5.5 (0.3)	27.4	0.9 (− 0.1, 2.4)	1.2 (0.7, 1.7)	− 0.3 (− 1.1, 1.0)
Women—with stroke							
65	18.4 (1.3)	9.1 (1.4)	9.3 (0.9)	49.6			
75	11.2 (0.8)	3.2 (0.6)	8.0 (0.6)	28.3			
85	6.7 (0.6)	0.9 (0.2)	5.8 (0.5)	13.4			

ADL activities of daily living; *LE* life expectancy; *SE* standard error; *Difference* LE without stroke – LE with stroke; *CI* confidence interval; *TLE* total life expectancy; *DFLE* disability-free life expectancy; *DLE* disabled life expectancy; %*DF* percentage of DFLE over TLE. Data source: Nihon University Japanese Longitudinal Study of Aging (NUJLSOA), 1999–2009. Models control for education, smoking status, drinking status, exercise status, number of chronic diseases (heart problems, hypertension, diabetes, kidney diseases, respiratory diseases), and BMI

Table 6 Status-based estimates with initial IADL disabled state: total, disability-free, and disabled life expectancies and proportion of disability-free life expectancy for older Japanese with and without stroke, by age and sex

Age	LE (SE)				Difference (95% CI)		
	TLE (SE)	DFLE (SE)	DLE (SE)	%DF	TLE (SE)	DFLE (SE)	DLE (SE)
Men—without stroke					Men		
65	17.0 (1.1)	11.7 (1.3)	5.4 (0.6)	68.5	3.3 (1.7, 5.7)	5.9 (4.4, 8.6)	− 2.6 (− 4.5, − 0.9)
75	10.2 (0.5)	5.0 (0.5)	5.2 (0.3)	49.0	2.0 (0.4, 3.1)	3.2 (2.2, 4.0)	− 1.2 (− 2.6, 0.0)
85	5.4 (0.4)	1.4 (0.2)	3.9 (0.3)	26.3	0.5 (− 0.5, 1.4)	0.9 (0.7, 1.3)	− 0.5 (− 1.5, 0.5)
Men—with stroke							
65	13.7 (1.0)	5.7 (0.9)	7.9 (0.8)	42.0			
75	8.3 (0.5)	1.8 (0.3)	6.5 (0.5)	22.1			
85	4.9 (0.4)	0.5 (0.1)	4.4 (0.4)	9.6			
Women—without stroke					Women		
65	21.3 (1.0)	12.9 (1.0)	8.4 (0.6)	60.8	3.6 (1.1, 5.7)	4.9 (2.6, 7.3)	− 1.3 (− 3.4, 0.6)
75	13.4 (0.5)	5.4 (0.4)	8.0 (0.4)	40.2	2.4 (0.7, 3.8)	2.7 (1.4, 3.6)	− 0.3 (− 1.8, 1.3)
85	8.1 (0.4)	1.6 (0.2)	6.5 (0.3)	20.0	1.3 (0.0, 2.4)	0.9 (0.5, 1.2)	0.4 (− 0.8, 1.5)
Women—with stroke							
65	17.7 (1.3)	8.0 (1.1)	9.6 (0.9)	45.5			
75	11.0 (0.8)	2.7 (0.4)	8.3 (0.7)	24.7			
85	6.8 (0.6)	0.7 (0.2)	6.1 (0.6)	10.6			

IADL instrumental activities of daily living; *LE* life expectancy; *SE* standard error; *Difference* LE without stroke – LE with stroke; *CI* confidence interval; *TLE* total life expectancy; *DFLE* disability-free life expectancy; *DLE* disabled life expectancy; *%DF* percentage of DFLE over TLE. Data source: Nihon University Japanese Longitudinal Study of Aging (NUJLSOA), 1999–2009. Models control for education, smoking status, drinking status, exercise status, number of chronic diseases (heart problems, hypertension, diabetes, kidney diseases, respiratory diseases), and BMI

Japan. This study reported total, disability-free, and disabled life expectancy estimates based on stroke status for adults aged 65 and older living in the community in Japan at the time of the 1999 baseline survey.

The TLE and DFLE of older Japanese residents with and without stroke history were significantly different ($p < 0.05$) for both men and women in terms of status-based estimates, but the same was only true for some DLEs. Overall, the same across age and sex, individuals with stroke history can expect to live shorter lives and experience fewer years of disability-free life and more years of disabled life compared with those without stroke history, regardless of their initial health states. Individuals in an initial disability-free state can expect to live more years and experience a larger proportion of disability-free life compared to those in an initial disabled state. Thus, it can be concluded that both life expectancy and the aforementioned proportions were greater for those without stroke history than for those with stroke history, with these two factors decreasing with age, especially in regard to those with stroke history.

These results are consistent with previous studies. First, research has documented that older individuals are at a higher risk of mortality and disability following a stroke [52, 53] and that both TLE and DFLE are lower among those with stroke history [40, 41]. Second, research has shown that females with stroke history are often left more disabled than their male counterparts [54].

Given the fact that a stroke can fatally impact disability and mortality separately, it is important to understand how it simultaneously impacts these two factors. DFLE is a useful indicator that assesses stroke outcomes in the elderly population by considering both health and mortality via measuring the number of remaining years an individual will spend with a disability. Using DFLE as a measure to evaluate health status in relation to the life expectancy of a population adequately reflects the costs and resources required for healthcare, social policies, and the distribution of health services [55].

Despite several studies having examined the association between stroke and mortality [56, 57] or between stroke and disability [58], few have explored the relationship between stroke and DFLE in the elderly population. Among the very few studies that have examined stroke and DFLE together is the study of Fang et al. [41] which uses data from the Beijing multi-dimensional longitudinal study on aging (BMLSA) to investigate the impact of stroke on life expectancy (LE) and DFLE in two cohorts: 1992–1997 and 2000–2004. Fang and colleagues concluded that life expectancy was reduced in those with stroke history by 20–40%, while disability-free life expectancy was reduced by up to 90%. Their findings suggest that a stroke considerably changed the functional status of patients—in a greater capacity than just life expectancy. This study also identified an age difference in terms of stroke impact on disability. For the oldest-old stroke patients, their disability-free years seemed to decrease the most. Additional research addressing stroke and DFLE was conducted by Laditka and Laditka [40]. They utilized data from the Panel Study of Income Dynamics (PSID) in the United States and interviewed elderly adults across six waves between 1999 and 2009. They discovered that strokes reduced life expectancy by 33% and increased years living with a disability by 31.6%. In addition, their study revealed gender differences in terms of disability with stroke, with women experiencing more remaining years in a disabled state than men.

The findings of the present Japanese study were similar to those of Fang et al. [41] on the elderly in Beijing, China, which used hazard rate models, and Laditka and Laditka's [40] study on elderly Americans, which used multinomial logistic regressions with microsimulation and the bootstrap technique. Both TLE and DFLE were observed to be lower among those with stroke history, with initial disability status being an important factor for TLE and DFLE values. The difference between stroke status in terms of TLE, DFLE, and their proportion was larger among those who were initially disabled compared to those who were initially disability-free. The DFLE/TLE proportion decreased as age increased. Individuals who were initially disabled had particularly low DFLE/TLE proportions.

The major strengths of this study include its relatively long research period, consisting of multiple waves of nationally representative longitudinal data along with time-varying stroke status. This allowed for the incorporation of the effect of stroke incidence for older respondents into the model. Additionally, the use of a more advanced method to estimate MSLT functions via the bootstrap technique provided the sampling variability that few of the previous studies have been to produce.

Several issues should be considered when interpreting these results. The data used represented community-dwelling older Japanese residents at the time of the baseline survey conducted in 1999. Thus, stroke prevalence might have been under-reported. There was also a decline in follow-ups, although subjects who were institutionalized or hospitalized at later waves were followed up with to the greatest possible extent. The loss to follow-ups could have created bias in the results. Stroke status was self-reported for each wave without the verification of clinical records. Moreover, there was no available information in the data regarding the type and severity of stroke experienced. According to the Japanese government's website [43], 1.3% of Japanese men aged 65 + and 1.4% of Japanese women aged 65 + had cerebrovascular diseases in 1999. Among these older individuals with cerebrovascular diseases, over 95% had experienced a stroke (subarachnoid hemorrhage, intracerebral hemorrhage, or cerebral infarction). Therefore, this study referred to cerebrovascular diseases as strokes [44]. In our analysis sample at baseline, 11.3% of older men and 6.7% of older women had experienced (or were experiencing) cerebrovascular diseases. Proportions were higher than indicated by population statistics, since the survey not only considered current strokes but also included previous stroke history. The measurement of disability was fairly basic, namely, difficulty with any ADL or with any IADL. Using MSLT methods, we had to categorize our outcome variables, and a continuous outcome variable was not allowed in the analysis. Although there was preference for using more refined disability measures (e.g., ones that take severity into account), this was impossible due to data limitations. Thus, it is unclear whether the identified patterns will hold for more refined disability measures. Additionally, the disability measures did not include depression and cognitive disabilities, although the IADL and ADL measures could be considered proxies. Due to data limitations, the examination of stroke-related mortality and stroke-caused disability could not take place.

In summary, by using nationally representative data and tracking long-term stroke status, this study provided important evidence regarding post-stroke TLE, DFLE, and DLE in the Japanese population. The findings suggest that older adults who have experienced a stroke experience shorter total life expectancy, shorter disability-free life expectancy, and longer disabled life expectancy than those without stroke experience. Among those with stroke history, those in an initial disability-free state could expect higher life expectancy along with higher disability-free life expectancy and less disabled life expectancy, which highlights the importance of remaining in a disability-free state. Such results can inform policymakers and rehabilitation practitioners on stroke survivor long-term care needs and post-stroke health status.

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Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

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