Research Article

Limitations in activities of daily living increase the risk of stroke in older Chinese adults: a population-based longitudinal study

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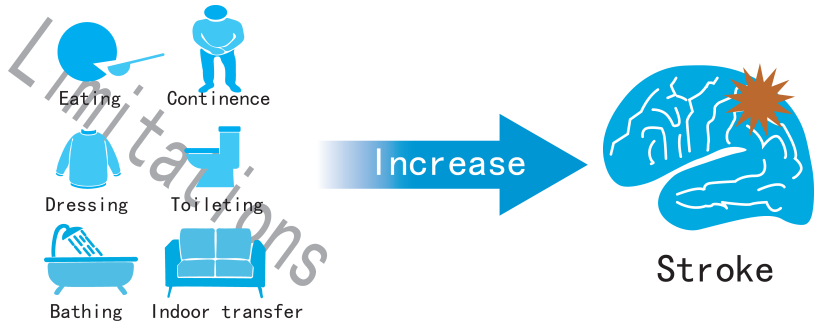
Graphical Abstract *Activities of daily living limitations increase the risk of stroke in older Chinese adults*



Abstract

It remains unclear whether limitations in activities of daily living (ADL) increase the risk of stroke in older Chinese adults. This longitudinal study used data from the Chinese Longitudinal Healthy Longevity Survey to investigate the effects of limitations in ADL on the incidence of stroke in older adults. Between 2002 and 2011, 46,728 participants from 22 provinces in China were included in this study. Of participants, 11,241 developed limitations in ADL at baseline. A 3-year follow-up was performed to determine the incidence of stroke. During the 3-year follow-up, 929 participants (8.26%) and 2434 participants (6.86%) experienced stroke in the ADL limitations group and non-ADL limitations group, respectively. Logistic regression was used to analyze the effect of ADL limitations on the risk of stroke. The results showed that after adjusting for the confounding factors gender, age, weight, hypertension, diabetes, heart disease, natural teeth, hearing impairment, visual impairment, smoking, alcohol abuse, exercise, ethnicity, literacy, residential area, and poverty, the ADL limitations group had a 77% higher risk of developing stroke than the non-ADL limitations group. After propensity score matching, the ADL limitations group still had a 33% higher risk of developing stroke than the non-ADL limitations group (OR = 1.326, 95% CI: 1.174–1.497). These findings suggest that limitations in ADL are a stroke risk factor.

Key Words: activities of daily living; Chinese Longitudinal Healthy Longevity Survey; cohort; older Chinese individuals; propensity score matching; risk; stroke; survey

Chinese Library Classification No. R455; R741; R592

Introduction

Stroke is the leading cause of death and disability worldwide (Sacco et al., 2013). Interventions to prevent stroke have become a global public health priority (O'Donnell et al., 2016). The main known risk factors for stroke are hypertension, hyperlipidemia, smoking, diet, and physical inactivity (O'Donnell et al., 2016; Diener and Hankey, 2020). Owing to scientific knowledge about these risk factors, as well as preventive and risk factor modification strategies, the incidence of stroke is decreasing (GBD 2019 Diseases and Injuries Collaborators, 2020). However, some potential risk factors remain to be identified and used to screen high-risk populations.

Activities of daily living (ADL) are the basic tasks that an individual is able to perform to function on a day-to-day basis. These include bathing, dressing, eating, indoor transferring, toileting, and continence (Katz et al., 1963; Edemekong et al., 2021). ADL limitations are defined as difficulty or the need for

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assistance with at least one task (Fuller-Thomson et al., 2009; Wen and Gu, 2011). Approximately 9.7% of older people experience ADL limitations, and older age, joint/nerve pain, stroke, pelvic/femoral fractures, heart disease, and diabetes are common causes of ADL limitations (Sousa et al., 2009; Malhotra et al., 2012). Because ADL limitations can affect diet, physical inactivity, and weight (Henry-Sánchez et al., 2012), they increase the risk of stroke. Several studies have explored the association between physical dependence and stroke risk (Henry-Sánchez et al., 2012), but results are inconsistent. To further investigate the effect of ADL limitations on the risk of stroke, we conducted a large-scale population-based longitudinal study involving 46,728 individuals with a 3-year follow-up.

Materials and Methods

Data source

The study data were drawn from the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The CLHLS is a high-quality international cooperative project hosted by the Center for the Study of Aging and Human Development at Duke University, the Center for Healthy Aging and Development Studies of Peking University, and other institutions. The CLHLS conducted seven surveys in 22 provinces of China in 1998, 2000, 2002, 2005, 2008, 2011, and 2014, respectively. The populations of these provinces comprise approximately 85% of the total population of China. To ensure sufficient participants for each age group, gender, and region, the CLHLS used the random sampling method of unequal probability proportions to obtain the required sample size for analysis. During the follow-up period, survivors and close relatives of deceased participants were reinterviewed, and deceased interviewees were replaced with new participants (Deng et al., 2020). The study followed the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) statement (**Additional file 1**). The present study is a secondary analysis using the CLHLS data. The need for ethical approval for the study was waived by an institutional review board (IRB00001052–13074) for the CLHLS study, which was approved by the research ethics committees of Duke University and Peking University. Thus, consent for participation was deemed unnecessary for this study. The data were anonymized before use.

Data collection

The CLHLS data were collected from household surveys by professionally trained investigators. They used the Katz scale to assess the ADL of older adults (Katz et al., 1963). Older adults were assessed on whether they exercised regularly by playing ball, swimming, or walking for fitness. Health data, such as vision, oral health, hearing, and previous medical history, were collected by doctors after detailed examination of participants. Details of the survey method can be found at https://sites.duke.edu/centerforaging/programs/chinese-longitudinal-healthy-longevity-survey-clhls/.

Study design and participants

Since 2002, the CLHLS has expanded the sample to include participants over 65 years old. Therefore, we used all survey waves from 2002 to 2011 and merged the data of these waves into one data set. After excluding participants who had had a stroke at baseline or had been followed for less than 3 years, we included the remaining participants in a 3-year cohort. Participants who experienced ADL limitations were included in the exposure group, and the rest were included in the control group.

The study outcome was stroke. Participants who had survived a stroke during the subsequent 3 years, those whose main cause of death was stroke, and those who had had a stroke before death were included in the outcome group with stroke. The remaining participants, whether alive or dead, were included in the outcome group without stroke.

Assessment of stroke occurrence

Stroke was defined according to the following items from the CLHLS questionnaire: "Q: Suffering from stroke or cerebrovascular diseases? A: Yes," "Q: Name of disease suffering from for the first time. A: Stroke, Cerebrovascular diseases," "Q: Name of disease suffering from for the second time. A: Stroke, Cerebrovascular diseases," "Q: Name of last disease suffering from. A: Stroke, cerebrovascular diseases," or "Q: Main cause of death? A: Cerebrovascular diseases (CVD)."

Assessment of ADL limitations

At baseline, six aspects of ADL were assessed: bathing, dressing, eating, indoor transferring, continence, and toileting (Katz et al., 1963). ADL limitations were defined as the inability to complete any ADL alone (Fuller-Thomson et al., 2009; Wen and Gu, 2011) and have been described above.

Assessment of covariates

To control for confounding factors, we included the following variables as covariates in the analysis: gender, age, weight, hypertension, diabetes, heart disease, natural teeth, hearing impairment, visual impairment, type of residential area, current smoking, drinking spirits, exercise, ethnicity, literacy, and poverty. These covariates were selected as potential confounders based on the literature (Woodward et al., 2005; Ferri et al., 2011; O'Donnell et al., 2016; Fang et al., 2019; Liccardo et al., 2019).

We divided age into five 10-year age brackets. Because of the lack of appropriate parameters (e.g., height or knee height) for calculation of body mass index in the 2005 wave, we could only divide body weight into four categories by quartiles. Having natural teeth was defined as the number of natural teeth > 0. In the raw data, hearing ability was recorded as "1 = yes, without hearing aid," "2 = yes, but needs hearing aid," "3 = partly, despite using hearing aid," and "4 = no." Hearing impairment was defined as hearing ability equal to 2, 3, or 4. Visual function was recorded as "1 = can see and distinguish the break in the circle," "2 = can see but cannot distinguish the break in the circle," "3 = cannot see," and "4 = blind." Visual impairment was defined as visual function equal to 2, 3, or 4. Participants were divided into Han and other ethnic groups. Literate was defined as years of schooling > 0. Poverty was defined according to the official definition (National Bureau of Statistics, 2012) of a per capita annual income < 2300 yuan.

Statistical analysis

Multiple imputation was used to handle missing data. Frequencies were used to describe the sample and to compare the ADL limitations group with the non-ADL limitations group. A logistic regression model was used to evaluate the relationship between ADL limitations and risk of stroke and to calculate the odds ratios (ORs). The covariates were adjusted in three analysis plans. In plan 1, gender, age, and weight were adjusted (Model 1). In plan 2, hypertension, diabetes, heart disease, natural teeth, hearing impairment, and visual impairment were adjusted based on plan 1 (Model 2). In plan 3, smoking, drinking spirits, exercise, literacy, ethnicity, and poverty were adjusted based on plan 2 (Model 3).

For various reasons, bias and confounding are major problems in observational studies and can lead to incorrect results. Propensity score matching (PSM) is a statistical method used to eliminate confounding factors by balancing baseline covariates between the observation and control groups to mimic the expected effects of randomization. Briefly, PSM creates matched sets of participants for observation and control groups with similar propensity scores to control confounding. If risk factors for the outcomes are balanced at

baseline, differences in outcome risk are likely to be caused by a different variable (Deb et al., 2016).

To eliminate the effects of potential confounding factors and increase the validity of the results, PSM was performed to balance the baseline characteristics of the samples (Deb et al., 2016). Logistic regression was used to build a propensity scoring model. Using 1:1 matching without replacement, the threshold was 0.02. It is not appropriate in statistical significance testing to evaluate the balance of covariates between groups (Austin, 2007; Deb et al., 2016; Benedetto et al., 2018). Standardized mean differences (SMD) were used to assess intergroup balance. SMDs < 10% are considered to indicate balance between the groups (Deb et al., 2016; Benedetto et al., 2018). The variance inflation factor was used to test whether there was multicollinearity among the independent variables. We considered a *P* value < 0.05 (two-sided) to be statistically significant. For cleaning, coding, and analyzing all data, we used Python (Version 3.6.10, Python Software Foundation, Wilmington, DE, USA) and the Python packages Pandas (Version 1.1.1; https://pandas.pydata.org/), Tableone (https://github.com/kaz-yos/tableone) (Pollard et al., 2018), and Statsmodels (Version 0.12.0; https://www.statsmodels.org/) (Seabold and Perktold, 2010).

Results

The merged data set comprised 58 421 participants. A total of 11 693 participants were excluded because of stroke at baseline or follow-up of less than 3 years. Finally, 46 728 participants were included in the study. **Figure 1** shows the process of participant inclusion and grouping.

Table 1 shows the participant characteristics at baseline. A total of 46,728 participants were included in the analysis: 11 241 in the ADL limitations group and 35,487 in the control group. The proportion of missing values for all variables was less than 5%. Of the 46,728 participants, 24.1% had ADL limitations, 42.6% were men, and 53.8% were 80–100 years old. Before PSM, the SMDs of gender, age, body weight,

Table 1 | **Baseline characteristics before and after propensity score matching**

			All participants				Propensity-matched participants			
				ADL limitations				ADL limitations		
Variables		Missing [*n*(%)]	Overall (*n* = 46728)	No (*n* = 35487)	Yes (*n* = 11241)	SMD	Overall (*n* = 15240)	No (*n* = 7620)	Yes (*n* = 7620)	SMD
Gender	Female	0	26804 (57.4)	18794 (53.0)	8010 (71.3)	0.384	10569 (69.4)	5325 (69.9)	5244 (68.8)	0.023
	Male		19924 (42.6)	16693 (47.0)	3231 (28.7)		4671 (30.6)	2295 (30.1)	2376 (31.2)	
Age (yr)	60 ≤ and ≤ 70	130 (0.2)	5382 (11.5)	5269 (14.8)	113 (1.0)	1.144	210 (1.4)	101 (1.3)	109 (1.4)	0.024
	70 < and ≤ 80		9523 (20.4)	9016 (25.4)	507 (4.5)		943 (6.2)	462 (6.1)	481 (6.3)	
	80 < and ≤ 90		12711 (27.2)	10476 (29.5)	2235 (19.9)		3831 (25.1)	1905 (25.0)	1926 (25.3)	
	90 < and ≤100		12452 (26.6)	7753 (21.8)	4699 (41.8)		6481 (42.5)	3283 (43.1)	3198 (42.0)	
	> 100		6660 (14.3)	2973 (8.4)	3687 (32.8)		3775 (24.8)	1869 (24.5)	1906 (25.0)	
Body weight (kg)	≤ 41	527 (0.9)	12358 (26.4)	8005 (22.6)	4353 (38.7)	0.402	5785 (38.0)	2892 (38.0)	2893 (38.0)	0.017
	41 < and ≤ 49		12154 (26.0)	9190 (25.9)	2964 (26.4)		4114 (27.0)	2078 (27.3)	2036 (26.7)	
	49 < and ≤ 56		11466 (24.5)	9240 (26.0)	2226 (19.8)		3044 (20.0)	1522 (20.0)	1522 (20.0)	
	> 56		10750 (23.0)	9052 (25.5)	1698 (15.1)		2297 (15.1)	1128 (14.8)	1169 (15.3)	
Hypertension	No	2287 (3.9)	38147 (81.6)	28754 (81.0)	9393 (83.6)	0.066	12853 (84.3)	6463 (84.8)	6390 (83.9)	0.026
	Yes		8581 (18.4)	6733 (19.0)	1848 (16.4)		2387 (15.7)	1157 (15.2)	1230 (16.1)	
Diabetes	No	2560 (4.4)	45641 (97.7)	34675 (97.7)	10966 (97.6)	0.01	14947 (98.1)	7488 (98.3)	7459 (97.9)	0.028
	Yes		1087 (2.3)	812 (2.3)	275 (2.4)		293 (1.9)	132 (1.7)	161 (2.1)	
Heart disease	No	2407 (4.1)	42713 (91.4)	32636 (92.0)	10077 (89.6)	0.08	14087 (92.4)	7092 (93.1)	6995 (91.8)	0.048
	Yes		4015 (8.6)	2851 (8.0)	1164 (10.4)		1153 (7.6)	528 (6.9)	625 (8.2)	
Have natural teeth	No	0	16464 (35.2)	10523 (29.7)	5941 (52.9)	0.485	7256 (47.6)	3633 (47.7)	3623 (47.5)	0.003
	Yes		30264 (64.8)	24964 (70.3)	5300 (47.1)		7984 (52.4)	3987 (52.3)	3997 (52.5)	
Hearing impairment	No	70 (0.1)	31649 (67.7)	27513 (77.5)	4136 (36.8)	0.903	7002 (45.9)	3507 (46.0)	3495 (45.9)	0.003
	Yes		15079 (32.3)	7974 (22.5)	7105 (63.2)		8238 (54.1)	4113 (54.0)	4125 (54.1)	
Visual impairment	No	486 (0.8)	29401 (62.9)	25333 (71.4)	4068 (36.2)	0.755	6679 (43.8)	3334 (43.8)	3345 (43.9)	0.003
	Yes		17327 (37.1)	10154 (28.6)	7173 (63.8)		8561 (56.2)	4286 (56.2)	4275 (56.1)	
Residence	City	0	8612 (18.4)	5695 (16.0)	2917 (25.9)	0.245	2903 (19.0)	1407 (18.5)	1496 (19.6)	0.042
	Town		10519 (22.5)	8232 (23.2)	2287 (20.3)		3155 (20.7)	1544 (20.3)	1611 (21.1)	
	Rural		27597 (59.1)	21560 (60.8)	6037 (53.7)		9182 (60.2)	4669 (61.3)	4513 (59.2)	
Smoking	No	138 (0.2)	37953 (81.2)	27851 (78.5)	10102 (89.9)	0.316	13544 (88.9)	6820 (89.5)	6724 (88.2)	0.04
	Yes		8775 (18.8)	7636 (21.5)	1139 (10.1)		1696 (11.1)	800 (10.5)	896 (11.8)	
Drinking spirits	No	0	41644 (89.1)	31460 (88.7)	10184 (90.6)	0.064	13917 (91.3)	7003 (91.9)	6914 (90.7)	0.041
	Yes		5084 (10.9)	4027 (11.3)	1057 (9.4)		1323 (8.7)	617 (8.1)	706 (9.3)	
Exercising	No	209 (0.4)	32818 (70.2)	23362 (65.8)	9456 (84.1)	0.432	12344 (81.0)	6195 (81.3)	6149 (80.7)	0.015
	Yes		13910 (29.8)	12125 (34.2)	1785 (15.9)		2896 (19.0)	1425 (18.7)	1471 (19.3)	
Literacy	No	258 (0.4)	29275 (62.6)	20802 (58.6)	8473 (75.4)	0.362	11432 (75.0)	5761 (75.6)	5671 (74.4)	0.027
	Yes		17453 (37.4)	14685 (41.4)	2768 (24.6)		3808 (25.0)	1859 (24.4)	1949 (25.6)	
Han ethnicity	No	0	3722 (8.0)	3128 (8.8)	594 (5.3)	0.138	880 (5.8)	398 (5.2)	482 (6.3)	0.047
	Yes		43006 (92.0)	32359 (91.2)	10647 (94.7)		14360 (94.2)	7222 (94.8)	7138 (93.7)	
Poverty	No	1129 (1.9)	20359 (43.6)	15701 (44.2)	4658 (41.4)	0.057	6079 (39.9)	3015 (39.6)	3064 (40.2)	0.013
	Yes		26369 (56.4)	19786 (55.8)	6583 (58.6)		9161 (60.1)	4605 (60.4)	4556 (59.8)	

The propensity score matching (PSM) was performed to balance the baseline characteristics of samples. The intergroup balance was assessed by standardized mean differences (SMD). If SMD is less than 10%, it is considered to be a balance between groups. ADL: Activities of daily living.

natural teeth, visual impairment, residential area, smoking, exercise, literacy, and Han ethnicity were greater than 10%. After PSM, the SMDs of the covariates were less than 10%. **Figure 2** shows the SMD of each variable more intuitively.

During the 3-year follow-up, 929 participants (8.26%) and 2434 participants (6.86%) experienced stroke in the ADL limitations and control groups, respectively. ADL limitations were significantly related to stroke. Compared with those without ADL limitations, participants with ADL limitations had a 77% higher risk of stroke (OR = 1.77, 95% confidence interval (CI): 1.56–2.016) after adjusting for gender, age, weight, hypertension, diabetes, heart disease, natural teeth, hearing impairment, visual impairment, smoking, drinking spirits, exercising, literacy, ethnicity, and poverty. The risk increase was slightly attenuated to 33% (OR = 1.326, 95% CI: 1.174–1.497) after PSM (**Table 2**).

In addition to ADL limitations, several covariates were associated with stroke. In the PSM model, participants older than 100 years had a lower OR than those aged ≥ 60 years and ≤ 70 years. Participants from rural or town areas had lower ORs of stroke than those from cities. The ORs and 95% CIs of body weight, hypertension, heart disease, and hearing impairment were greater than 1. The risk of ADL limitations ranked fourth after hypertension (OR = 1.64, 95% CI: 1.41–1.9), body weight over 56 kg (OR = 1.38, 95% CI: 1.12–1.69), and heart disease (OR = 1.33, 95% CI: 1.09–1.61).

We also conducted a subgroup analysis based on gender, age, and residential area. ADL limitations significantly increased the

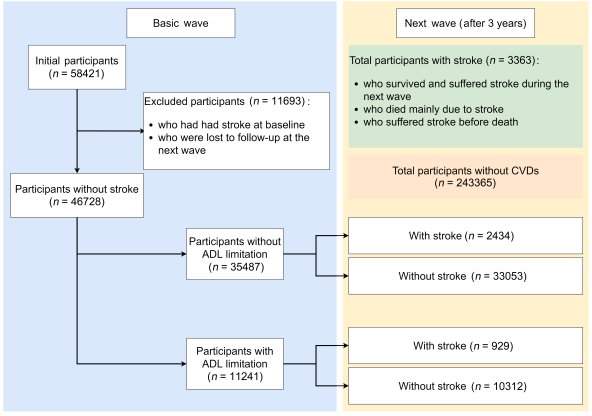


Figure 1 | **Flow chart of participant inclusion and grouping.**
ADL: Activities of daily living; CVD: cerebrovascular diseases.

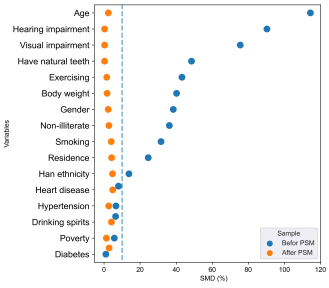


Figure 2 | **The standardized mean differences (SMD) of the variables.**
The propensity score matching (PSM) was performed to balance the baseline characteristics of samples. The intergroup balance was assessed by SMD. If the SMD is less than 10%, it is considered to be a balance between groups.

Table 2 | **The result of logistic regression between ADL limitations and stroke**

	Model 1				Model 2				Model 3				Model 4			
			95% CI				95% CI				95% CI				95% CI	
Variables	OR	P	[0.025	0.975]	OR	P	[0.025	0.975]	OR	P	[0.025	0.975]	OR	P	[0.025	0.975]
Intercept	0.04	***	0.04	0.05	0.03	***	0.03	0.04	0.04	***	0.03	0.05	0.08	***	0.04	0.14
ADL limitations (*vs*. No)	2.15	***	1.91	2.44	1.79	***	1.58	2.04	1.77	***	1.56	2.02	1.33	***	1.17	1.5
Gender (*vs*. female)	0.96		0.89	1.03	1.11	**	1.03	1.2	1.15	**	1.06	1.26	1.16		0.99	1.37
Age (yr) (*vs*. 60 ≤ and ≤ 70 yr)																
70 < and ≤ 80	1.25	***	1.16	1.35	1.21	***	1.12	1.31	1.21	***	1.12	1.31	1.09		0.69	1.71
80 < and ≤ 90	1.23	***	1.09	1.38	1.16	*	1.03	1.31	1.15	*	1.02	1.31	0.86		0.56	1.33
90 < and ≤ 100	1.03		0.7	1.5	1		0.68	1.47	0.98		0.66	1.44	0.7		0.46	1.09
> 100	0.72		0.05	10.01	0.7		0.05	9.89	0.68		0.05	9.59	0.53	**	0.34	0.84
Body weight (kg) (*vs*. ≤ 41 kg)																
41 < and ≤ 49	1.27	**	1.1	1.47	1.23	**	1.06	1.42	1.21	*	1.05	1.4	1.15		0.98	1.36
49 < and ≤ 56	1.66	***	1.44	1.9	1.51	***	1.31	1.74	1.47	***	1.27	1.69	1.25	*	1.05	1.5
> 56	2.18	***	1.9	2.51	1.74	***	1.51	2.01	1.64	***	1.42	1.9	1.38	**	1.12	1.69
Hypertension (*vs*. No)					1.58	***	1.46	1.71	1.57	***	1.45	1.7	1.64	***	1.41	1.9
Diabetes (*vs*. No)					1.97	***	1.73	2.25	1.89	***	1.66	2.16	1.26		0.9	1.76
Heart disease (*vs*. No)					1.81	***	1.64	1.98	1.74	***	1.59	1.92	1.33	**	1.09	1.61
Have natural teeth (*vs*. No)					1.01		0.92	1.11	1.02		0.92	1.12	1.01		0.89	1.14
Hearing impairment (*vs*. No)					1.28	***	1.12	1.46	1.28	***	1.12	1.46	1.15	*	1.01	1.31
Visual impairment (*vs*. No)					1.07		0.98	1.17	1.08		0.98	1.19	0.9		0.79	1.02
Residence (*vs*. City)																
Town									0.78	***	0.69	0.87	0.76	**	0.63	0.91
Rural									0.82	***	0.74	0.9	0.8	**	0.68	0.94
Smoking (*vs*. No)									0.95		0.87	1.04	0.89		0.73	1.09
Drinking spirits (*vs*. No)									0.99		0.88	1.11	0.85		0.68	1.07
Exercising (*vs*. No)									1		0.93	1.08	0.88		0.75	1.03
Literate (*vs*. No)									0.99		0.91	1.07	1.06		0.91	1.24
Han ethnicity (*vs*. No)									1.18	*	1	1.38	1.18		0.88	1.57
Poverty (*vs*. No)									0.98		0.91	1.06	0.91		0.8	1.03

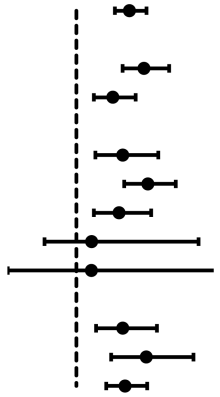
Model 1: Gender, age, and weight were adjusted. Model 2: Hypertension, diabetes, heart disease, natural teeth, hearing impairment, and visual impairment were additionally adjusted. Model 3: Smoking, drinking hard alcohol, exercising, literacy, ethnicity, and poverty were additionally adjusted; Model 4: A model that uses propensity score matching (PSM) to balance the baseline before adjusting for covariates. *P < 0.05, **P < 0.01, ***P < 0.001. ADL: Activities of daily living.

risk of stroke in subgroups of different genders, subgroups of different residential areas, and subgroups of participants ≤ 90 years old. In the two subgroups of participants older than 90 years, ADL limitations did not increase the risk of stroke (**Table 3**).

The variance inflation factor of each variable was less than 10, which indicated that there was no serious multicollinearity among the independent variables (**Table 4**).

Table 3 | **The relationship between ADL limitations and stroke in each subgroup**

Variables	OR	95% CI [0.025	0.975]	*P*
All participants	1.56	1.77	2.02	***
Gender				
Female	1.98	1.67	2.35	***
Male	1.53	1.26	1.86	***
Age (yr)				
60 ≤ and ≤ 70	1.67	1.28	2.19	***
70 < and ≤ 80	2.04	1.70	2.45	***
80 < and ≤ 90	1.62	1.26	2.09	***
90 < and ≤ 100	1.22	0.54	2.78	
100 <	1.22	0.00	392.75	
Residence				
City	1.67	1.29	2.17	***
Town	2.02	1.50	2.70	***
Rural	1.71	1.44	2.03	***



***P < 0.001. ADL: Activities of daily living.

Table 4 | **Variance inflation factor of each variable**

Variables	Variance inflation factor	Variables	Variance inflation factor
Intercept	41.5	Visual impairment	1.3
ADL limitation	1.3	Residence	1.2
Gender	1.7	Smoking	1.2
Age	1.7	Drinking spirits	1.1
Body weight	1.5	Exercising	1.1
Hypertension	1.1	Literacy	1.5
Diabetes	1	Han ethnicity	1
Heart disease	1.1	Poverty	1.1
Have natural teeth	1.1		
Hearing impairment	1.5		

ADL: Activities of daily living.

Discussion

In this study, we found a significant correlation between ADL limitations and stroke. When covariates were adjusted or subjected to PSM, having ADL limitations increased the odds of stroke by 77% or 33%, respectively, compared with having no ADL limitations. Therefore, ADL limitations increase the risk of stroke.

ADL limitations are associated with aging and chronic diseases, such as heart disease and diabetes (Sousa et al., 2009; Hou et al., 2018; Fong, 2019), which may also be stroke risk factors (O'Donnell et al., 2016). ADL limitations restrict activities and increase financial burden. Older adults with ADL limitations may delay the treatment of related chronic diseases, such as hypertension and diabetes, because of difficulties in seeing a doctor. ADL limitations may also increase the prevalence of depression (Wada et al., 2004) and further increase the prevalence of stroke (Van der Kooy et al., 2007). ADL limitations may increase the risk of stroke through the above mechanisms.

Previous large prospective studies have reported a relationship between ADL and stroke risk. In a study by Heshmatollah et al. (2020), 489 of 8519 individuals had stroke, and 20 ADL items (per standard deviation decrease) were associated with higher stroke risk. In a study by Capistrant et al. (2013), of 18 441 participants, those who developed stroke had worse ADL independence (five items) than those who remained stroke-free throughout the follow-up period. Colantonio et al. (1992) measured physical function using ADL and the Rosow scale, and found an association between impairment of physical function and stroke risk among 2812 participants. However, in another prospective study of 9451 participants, ADL limitations had no effect on the odds of stroke (Clarke et al., 2011). There are several differences between the above studies and our study. First, this study had a larger sample (46,728 participants). Second, 16 covariates were considered and subjected to PSM. Third, the participants in this study were Asian people from developing countries, which further confirmed that ADL limitations are a risk factor for different groups of people. Moreover, in the present study, a simpler definition of ADL limitations was used that was more suitable for stroke screening.

When the baseline was balanced using PSM, participants older than 100 years had lower stroke odds than participants aged 60–70 years. This may be because the overall life expectancy of cardiovascular disease patients is relatively short (Wang et al., 2014), and it is difficult for them to live beyond 100 years. As a result, the incidence of stroke is lower in adults older than 100 years. In all models adjusted for hypertension and heart disease, the OR of these variables was greater than 1 and P < 0.001. These risk factors have long been confirmed by many studies (Turin et al., 2016; Zhang et al., 2020). These findings also indicate that early intervention for these risk factors is essential. In all models adjusted for hearing impairment, this variable was a risk factor for stroke. In model 3, hearing impairment increased participants' odds of stroke by 28%. This finding is similar to the results of a study by Fang et al. (2019). However, the mechanism underlying the interaction between hearing impairment and stroke needs further research. Compared with participants who lived in cities, participants who lived in towns or rural areas had lower stroke odds. Participants living in cities may have greater life pressures. Additionally, air pollution in urban areas is more severe, and air pollution is another risk factor for stroke (Li et al., 2020). Compared with nonurban participants, urban participants have better economic status, a better medical environment, and better health awareness, which may explain why participants in urban areas have a higher stroke diagnosis rate. Nonurban participants may have experienced a stroke without knowing it.

This study had the following shortcomings. First, because of the lack of an exact diagnosis date for stroke, accurate survival analysis could not be performed. Second, the diagnosis of stroke was based on participant self-reports or reports from relatives of deceased individuals. This may have led to bias in the entry results. Third, although we used a variety of methods to correct for confounding factors, there is no perfect correction method for retrospective data.

In summary, after adjusting for age, gender, chronic diseases, and other covariates, a significant correlation between ADL limitations and stroke incidence remained. Therefore, ADL limitations are a risk factor for stroke. The ADL scale is simple, easy to learn, and inexpensive. It is recommended that ADL limitations be used as a screening tool for stroke to quickly identify high-risk populations.

Author contributions: *Study design, statistical analysis, and manuscript writing: ZL, ZSW, YSC; data collection and analysis and reference retrieval: YW, CYK; data analysis and results interpretation: JYW, YY, HW; manuscript drafting: ZL; manuscript revision: BZ, ZL. All authors approved*

the final version of the manuscript.

Conflicts of interest: *The authors declare that they have no competing interests.*

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Institutional review board statement: *The present study is a secondary analysis using the CLHLS data, and the ethical approval is waived by an IRB (IRB00001052–13074) to the CLHLS study that was approved by the Research Ethics Committees of Duke University and Peking University.*

Declaration of patient consent: *The present study is a secondary analysis using the CLHLS data, and the CLHLS study was approved by the Research Ethics Committees of Duke University and Peking University. Thus, consent to participate from participants is deemed unnecessary for this study. The data were anonymized before its use.*

Reporting statement: *The study followed the STrengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement*

Biostatistics statement: *The statistical methods of this study were reviewed by the epidemiologist of Affiliated Hospital of Guangdong Medical University, China.*

Data sharing statement: *The CLHLS questionnaire can be obtained from https://sites.duke.edu/centerforaging/programs/chinese-longitudinal-healthy-longevity-survey-clhls/survey-documentation/questionnaires/. The complete data set of CLHLS can be obtained from its official website. If there are reasonable requirements, the codes used for data extraction, data coding and statistical analysis in this study can be obtained from the corresponding author.*

Plagiarism check: *Checked twice by iThenticate.*

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Additional files:

Additional file 1: *STROBE checklist.*

Additional file 2: *Open peer review reports 1 and 2.*

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Reported on page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	p.1,2 and 3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	p.2 and 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	p.3
Objectives	3	State specific objectives, including any prespecified hypotheses	p.3
Methods			
Study design	4	Present key elements of study design early in the paper	p.4 and 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	p.4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	p.4 and 5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	p.6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	p.4,5 and 6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*p.4,5 and 6*
Bias	9	Describe any efforts to address potential sources of bias	p.6
Study size	10	Explain how the study size was arrived at	p.7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	p.5 and 6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	p.6
		(*b*) Describe any methods used to examine subgroups and interactions	p.7
		(*c*) Explain how missing data were addressed	p.6
		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	p.6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	p.7
		(b) Give reasons for non-participation at each stage	p.7
		(c) Consider use of a flow diagram	p.13
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	p.7 and 15
		(b) Indicate number of participants with missing data for each variable of interest	p.7 and 15

		(c) Summarise follow-up time (eg, average and total amount)	p.4 and 7
Outcome data	15*	Report numbers of outcome events or summary measures over time	p.7,13 and 15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	p.5, 7 and 17
		(*b*) Report category boundaries when continuous variables were categorized	p.4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	p.7 and 17
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	p.7, 17 and 18
Discussion			
Key results	18	Summarise key results with reference to study objectives	p.8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	p.8 and 9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	p.8 and 9
Generalisability	21	Discuss the generalisability (external validity) of the study results	p.8 and 9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	p.9

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.