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Prevalence and risk factors of stroke in China: a national serial cross-sectional study from 2003 to 2018

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ABSTRACT

Stroke imposes a substantial burden worldwide. With the rapid economic and lifestyle transition in China, trends of the prevalence of stroke across different geographic regions in China remain largely unknown. Capitalizing on the data in the National Health Services Surveys (NHSS), we assessed the prevalence and risk factors of stroke in China from 2003 to 2018. In this study, data from 2003, 2008, 2013, and 2018 NHSS were collected. Stroke cases were based on participants' self-report of a previous diagnosis by clinicians. We estimated the trends of stroke prevalence for the overall population and subgroups by age, sex, and socioeconomic factors, then compared across different geographic regions. We applied multivariable logistic regression to assess associations between stroke and risk factors. The number of participants aged 15 years or older were 154,077, 146,231, 230,067, and 212,318 in 2003, 2008, 2013, and 2018, respectively, among whom, 1435, 1996, 3781, and 6069 were stroke patients. The age and sex standardized prevalence per 100,000 individuals was 879 in 2003, 1100 in 2008, 1098 in 2013, and 1613 in 2018. Prevalence per 100,000 individuals in rural areas increased from 669 in 2003 to 1898 in 2018, while urban areas had a stable trend from 1261 in 2003 to 1365 in 2018. Across geographic regions, the central region consistently had the highest prevalence, but the western region has an alarmingly increasing trend from 623/100,000 in 2003 to 1898/100,000 in 2018 (P_{trend}<0.001), surpassing the eastern region in 2013. Advanced age, male sex, rural area, central region, hypertension, diabetes, depression, low education and income level, retirement or unemployment, excessive physical activity, and unimproved sanitation facilities were significantly associated with stroke. In conclusion, the increasing prevalence of stroke in China was primarily driven by economically underdeveloped regions. It is important to develop targeted prevention programs in underdeveloped regions. Besides traditional risk factors, more attention should be paid to nontraditional risk factors to improve the prevention of stroke.

INTRODUCTION

Stroke is a leading cause of disability and mortality worldwide and imposes a severe global burden.[1 2] The Global Burden of Disease (GBD) Study showed the cases and deaths due to stroke markedly expanded between 1990 and 2019 across the world.[2] With the wide implementation of stroke prevention strategies and good health services, the burden of stroke has decreased in high-income countries. However, reversed trends have been found in low-income and middle-income countries.[2] Accompanied by the fast-growing economies and urbanisation, the burden of stroke in China has also changed substantially in the past decades, Recently, stroke has surpassed cancer and coronary heart disease as the top cause of death in China.[3] The prevalence of stroke in China in 2013 was more than three times that in the 1990s,[4] Thus, monitoring the epidemiological features of stroke has important implications for public health in China. A few epidemiological surveys on the prevalence of stroke and associated risk factors had been completed in China, but most of these studies were either outdated, local or small samples based, or suffered from selection bias.[5–8] Prior studies have also noticed regional variations in stroke prevalence before 2013, Most prominent among them is rural–urban difference, to the disadvantage of rural areas.[8 9] However, there is no most up-to-date study on the changes of prevalence of stroke across China.

While traditional stroke risk factors such as old age, male, hypertension, diabetes, smoking and cardiac causes, collectively explain the majority of the population attributable risks of stroke,[10] there was evidence indicating excessive stroke risk unaccounted by these traditional risk factors.[11] Meanwhile, several strategies for preventing these traditional stroke risk factors, such as health screenings for elderly, hypertension and diabetes management, tobacco control, and cardiovascular diseases therapy have been implemented in China to control stroke,[12–15] yet stroke burden continue to grow. As a result, a better understanding of the potentially modifiable non-traditional factors is critically important to formulate strategies for stroke prevention.

Using the most updated data from the National Health Services Surveys (NHSS),[15–17] a large-scale population-based health status screening project in China, we evaluate the national trends of stroke prevalence and the associated risk factors in China from 2003 to 2018, with a focus on identifying potentially modifiable risk factors.

METHODS

Data sources and study sample

This study obtained data from the NHSS system, which is a series of national observational cross-sectional studies covering all 31 provinces, autonomous regions and municipalities in mainland China conducted every 5 years since 1993.[15–17] The NHSS is representative of national geographical distribution, socialeconomic status and basic characteristics of the population, providing important information about the health status of the Chinese population. In this survey series, we used a multistage stratified cluster sampling procedure, which was described in online supplemental appendix 1. We divided mainland China into three regions: west, central and east, and then sampled counties stratified by urban and rural areas from each region. Covering 0.02% of the total population with a 5% non-response rate, each country required at least 90 counties and 600 households. The 2003 survey selected 95 counties at random, with 28 counties from urban areas and 67 counties from rural areas; the 2008 survey selected the same 94 counties as the 2003 survey, with one country not selected due to administrative division changes; the 2013 survey selected 62 other counties in addition to those surveyed in 2008; while the 2018 survey selected 84 counties from urban areas and 72 counties from rural areas, taking into account China's urbanisation transition. Then, from each county, five streets (from urban areas) or townships (from rural areas) were selected, and two communities or villages were selected from each street or township. Finally, 60 households were selected at random from each village or community. In addition, we selected 10 standby households at random in each village or community; if we were unable to interview the initially selected households, we could go on to 1 of 10 standby households. The investigation was open to all members of the selected household.

The detailed interview processes have previously been reported.[15–17] In brief, local healthcare workers were recruited and trained to conduct interviews in person. Participants aged 15 years or older were questioned after reading a statement explaining the objective of the survey and obtaining consent. Each round used the same stringent quality control programme. All investigators and research staff underwent unified procedure and data collecting training. The interviewers ensured that the questionnaire was completed at the end of each interview, and the questionnaires were checked daily by the supervisors. Five per cent of the total households with completed surveys were randomly selected to be reinterviewed.

Assessment of stroke and related risk factors

Stroke was assessed based on participants' self-report in the questionnaire according to the International Classification of Diseases 10 at each round of the survey.[15–17] We began the questionnaire by asking the respondents whether they had any chronic diseases that had been diagnosed by doctor. If they answered they had stroke, we inquired when they were diagnosed and whether they had been treated within the previous 6 months (online supplemental appendix 2). As proof of the diagnosis, medical records or prescriptions from medical institutions were necessary. These diagnoses were included in the survey data under the supervision by doctors from township or higher-level hospitals, and the investigator then documented them in the questionnaire.

The NHSS questionnaire provided us with data on stroke related factors (online supplemental appendix 2). We assessed demographic (age and sex) and geographical characteristics (residence and region), socioeconomic status (educational level, occupation, gross annual income and marital status), lifestyle (smoking, alcohol consumption and physical activity), health status (hypertension, diabetes and depression) and household environment (sanitation facilities) in each round. At each round of the survey, participants were asked to self-report their history of hypertension and diabetes, and conformation of the diagnosis was required in the form of medical records or prescriptions from medical institutions. Depression was measured using a quality of life questionnaire and self-perceived health. Participants who had smoked a total of at least 100 cigarettes in their lifetime and either continued or ceased smoking during the survey were classified as smokers; that is, both ex-smokers and current smokers are counted as smokers in the analyses. Participants who had an alcoholic drink in the 12 months prior to the survey were considered as alcohol consumption. Physical activity was defined as participating in physical activity (including tai chi, jogging, dancing, swimming, ball sports, aerobics and apparatus exercise) at least once a week in the previous month. Unimproved sanitation facility is defined as not ensuring hygienic separation of human excreta from human contact and open defecation. Improved sanitation facility is defined as likely to ensure hygienic separation of human excreta from human contact. Online supplemental appendix 3 presents a detailed definition of each risk factor.

Statistical analysis

All data were recorded on a printed questionnaire and double entered into an online system provided by the National Health Commission of the People's Republic of China. A database was established using Access software.

The overall population's stroke prevalence was determined, as well as subgroups stratified by age, sex, residential area and geographical region. We also assessed socioeconomic factors such as education level, occupation, income and marital status. The age-standardised and sex-standardised prevalence of stroke was standardised for age and sex using the 2010 Chinese census for both the overall population and subgroups. To analyse trends in stroke prevalence across time, we used the one-sided (increasing trend) Cochran-Armitage trend test. The Pearson χ^2 test was used to assess between-group differences in stroke prevalence. We also compared the evolution of stroke prevalence between urban and rural areas by sex and geographical subgroups. To estimate the ORs and 95% CIs of all recorded factors potentially associated with stroke, we constructed multiple logistic regression models involving age, sex, residence, region, educational level, occupation, income, marital status, hypertension, diabetes, depression, smoking, alcohol consumption, physical activity and sanitation facilities, separately for each survey (online supplemental appendix 4). Meta-analyses were performed for OR value of risk factors from serial surveys. We assessed heterogeneity using the I^2 statistic. Individuals with missing values did not have their values imputed. SAS V.9.4 software was used for all statistical analyses.

RESULTS

We sampled 57 023, 56 456, 93 613 and 94 076 households in 2003, 2008, 2013 and 2018, respectively. A total of 154 077, 146 231, 230 067 and 212 318 participants in 2003, 2008, 2013 and 2018, respectively, were included in the final analysis. Overall, 1435 (0.93%), 1996 (1.36%), 3781 (1.64%) and 6069 (2.86%) people had stroke in 2003, 2008, 2013 and 2018, respectively. The age-standardised and sex-standardised prevalence of stroke per 100 000 people in China was 879 (95% CI 834 to 924) in 2003, 1100 (95% CI 1052 to 1147) in 2008, 1098 (95% CI 1063 to 1133) in 2013 and 1613 (95% CI 1572 to 1655) in 2018, respectively (table 1).

The elderly were more likely to be affected, especially those aged 70 years or older, of whom 8137 per 100 000 had a stroke in 2018. The subgroup aged 50–59 years experienced a rapid increase in stroke prevalence, from 1228 per 100 000 people in 2003 to 2448 in 2018. Comparing residential areas (figure 1, table 2), the prevalence of stroke was significantly higher in urban (1261/100 000) than in rural areas (669/100 000) in 2003, but the difference diminished by 2008 (1159/100 000 in urban vs 1052/100 000 in rural areas). Furthermore, the prevalence of stroke in rural areas (1898/100 000) had surpassed that of urban areas (1365/100 000), by 2018. Similarly, while the prevalence increased in all regions in China, the western region has a more dramatic increase (from 623/100 000 in 2003 to 1439/100 000 people in 2018) than the eastern region (from 918/100 000 in 2003 to 1306/100 000 people in 2018). We also estimated stroke prevalence in different provinces of China (online supplemental appendix 5), among which the Jiangxi province experienced the most rapid increase from 253 cases per 100 000 people in 2003 to 1133 in 2018. While most provinces displayed a significant increasing trend in stroke prevalence (P_{trend}<0.05), four provinces had stabilised prevalence, including Liaoning, Hainan, Henan and Xinjiang Uygur Autonomous region.

Table 2 shows the disparity of stroke prevalence between Chinese urban and rural areas by age, sex and geographical regions from 2003 to 2018. Stroke prevalence was higher in urban than in rural areas in 2003 for all geographical regions. However, the prevalence was greater in rural than urban areas in 2018 across all geographical regions. Furthermore, in the western region, the prevalence of stroke increased in both urban and rural areas in the past decades. Similarly, for each age or sex subgroup, the prevalence of stroke significantly increased in rural areas during this period. A different trend was observed in urban areas.

Table 3 summarises the risk factors for stroke in 2003, 2008, 2013 and 2018, respectively. We found that advanced age, as well as males, was associated with an increased prevalence of stroke. People in the rural area and central regions had higher stroke prevalence than those in urban areas and western regions. Retired or unemployed people tended to be associated with higher stroke prevalence compared with employed people. We also observed the prevalence of stroke was also associated with hypertension and diabetes. Meanwhile, a higher prevalence of stroke was found in people with severe depression, with the highest OR values. Interestingly, we found unimproved sanitation facilities were consistently associated with a high risk of stroke. The meta-analysis of serial surveys also showed that advanced age, male sex (OR 1.41, 95% CI 1.34 to 1.47), rural area (OR 1.16, 95% CI 1.10 to 1.21), central region (OR 1.37, 95% CI 1.31 to 1.43), retirement (OR 1.78, 95% CI 1.67 to 1.90) or unemployment (OR 1.74, 95% CI 1.65 to 1.82), hypertension (OR 1.79, 95% CI 1.71 to 1.87), diabetes (OR 1.79, 95% CI 1.71 to 1.87), depression (moderate depression: OR 2.71, 95% CI 2.59 to 2.83; severe depression: OR 4.01, 95% CI 3.53 to 4.49) and unimproved sanitation facilities (OR 1.38 95% CI 1.32 to 1.44) were associated with an increased prevalence of stroke. Furthermore, people with high income and having a college education were protective against stroke. Cigarette smoking was not proven to be a risk factor (OR 1.01, 95% CI 0.97 to 1.06), but alcohol consumption was found to be a protective factor against stroke. Excessive physical activity was also associated with a higher risk of stroke in 2003 (OR 1.22, 95% CI 1.04 to 1.43) and 2013 (OR 1.27, 95% CI 1.16 to 140). Results of the analyses stratified by urban and rural areas are shown in online supplemental appendices 6 and 7, respectively. Similar to the overall population, advanced age, male sex, central region, retirement or unemployment, hypertension, diabetes, depression and unimproved sanitation facilities were risk factors for stroke in both urban and rural areas. Risk factors did not differ between urban and rural areas.

Table 1 Prevalence of stroke by age, sex and socioeconomic factors in China from 2003 to 2018

	2003		2008		2013		2018		
	No of Participants	Rates/100 000 people (95% CI)*	No of Participants	Rates/100 000 (95% CI)	No of Participants	Rates/100 000 (95% CI)	No of Participants	Rates/100 000 (95% CI)	P value for trend†
Overall	154 077	879 (834 to 924)	146 231	1100 (1052 to 1147)	230 067	1098 (1063 to 1133)	212 318	1613 (1572 to 1655)	<0.001
Age									
< 30 years	38 424	36 (17 to 56)	32 368	34 (14 to 54)	41 312	38 (19 to 57)	26 898	30 (9 to 51)	0.71
30–39 years	34 367	112 (77 to 147)	26 449	139 (94 to 184)	33 173	122 (85 to 160)	29 530	106 (68 to 143)	0.78
40–49 years	30 953	426 (353 to 498)	29 495	536 (452 to 619)	49 622	556 (491 to 622)	40 291	787 (701 to 873)	<0.001
50–59 years	24 077	1228 (1089 to 1367)	28 360	1691 (1541 to 1842)	44 903	1661 (1543 to 1780)	45 941	2448 (2306 to 2589)	<0.001
60–69 years	14 696	2822 (2555 to 3089)	16 017	3687 (3395 to 3979)	35 952	3506 (3315 to 3696)	41 793	5575 (5354 to 5795)	<0.001
≥70 years	11 560	4650 (4267 to 5034)	13 542	5305 (4928 to 5683)	25 105	5748 (5460 to 6035)	27 865	8137 (7816 to 8459)	<0.001
Sex									
Female	77 282	815 (753 to 878)	74 236	1059 (992 to 1126)	117 830	1088 (1038 to 1137)	109 142	1542 (1485 to 1599)	<0.001
Male	76 792	941 (876 to 1007)	71 955	1139 (1070 to 1208)	112 235	1109 (1059 to 1159)	103 176	1686 (1626 to 1747)	<0.001
Education									
College	8774	1308 (986 to 1631)	9563	769 (547 to 991)	25 522	723 (592 to 855)	11 763	857 (620 to 1094)	0.99
Senior high	22 864	1363 (1110 to 1616)	23 365	1206 (1027 to 1385)	42 325	971 (874 to 1069)	27 439	1409 (1271 to 1547)	0.74
Junior high	52 575	1106 (946 to 1266)	51 891	1235 (1096 to 1374)	79 492	1221 (1141 to 1302)	67 420	1614 (1531 to 1696)	<0.001
Primary	40 661	887 (792 to 982)	38 589	1134 (1041 to 1226)	55 629	1158 (1088 to 1229)	51 882	1808 (1711 to 1906)	<0.001
None	28 964	803 (692 to 914)	22 591	1044 (925 to 1164)	27 051	1013 (912 to 1115)	25 201	1731 (1578 to 1885)	<0.001
Occupation									
Employed	117 169	573 (526 to 621)	99 625	787 (724 to 851)	151 692	820 (769 to 870)	119 290	1285 (1213 to 1358)	<0.001
Retired	11 788	1438 (1200 to 1676)	13 942	1478 (1064 to 1892)	31 383	1244 (1038 to 1449)	31 827	1941 (1433 to 2449)	<0.001
Unemployed	14 870	1452 (1256 to 1648)	22 042	1756 (1596 to 1917)	36 328	1823 (1687 to 1959)	49 273	2250 (2129 to 2371)	<0.001
Income									
High	53 259	907 (827 to 986)	50 492	1087 (1004 to 1170)	78 765	1010 (952 to 1069)	81 324	1229 (1172 to 1287)	<0.001
Middle	50 691	844 (765 to 923)	48 251	1092 (1007 to 1177)	75 792	1098 (1035 to 1160)	68 128	1675 (1596 to 1753)	<0.001
Low	50 127	895 (816 to 974)	47 488	1134 (1050 to 1217)	75 510	1207 (1143 to 1271)	62 496	2052 (1966 to 2139)	<0.001
Marital status									
Married	115 086	925 (867 to 982)	109 292	1138 (1073 to 1204)	181 364	1103 (1061 to 1145)	20 800	1276 (858 to 1694)	<0.001
Single	27 738	680 (292 to 1069)	23 949	920 (594 to 1245)	29 738	913 (636 to 1189)	172 082	1599 (1552 to 1646)	<0.001
Divorced	1649	789 (267 to 1311)	2021	736 (341 to 1131)	3214	1280 (851 to 1710)	15 172	1549 (1368 to 1729)	<0.001
Widowed	9504	700 (550 to 849)	10 409	1274 (950 to 1598)	15 453	1156 (843 to 1470)	3917	1715 (1351 to 2080)	<0.001

*All estimates were age and sex standardised to the 2010 Chinese census. Presence of stroke was based on participants' self-report of a previous diagnosis by medical institution.
†P value for trend calculated using one-sided (increasing trend) Cochran-Armitage trend test.

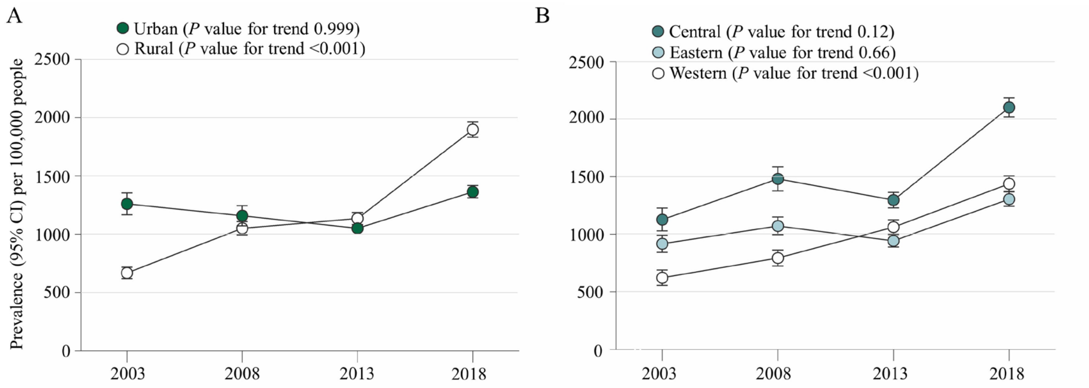

Figure 1 The scissors phenomenon: prevalence of stroke by residence and region in China from 2003 to 2018. All estimates were age and sex standardised to the 2010 Chinese census. Error bars indicate 95% CI. P value for trend calculated using one-sided (increasing trend) Cochran-Armitage trend test.

DISCUSSION

This study involves serially collected participants representative of all regions in mainland China with the largest sample size to date, enabling accurate estimation of the trend of stroke prevalence over time and across the country. We observed distinct trends in the stroke prevalence between underdeveloped (rural, western) and developed (urban, eastern) regions in China, with the curves resembling the shape of scissors (figure 1). Furthermore, we identified advanced age, male sex, rural area, central region, hypertension, diabetes, depression, low education and income level, retirement or unemployment, excessive physical activity, and unimproved sanitation facilities as risk factors for stroke.

Our results highlight a marked increase in the age-adjusted prevalence of stroke in 2018 (1613 cases per 100000 people) compared with that in 2003 (879 cases per 100000 people), consistent with previous studies.[9 18 19] According to the National Epidemiological Survey of Stroke in China, the age-standardised stroke prevalence had reached 1115 cases per 100 000 people in 2013.[9] The China National Stroke Screening and Prevention Project, done between 2014 and 2015, showed higher stroke prevalence (2450 cases per 100000 people) in adults aged 40 years or older.[19] The age-standardised prevalence of stroke reported in the GBD Study increased by 13.2% from 1990 to 2019 in China, reaching 1469 cases per 100 000 people in 2019.[18] Such an increasing trend in stroke prevalence is comparable to the pattern in other low-income and middle-income countries, whereas it is decreasing prevalence in high-income countries.[2] All these results point to a high and growing prevalence of stroke in China. Our findings could be partly explained by changes in the demographic structure, such as rapid population ageing.[20] In addition, the prevalence of stroke depends on the stroke incidence, mortality and length of survival after stroke. First, according to updated GBD Study statistics, over 4 million new patients who had a stroke were diagnosed in China in 2019 and the age-standardised incidence rate of stroke was 201 cases per 100000 people.[2] Although the current stroke incidence rate was a little lower than that in 2013 when reported as 247 cases per 100 000 people. It was still significantly higher than in previous comparable surveys, suggesting a substantial increase in stroke incidence over the past three decades.[9] Moreover, in comparison with results in 1990, the age-standardised stroke mortality rate fell by 39.8%, reaching 127 cases per 100 000 people in 2019.[18] Improvements in emergency services, stroke prevention and treatment decreased the stroke mortality rate and increased length of survival after stroke. Finally, another possible explanation for the heightened prevalence of stroke could be the improvement in access to diagnosis, such as the use of better diagnostic methods. Together, these factors could have led to the rapid increase in stroke prevalence in China.

There are largely geographical and regional variations in stroke burden in China.[4] Epidemiological studies have reported a north-south gradient, with the highest stroke prevalence in northern China and the lowest in the southern region.[8 9] However, less research has focused on the eastern, central and western regions. We found that the age-standardised and sex-standardised prevalence of stroke in the eastern was consistently higher than that in the western region up to 2008, but became lower than in the western region in 2018. Historically, China has had a higher stroke burden in urban areas than in rural areas.[21] A large-scale Chinese population survey in 1986 indicated that stroke prevalence was much higher in cities than in rural areas.[22] In our study, stroke prevalence was also significantly higher in urban than in rural participants in 2003, but this difference became smaller over time, and the trend has reversed in 2018. The 'scissors phenomenon' describes vividly the disparity of stroke prevalence between underdeveloped and developed regions in China from 2003 to 2018. This phenomenon was also supported by several epidemiological studies.[4 9 23] Recent studies have reported a higher stroke incidence in rural China,[9] and that the stroke mortality in rural regions has surpassed that of urban areas.[9 23] Thus, the current

Table 2 Prevalence of stroke in urban and rural areas by age, sex and region in China from 2003 to 2018

	2003		2008		2013		2018		
	No of Participants	Rates/100 000 (95% CI)	No of Participants	Rates/100 000 (95% CI)	No of Participants	Rates/100 000 (95% CI)	No of Participants	Rates/100 000 (95% CI)	P value for trend
Urban areas									
Overall	42796	1261 (1168 to 1354)	40975	1159 (1073 to 1245)	115114	1052 (1005 to 1100)	113519	1365 (1312 to 1417)	0.99
Age									
<30 years	8730	33 (0 to 70)	7727	27 (0 to 65)	20147	43 (15 to 71)	14284	21 (0 to 45)	0.80
30–39 years	8691	100 (35 to 166)	6957	71 (9 to 134)	17729	94 (49 to 139)	17748	64 (26 to 101)	0.98
40–49 years	9127	448 (311 to 584)	7917	521 (362 to 680)	23263	433 (348 to 518)	20870	601 (496 to 707)	<0.001
50–59 years	6598	1699 (1387 to 2011)	8171	1421 (1164 to 1677)	21944	1519 (1356 to 1682)	22943	2085 (1899 to 2271)	<0.001
60–69 years	5177	4150 (3602 to 4698)	4956	4248 (3683 to 4813)	18168	3318 (3057 to 3579)	22151	4573 (4296 to 4849)	0.32
≥70 years	4471	7485 (6715 to 8255)	5247	6407 (5744 to 7069)	13863	6063 (5666 to 6460)	15523	7316 (6905 to 7726)	0.90
Sex									
Female	22058	1138 (1013 to 1264)	21321	1087 (971 to 1203)	59816	1012 (946 to 1078)	59113	1209 (1141 to 1276)	0.28
Male	20735	1380 (1244 to 1517)	19645	1229 (1103 to 1356)	55297	1092 (1022 to 1161)	54406	1520 (1440 to 1600)	0.12
Region									
Eastern	17666	1256 (1116 to 1396)	16804	1170 (1038 to 1302)	39468	833 (762 to 903)	45155	1161 (1086 to 1236)	0.99
Central	13290	1626 (1433 to 1819)	12765	1612 (1427 to 1797)	38467	1243 (1152 to 1334)	34167	1714 (1606 to 1822)	0.73
Western	11837	818 (668 to 968)	11406	596 (480 to 713)	37179	1103 (1015 to 1190)	34197	1261 (1170 to 1352)	<0.001
Rural areas									
Overall	111281	669 (620 to 718)	105256	1052 (995 to 1109)	114953	1135 (1084 to 1187)	98799	1898 (1833 to 1964)	<0.001
Age									
<30 years	29694	37 (15 to 59)	24641	37 (13 to 60)	21165	33 (9 to 58)	12614	40 (5 to 75)	0.44
30–39 years	25676	116 (74 to 157)	19492	163 (107 to 220)	15444	155 (93 to 216)	11782	169 (95 to 143)	0.005
40–49 years	21824	417 (331 to 502)	21578	541 (443 to 639)	26359	665 (567 to 764)	19421	987 (848 to 1125)	<0.001
50–59 years	17479	1052 (901 to 1203)	20189	1802 (1619 to 1986)	22959	1800 (1628 to 1972)	22998	2813 (2599 to 3027)	<0.001
60–69 years	9519	2136 (1847 to 2426)	11061	3438 (3098 to 3777)	17784	3695 (3417 to 3972)	19642	6725 (6376 to 7077)	<0.001
≥70 years	7089	2862 (2474 to 3250)	8295	4608 (4157 to 5058)	11242	5359 (4943 to 5775)	12342	9164 (8662 to 9681)	<0.001
Sex									
Male	56057	706 (636 to 776)	52310	1083 (1002 to 1164)	56938	1117 (1045 to 1188)	48770	1872 (1779 to 1964)	<0.001
Female	55224	631 (563 to 699)	52915	1020 (940 to 1101)	58014	1155 (1081 to 1229)	50029	1929 (1835 to 2023)	<0.001
Region									
Eastern	34726	683 (600 to 766)	33604	995 (901 to 1089)	38636	1053 (969 to 1136)	28533	1533 (1422 to 1643)	<0.001
Central	29859	819 (712 to 925)	28461	1399 (1272 to 1526)	36386	1344 (1246 to 1442)	33523	2486 (2360 to 2611)	<0.001
Western	46696	547 (476 to 618)	43191	845 (762 to 927)	39931	1009 (922 to 1095)	36743	1605 (1502 to 1707)	<0.001

Table 3 Risk factors for stroke among overall population in China from 2003 to 2018

	2003		2008		2013		2018		Meta-analysis†	
	OR (95% CI)*	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Age										
< 30 years	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
30–39 years	1.92 (0.97 to 3.80)	0.06	3.21 (1.48 to 6.99)	0.003	2.59 (1.40 to 4.81)	0.003	2.85 (1.27 to 6.42)	0.01	2.40 (1.46 to 3.34)	0.82
40–49 years	6.49 (3.46 to 12.19)	<0.001	11.25 (5.47 to 23.13)	<0.001	9.11 (5.24 to 15.84)	<0.001	18.67 (8.91 to 39.16)	<0.001	8.46 (5.38 to 11.54)	0.40
50–59 years	15.67 (8.42 to 29.14)	<0.001	28.94 (14.21 to 58.95)	<0.001	20.04 (11.60 to 34.64)	<0.001	49.55 (23.75 to 103.40)	<0.001	19.82 (12.65 to 26.98)	0.33
60–69 years	26.64 (14.26 to 49.76)	<0.001	48.78 (23.88 to 99.65)	<0.001	29.10 (16.82 to 50.36)	<0.001	93.41 (44.75 to 194.99)	<0.001	31.38 (19.91 to 42.84)	0.29
≥70 years	38.69 (20.6 to 72.69)	<0.001	53.74 (26.15 to 110.44)	<0.001	38.86 (22.39 to 67.44)	<0.001	121.73 (58.24 to 254.42)	<0.001	42.93 (27.34 to 58.53)	0.40
Sex										
Female	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Male	1.60 (1.40 to 1.83)	<0.001	1.46 (1.30 to 1.64)	<0.001	1.40 (1.29 to 1.53)	<0.001	1.36 (1.27 to 1.45)	<0.001	1.41 (1.34 to 1.47)	0.21
Residence										
Urban	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Rural	0.83 (0.70 to 1.00)	0.05	1.06 (0.90 to 1.25)	0.49	1.14 (1.05 to 1.25)	0.003	1.28 (1.20 to 1.36)	<0.001	1.16 (1.10 to 1.21)	<0.001
Region										
Western	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Central	1.82 (1.58 to 2.10)	<0.001	2.10 (1.85 to 2.37)	<0.001	1.16 (1.07 to 1.26)	<0.001	1.43 (1.34 to 1.53)	<0.001	1.37 (1.31 to 1.43)	<0.001
Eastern	1.42 (1.23 to 1.63)	<0.001	1.52 (1.34 to 1.72)	<0.001	0.88 (0.80 to 0.96)	0.004	0.98 (0.91 to 1.05)	0.53	1.01 (0.96 to 1.05)	<0.001
Education										
College	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Senior high	0.91 (0.69 to 1.20)	0.50	1.35 (1.01 to 1.81)	0.05	1.23 (1.01 to 1.50)	0.04	1.21 (0.93 to 1.56)	0.16	1.19 (1.04 to 1.33)	<0.001
Junior high	0.84 (0.65 to 1.08)	0.18	1.45 (1.10 to 1.93)	0.009	1.56 (1.29 to 1.88)	<0.001	1.39 (1.08 to 1.79)	0.009	1.12 (0.97 to 1.26)	0.01
Primary	0.87 (0.67 to 1.13)	0.30	1.49 (1.12 to 1.98)	0.006	1.49 (1.23 to 1.81)	<0.001	1.45 (1.12 to 1.86)	0.004	1.21 (1.06 to 1.37)	0.002
None	0.82 (0.62 to 1.08)	0.15	1.29 (0.95 to 1.74)	0.10	1.32 (1.07 to 1.62)	0.009	1.34 (1.04 to 1.74)	0.03	1.14 (1.00 to 1.28)	0.18
Occupation										
Employed	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Retired	2.40 (1.97 to 2.92)	<0.001	1.98 (1.66 to 2.37)	<0.001	1.64 (1.46 to 1.84)	<0.001	1.77 (1.62 to 1.95)	<0.001	1.78 (1.67 to 1.90)	0.02
Unemployed	1.93 (1.63 to 2.29)	<0.001	1.73 (1.52 to 1.96)	<0.001	1.70 (1.55 to 1.87)	<0.001	1.73 (1.61 to 1.86)	<0.001	1.74 (1.65 to 1.82)	0.68
Income‡										
High	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Medium	0.98 (0.86 to 1.13)	0.80	0.98 (0.87 to 1.11)	0.77	1.08 (0.99 to 1.18)	0.07	1.22 (1.13 to 1.31)	<0.001	1.11 (1.06 to 1.17)	<0.001
Low	1.05 (0.92 to 1.21)	0.47	0.92 (0.81 to 1.03)	0.16	1.09 (1.00 to 1.19)	0.05	1.37 (1.27 to 1.49)	<0.001	1.09 (1.04 to 1.15)	0.003
Marital status										
Married	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Single	0.58 (0.36 to 0.95)	0.03	0.80 (0.57 to 1.13)	0.20	0.68 (0.51 to 0.90)	0.007	0.75 (0.58 to 0.96)	0.02	0.71 (0.60 to 0.82)	0.71
Divorced	0.85 (0.47 to 1.53)	0.59	0.81 (0.49 to 1.32)	0.39	1.15 (0.85 to 1.56)	0.37	1.27 (1.04 to 1.57)	0.02	1.11 (0.93 to 1.29)	0.22

Continued

Table 3 Continued

	2003		2008		2013		2018		Meta-analysis†	
	OR (95% CI)*	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Widowed	0.74 (0.63 to 0.87)	<0.001	0.88 (0.77 to 1.00)	0.06	0.92 (0.83 to 1.01)	0.08	0.98 (0.91 to 1.06)	0.63	0.91 (0.86 to 0.96)	0.01
Hypertension§										
No	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Yes	1.41 (1.20 to 1.64)	<0.001	2.17 (1.95 to 2.42)	<0.001	3.38 (3.14 to 3.62)	<0.001	1.55 (1.46 to 1.65)	<0.001	1.79 (1.71 to 1.87)	<0.001
Diabetes¶										
No	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Yes	1.57 (1.20 to 2.05)	0.001	1.28 (1.03 to 1.58)	0.03	1.43 (1.29 to 1.59)	<0.001	1.33 (1.19 to 1.48)	<0.001	1.38 (1.28 to 1.47)	0.54
Depression**										
No	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Moderate	3.37 (3.00 to 3.79)	<0.001	3.98 (3.56 to 4.46)	<0.001	2.73 (2.50 to 2.97)	<0.001	2.43 (2.27 to 2.59)	<0.001	2.71 (2.59 to 2.83)	<0.001
Severe	10.67 (8.48 to 13.43)	<0.001	9.73 (7.71 to 12.28)	<0.001	5.26 (4.22 to 6.54)	<0.001	3.07 (2.57 to 3.67)	<0.001	4.01 (3.53 to 4.49)	<0.001
Cigarette smoking††										
Never	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Smoker	0.89 (0.78 to 1.02)	0.10	0.92 (0.82 to 1.04)	0.19	1.11 (1.01 to 1.21)	0.03	1.05 (0.98 to 1.13)	0.18	1.01 (0.97 to 1.06)	0.01
Alcohol consumption (times per week)‡‡										
Never	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
<3	0.51 (0.41 to 0.64)	<0.001	0.44 (0.30 to 0.65)	<0.001	0.61 (0.53 to 0.69)	<0.001	0.56 (0.51 to 0.60)	<0.001	0.56 (0.52 to 0.60)	0.26
≥3	0.46 (0.36 to 0.59)	<0.001	0.44 (0.35 to 0.55)	<0.001	0.41 (0.35 to 0.48)	<0.001	1.11 (1.00 to 1.23)	0.06	0.53 (0.49 to 0.58)	<0.001
Physical activity (times per week)§§										
Never	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
<1	1.47 (0.79 to 2.75)	0.22	1.15 (0.78 to 1.68)	0.48	1.02 (0.76 to 1.37)	0.91	1.07 (1.01 to 1.14)	0.03	1.07 (1.01 to 1.13)	0.83
1–2	0.71 (0.39 to 1.32)	0.28	1.01 (0.80 to 1.29)	0.92	1.04 (0.89 to 1.22)	0.59	1.05 (0.95 to 1.16)	0.37	1.03 (0.95 to 1.11)	0.57
3–5	0.90 (0.68 to 1.18)	0.44	0.99 (0.79 to 1.23)	0.90	1.02 (0.89 to 1.18)	0.75	0.95 (0.85 to 1.06)	0.36	0.97 (0.89 to 1.05)	0.82
≥6	1.22 (1.04 to 1.43)	0.01	1.07 (0.92 to 1.25)	0.40	1.27 (1.16 to 1.40)	<0.001	1.04 (0.82 to 1.31)	0.77	1.19 (1.10 to 1.27)	0.15
Sanitation facilities										
Improved¶¶	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Unimproved***	1.36 (1.18 to 1.58)	<0.001	1.31 (1.15 to 1.50)	<0.001	1.39 (1.27 to 1.51)	<0.001	1.39 (1.30 to 1.47)	<0.001	1.38 (1.32 to 1.44)	0.87

*Multiple logistic regression models included age, sex, residence, region, educational level, occupation, income, marital status, hypertension, diabetes, depression, smoking, alcohol consumption, physical activity and sanitation facilities.
†The meta estimates of serial surveys.
‡Categorised into high, middle and low levels. High level presented top third of annual per capital income in the sampled county at the survey year, the second third was middle level and others belonged to low level.
§Self-reported for ever being diagnosed with hypertension by medical institution.
¶Self-reported for ever being diagnosed with diabetes by medical institution.
**Self-perceived health according to quality of life questionnaire.
††Participants have smoked a total of at least 100 cigarettes and either continued or ceased smoking at the survey.
‡‡Participants have had an alcoholic drink in the 12 months prior to the survey.
§§Participants have done physical activity in the past 6 months at least once.
¶¶Not ensure hygienic separation of human excreta from human contact and open defecation.
***Likely to ensure hygienic separation of human excreta from human contact.
Ref, reference.

burden of stroke in China appears to be more serious in the central and western regions, as well as rural areas. The regional variations in stroke prevalence may be attributed to the rapid transformations in socioeconomic conditions, and lifestyle over the past decades in China, especially in underdeveloped regions. As a result of urbanisation and economic boom, the main risk factors for stroke, such as hypertension and diabetes, are becoming more prevalent in rural areas than in urban areas.[23–25] Urban and eastern regions performed more effectively in preventing and controlling these risk factors than rural and western regions.[26] In addition, coupled with the advancement of diagnostic tools, the adoption of CT and MRI ensured the accuracy of stroke diagnosis in underdeveloped regions.[27] All these changes could be linked to the dramatic rise in stroke prevalence in rural areas and western regions.

An increase in stroke prevalence likely reflects the change in lifestyle and socioeconomic status. The significance of socioeconomic risk factors as predictors of stroke burden has already been discussed.[28] Overall, people with lower socioeconomic level tended to have a higher prevalence of stroke. Our results confirmed previous observations that people with higher income and the highest level of education have a lower risk of stroke. However, it is unclear what explains the association between socioeconomic status and stroke prevalence. Traditional stroke risk factors such as older age, male, hypertension and diabetes may help to explain why people with lower socioeconomic status have a higher rate of stroke, as a larger burden of stroke risk factors was found in people with lower socioeconomic status.[29 30] Moreover, we identified occupational status as the most reliable risk factor for stroke; a higher prevalence was seen in unemployed or retired individuals. Of the few studies that have investigated the relationship between occupational status and stroke, one reported that unemployed/retired Japanese women could be at risk for stroke,[31] and another from Finland also suggested that occupation status is one of the most common health indicators.[32] As far as those who were retired, they generally lost their jobs because of old age or poor health, including possible stroke or other diseases. For those who were unemployed, financial stress, depression and social stigma could have triggered unhealthy behaviours and poor mental health.[33] Our findings suggest that, of all the socioeconomic factors, occupational status is the strongest risk factor for stroke among the Chinese population. As such, encouraging individuals to work or further study may help minimise the risk of sustaining a stroke. Occupational status is certainly also influenced by education, income and marital status; their independent impacts cannot be separated altogether. We should thus consider all these factors together during analysis, instead of just focusing on one.

It is generally known that modifiable lifestyles, such as smoking, alcohol consumption, diet and physical activity, have been consistently linked to stroke risk. However, the link between some of these factors and stroke is yet unclear. Several studies have shown drinking is associated with a higher stroke burden, due to increased blood pressure caused by alcohol,[34 35] whereas other studies have reported a null or inverse association[36 37] and still others reported a J-shaped relationship.[38] In our study, drinking was consistently associated with low stroke prevalence. A plausible explanation is that alcohol raises high-density lipoprotein cholesterol levels while reducing platelet aggregation and fibrinolytic activity.[39] Although alcohol consumption may be beneficial in terms of stroke prevention, high intake is linked to an increased risk of alcohol-related cancers and injuries.[36] Therefore, estimating the health influence of drinking is essential. Physical activity is considered beneficial for stroke prevention by reducing hypertension and diabetes. However, high-intensity physical activity was shown to be associated with an increased risk of stroke in this study. These mirrors findings from a Japanese public health centre-based prospective study.[40] Several studies have suggested that high-intensity physical activity may cause haemorrhagic stroke by triggering a sudden and short-lasting increase in blood pressure.[40–42] Moreover, greater physical activity might enhance the effect of the increased risk of stroke due to longer exposure to polluted air in developing countries.[43] Thus, high-intensity physical activity might not be suitable for the prevention of stroke in China. Depression is highly prevalent not only in China but also worldwide, imposing a huge burden on public health. Several prospective studies have confirmed that in developed countries, depression is related with a considerably increased risk of stroke.[44 45] In general, the development of poststroke depression is well recognised, but the function of depression as a risk factor for stroke is less well studied in China. Depression was found to be a significant risk factor for stroke in our study. This suggests that as in developed countries, depression may have a significant influence in stroke prevalence in China. Interestingly, we found people living with unimproved sanitation facilities have a higher risk of stroke, particularly in rural areas. In low-income and middle-income countries, unimproved sanitation facilities are more commonly used in rural areas compared with urban areas. It is likely that poor sanitation is a surrogate for the low socioeconomic status, which is often related to poor access to care. Many diseases have been linked to inadequate sanitation such as malnutrition, diarrhoea, intestinal nematode infections and trachoma.[46 47] Nonetheless, no prior research has looked into the association between poor sanitation and stroke. The mechanism through which unimproved sanitation facilities contribute to stroke risk is unknown. Infection and alteration of gut microbiota caused by poor sanitation might increase stroke risk through pathways such as platelet hyperreactivity and immunomodulation.[48 49] It is recognised that the gut microbiota-brain axis affects the brain's pathophysiology.[50] A prospective clinical study also showed intestinal microbiota-dependent metabolism of phosphatidylcholine was associated with an increased risk of stroke.[51] Furthermore, a study from India indicated over a third of stroke occurred in toilets because squatting could increase blood pressure and thus trigger stroke.[52] Most people living with unimproved sanitation facilities perform their ritual in the squatting posture, which might explain why unimproved sanitation was associated with significantly higher stroke risk. Overall, we speculate that improving socioeconomic status and sanitation may help lower stroke risk in rural areas of China, as well as other developing countries.

There are some limitations in our study. First, due to the cross-sectional nature of this study's methodology, we cannot infer causality from the findings. Also, the self-reported questionnaire may cause recall bias. Second, several well-documented contributing factors that may affect stroke prevalence, such as hyperlipidaemia, dietary factors and obesity, were not included in the questionnaire, making it impossible to analyse their relationship to stroke prevalence. Third, people with stroke risk factors like hypertension and diabetes were likely to have better access to medical care due to their current morbidity and hence more likely to be diagnosed with stroke and this association may be due to a care-seeking bias. Furthermore, risk factors such as lifestyle and health status may have changed after suffering stroke, which may introduce bias. This bias may explain some results such as alcohol consumption which is found to be a protective factor, and high-intensity physical activity might not be suitable for the prevention of stroke. Finally, our study only analysed stroke prevalence, with no data on the incidence and mortality. In the future, we plan to prospective follow-up participants, investigate stroke incidence and collect information about mortality.

CONCLUSIONS

In summary, our study presents updated estimates of the prevalence and risk factors of stroke from 2003 to 2018 in China. In the past decade, the scissors phenomenon of stroke prevalence occurred in China. These novel findings indicate that the stroke prevalence may continue to increase in rural areas, and in western and central regions without interventions. Therefore, it is important to develop targeted programmes for stroke prevention in these regions. In addition to traditional risk factors of stroke, more attention should be given to nontraditional risk factors in the public health policies for stroke prevention.

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