Gao et al. BMC Public Health (2024) 24:2155
https://doi.org/10.1186/s12889-024-19615-2

BMC Public Health

RESEARCH

Open Access

Trend analysis of stroke subtypes mortality attributable to high body-mass index in China from 1990 to 2019

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Abstract

Background The prevalence of stroke disability associated with high BMI has significantly increased over the past three decades. However, it remains uncertain whether high body-mass index (BMI) exerts a similar impact on the disease burden of different stroke subtypes. The aim of this study is to assess the long-term trends of stroke and subtypes mortality attributable to high BMI in China between 1990 and 2019.

Methods Data on stroke and subtypes mortality attributable to high BMI in China was extracted in the Global Burden of Disease (GBD) 2019. The trends of age-standardized mortality rate (ASMR) were calculated using the linear regression and age-period-cohort framework.

Results The changing trend of ASMR on stroke attributable to high BMI in China differed among subtypes, with an estimated annual percentage change (EAPC) and 95%CI of 2.04 (1.86 to 2.21) for ischemic stroke (IS), 0.36 (-0.03 to 0.75) for intracerebral hemorrhage (ICH), and −4.62 (-5.44 to -3.78) for subarachnoid hemorrhage (SAH). Net and local drift analyses revealed a gradual increase in the proportion of older people with IS and a gradual increase in the proportion of younger people with hemorrhagic strokes. The cohort and period rate ratios varied by subtype, showing an increasing trend for IS and ICH but a decreasing trend for SAH. The stroke mortality attributable to high BMI increased significantly with age for IS and ICH, peaking between ages 50–70 for SAH. Notably, males had higher ASMR related to stroke but exhibited slighter declines or higher growth compared to females in China. Moreover, the population affected by fatal strokes tended to be older among females but more evenly distributed across a wider age range encompassing both younger and older individuals.

Conclusion The research findings indicate a rising trend in the ASMR of stroke and subtypes attributable to high BMI in China from 1990 to 2019, with different patterns of change for different subtypes, genders and ages. Consequently, it is imperative for public health authorities in China to formulate guidelines for specific stroke subtypes, genders and ages to prevent the burden of stroke attributable to high BMI.

Keywords Stroke, Ischemic stroke, Intracerebral hemorrhage, Subarachnoid hemorrhage, Body mass index, Global burden of disease

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Introduction

Stroke is the second leading cause of both death and disability globally, with developing countries bearing the greatest burden of this condition [1, 2]. In the year 2019, stroke caused 6.6 million deaths and 143.2 million disability-adjusted life years (DALYs) lost worldwide [3]. Within China, a densely populated nation, the impact is notably severe, with 2.2 million reported deaths and 45.9 million DALYs in the same year [3, 4]. Furthermore, the crude incidence rate of stroke in China increased from 1990 to 2019 [4], underscoring the significant public health challenge posed by stroke in the country.

In addition to the traditional risk factors for stroke, such as hypertension, elevated lipids, and diabetes, high body-mass index (BMI) also has been widely accepted as a leading risk factor for stroke [5, 6]. Based on the findings of the GBD 2019 (Global Burden of Disease), it was observed that there was a significant rise in the proportion of stroke-related DALYs attributed to high BMI on a global scale between 1990 and 2019 [3]. With rapid economic development, the diet, lifestyle and work environment in China have changed dramatically [7, 8]. Obesity has also become a major public health issue in China. Overweight and obesity have increased rapidly in China in the past four decades, with the prevalence estimated at 34.3% for overweight and 16.4% for obese adults in 2015-19 based on Chinese criteria [9]. High BMI has also become one of the major risk factors for stroke in China, especially for hemorrhagic stroke and for males [4]. Previous studies have demonstrated a positive correlation between stroke risk and BMI, suggesting that reducing BMI could serve as an effective preventive measure against stroke [5, 10]. However, it is unclear what are the trends in stroke mortality attributable to high BMI, whether high BMI had different effects on stroke subtypes, including ischemic stroke (IS), intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH).

In this study, we used data from the GBD 2019 Results Tools calculating the estimated annual percentage change (EAPC) to illustrate the trend of disease burden for stroke and subtype attributable to high BMI in China from 1990 to 2019. We also performed the age-period-cohort analysis to illustrate the effect of age, period, and cohort on stroke and subtypes mortality attributable to high BMI.

Methods

Data sources

We obtained the data about age-specific cases and age-standardized mortality rate (ASMR) of stroke and subtypes attributable to high BMI in China and globally during 1990 to 2019 from the GBD 2019 Results Tool of the GHDx (ghdx.healthdata.org/gbd-results-tool). GBD 2019 is a publicly accessible database that has previously published descriptions of methods used to evaluate risk factor data [12]. This study followed the Guidelines for Accurate and Transparent Health Estimation Reporting for Population Health Research, which includes 18 items designed to provide best reporting practices for studies evaluating health estimates for multiple population [11], and does not require informed consent.

China stroke mortality in GBD 2019 is mainly from the Chinese surveillance system, which provided provincial representative mortality data on decades [4]. Stroke mortality attributable to high BMI in GBD 2019 were estimated as follows: (1) identifying high BMI-stroke subtype pairs; (2) estimating relative risks as functional exposure based on systematic reviews; (3) estimating of exposures for high BMI by age, sex, location, and year; (4) identifying the theoretical minimum risk exposure level; (5) estimating the attributable burden and population attributable fractions; (6) estimating the deaths attributable to combinations of risk factors accounting for the mediation of high fasting plasma glucose, high low density lipoprotein cholesterol, and high systolic blood pressure [12].

Definitions

Stroke is defined as a rapidly progressing clinical condition that presents with focal (sometimes global) brain dysfunction, lasts longer than 24 h, or leads to death with no apparent cause other than vascular origin, data on transient ischemic attacks were not included. IS was defined as all vascular events that result in limited blood flow to the brain tissue leading to infarction, including atherosclerotic and thromboembolic factors, but excluding factors that lead to intracranial hemorrhage. ICH is defined as stroke with a focal concentration of blood in the brain that is not caused by trauma. SAH was defined as non-traumatic stroke due to bleeding into subarachnoid space of the brain. High BMI for adults (age 20+) was defined as BMI greater than 23 kg/m^2 [3].

Statistical analysis

The EAPC and its 95% CI were used to reflect the temporal trends in ASMR from 1990 to 2019, which were calculated using a log-linear regression as follows:

$\mathrm{Ln}\ (\mathrm{ASMR}) = \alpha + \beta x + \varepsilon$.

x is the year, and β is the regression coefficient, ε represents error term, α represents intercept. EAPC was calculated as $100 \times (\exp[\beta] - 1)$, and the 95% CI was generated based on the standard errors generated by the log-linear regression. The ASMR was considered increased if the EAPC and its 95% CI were >0, decreased if they were <0, if the 95% CI included 0, the rate was regarded as no significant change [13].

Age-period-cohort (APC) analysis was used to evaluate the effect of age, period, and cohort on high BMI-related stroke and subtypes mortality. The age effect represents different outcome risks associated with different age groups. The period effects are changes in outcomes over time that affect all age groups simultaneously, such as the development of disease screening methods, medical techniques, or disease classifications. The cohort effects are related to changes in outcomes of stroke and subtypes attributable to high BMI across groups of individuals of the same birth year.

The follow indicators were estimated in the APC analysis to illustrate the effect of age, period and cohort: (1) The net drift represents the overall log-linear trend by calendar period and birth cohort that indicates the overall annual percentage change. (2) The local drift reflects the log-linear trend by calendar period and birth cohort for each age group that indicates annual percentage changes for each age group. (3) The longitudinal age curve which show the fitted longitudinal age-specific rates in the reference cohort adjusted for period deviations. (4) The cohort (or period) rate ratios (RR) represent the cohort (or period) relative risk adjusted for age and nonlinear period (or cohort) effects in a cohort (or period) versus the reference one [14, 15].

In the process of APC performance, the death cases and the populations were divided into group by 5-year period, with consecutive 5-year groups covering the period 1990–2019 and age groups ranging from 25 to 29 years to 90–94 years. Since stroke mortality attributable to high BMI under the age of 25 years is rare, and all those older than 95 years are showed as one group in the GBD database, so we excluded the two groups from our analysis. Our study defined the reference group as the age group 50–55, the period 2005–2009 and the cohort of 1955. All analyses were performed using R version 4.2.3.

Results

The trends of ASMR for stroke and subtypes attributable to high BMI from 1990 to 2019 in China and globally are shown in Fig. 1, Figure S1 and Table S1. The global ASMR trends for stroke and subtypes related to high BMI showed a decreasing trend, with EAPC −0.57 for stroke, -1.06 for IS, -0.12 for ICH and −1.14 for SAH, respectively. The trends are different in China and globally. We found that ASMR per 100 000 population in China increased from 12.17 in 1990 to 13.15 in 2019 for stroke [EAPC and 95%CI: 0.29 (0.07 to 0.5)], increased from 2.55 to 4.43 for IS [EAPC and 95%CI: 2.04 (1.86 to 2.21)], increased from 7.52 to 7.93 for ICH [EAPC and 95%CI: 0.36 (-0.03 to 0.75)], but decreased from 2.1 to 0.79 for SAH [EAPC and 95%CI: -4.62 (-5.44 to -3.78)]. In addition, our results demonstrated that the ASMR for stroke

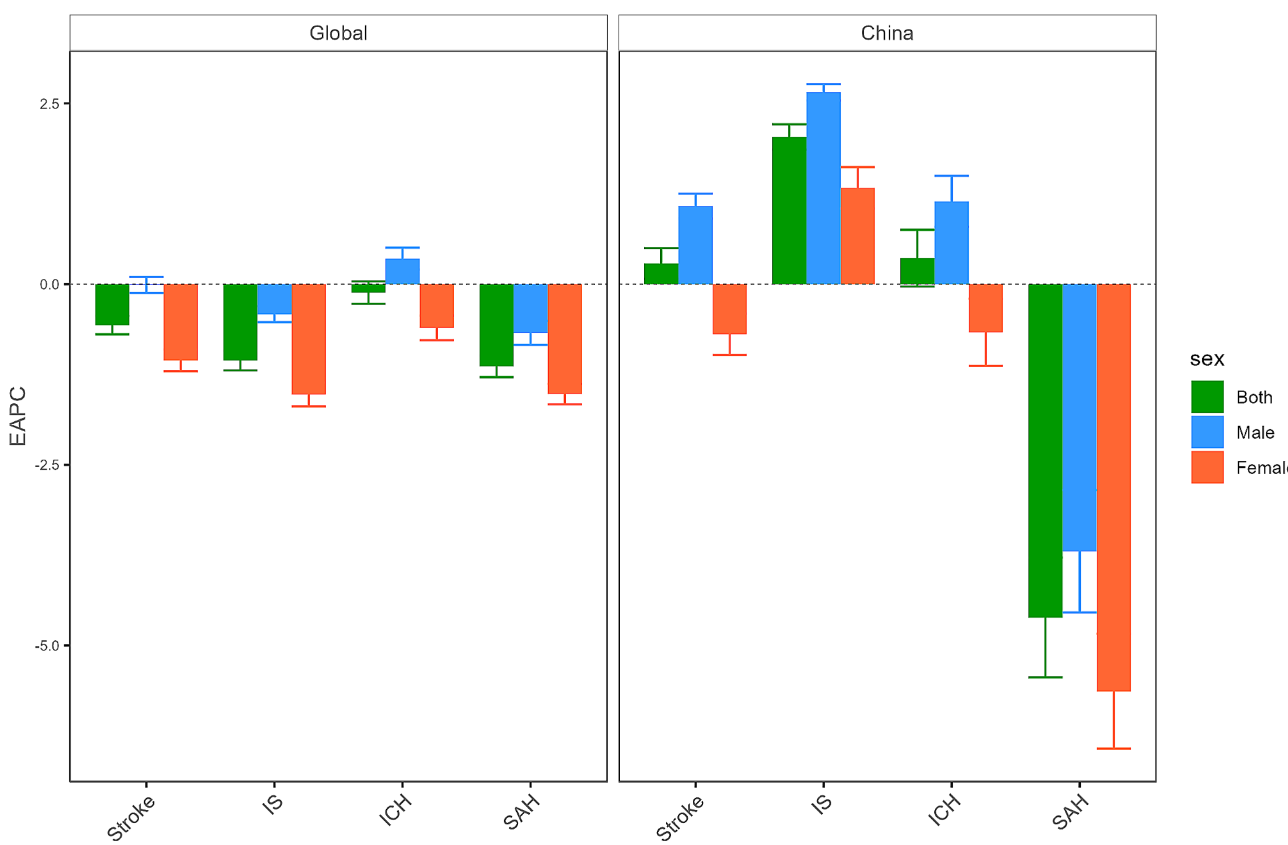

Fig. 1 EAPC of ASMR for stroke and subtypes attributable to high BMI from 1990 to 2019 in China and globally
Error bars represent the 95% CI for the EAPC. IS: ischemic stroke; ICH: intracerebral hemorrhage; and SAH: subarachnoid hemorrhage

and subtypes related to high BMI is higher in males than in females in China, with a slower rate of decline or faster rate of increase in ASMR.

The local drift and the net drift calculated using the APC model are illustrated in Fig. 2. The colored horizontal and curved solid lines represent the net and local drift, respectively. The black horizontal dashed line indicates a steady trend with zero value of the annual change. The colored horizontal dashed line indicates the 95% CI of the net drift for the corresponding group. Taking the stroke section in Fig. 2 as an illustration, the net drift is lower than zero in the female group and greater than zero in the male group, implying that their ASMR has declined in females and increased in males after adjusting for the period and cohort from 1990 to 2019. The local drift curve of the males is U-shaped and cross with the net drift with two intersections. This suggests that the proportion of the younger age group (around <40 to 44 age group) and the older group (around >75 to 79 age group) in males was rising. The local drift curve for males above the black horizontal dashed line means that the ASMR had an increasing trend across all age groups. For females, the local drift of stroke is an ascending curve with age, with a single intersection with the net drift (around 55 to 59 age group). This reflects the fact that the female stroke death population tends to be older. The trend of the local drift curves for IS was similar to that of stroke, but the net drift is greater than zero both for males and females. This means that ASMR increased for both males and females, with a polarized age distribution for males and an older age distribution for females. The net and local drift curves for ICH showed an increasing trend of ASMR associated with high BMI for males with faster growth in the young age group, but a descending trend for females in all age groups with faster decline in the young age group. For SAH, the local drift curve was declined with age and the net drift is less than zero for both males and females.

Figures 3 and 4 showed the estimated period and cohort effects of stroke and subtypes mortality attributable to high BMI in China. The period RR showed an increasing trend for IS, but a decreasing trend for SAH from 1990 to 2019, both for males and females. As in ICH, the period RR decreased for females but increased for males. Cohort

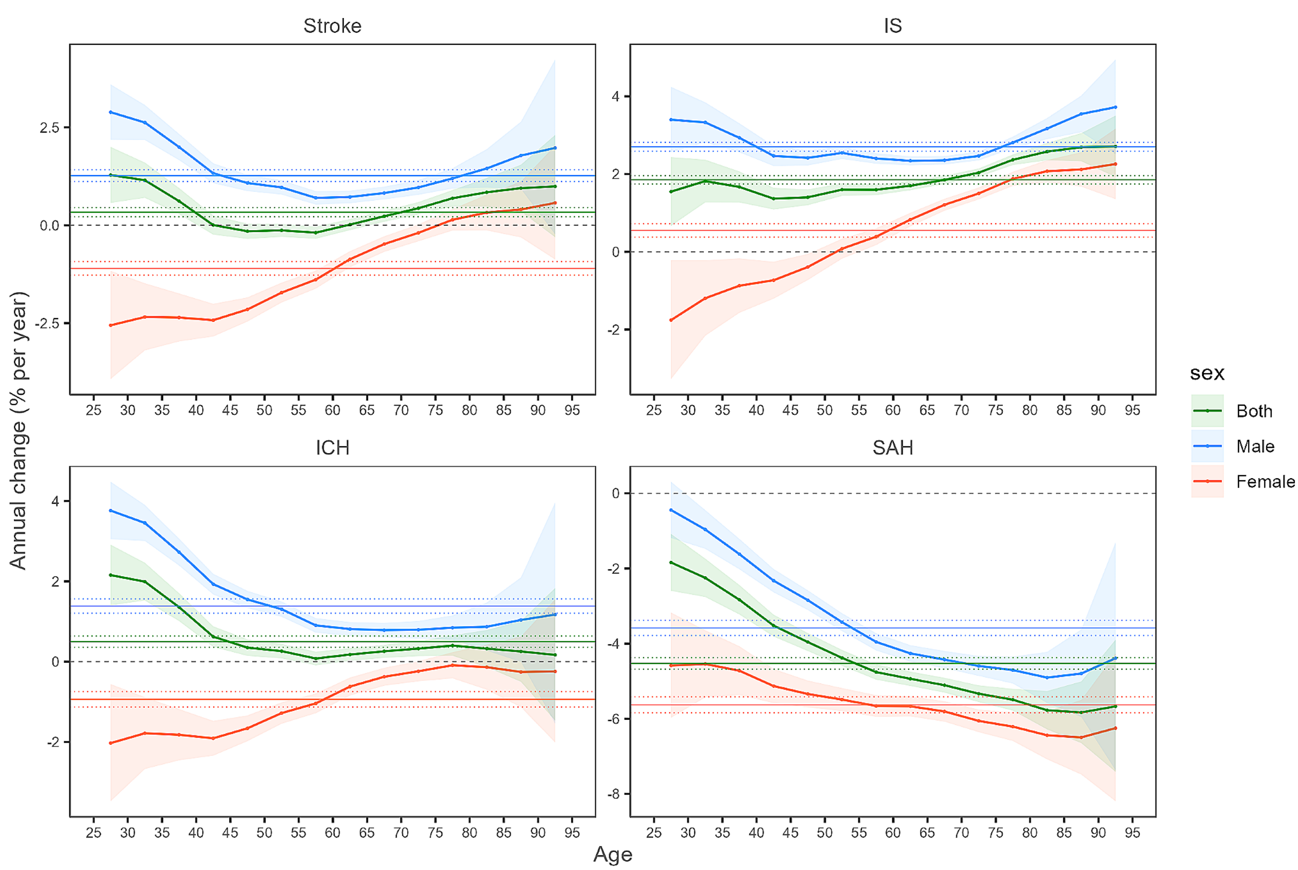

Fig. 2 Net and local drift for stroke and subtypes mortality attributable to high BMI in China
The net drift shows the EAPC of ASMR for the stroke and subtypes adjusted by the APC model. The local drift value represents the annual percentage change within specific age groups. The net drift value < 0 signifies a decreasing trend, while > 0 indicates an increasing trend. Similarly, the local drift value conveys the same meaning but with a particular age group. The colored dashed lines and translucent ribbons represent the 95% CI of the net and the local drift for the specific sex groups, respectively

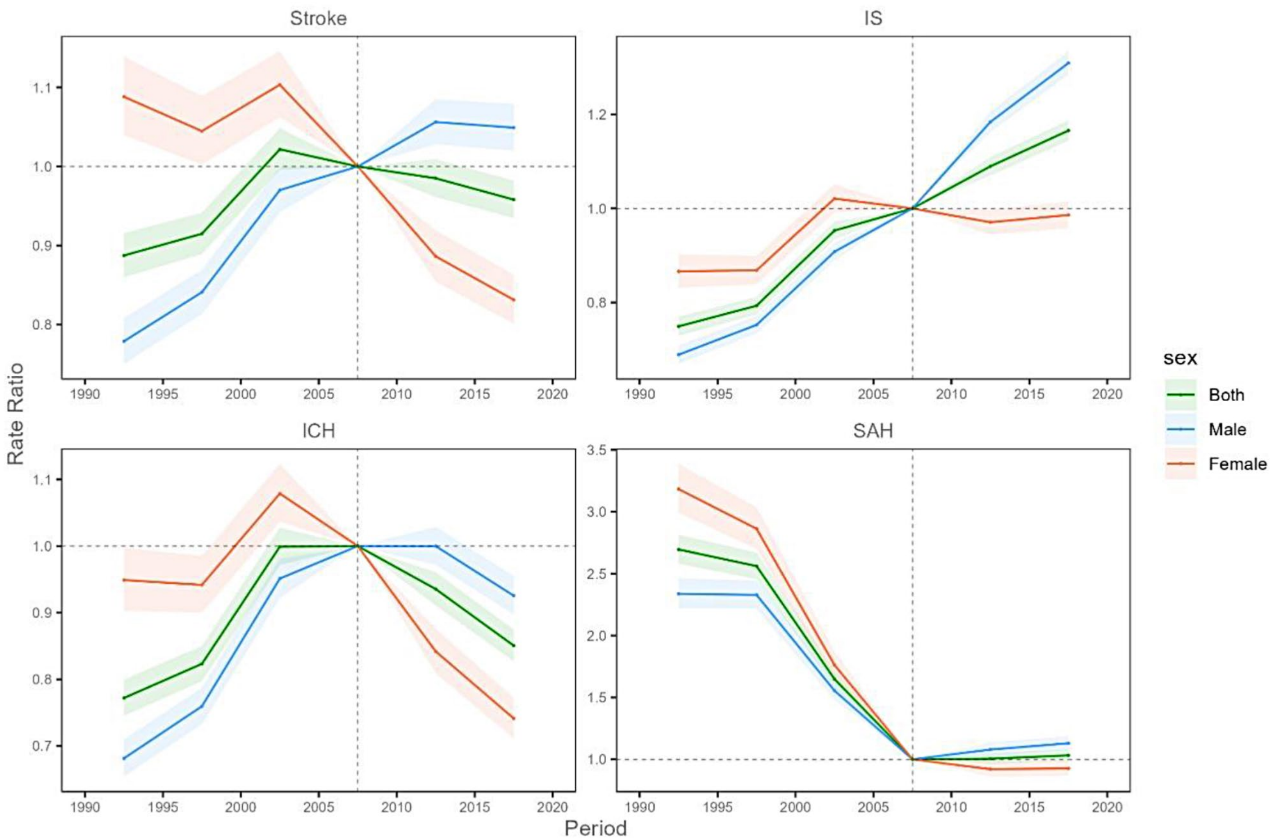

Fig. 3 Period rate ratio (RR) of stroke and subtypes mortality attributable to high BMI in China
The period RR of each period group compared with the reference period (2005 to 2009) adjusted for age and cohort effects. The translucent ribbons represent the 95% CI of the period RR for the specific sex group

RR showed a similar trend as the period RR. Remarkably, the effect of period and cohort decline more sharply or increased more slowly for females than for males.

The longitudinal age curves of stroke and subtypes mortality attributable to high BMI in China are shown in Fig. 5. The mortality rates for IS and ICH increased prominently with age, showing a steeper slop at higher ages. We found that the significant increase in mortality for IS began at the 45 to 49 age group, but for ICH at the 30 to 34 age group. However, the mortality curves for SAH showed reverted U-shape, peaking in the 50 to 70 age group. In addition, male mortality was significantly higher than female mortality in all age groups.

Discussion

Our study showed that stroke mortality attributable to high BMI decreased globally from 1990 to 2019 but increased in China, with trends varying across subtypes and sexes. The mortality increased for IS but decreased for SAH in both males and females, and increased in males but decreased in females for ICH from 1990 to 2019 in China. The results of the APC analysis showed that stroke mortality attributable to high BMI increased significantly with age. This is demonstrated different trends in the ASMR, period, and cohort RR for stroke subtypes associated with high BMI from 1990 to 2019 in China, with a clear decrease for SAH but an increase for IS. The age structure of different stroke subtypes and sex varied. Notably, for both ICH and IS, ASMR attributable to high BMI tended to be older in female. In males, it showed a younger trend for ICH and a bipolar trend for IS. Males had higher stroke ASMR but slighter declines (or higher growth) than females in China.

High BMI is generally considered as a risk factor for stroke [5, 16, 17]. Previous study has revealed a positive association between stroke risk and BMI, with a stronger association in males and IS [5]. Our study showed that the ASMR of stroke attributable to high BMI increased in China but decreased worldwide from 1990 to 2019. This may be that the prevalence of overweight and obesity in China has been steadily increasing since the 1990s [18], possibly due to significant social and economic changes experienced by the country over the past three decades, including rapid economic growth, transformations in living and working environments, alterations in food environments, dietary patterns, and lifestyles [19].

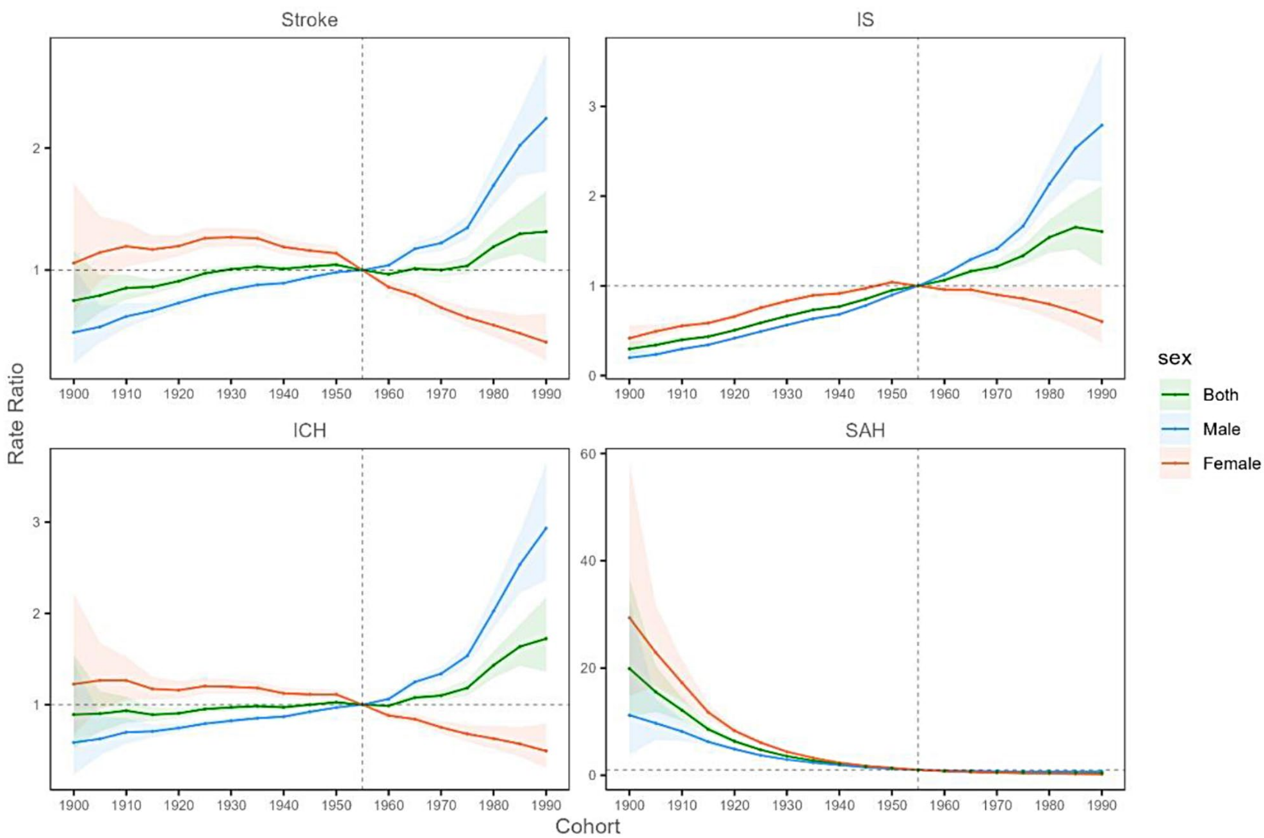

Fig. 4 Cohort rate ratio (RR) of high BMI-related mortality of stroke subtypes in China
The cohort RR of each cohort compared with the reference cohort (cohort 1955) adjusted for age and period effects. The translucent ribbons represent the 95% CI of the cohort RR for the specific sex group

Consequently, China now harbors the largest number of individuals with overweight and obesity worldwide [18]. Analysis of stroke subtypes showed that between 1990 and 2019 in China, the ASMR decreased for SAH but increased for IS, with a relatively stable trend for ICH. This may be attributed to a stronger positive association between BMI and IS compared to ICH [5]. Although the ASMR of SAH declined most significantly, we considered that advances in medical technology and surgical management rather than solely BMI changes were primarily responsible for this improvement [20].

The net and local drift curves for stroke subtypes indicate that the hemorrhagic stroke death population tends to be younger and the IS population tends to be older. For the sex analysis, the death population tends to be younger for ICH, but shows a bipolar trend with age for IS in males, and older in female for both ICH and IS. The possible reason is that the rates of overweight and obesity in Chinese men are growing faster than in women [9]. Another reason could be gonadal hormone, a protective factor against stroke in women before menopause [21]. Based on Chinese criteria, the prevalence of overweight and obesity among children and adolescents age 7–18 years in the Chinese National Survey on Students' Constitution and Health increased from 1.1% to 0.1% in 1985 to 12.1% and 7.3% in 2014, respectively [22, 23]. As the overweight and obesity rates of childhood and adolescent increase [22, 24], the burden of stroke attributable to high BMI on the public health system will not disappear soon. Increasing ASMR among the young population stroke will have a negative impact on China's social and economic development. To control the disease burden and economic loss from stroke attributable to high BMI, more attention should be paid to controlling overweight and obesity in China, especially in the young population and among men.

Our study showed a significant decline in period RR and cohort RR for SAH, but an increased for IS, for both males and females. For ICH, it showed a decrease for females but an increase for males. This may be due to differences in the severity of ICH and IS caused by high BMI, as well as the effect of estrogen as discussed above. Period and cohort analyses also showed that the young Chinese population is at increased risk of stroke mortality attributable to high BMI. This could be caused by the increase in pediatric obesity in China in recent years, which is positively associated with economic development [25]. With the rapid economic development, there

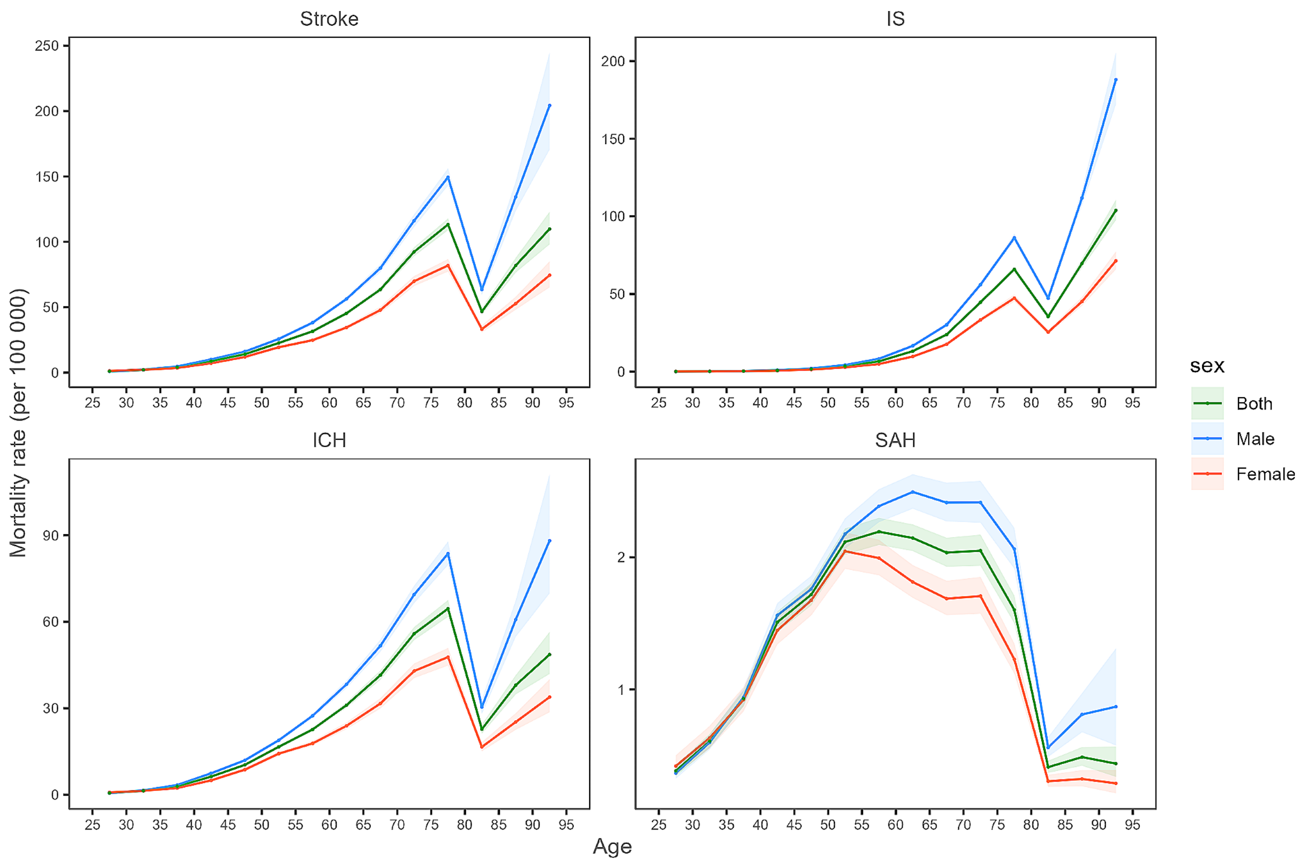

Fig. 5 Longitudinal age curves for stroke subtypes mortality attributable to high BMI in China
Longitudinal age-specific mortality rates for stroke and subtypes attributable to high BMI (per 100 000). The translucent ribbons represent the 95% CI of the mortality for the specific sex group

have been behavioral, and nutritional transitions that are highly relevant to high BMI transitions in China [26]. Our study suggested that overweight and obesity prevention policies targeting children and young adults are necessary to reduce the burden of stroke in China.

Aging was widely believed to be the most powerful nonmodifiable risk factor for stroke. The high incidence of stroke and poor functional recovery resulted in the high mortality in the elderly population [27]. Previous study has shown that the prevalence of overweight and obesity generally increases with age but declines slightly in later adulthood [9], which is at odds with our results that the stroke mortality attributed to high BMI increases with age. The potential explanation could be that comorbidities that accumulate with age, such as hypertension, diabetes and coronary heart disease, greatly increase the risk of stroke mortality [28]. Our study also revealed that ICH mortality was higher in early adulthood and IS mortality was higher in late adulthood. This may be attributable to other risk factors, such as hypertension, which is increasing in prevalence in the young Chinese population but has low treatment rates [29].

Our study found that there are sex differences in stroke ASMR attributable to high BMI in China from 1990 to 2019. Male had a higher ASMR and a faster increasing (or slower decreasing) trend than female, which is consistent with previous study [4]. The probable reasons for this may be as follows. The first is that BMI increased faster in men than in women in China, the mean BMI increased from 22·7 kg/m² (22·5 kg/m² in men and 22·9 kg/m² in women) in 2004 to 24·0 kg/m² (24·2 kg/m² in men and 23·9 kg/m² in women) [9]. The second is that BMI has a strong association with IS and male [5]. One observational study found that overweight and obesity were associated with a higher incidence of total and IS in both men and women, but for hemorrhagic stroke, they were associated with a higher incidence in men, but not in women [10]. Another reason is the protective effect of gonadal hormone and women's healthier lifestyles, with less smoking and drinking [21, 30].

This is the first study to illustrate the temporal trends of stroke and subtypes mortality attributable to high BMI and its sex differences. Data from the GBD 2019 provided internally consistent estimates of age- and sex-specific all-cause and cause-specific mortality and are of satisfactory quality to reduce the possibility of misclassification of outcomes. However, there are several limitations. First, the GBD data are not direct surveillance data, which were estimated using mathematical models based on surveillance data. However, the GBD data estimated the distribution of high BMI by year, sex, age group, and relative risk per unit of exposure, and was a more comprehensive system than any previous national analysis that has been able to assess changes in disease burden caused by high BMI. Second, this study used a global perspective to analyze stroke and subtypes mortality attributable to high BMI in China. The interpretation of the study results at the population level may not hold at the individual level. Therefore, more studies are necessary to confirm the findings based on individual level studies. Third, the definition of high BMI in the GBD China data is greater than 23.0 kg/m^2, which is not graded. The impact of different levels of high BMI on stroke mortality needs further study. Finally, rapid changes in computed tomography rates in China in the 1990s may have led to incorrect classification of causes of death. However, GBD 2019 minimizes the bias by using the Cause of Death Ensemble modeling framework.

Conclusion

The disease burden of stroke attributable to high BMI still was considered to be a major public health issue in China. This study concludes that (1) Stroke mortality attributable to high BMI showed different trends over the past three decades, with a decreasing trend for SAH but increased for IS and ICH. (2) Stroke mortality has a higher increasing or a lower decreasing trend for males than that for females. (3) Mortality in males presents an age polarization trend, with increasing trend for younger and older group, but decreasing for the middle age group. It is necessary for Chinese public health organizations to advance guidelines for specific subtypes, genders and ages to prevent the mortality caused by stroke attributable to high BMI.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19615-2.

Supplementary Material 1

Acknowledgements

This study used publicly available data accessed from GBD (Global Burden of Disease) 2019, which is provided by the Institute for Health Metrics and Evaluation.

Author contributions

Ying Gao performed data collection and analysis, and prepared the manuscript. Kangding Liu and Shaokuan Fang revised this article. All authors have read and approved the manuscript.

Funding

This study was supported by the National Natural Science Foundation of China (No. 82371304) and Jilin Provincial Department of Science and Technology (No. YDZJ202201ZYTS684).

Data availability

This study used publicly available deidentified data accessed from GBD (Global Burden of Disease) 2019, which is provided by the Institute for Health Metrics and Evaluation.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 17 February 2024 / Accepted: 26 July 2024
Published online: 08 August 2024

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