Age–Period–Cohort Analysis of Stroke Mortality in China
Data From the Global Burden of Disease Study 2013

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Background and Purpose—Stroke has been the leading cause of death in China. The aim of this study is to assess the long-term trends of stroke mortality in China between 1994 and 2013.

Methods—The mortality data were obtained from the GBD 2013 (Global Burden of Disease Study 2013) and were analyzed with the age–period–cohort framework.

Results—We found that the net drift was −2.665% (95% confidence interval, −2.854% to −2.474%) per year for men and −4.064% (95% confidence interval, −4.279% to −3.849%) per year for women, and the local drift values were below 0 in all age groups (P<0.05 for all) in both sexes during the period of 1994 to 2013. In the same birth cohort, the risk of death from stroke rose exponentially with age for both sexes after controlling for period deviations. The estimated period and cohort relative risks were found in similar monotonic downward patterns (significantly with P<0.05 for all) for both sexes, with more quickly decreasing for women than for men during the whole period (significantly with P<0.05 for both).

Conclusions—The decreased mortality rates of stroke in China are likely to be related to improvements in medical care and techniques, spectacular economic growth and fast urbanization, and better early life nutrition conditions of Chinese people. Besides, better education and better awareness of stroke-related knowledge in successive generations could also probably play a role. (Stroke. 2017;48:271-275. DOI: 10.1161/STROKEAHA.116.015031.)

Key Words: cause of death ■ China ■ mortality rate ■ risk ■ stroke ■ trends
Results

Trends of the crude mortality rates and the age-standardized mortality rates (ASMR) for stroke by sex for the period of 1994 to 2013 are shown in Figure 1. We can observe that although the crude mortality rates for stroke of Chinese males and females showed overall increasing trends, from 123.5 to 154.7 per 100000 for men and 110.2 to 121.4 per 100000 for women, the ASMRs in both sexes showed general declining trends, from 232.8 to 188.9 per 100000 for men and 169.7 to 127.5 per 100000 for women. We should note that since 2009, the ASMR for stroke in males began to rebound slightly. The reduction in the ASMR for stroke from 1994 to 2013 was 18.9% in men and 24.9% in women. The net drift, which represents the overall annual percentage change, and local drifts, which represent annual percentage changes for each age group, are displayed in Figure 2. We found that the net drift was −2.665% (95% confidence interval, −2.854% to −2.474%) per year for men and −4.064% (95% confidence interval, −2.479% to −3.849%) per year for women. The net drift, and local drifts were below 0 in all age groups in both sexes.

The longitudinal age curves of stroke mortality by sex are illustrated in Figure 3. For both men and women, in the same birth cohort, the risk of death from stroke showed an accelerated increase from age 15 to 19 to 75 to 79 years. We further performed curve estimation for the longitudinal age curves and found both of them followed an exponential distribution. These curves can be expressed as rate=1.667×e0.082×mean_age for men (R-squared =0.994) and rate=1.366×e0.076×mean_age for women (R-squared =0.985). This indicated that the relative risk for stroke mortality in each life stage from age 20 to 24 to 75 to 79 years were 1.51 for men and 1.46 for women compared with its previous life stage. The estimated period and cohort RRs by sex are displayed in Figures 4 and 5. Period RRs were found in similar monotonic declined patterns for both sexes, with more quickly decreasing for women than for men overall (significantly with P<0.05), but these downward tendencies were slowing down in the recent cohorts, especially for those born after the year 1969. In addition, using the specific results of Wald tests, we found statistically significant cohort and period effects for both sexes (P<0.05 for all) and so were the net drift and local drifts (P<0.05 for all).

Discussion and Summary

This is the first published study, to our knowledge, to investigate the long-term trends of stroke mortality in China and to examine age-, period-, and cohort-specific effects by sex using the APC framework. Our results indicated that although the crude mortality rates for stroke of Chinese males and females generally increased during the period of 1994 to 2013, the age-standardized stroke mortality rates of them showed overall trend of males decelerated from 2009 to 2013. Cohort RRs were also found in similar monotonic downward patterns for both sexes, with more quickly decreasing for women than for men overall (significantly with P<0.05), but these downward tendencies were slowing down in the recent cohorts, especially for those born after the year 1969. In addition, using the specific results of Wald tests, we found statistically significant cohort and period effects for both sexes (P<0.05 for all) and so were the net drift and local drifts (P<0.05 for all).
decreasing trends with a decrease in the stroke mortality rate for every age group.

Age is the most important risk factor for stroke among a series of demographic factors. The risk of death from stroke varies from different life stages because of physiological changes, amassing of exposure to risk factors, unhealthy living habits, or a blend of these. In previous studies on stroke patterns in China, authors mainly focused on the age distribution of the incidence; only a few of them depicted the age pattern of stroke mortality. Although they found that stroke incidence and mortality rates rose rapidly with age, their studies were not comprehensive and accurate enough to some extent for their relatively small number of age groups and small sample size. More importantly, none of them took the uncontrolled cohort and period effects into account in their studies.

Using the most recent data from GBD 2013, our results showed that, in the same birth cohort, the risk of death from stroke rose exponentially with age after adjusting for period deviations. Specifically, the relative risk of the stroke mortality was about one and a half times each 5-year life stage from age 20 to 24 to 75 to 79 years for both sexes in China, which is similar to the findings of the Western countries. It should be noted that the crude mortality rates for stroke in Chinese males and females showed overall increased trends, which is different from the results of ASMRs in both sexes. We believed that the problem of aging society plays an important role in this difference. It is generally known that China has the largest population in the world, and it has witnessed a decreasing number of births since the 1990s, which will make its problem of aging society more serious because of the large amount of the elderly and the more rapidly aging population. In Figure 3, we can see that >70% of mortality risk from stroke in China occurred in people aged ≥65 years; >80% of that occurred in people aged ≥60 years. So there is no doubt that the increasing proportion of the elderly in China would lead to a growth in the crude mortality rate. According to World Population Ageing 2013 published by United Nations, China would witness an increase in the proportion of people aged ≥60 years from 12.4% to 28.1% in the next 3 decades (2010–2040). So we speculated that the death toll and the crude mortality rates for stroke in Chinese males and females will continue to rise in the future, given the fact that other factors are under their current trends.

Although the period effect and cohort effect can be estimated separately as the period RR and cohort RR by certain restriction, in fact, it is not easy to interpret them separately in the real world. This is because the period effect often influences certain age group(s) more or less when it influences all age groups simultaneously, which leads to the cohort effect to some extent. The cohort effect essentially reflects different birth cohorts’ various risk, but in reality, different cohorts were born in different periods and, thus, inevitably have confounding impact on the period effect to some extent. So we comprehensively discussed the possible reasons for the decreasing trends of period and cohort effects.

Figure 3. Longitudinal age curves of stroke mortality in China. Fitted longitudinal age-specific rates of stroke mortality (per 100,000 person-years) and the corresponding 95% confidence intervals (some of them were too narrow to show in the figure).

Figure 4. Period relative risks (RRs) of stroke mortality rate by sex in China. The relative risk of each period compared with the reference one (year 2001) adjusted for age and nonlinear cohort effects and the corresponding 95% confidence intervals (some of them were too narrow to show in the figure).

Figure 5. Cohort relative risks (RRs) of stroke mortality rate by sex in China. The relative risk of each cohort compared with the reference one (cohort 1955) adjusted for age and nonlinear period effects and the corresponding 95% confidence intervals (some of them were too narrow to show in the figure).
When it comes to the trend of ASMR for stroke, the first thing we should consider is the revision of International Classification of Diseases code during the study period. But it has been proven that changes from International Classification of Diseases-Ninth Revision to International Classification of Diseases-Tenth Revision had no substantial influence on the analysis of temporal trends for stroke, so the reason behind the decreasing trend of ASMR for stroke is likely to be other factors. Because many developed countries also experienced a declined ASMR of stroke, it is generally regarded as the consequence of improved medical care and the effective control of risk factors. For China, the main reason seems to be the former. Significant improvements on techniques for diagnosis, treatment, and management, accompanied by more and better healthcare professionals, played a critical role in the declining case fatality and, thus, decreasing stroke mortality. Most patients could receive computed tomography or magnetic resonance image scanning to aid diagnosis for stroke when they are in a county-level hospital or a more advanced one, and it is believed that early detection could also contribute to better treatment and the reduced mortality. What is more, spectacular economic growth and fast urbanization (the proportion of residents living in urban areas was 26% in 1990 and 50% in 2010) have made those medical-care services more available, accessible, and affordable for hundreds of millions of Chinese people, especially given the fact that the emergency services were usually centered in urban areas.

Improvement of early-life nutrition conditions is also likely to be one of the main reasons for the decreasing ASMR for stroke in China. There were many studies that indicated maternal and early-child undernutrition have strong associations with the risk of stroke. Although the mechanisms are not clear at present, it has been reported that undernutrition in early life would cause a high blood pressure and even a permanent harmful impact on vascular function and structure. In addition, better education and better awareness of stroke-related knowledge in successive generations probably played a partial role. We should note that in both sexes, the decreasing trend of the cohort effect witnessed a small deceleration in the cohorts born after 1980. This similar deceleration phenomenon also happened in many European regions and in Hong Kong, in earlier cohorts who were born approximately between 1950 and 1970. It is generally believed that the rising prevalence of the hazard factors (eg, hypertension, obesity, diabetes mellitus, vascular diseases, cholesterol level, and smoking), the more westernized dietary pattern, and the increasingly sedentary lifestyle were the underlying reasons for the decelerating cohort effect. This is basically in accordance with the fact that the lifestyle of the post-80s generation in China is different from that of preceding generations.

It should be noted that many major risk factors for stroke were actually not well controlled in China during the study period. For example, the prevalence of hypertension (the most important risk factor for stroke) in China has increased rapidly in adult population since 1991, according to existing studies. However, we should also note that effective and increasingly generalized use of antihypertensive treatments could make contributions to the decreasing period effect to some extent. The phenomenon that there was a decelerated decreasing trend and then a reversed slight increase of ASMR in men (see Figure 1) is somehow intriguing. We suggest that the underlying reason might be associated with the smoking. This is because there was a rapid increase of tobacco consumption in China since the early 1980s because men represent the overwhelming majority of Chinese smokers, and the lag period between smoking and stroke mortality was estimated to be 20 to 30 years.

Some limitations of the present study should be noted. First, because age and period intervals should be fixed and equal in APC analysis, seniors aged ≥80 years could not be considered in this study because of the data availability (they were only recorded as one group in GBD database). However, substantial numbers of death from stroke happen in seniors aged ≥80 years, and variations in people ≥80 years do not necessarily reflect those of the older people. But we still can confirm from the data that the stroke mortality rate of Chinese seniors aged ≥80 years is also decreasing, which was just more moderate than that of younger age groups. This phenomenon was consistent with that in Figure 2, whose potential trends showed that age group-specific annual percent change in old people was getting smaller with age. Second, it is evitable that problems of completeness and accuracy on stroke mortality data in this study may somehow lead to bias, although there were many steps, including incompleteness, under-reporting, and misclassification corrections, as well as the redistribution of the garbage codes in GBD 2013, to enhance the data quality and comparability. But it is fair to say that the bias in the present study has been reduced a lot to some extent, compared with that of research using raw data without those correction and adjustment steps. Third, like other APC analyses, there was the inevitability of being affected by ecological fallacy because interpretations from results at population levels do not necessarily hold for individuals. Therefore, related hypotheses raised in this study still need further confirmation in the future individual-based studies.

In summary, our study showed that although the crude mortality rates for stroke of Chinese males and females generally increased from 1994 to 2013, the age-standardized stroke mortality rates of them showed overall decreasing trends. By APC analysis, we affirmed that in the same birth cohort, the risk of death from stroke rose exponentially with age for both sexes after controlling for period deviations. The estimated period and cohort RRss were found in similar monotonic downward patterns for both sexes, with more quickly decreasing for women than for men during the whole period. The patterns are likely to be related to improvements in medical care and techniques, spectacular economic growth and fast urbanization, and better early-life nutrition conditions of Chinese people. Besides, better education and better awareness of stroke-related knowledge in successive generations could also probably play a role.

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Disclosures

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