

A cross country comparison for the burden of cardiovascular disease attributable to tobacco exposure in China, Japan, USA and world

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Abstract

Background Tobacco exposure (TE) is the major contributor for CVD mortality, but few published studies on CVD mortality attributable to TE have analyzed the potential reasons underlying long-term trends in China. Our study sought to find the potential reasons and compared CVD mortality attributable to TE in China, Japan, the United States of America (USA), and the world between 1990 and 2017.

Methods The mortality data in China, Japan, the USA, and the world were obtained from Global Burden of Disease Study 2017 (GBD 2017). Joinpoint regression was used to assess the trend magnitude and directions over time for CVD mortality, while the age-period-cohort method was used to analyze the temporal trends of CVD mortality according to age, period, and cohort.

Results A significant downward trend was found in the age-standardised mortality rate (ASMR) of CVD attributable to smoking in four regions. China had the smallest decline and the Chinese ASMR became the highest in 2017. All the annual net drifts in the four regions were negative and the local drifts were below zero. The longitudinal age curves of CVD mortality attributable to smoking increased in four regions, with China having the largest increase. The period or cohort RRs indicated a decline, and China had the smallest decline. The researchers further analyzed the IHD and stroke trends, finding that the mortality and period or cohort RR of IHD in China was always at a high level.

Conclusions CVD mortality attributable to TE declined in four regions, and was highest in China. The proportion of IHD mortality attributable to TE was similar to stroke, which significantly changed the traditional cognition of CVD composition, but the control measure was not sufficient for IHD in China.

Introduction

Accompanying economic development and urbanisation, disease patterns have shifted from infectious to noncommunicable diseases. As a noncommunicable disease, cardiovascular disease (CVD) is the world's leading cause of premature morbidity and mortality. An estimated 17.8 million people died of CVD in 2017, representing the cause of 30% of total deaths from around the world [1]. In China, CVD mortality increased from 187.58 per 100,000 people in 1990 to 309.95 per 100,000 people in 2017, resulting in a very high CVD burden. The estimated number of CVD caused deaths almost doubled from 2.25 million in 1990 to 4.38 million in 2017 [2]. China has the world's highest burden of CVD and faces enormous challenges in tackling the burden of CVD [3].

Tobacco exposure (TE) mainly includes active smoking and second-hand smoke (SHS). Globally, almost 7 million people died from TE, including approximately 6 million tobacco users and an estimated 890,000 among non-smokers exposed to SHS [4]. On average, long-term smokers lost at least 10 years of life. Furthermore, over 22,000 people die from TE each day, equivalent to one person dying every 4 seconds. Smoking is widely recognised as a risk factor for premature morbidity and mortality, and it has been challenging to achieve adequate monitoring of smoking levels and trends throughout the world. Nearly two-thirds of the world's smokers live in ten countries, with China accounting for 30% of them. In 2017, active smoking became the primary leading risk factor for DALYs (disability adjusted life years) and the second risk factor for death in China [5].

TE causes CVD through atherosclerosis and thrombosis. The mechanism of smoking-induced atherosclerosis and thrombosis involves oxidative stress mediated by cigarette smoke or endogenous oxygen free radicals, which has multiple thrombosis-promoting and anti-fibrinolysis effects, leading to intravascular thrombosis and the triggering

of acute cardiovascular events [6-8]. Eventually, TE can result in plaque and blood clots, blood flow restriction, as well as heart attacks and strokes. Similar to heart disease, strokes have a high risk of death and stroke survivors may experience disastrous disabling conditions, including paralysis or the loss of vision or speech [9-11]. Several epidemiological studies have concluded that smoking is a major cause of CVD and is the cause of a quarter of deaths from CVD [12]. SHS also can cause CVD, including heart attacks and strokes. Non-smokers who breathe SHS at home or work increase their risk of developing heart disease by 25–30%, while SHS increases the risk for stroke by 20–30% [13]. The World Health Organization (WHO) considered that TE is an entirely avoidable CVD risk factor [14]. The probability of TE varies according to age and gender, while different regions have different tobacco control strategies. The disease burden attributable to TE therefore varies according to age, sex, and region [15].

Although previous studies have analyzed disease caused by tobacco exposure, there has been a lack of analysis on the impact of traditional factors (such as age, period, and generation), and previous studies have been unable to find a suitable way of reducing harm from tobacco exposure [16, 17]. In the present study, the researchers wanted to find the potential reasons underlying the long-term trends and the differences between age-groups. Furthermore, this study compares CVD mortality attributable to TE between China, Japan, the United States of America (USA), and the world in the period 1990 to 2017. The world represents the average level, the USA was among the first countries to implement tobacco control measures, while Japan is a neighbouring country to China and its population is of a similar race and harm level from smoking for the population. By comparing China with the aforementioned regions, it was hoped that methods could be found to reduce CVD mortality attributable to TE in China.

Methods

Due to technological limitations, the Methods section can only be found as a download in the supplementary files.

Results

(1) The temporal trend in the age-standardized mortality rate (ASMR) of CVD (including IHD and stroke) attributable to TE from 1990 to 2017

Smoking: For both sexes, the ASMR of CVD attributable to smoking in China, Japan, the USA, and the world significantly decreased by 0.4% (95%CI: 0.0%-0.7%), 4.0% (95%CI: 3.7%-4.3%), 4.9% (95%CI: 4.7%-5.1%), and 2.1% (95%CI: 1.8%-2.4%) per year, respectively (Figure 1). The ASMR of IHD attributable to smoking in Japan, the USA, and the world significantly decreased by 4.2% (95%CI: 3.9%-4.5%), 5.1% (95%CI: 4.9%-5.3%), and 2.2% (95%CI: 2.0%-2.4%) per year. Nonetheless in China, the ASMR of IHD attributable to smoking in China increased by 0.6% (95%CI: 0.1%-1.0%) (Figure S1). There was a significant downward trend in the ASMR of stroke attributable to smoking in China, Japan, the USA, and the world. In 1990, China was not the first-ranked country for this measure, but it was in 2017 (Figure S2). The CVD, IHD, and stroke attributable to smoking rates was similar between males and females in each region. The above detailed results are shown in Table 1.

Second-hand smoke: For both sexes, the ASMR of CVD attributable to SHS in China, Japan, the USA, and the world significantly decreased by 1.2% (95%CI: 0.7%-1.7%), 3.8% (95%CI: 3.5%-4.1%), 3.9% (95%CI: 3.6%-4.2%), and 1.8% (95%CI: 1.5%-2.0%) per year, respectively (Figure S3). The ASMR of IHD attributable to SHS in Japan, the USA, and the world significantly decreased by 3.8% (95%CI: 3.5%-4.0%), 4.1% (95%CI: 3.8%-4.4%), and 1.6% (95%CI: 1.3%-1.9%) per year, but there was no significant trend change in China (Figure S4). There were therefore significant

downward trends in the ASMR of stroke attributable to SHS in China, Japan, the USA, and the world (Figure S5). The change of CVD, IHD, and stroke attributable to SHS in males and females was similar within each region. The results described above are shown in Table S1.

(2) APC analysis of the CVD mortality rate (including IHD and stroke) attributable to TE from 1990 to 2017

Smoking: For both sexes in the same birth cohort in China, the mortality rate of CVD attributable to smoking rapidly increased from 7.38 (95%CI: 6.34, 8.58) per 100,000 in the 30-34 age-group to 360.15 (95%CI: 338.97, 382.67) per 100,000 in the 75-79 age-group in China. Similar changes are observed in Japan, the USA, and the world (Figure 2A). The mortality rate of IHD and stroke attributable to smoking also increased between the 30-34 age-group and the 75-79 age-group (Figures S6A and S7A). All the period RRs of CVD and stroke showed a decreasing trend from 1990 to 2017 in the four regions studied (Figures 2B and S7B). The period RRs of IHD in Japan, the USA, and the world also showed a downward trend from 1990 to 2017. In China, the period RRs of IHD originally showed a downward trend, but then showed an upward trend (Figure S6B). All the cohort RRs of CVD and stroke showed decreasing trends in the four regions (Figures 2C and S7C). The cohort RRs of IHD in Japan, the USA, and the world also showed a downward trend from 1990 to 2017, but in China the cohort RRs of IHD showed an upward trend, and then showed a downward trend (Figure S6C). The effects of age, period, and cohort on CVD, IHD, and stroke attributable to smoking were similar for males in females in each region.

For CVD, the overall annual net drifts in China, Japan, the USA, and the world were below zero. For IHD, the overall annual net drifts in Japan, the USA, and the world were below zero, but in China this was 0.01% (95%CI: -0.22%, 0.23%). For stroke, the overall annual net drifts in China, Japan, the USA, and the world were below zero. All the local drift values increased by age groups in China, decreased in Japan and the USA, and fluctuated in the world (Figure S8). The changes to CVD, IHD, and stroke were similar for males and females within each region. The above detailed results are shown in Table 2.

Second-hand smoke: All the results for second-hand smoke were similar to those of smokers for each disease and within each region. The results are shown in Table S2.

Discussion

Globally, a third of deaths can be attributed to CVD, while TE is the major contributor and causes approximately 3 million cardiovascular deaths per year [21]. In 2019, WHO reported estimates for the prevalence of smoking in all countries in response to the global tobacco epidemic [22]. From the report, it is found that China has the highest smoking prevalence compared to the other three regions in this study. Meanwhile, the smoking prevalence decline was smallest in China and the country has the highest level of exposure to second-hand smoke. Due to the possibility of TE, sex is an important demographic risk factor for CVD [23]. From the results in this study, it is found that the mortality rates of CVD, IHD, and stroke attributable to smoking and SHS were similar for both sexes. It is suggested that males were the primary victims from smoking, while women were the primary victims from SHS.

The results show a significant downward trend in ASMRs for CVD attributable to smoking from 1990 to 2017 in the four regions studied. Compared to the world, the ASMRs of CVD, IHD and stroke attributable to smoking had the biggest decline in the USA and Japan, while China had the smallest rate of decline from 1990 to 2017. It is found that in China, the ASMRs of CVD and IHD attributable to smoking became the highest in 2017, while the ASMR of stroke continued to be highest in China from 1990 to 2017. All the ASMRs of CVD, IHD, and stroke attributable to smoking in China were higher compared to the world, and the ASMRs of CVD, IHD, and stroke attributable to smoking in Japan and the USA were lower than those in the world. For SHS in China, the ratio of SHS to smoking in the ASMR of CVD ranged from one-quarter to one-third in the period 1990 to 2017. Compared with the other three regions, SHS exposure had caused a serious CVD burden in China. One study on SHS found that non-smoking women married to husbands that smoke had an almost 40% increased mortality risk, while the incidence of heart disease also increased [18]. A national population-based case-control study found that SHS can increase the risk of death by 10% for all forms of strokes by adjusting for related variables [19]. In 2017, the researchers also found all the ASMRs of CVD, IHD, and stroke attributable to SHS in China were higher than those in the world, while the results for Japan and USA were the reverse.

In 2017, the researchers found that China had the highest levels of ASMRs of CVD, IHD, and stroke attributable to TE. This may be due to when tobacco control measures were implemented. Tobacco control is a global health priority for non-communicable diseases. The USA and Japan started tobacco control relatively early compared to the world, while this only happened later in China [22]. The WHO Framework Convention on Tobacco Control (FCTC) was formalised global commitment by 180 countries and began to be implemented in 2005 [24]. The United States Congress passed the Federal Cigarette Labelling and Advertising Act and the Cigarette Act in 1965 and 1969, respectively. The Family Smoking Prevention and Tobacco Control Act, which passed in 2007, was stricter than FCTC [25]. In Japan, tobacco control started later than most developed countries. In 1978, a non-governmental movement for tobacco control was launched, and in 1985 the tobacco monopoly system was reformed [25]. In 2010, tax on cigarettes was raised by a large amount. China signed FCTC, which came into operation in 2006. China implemented restrictions on the packaging, advertising, and ingredients of tobacco products, for instance one cigarette with 15mg of tar would be regarded as an unqualified products and not be allowed to enter the cigarette market [26].

In APC analysis, the longitudinal age curve reflects the impact of age on the mortality rate of disease. In this study, the longitudinal age curves of the mortality rate of CVD, IHD, and stroke attributable to smoking increased by age in China, Japan, the USA, and the world, with this increasing in China more than the other regions studied. Before age 60, the mortality rates of CVD, IHD, and stroke attributable to smoking were at lower levels with slight differences in the four regions, but they became wider after the age of 60. In each age group, the mortality rates of CVD, IHD, and stroke attributable to smoking were lowest in Japan. Similar results were also found for the mortality rate of CVD, IHD, and stroke attributable to SHS. Age is an important factor for CVD, and the results in the present study could be due to two reasons: First, long-term TE results in vascular damage; second, physical resistance declines with age [27]. In China, it is suggested that the elderly should be listed as key persons in the prevention and treatment of CVD, basic public health services should be optimised for them, and the screening and management of the elderly should be performed well.

In four regions, the period RRs indicate a downwards trend in the mortality rate of CVD attributable to smoking from 1990 to 2017. Similarly, the cohort RRs also indicate a downwards trend in CVD mortality from births in 1910 to births in 1990. China is found to have experienced the smallest decline in the cohort and period RRs, while the cohort and period RRs in females declined faster than for males. The changes of the period and cohort RRs for

stroke were similar to CVD, while IHD was found to be little different from CVD. While the period and cohort RRs indicate a down trend in the USA, Japan, and the world, these fluctuated in China. In the four regions, all the net drifts were significant and below zero, with the exception of the net drift of IHD in China. All the SHS results are similar to those for smokers, while the results for males and females are also similar. Compared with the USA, there were significant differences in the morality pattern of CVD in China, since the proportion of stroke was higher, the proportion of IHD was lower, and the morality pattern of CVD in China was similar to Japan [28]. Similar patterns are also identifiable in Tables S3 and S4. Due to improvements to medical conditions in China, increased public health funding, and the early diagnosis and treatment of noncommunicable diseases such as CVD and cancer, the occurrence and death of CVD has been effectively controlled. In particular, there have been significant improvements in stroke mortality, which could be due to more attention paid to strokes due to its prevalence. But the results reflect that the downwards trend in the mortality rate of IHD is not obvious. Through comparison, it is found that the mortality rate of IHD decreased in the USA, where IHD is the main component of CVD. Meanwhile, the mortality rate of IHD also decreased in Japan with a similar CVD composition to that of China in which IHD was not the main component of CVD. Based on China's actual situation, China should learn from these two countries to explore appropriate measures for CVD and tobacco control.

A number of limitations are identified in the present study. First, GBD 2017 underwent many modifications and adjustments to its data sources, collation, and evaluation methods to fulfil missing data and improve its data quality and comparability, but it is still difficult to avoid bias. Therefore, the integrity and accuracy of the data in the present study was affected. Yet using the GBD database to show the long-term trends minimises the adverse effects, meaning that the bias from the GBD database will not have an intolerable impact to the present study and barely affects the changes to the long-term trends [29-31]. Second, the APC model only regards population as the unit of observation and analysis, which could lead to ecological fallacy. Therefore, the results of this study must be further confirmed by future research. Third, the researchers only estimated the effects of age, period, and cohort on the CVD mortality data attributable to tobacco exposure, while no further analysis was conducted on other risk factors.

Conclusions

In China, with its economic development and social progress, people have a certain level of understanding of the dangers of TE, resulting in a lower smoking prevalence and exposure to SHS in public areas, thereby leading to a decline in the mortality rate of CVD attributable to TE. In our study, we analyzed the long-term trends of CVD mortality attributable to TE under the effects of age, period, and cohort, and compared CVD burden in China, Japan, USA and the world. It is found that in four regions, CVD mortality attributable to TE had the smallest rate of decline in China from 1990 to 2017, and China had the highest levels of ASMRs of CVD, IHD, and stroke attributable to TE in 2017. It is also found that the mortality rate of CVD in older people was higher in China, probably because tobacco control happened relatively late in China. In addition, due to the changes of the traditional cognition of CVD composition in China, the proportion of IHD mortality attributable to TE was similar to stroke, but the control measures were not sufficient for IHD. Therefore, China should strengthen tobacco control measures for the key population (e.g., older people) and disease (e.g., IHD) to reduce CVD burden in the next few years.

Declarations

Ethics approval and consent to participate

GBD 2017 was publicly available for free use, the protocol was approved by the Medical Research Ethics Committee of the First Hospital of China Medical University.

Consent to publish

Not applicable

Availability of data and materials

All our research data are obtained from GBD 2017, the website was <http://ghdx.healthdata.org/gbd-results-tool>.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

XM Wand B Z designed the whole research, B Z, S X, and YL conducted the data collection, B Z and XM W analyzed the data. B Z, YF B and XM W wrote the manuscript. JP S, B Z, SX, YL, YF B and XM W discussed the relevant results. All authors read and approved the final manuscript.

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Not applicable.

Abbreviations

Cardiovascular Disease: CVD

Secondhand smoke: SHS

World Health Organization: WHO

Ischemic heart disease: IHD

Average annual percentage change: AAPC

The age–period–cohort: APC

Age-standardized mortality rate: ASMR

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Tables

Table 1 The temporal trend of the mortality rate of CVD, IHD, and stroke attributable to smoking in China, Japan, the USA, and the world from 1990 to 2017.

		China		Japan		USA		World	
		AAPC (%)	95%CI (%)						
CVD	both sexes	-0.4*	(-0.7,0.0)	-4.0*	(-4.3,-3.7)	-4.9*	(-5.1,-4.7)	-2.1*	(-2.4,-1.8)
	male	-0.3	(-0.6,0.0)	-3.9*	(-4.4,-3.5)	-4.9*	(-5.1,-4.7)	-1.8*	(-2.2,-1.5)
	female	-1.1*	(-1.4,-0.7)	-5.1*	(-5.4,-4.8)	-5.0*	(-5.2,-4.8)	-3.5*	(-3.6,-3.4)
IHD	both sexes	0.6*	(0.1,1.0)	-4.2*	(-4.5,-3.9)	-5.1*	(-5.3,-4.9)	-2.2*	(-2.4,-2.0)
	male	0.7*	(0.3,1.0)	-4.1*	(-4.5,-3.7)	-5.1*	(-5.3,-4.9)	-1.9*	(-2.2,-1.7)
	female	0.2	(-0.4,0.8)	-5.4*	(-5.8,-5.1)	-5.2*	(-5.4,-5.0)	-3.6*	(-3.7,-3.4)
stroke	both sexes	-1.2*	(-1.4,0.9)	-4.5*	(-4.7,-4.2)	-4.3*	(-4.6,-4.1)	-2.0*	(-2.2,-1.8)
	male	-1.0*	(-1.2,-0.8)	-4.5*	(-4.9,-4.1)	-4.1*	(-4.3,-3.9)	-1.7*	(-1.9,-1.5)
	female	-2.3*	(-2.9,-1.8)	-5.4*	(-5.8,-5.0)	-4.7*	(-4.9,-4.4)	-3.5*	(-3.6,-3.3)

*: statistically significant (p<0.05); AAPC: average annual percent change.

Table 2 The net drift value of the mortality rate of CVD, IHD and stroke attributable to smoking

		China		Japan		United States		Global	
		Net Drift (%/year)	95%CI						
CVD	both sexes	-1.049	(-0.837,-1.26)	-2.983	(-2.855,-3.11)	-4.341	(-4.25,-4.433)	-2.126	(-2.085,-2.167)
	male	-0.847	(-0.624,-1.071)	-2.895	(-2.8,-2.989)	-4.359	(-4.256,-4.462)	-1.845	(-1.803,-1.888)
	female	-2.507	(-1.817,-3.192)	-3.774	(-3.458,-4.089)	-4.379	(-4.259,-4.499)	-3.593	(-3.488,-3.698)
IHD	both sexes	0.005	(0.234,-0.224)	-2.982	(-2.835,-3.128)	-4.472	(-4.369,-4.576)	-2.100	(-2.058,-2.143)
	male	0.198	(0.434,-0.037)	-2.890	(-2.771,-3.008)	-4.564	(-4.451,-4.676)	-1.838	(-1.798,-1.878)
	female	-1.323	(-0.709,-1.932)	-3.799	(-3.447,-4.149)	-4.319	(-4.173,-4.465)	-3.420	(-3.315,-3.526)
stroke	both sexes	-1.904	(-1.688,-2.12)	-3.665	(-3.521,-3.809)	-4.100	(-3.996,-4.203)	-2.236	(-2.165,-2.307)
	male	-1.684	(-1.45,-1.917)	-3.594	(-3.445,-3.744)	-3.631	(-3.492,-3.771)	-1.901	(-1.823,-1.979)
	female	-3.618	(-2.834,-4.395)	-4.327	(-4.007,-4.646)	-4.688	(-4.533,-4.842)	-4.024	(-3.88,-4.167)

Figures

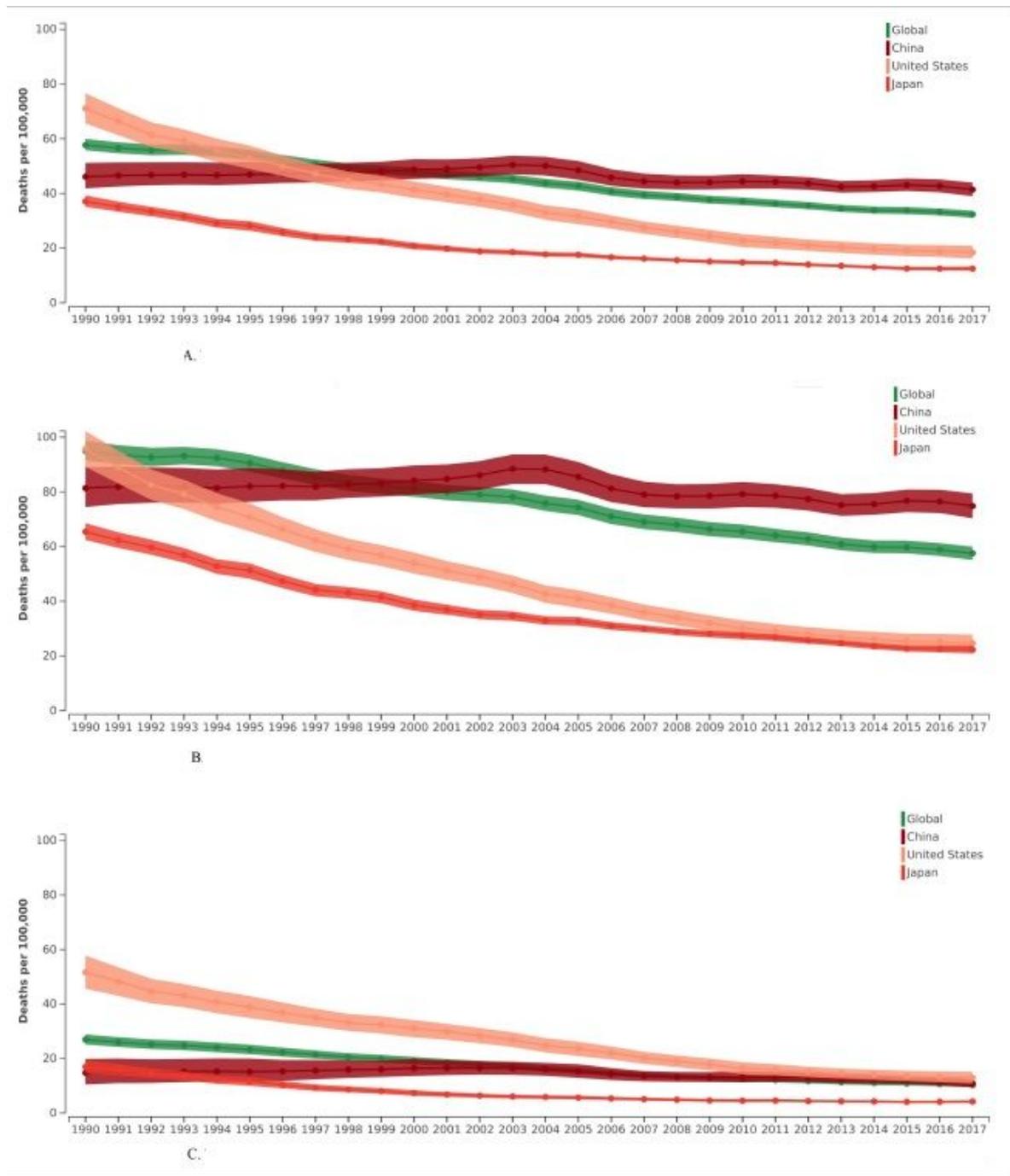


Figure 1

The ASMR of CVD attributable to smoking in China, Japan, the USA, and the world from 1990 to 2017.

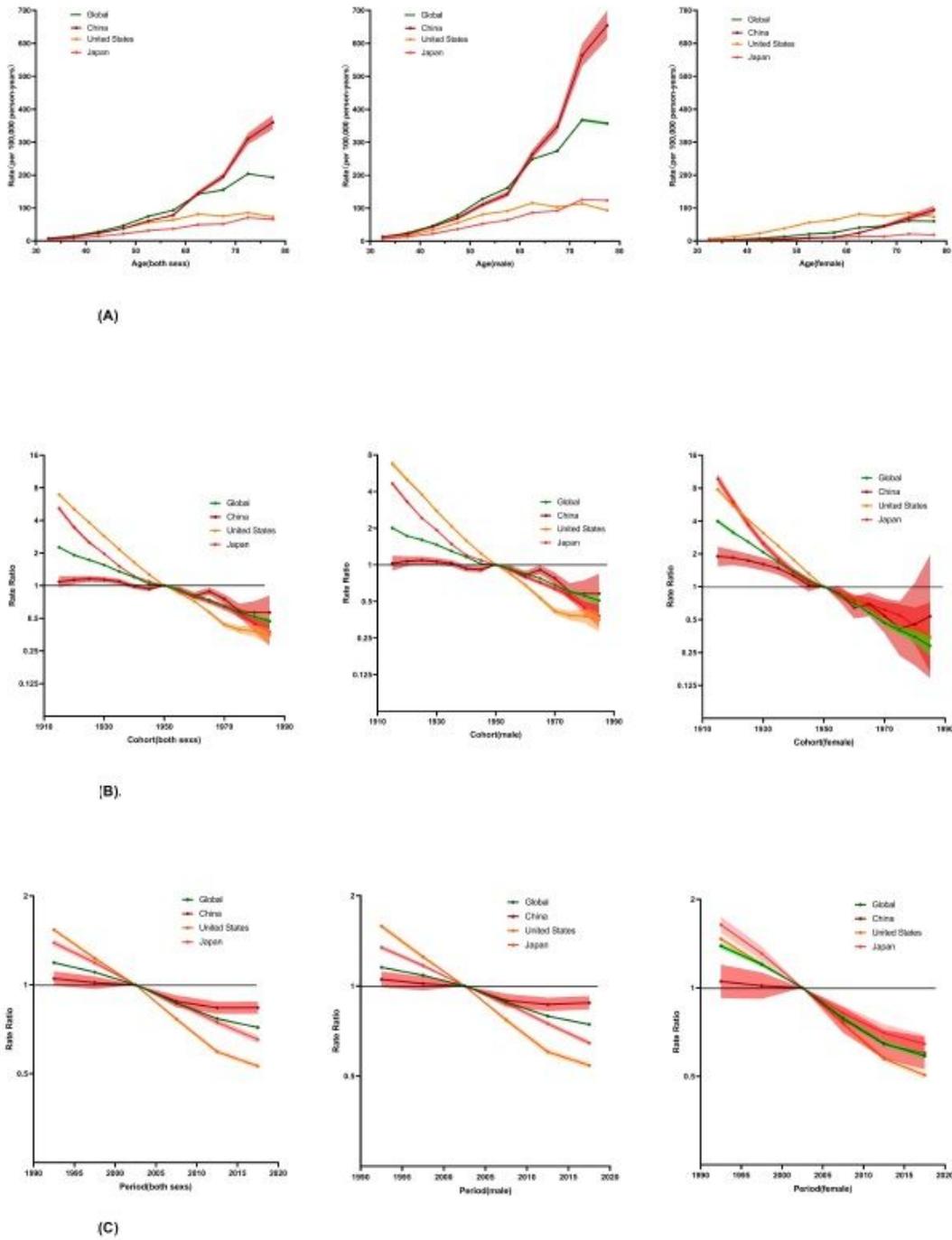


Figure 2

The APC results of CVD attributable to smoking in China, Japan, the USA, and the world from 1990 to 2017.

Supplementary Files

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- [Supplementarytables.docx](#)
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- [StatisticalAnalysis.pdf](#)

- [Methods.docx](#)