Postprint: Burden of Ischemic Heart Disease Attributable to Second-Hand Smoke in China, 1990-2021

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Abstract

Background: Ischemic heart disease (IHD) is the second leading cause of death in China, and secondhand smoke exposure constitutes an important risk factor for IHD. Objective: To analyze the disease burden of IHD attributable to secondhand smoke and its temporal trends in China and across five Socio-demographic Index (SDI) regions from 1990 to 2021, providing scientific evidence for reducing IHD morbidity and mortality risks associated with secondhand smoke. Methods: Data were obtained from the Global Burden of Disease Study 2021 (GBD 2021). The impact of secondhand smoke on IHD disease burden was evaluated using population attributable fractions. Joinpoint regression analysis was employed to determine the average annual percent change (AAPC) in mortality and disability-adjusted life years (DALYs) among individuals aged 25–94 years. An age-period-cohort model was applied to examine age, period, and cohort effects on mortality and DALYs rates. Results: Ranking as the sixth leading risk factor for IHD in the Chinese population, secondhand smoke exhibited population attributable fractions for mortality and DALYs that remained relatively elevated compared to the five SDI regions, decreasing by 0.66% and 0.67%, respectively, during 1990–2021. The age-standardized mortality rate (1990: 12.27/100,000; 2021: 11.62/100,000) and age-standardized DALYs rate (1990: 284.58/100,000; 2021: 239.26/100,000) for IHD attributable to secondhand smoke in China demonstrated a modest overall decline, with AAPCs of -0.20% (95% CI: -0.65% to 0.24%) and -0.58% (95% CI: -0.98% to -0.19%), respectively. In the total population, the age-effect risk of IHD mortality and DALYs attributable to secondhand smoke increased with age, accelerating substantially after age 75; the period effect displayed a declining trend, whereas the cohort effect showed an initial rise followed by a decline. Notably, both period and cohort effects exhibited upward trends in males. Conclusion: China faces a substantial disease burden of IHD attributable to secondhand smoke, with

the overall declining trend primarily driven by reduced burden rates among females. Enhanced focus on secondhand smoke risk control in males and disease management in elderly populations is warranted.

Full Text

Analysis of Ischemic Heart Disease Burden Attributable to Second-hand Smoke in China from 1990 to 2021

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Abstract

Background: Ischemic heart disease (IHD) is the second leading cause of death in China, and second-hand smoke exposure represents a significant risk factor for IHD mortality. **Objective:** To analyze the disease burden and temporal trends of IHD attributable to second-hand smoke in China and across five Socio-demographic Index (SDI) regions from 1990 to 2021, providing scientific evidence for reducing IHD mortality risk associated with second-hand smoke exposure. **Methods:** Data were obtained from the Global Burden of Disease Study 2021 (GBD 2021). Population attributable fraction (PAF) was used to assess the impact of second-hand smoke on IHD burden. Joinpoint regression was employed to calculate the average annual percentage change (AAPC) in mortality and disability-adjusted life years (DALYs) among populations aged 25–94 years. An age–period–cohort (APC) model was applied to analyze age, period, and cohort effects on mortality and DALYs rates. **Results:** Second-hand smoke ranked as the sixth leading risk factor for IHD in China, with PAF values for mortality and DALYs higher than those in the five SDI regions, decreasing by 0.66% and 0.67% respectively from 1990 to 2021. The age-standardized mortality rate (1990: 12.27/100,000; 2021: 11.62/100,000) and age-standardized DALYs rate (1990: 284.58/100,000; 2021: 239.26/100,000) attributable to second-hand smoke showed slight downward trends, with AAPC values of -0.20% (95%CI: -0.65% to 0.24%) and -0.58% (95%CI: -0.98% to -0.19%), respectively. In the overall population, age-effect risk for IHD mortality and DALYs attributable to second-hand smoke increased with age, accelerating significantly after age 75; period effects showed a declining trend, while cohort effects exhibited an initial rise followed by a decline. However, both period and cohort effects showed upward trends among males. **Conclusion:** China faces a substantial disease burden of IHD attributable to second-hand smoke, with the overall declining trend primarily driven by reduced burden among females. Greater attention should be directed toward second-hand smoke control among males and disease

management in elderly populations.

Keywords: Second-hand smoke; Ischemic heart disease; Disease burden; Age-period-cohort model; Socio-demographic index

Introduction

Ischemic heart disease (IHD) constitutes a major cause of mortality and morbidity worldwide. IHD arises when oxygen supply fails to meet cardiac demand, manifesting primarily as myocardial infarction, angina, and ischemic cardiomyopathy. As of 2017, IHD ranked as the second leading cause of death in China, with its proportion of total mortality continuing to rise. Second-hand smoke exposure adversely affects cardiovascular health and represents a primary risk factor for premature mortality and disability from chronic diseases in China. The pathophysiological mechanisms include nicotine-mediated stimulation of the sympathetic nervous system and vascular oxidative stress. A causal relationship exists between second-hand smoke exposure and IHD, increasing IHD risk by 25–30%, with population attributable fractions identifying second-hand smoke among the top ten risk factors for IHD mortality and DALYs.

Disease incidence and mortality patterns exhibit regional heterogeneity. As regional economic levels decline, lower-education populations face higher cardiovascular disease risk compared to their higher-education counterparts. Compared with the United States, second-hand smoke exposure more substantially strengthens the association between IHD risk and all-cause mortality in China. The Socio-demographic Index (SDI) integrates regional economic and educational indicators. While numerous studies have examined disease burden from tobacco exposure, few have investigated IHD burden attributable to second-hand smoke in relation to SDI disparities. This study utilizes the Global Burden of Disease Study 2021 (GBD 2021), which updated SDI values for global regions since 1970 and classifies regions into five SDI categories (high, high-middle, middle, low-middle, and low) based on these values.

Methods

Data Sources

This study extracted data from the GBD 2021 Global Health Data Exchange database (https://vizhub.healthdata.org/gbd-results/), analyzing IHD mortality and disability-adjusted life years (DALYs) attributable to second-hand smoke among populations aged 25–94 years in China and the five SDI regions from 1990 to 2021. Socio-demographic development has been a key driver of health improvements over the past 50 years.

Definitions

Second-hand Smoke Also termed "passive smoking" or "involuntary smoking," second-hand smoke comprises sidestream smoke emitted from burning tobacco products between puffs and mainstream smoke exhaled by smokers. The GBD 2021 methods appendix (https://www.healthdata.org/gbd/methods-appendices-2021) defines second-hand smoke exposure as current exposure in home or workplace settings. Household structure serves as a proxy for residential second-hand smoke exposure, assuming all individuals living with daily smokers encounter tobacco smoke. GBD uses surveys to estimate the population proportion exposed to second-hand smoke in workplaces. Second-hand smoke exposure considers only non-smokers; all individuals who are not daily smokers, former smokers, or occasional smokers are classified as non-smokers.

Ischemic Heart Disease According to the International Classification of Diseases (ICD) coding system, IHD in GBD 2021 encompasses codes I20–I25.9 (ICD-10) and 410–414.9 (ICD-9), including myocardial infarction, angina, and ischemic cardiomyopathy.

Observation Indicators

Key indicators include incidence, mortality, DALYs, years of life lost (YLLs), and years lived with disability (YLDs). Mortality rate is calculated as total deaths in a population divided by the average population size in the same year, multiplied by a constant K. YLDs equal the number of incident cases multiplied by disability weight and average duration of disability. YLLs equal standard life expectancy minus age at death. DALYs represent the total healthy life years lost from disease onset to death, summing YLLs and YLDs.

Statistical Methods

Population Attributable Fraction (PAF) quantifies the proportional reduction in population disease incidence or mortality that would occur if a risk factor were eliminated, holding significant public health importance. This study analyzed all GBD Level 3 risk factors for IHD mortality and DALYs in China in 2021 and examined PAF values for second-hand smoke as a risk factor for IHD mortality and DALYs in China and the five SDI regions from 1990 to 2021.

Joinpoint regression analysis (Joinpoint software version 5.0.2) calculated the average annual percentage change (AAPC) in age-standardized mortality rates (ASMR) and age-standardized DALYs rates (ASDR) for IHD attributable to second-hand smoke among populations aged 25–94 years in China and the five SDI regions. Age-standardized rates were calculated using the WHO standard population: $ASR = \Sigma[ri \times (nis / \Sigma inis)]$, where ri represents the mortality/DALYs rate in age group i and nis represents the WHO standard population weight for age group i.

The Age–Period–Cohort (APC) model estimates disease burden risk across specific ages, time periods, and birth cohorts—representing age effects, period effects, and cohort effects. Age effects reflect changes in disease burden risk with age; period effects represent temporal changes in risk; cohort effects capture cumulative changes in risk arising from lifestyle or exposure differences across birth cohorts. Due to collinearity among age, period, and cohort parameters, we utilized the web-based APC analysis tool from the National Cancer Institute (https://analysistools.cancer.gov/apc/), which employs interpretable estimable functions and Wald tests to compute age, period, and cohort effects. Age was categorized into 14 five-year groups (25–29 years through 90–94 years), and time into seven period groups (1990–1994 through 2015–2019, with 2020–2021 combined due to data limitations).

Results

Population Attributable Fraction of Second-hand Smoke for IHD in China

Among all GBD Level 3 risk factors for IHD burden in 2021, second-hand smoke ranked seventh for mortality and sixth for DALYs in China, with PAF values of 7.45% and 8.09%, respectively . Figure 1 [Figure 1: see original paper] illustrates temporal trends in second-hand smoke PAF for IHD mortality and DALYs in China and the five SDI regions from 1990 to 2021. China' s PAF values showed modest declines of 0.66% and 0.67% for mortality and DALYs, respectively. Compared with the five SDI regions, China' s PAF remained at relatively high levels throughout the 32-year period, reflecting China's transition from low-middle SDI (1990–2008) to middle SDI (2008–2019) to upper-middle SDI (2020–2021).

Temporal Trends in IHD Burden Attributable to Second-hand Smoke (1990–2021)

ASMR and ASDR attributable to second-hand smoke in China exhibited an initial rise followed by a decline, with overall AAPC values of -0.20% (95%CI: -0.65% to 0.24%) and -0.58% (95%CI: -0.98% to -0.19%), respectively . Female ASMR and ASDR exceeded male rates before 2015, but this gap narrowed over time, with female rates falling below male rates after 2014. Male ASMR and ASDR demonstrated upward trends (Figure 2 [Figure 2: see original paper]A, 2B). All five SDI regions showed declining ASMR and ASDR, with high and upper-middle SDI regions experiencing larger reductions than low and low-middle SDI regions. Globally, China' s ASMR was comparable to low-middle SDI regions before 1999, then exceeded all SDI regions until 2012. China' s ASDR remained below low-middle SDI regions before 2009, subsequently showing a rise-decline pattern but maintaining levels slightly above comparable SDI regions (Figure 2 [Figure 2: see original paper]C, 2D).

APC Model Analysis of IHD Burden Attributable to Second-hand Smoke in China (1990-2021)

The net drift for IHD mortality attributable to second-hand smoke was -0.54% (95%CI: -0.64% to -0.44%), indicating a modest declining trend. Net drift values were -1.51% (95%CI: -1.64% to -1.38%) for females and +0.54% (95%CI: 0.42% to 0.66%) for males. Local drift values increased with age, exceeding zero after age 75, indicating rising mortality in older age groups. Nearly all age groups from 25–94 years showed positive local drift values for males, signifying increasing mortality across these ages (Figure 3 [Figure 3: see original paper]A). Mortality risk increased with age, accelerating substantially after age 75, with a greater increase among males (Figure 3 [Figure 3: see original paper]B). Cohort effects showed an initial rise followed by decline, with female mortality risk peaking in the 1925 birth cohort before decreasing markedly, while male cohort effects continued rising (Figure 3 [Figure 3: see original paper]C). Period effects showed fluctuating trends overall, with consistent declines for females and an initial rise followed by gradual decline after 2014 for males (Figure 3 [Figure 3: see original paper]D).

DALYs rates showed similar patterns: net drift was -0.52% (95%CI: -0.60% to -0.44%) overall, -1.45% (95%CI: -1.55% to -1.35%) for females, and +0.53% (95%CI: 0.43% to 0.66%) for males. Local drift for DALYs rates increased with age, exceeding zero after age 75, with males showing upward trends across all age groups (Figure 4 [Figure 4: see original paper]A). DALYs rates increased with age, rising rapidly after age 75, particularly among males (Figure 4 [Figure 4: see original paper]B). Cohort effects for DALYs rates rose then fell, peaking around the 1925 birth cohort for females while showing upward trends for males (Figure 4 [Figure 4: see original paper]C). After adjusting for age and cohort effects, DALYs rates remained stable before 2012 then declined, with females showing continuous decline and males showing an initial rise followed by gradual decline (Figure 4 [Figure 4: see original paper]D).

Comparison of IHD Burden Trends Between China and Five SDI Regions

Across all age groups in China and the five SDI regions, low, low-middle, and middle SDI regions showed annual declines in mortality and DALYs rates from 25–94 years, with similar magnitude reductions. China exhibited comparable declines to these regions before age 65–69, after which reductions diminished with advancing age, turning to increases after age 75–79 (local drift > 0). Upper-middle and high SDI regions showed substantial declines across all 14 age groups, particularly in high SDI regions where the largest reductions occurred in the 75–79 age group (Figure 5 [Figure 5: see original paper]A, Figure 6 [Figure 6: see original paper]A). Age effects showed upward trends in all regions, with China' s rates closely matching middle SDI regions before age 75–79, after which they rose sharply (Figure 5 [Figure 5: see original paper]B, Figure 6 [Figure 6: see original paper]B). Cohort effects declined across all five SDI regions, with high

SDI regions showing the largest reductions in earliest cohorts. China' s cohort effects peaked in the 1935 birth cohort, then declined similarly to low, low-middle, and middle SDI regions (Figure 5 [Figure 5: see original paper]C, Figure 6 [Figure 6: see original paper]C). Period effects decreased across all regions, with high SDI regions showing the largest reductions, followed by upper-middle SDI regions. China' s period effects, after initial fluctuations, trended similarly to low, low-middle, and middle SDI regions (Figure 5 [Figure 5: see original paper]D, Figure 6 [Figure 6: see original paper]D).

Discussion

Tobacco exposure constitutes a critical secondary risk factor for lung cancer, IHD, and other diseases, comprising smoking, second-hand smoke, and smokeless tobacco use. Among over 8 million annual deaths from tobacco exposure, more than 1 million result from second-hand smoke exposure. In China, second-hand smoke ranks among the top ten risk factors for IHD mortality and DALYs, with PAF values consistently high globally. The overall ASMR and ASDR remain at elevated international levels, indicating suboptimal control of second-hand smoke risk factors. High and upper-middle SDI regions demonstrated significant PAF reductions over the past three decades, with corresponding declines in attributable mortality, DALYs, and age/period/cohort effects, offering valuable lessons for health policy.

While 80% of global tobacco consumption occurs in developing countries where the tobacco industry represents an important economic sector, comprehensive smoking bans may be unrealistic. Nevertheless, tailored tobacco control measures can yield substantial effects, with public smoking restrictions and heightened public awareness immediately reducing second-hand smoke transmission and harm.

Age-standardized rate analyses from 1990–2021 revealed that female ASMR and ASDR exceeded male rates before 2015, but females showed greater reductions in cohort and period effects, resulting in lower rates than males after 2015. In contrast, male cohort effects rose while period effect declines were modest, with mortality and DALYs rates increasing across age groups 25–94 years. Potential explanations include: males being primary victims of active smoking while females suffer more from second-hand smoke; reduced second-hand smoke exposure in households and public spaces as public awareness increased; and divergent tobacco use patterns between sexes, with female smoking rates declining nearly tenfold from the 1930s to post-1960s while male rates remained high, creating differential workplace exposure patterns that manifest as distinct disease burden profiles. This aligns with female cohort effects peaking around the 1925 birth cohort before substantial decline.

China' s ASMR and ASDR trends across SDI regions showed that all regions experienced reductions of varying magnitude, with larger declines corresponding to higher SDI. Based on GBD 2021 SDI reference values, China' s SDI increased

from 0.45 in 1990 to 0.71 in 2021, transitioning from low-middle (1990–2008) to middle (2008–2019) to upper-middle (2020–2021) SDI categories. China' s ASMR was similar to low-middle and middle SDI regions during 1990–2000, then fluctuated upward during 2000–2011, surpassing these regions and approaching low-middle SDI levels. After 2011, China' s elevated ASMR and ASDR intersected with declining upper-middle SDI trends before decreasing, with ASMR remaining above all five SDI regions and ASDR falling below low-middle SDI levels.

Notably, global mortality and DALYs rates do not decrease linearly with SDI but follow a U-shaped pattern, with low and high SDI regions showing lower burden rates while middle and upper-middle SDI regions exhibit higher rates. As low-SDI countries develop socioeconomically, their disease burden patterns shift toward chronic non-communicable diseases (including cardiovascular disease), forcing them to confront dual threats from both infectious and chronic diseases simultaneously. Residents in lower-development areas face chronic exposure to environmental and occupational hazards far exceeding those in high-development regions, with limited access to healthcare services, missing opportunities for early diagnosis and treatment. Lower education levels universally reduce life opportunities, meaning individuals may be unable to afford necessary healthcare, particularly in areas lacking universal health coverage, creating cumulative disadvantages from detection through treatment and control. Consequently, low-development areas do not exhibit the same effective control over age, period, and cohort effects seen in high-development regions.

APC model analyses revealed that high SDI regions showed greater reductions in older age groups than younger groups, with longitudinal age curves demonstrating lower mortality and DALYs rates in older age groups—significantly different from other regions. This likely reflects earlier implementation of tobacco control measures in high SDI regions, with research confirming that smoke-free policies positively reduce cohort effects. Sustained, effective implementation has also produced continuously declining period effects. In a large meta-analysis, public and workplace smoking restrictions effectively reduced acute myocardial infarction hospitalizations by approximately 20% (effect size 0.83, 95% CI=0.80–0.87). A subsequent Cochrane review reached similar conclusions, emphasizing that legislative smoking bans improve health outcomes by reducing second-hand smoke exposure, with the clearest evidence being reduced acute coronary syndrome admissions. A comprehensive 2024 review of literature published through July 2022 quantified exposure-response associations, accounting for various uncertainty sources and using burden-of-proof risk function methods to assess evidence strength, finding that second-hand smoke exposure increases IHD risk by at least 8%. These findings reinforce the harmful health effects of second-hand smoke and the need to prioritize public health policies and educational initiatives reducing both active and passive smoking, offering references for China' s tobacco control efforts. Smoke-free policies targeting younger populations effectively reduce tobacco prevalence, and limiting second-hand smoke transmission reduces youth tobacco exposure. High SDI regions' more effective and

comprehensive IHD treatment and prevention measures, particularly for vulnerable groups (low-education, low-income, elderly populations), can guide policy implementation in China and other regions.

This study has limitations. The APC model requires five-year interval formatting, but GBD studies group ages 95+ into a single category, limiting comprehensive coverage of the oldest-old population. The APC model analyzes second-hand smoke effects on disease burden at the macro level without considering individual physiological and behavioral factors. Therefore, conclusions require further validation in future individual-level studies.

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Note: Figure translations are in progress. See original paper for figures.