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Do deaths from competing risks influence COPD patterns in China and high socio-demographic index countries?: a cross-sectional analysis of summary statistics from the Global Burden of Disease Study 2017

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ABSTRACT

Objective To explore possible reasons for the difference in chronic obstructive pulmonary disease (COPD) incidence/mortality rates between China and high socio-demographic index (SDI) countries.

Design A cross-sectional analysis of summary statistics from the Global Burden of Disease Study 2017.

Participants Data were publicly available and de-identified, and individuals were not involved.

Measurement and methods We extracted the age-standardised and age-specific incidence/mortality rates, and risk factors attributed to COPD in China and high SDI countries from the Global Burden of Disease Study 2017. We first described differences in COPD patterns (ie, incidence and mortality rates) in China and high SDI countries briefly, and then explored possible reasons for driving such differences by comparing rankings for six well-established COPD risk factors and estimating change points in age-specific incidence and mortality rates for COPD and several commonly encountered competing risks using segmented regression models.

Results Differences in age-standardised incidence and mortality rates for COPD between China and high SDI countries converged during 1990–2017 but still differed, particularly for mortality rates. Smoking was the leading attributable risk factor followed by ambient air pollution, with higher rankings for occupational risks in China than in high SDI countries. The change point was ~80 years for age-specific COPD mortality rate in both China and high SDI countries. However, the change point for COPD incidence was 5-year later in China (~65 years) than in high SDI countries (~60 years). The change points for mortality rates due to competing risks (eg, ischaemic heart disease) also varied between settings.

Conclusion Differences in risk factors largely shaped the differences in COPD patterns between China and high SDI countries. Varying patterns of mortality due to competing risks might also contribute to the discrepancy in COPD mortality rates, by affecting the survival of the underlying population.

Strengths and limitations of this study

► This study systematically investigates possible reasons for driving differences in chronic obstructive pulmonary disease (COPD) patterns between China and high socio-demographic index (SDI) countries.

► This study compares rankings of attributable risk factors to COPD and estimated change points of the age-specific incidence/mortality rates for COPD and competing risks between China and high SDI countries.

► This study suggests that beyond established risk factors, varying patterns of mortality due to competing risks might also contribute to the difference in COPD patterns between China and high SDI countries; however, such an explanation might be speculated and open to alternative interpretations.

► This study fails to evaluate the effects of implementation and compliance of treatments for COPD and competing risks that contribute to differences in COPD patterns between China and high SDI countries due to no data on treatment.

► This study cannot assess the effects of prevention against modifiable risk factors, such as tobacco control, which also affect the mortality rate of COPD between China and high SDI countries.

INTRODUCTION

China has experienced rapid development over the past decades with increasing concern about smoking and air pollution. Improved healthcare and health policies (eg, Healthy China 2030, which aims to achieve health equality by 2030 and tobacco control) have contributed to better prevention and treatment or management of chronic obstructive pulmonary disease (COPD).[1–5] However, the societal burden of COPD remains high, with 0.97 million people dying from COPD in China in 2017,[6] which corresponds to a rate

threefold higher than in high socio-demographic index (SDI) countries, despite comparable age-standardised incidence.[6–8] Steady declines in COPD in China have been ongoing for decades, especially in the mortality rate in past decades. However, considerable differences in COPD incidence and mortality rates between China and high SDI countries remained. This raises a question as to what may underlie such a discrepancy. The higher prevalence of tobacco smoke exposure (from active smoking to secondhand smoke) and population ageing in high SDI countries, as well as more serious air pollution and more common use of biomass fuels in China, are considered the main drivers.[9–14] Furthermore, suboptimal implementations of the recommended COPD treatment/management,[15 16] uneven economic development and healthcare disparities across China[17–19] may explain some of the discrepancies, especially in resource-limited areas.

Undoubtedly, declines in smoking, especially in high SDI countries, and improvements in medical care, especially in China, explain most of the difference in COPD patterns between high SDI countries and China. However, the population attributable risk of smoking for COPD mortality rate was 12.1% for men and 5.6% for women in China,[20] with the corresponding values for developed countries ranging from 9.7% to 97.9%.[21] This shows that different prevalence of smoking across settings are insufficient to explain the difference in COPD incidence rates between China and high SDI countries. Moreover, COPD remains incurable, and currently available therapies have limited impact on disease progression and mortality,[21] especially among patients with comorbidities (eg, ischaemic heart disease (IHD)[22 23]). These findings suggest that the discrepancy in COPD mortality rates is likely partly attributable to other factors apart from these well-established risk factors and the treatment or management.

Few studies have systematically investigated the possible reasons for driving the difference in COPD patterns indicated by incidence and mortality rates between China and high SDI countries.[11 16] To fill this gap, we first described the difference in COPD patterns between China and high SDI countries by showing trends in age-standardised incidence and mortality rates during 1990–2017, and then explored the possible reasons for such a discrepancy by (1) comparing rankings of six well-established attributable risk factors for COPD, and (2) estimating change points (ie, abrupt change) of age-specific incidence and mortality rates for COPD and several commonly encountered competing risks based on summary statistics from the Global Burden of Disease (GBD) Study 2017.

METHODS
Data sources and socio-demographic index
We extracted the age-standardised and age-specific incidence/mortality rates, and risk factors attributed to COPD from the GBD Study 2017 (accessed on July 2020

from https://gbd2017.healthdata.org/gbd-search/).[24–26] The GBD protocol and data are publicly accessible (http://www.healthdata.org/). SDI classifies countries by level of development.[24–27] In 2017, China was categorised as a high-middle SDI country with SDI being 0.71, while that for high SDI countries ranged from 0.81 to 0.93 on a global scale.[28]

COPD and competing risks
In the GBD Study, COPD was defined as the Global Initiative for Chronic Obstructive Pulmonary Disease classification, that is, a measure of forced expiratory volume in one second:forced vital capacity <0.7 in spirometry after bronchodilation.[29 30] Estimations for COPD, including case definitions, epidemiological measures/metrics and risk factors stratified by year, region, age, and sex, were directly retrieved from the Global Health Data Exchange (http://ghdx.healthdata.org/gbd-2017). Competing risks were defined as events whose occurrence precludes the diagnosis of or death from COPD.[31] For example, deaths from the other leading causes, such as low respiratory infections (LRIs) and asthma during adolescence[15 32] and IHD, stroke as well as tracheal, bronchus and lung cancer (TBLC) during mid-to-late adulthood,[15 22 23 33–38] might preclude COPD occurring at older ages. Furthermore, comorbidities of COPD (eg, IHD, stroke and TBLC) may also preclude death from COPD. Here, we considered five commonly encountered competing risks throughout life, that is, LRIs, asthma, IHD, stroke and TBLC, which may overlap with COPD co-morbidities.

Risk factors for COPD
We obtained estimates of COPD attributable to risk factors from the GBD Study 2017.[25] Of these, six well-established risk factors (ie, smoking, secondhand smoke, household air population from solid fuels, ambient particulate matter, ozone and occupational risks)[32] were included in the analysis. Their definitions have been described elsewhere.[24 25]

Statistical analysis
For China and high SDI countries, we first describe the differences in COPD incidence and mortality rates by illustrating trends in age-standardised incidence/mortality rates (per 100 000 population) in 3 time periods, that is, 1990–2007, 2007–2017 and 1990–2017, as per 10-year interval used in the GBD Study. Second, we explored the possible reasons driving such a discrepancy between China and high SDI countries by (1) comparing rankings for attributable risk factors for COPD and competing risks for mortality rates in 2017 and (2) estimating and comparing change points for age-specific incidence and mortality rates for COPD and its competing risks via segmented regression models.[39 40] Specifically, we used a negative-binominal segmented regression model to address overdispersion.[40–42] We considered one change point for age-specific incidence/mortality rates to ensure a sufficient number of data points given a rule of thumb

of 12 data points before and 12 data points after the change point.[43] Additionally, the conventional Davies test was used to infer a change point, in which a p value of <0.05 indicates the presence of at least one change point.[42] Furthermore, we conducted sensitivity analysis by repeating the segmented regression analysis using summary statistics for 2015 and 2016 from the GBD Study 2017.

We performed all analyses using GBD results tools (http://ghdx.healthdata.org/gbd-results-tool) and R V.3.6.3 software platform (R Foundation for statistical computing, https://cran.r-project.org/). We reported the point estimate with a 95% uncertainty interval (UI), which is used in the GBD studies to quantify the uncertainty of estimates after bootstrapping or a 95% CI.

Patients and public involvement
Patients or the public were not involved in the conceptualisation or execution of this research.

RESULTS
Differences in COPD age-standardised incidence/mortality rates between China and high SDI countries
In 2017, in China, an estimated 66.5 million (95% UI 54.2–73.5) individuals had COPD, resulting in a total of 0.48 million deaths (95% UI 0.47–0.50), equivalent to an 18.3% decrease compared with the number of deaths in 1990 (1.2 million; 95% UI 1.02–1.24). Since 1990, the age-standardised incidence and mortality rates have drastically declined in China (figure 1 and online supplementary table S1). By contrast, the total number of COPD cases in high SDI countries was around 70.1 million (95% UI 63.0–77.7), resulting in a total number of 0.97 million deaths (95% UI 0.93–1.07), equivalent to a 51.3% increase compared with the number of deaths in 1990 (0.32 million; 95% UI 0.31–0.32). In high SDI countries, the age-standardised mortality rate slightly declined during 1990–2007, but the incidence rate remained stable (online supplemental table S1). Specifically, the age-standardised incidence rate of COPD was higher in China than in high SDI countries but converged gradually. However, a difference existed. When stratified by sex, both incidence and mortality rates declined slightly more for women than men in China, whereas incidence remained stable in both sexes in high SDI countries but the mortality rate declined mainly in men but not women (online supplemental table S1).

Differences in rankings of attributable risk factors for COPD and competing risks between China and high SDI countries
Figure 2 shows the rankings of the age-standardised mortality rates for COPD and competing risks, including stroke, IHD, TBLC, LRIs and asthma attributable to risk factors in China and high SDI countries in 2017. As expected, in China, smoking, ambient particulate matter pollution and occupational risks were the three leading risk factors for COPD, accounting for 26.1 (95%

UI 23.8–28.6), 14.2 (95% UI 9.3–18.7) and 11.2 (95% UI 8.7–13.9) of the mortality rates per 100 000 population, respectively (online supplementary table S2). Furthermore, smoking and ambient particulate matter pollution were also the commonly attributable risk factors for stroke, IHD, TBLC and LRIs. Similar patterns were noted for Chinese men but not for Chinese women, where ambient particulate matter pollution, ambient ozone pollution and occupational risks, accounting for 10.6 (95% UI 6.9–14.6), 8.7 (95% UI 3.3–14.5) and 8.3 (95% UI 5.2–11.4) mortality rate per 100 000 population, were the three leading risk factors. However, in high SDI countries, the three leading attributable risk factors for COPD were smoking, ambient particulate matter pollution and ambient ozone pollution.

Differences in change points in age-specific incidence rates of COPD and competing risks between China and high SDI countries
Table 1 and Figure 3 show change points of age-specific incidence rates for COPD and several commonly encountered competing risks, including IHD, stroke, TBLC, LRIs and asthma in China and high SDI countries in 2017, with the age-specific leading causes of death. In China, age-specific incidence rates of COPD changed rapidly (figure 3). From the late adolescence (ie, 15–19 years) to old age, the COPD incidence rate slightly increased up to 64 years (ie, change point being ~65 years), then exponentially increased afterward, and peaked at 95+ years. The change point occurred at ~65 years, and the age-specific leading cause of death varied. For instance, LRIs was the leading cause of death among people aged <14 years, stroke among those aged 15–19 years, IHD among those aged 20–39 years, stroke among those aged 40–84 years and IHD among those aged 85+ years. The corresponding change points for IHD, stroke, TBLC and asthma incidence rates were ~70 years, ~70 years, ~65 years and ~80 years. In contrast, the COPD incidence rate in high SDI countries increased slightly from the onset of adulthood (ie, 25–29 years) to 59 years (ie, change point being ~60 years), then fluctuated afterward, and finally peaked at 95+ years. LRIs was the leading cause of death among people aged <19 years and then IHD among those aged 20+ years. The change point of age-specific incidence rate in high SDI countries was 5-year earlier than that in China. The corresponding change points for IHD, stroke, TBLC and asthma were ~65 years, ~70 years, ~65 years and ~75 years. Identical results were also observed when using summary statistics for 2016 and 2015, expect for IHD in high SDI countries, as shown in online supplemental figures S1,S2.

COPD incident patterns differed by sex between China and high SDI countries. Specifically, change points for COPD and competing risks were the same in men in both countries, except for LRIs, whose change point was ~20 years in China, but ~85 years in high SDI countries (online supplemental figure S3). For women,
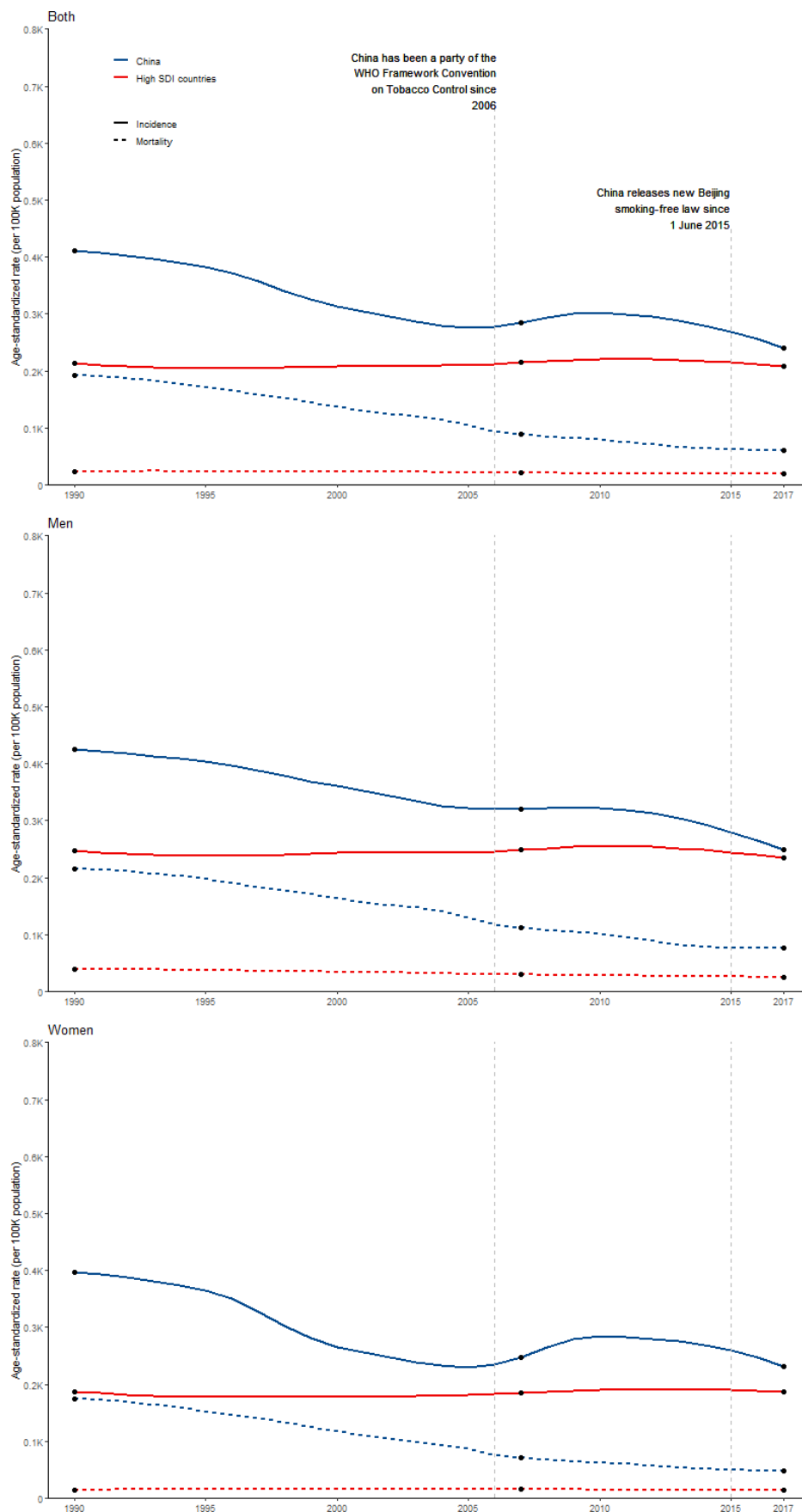
Figure 1 Age-standardised incidence and mortality rates of COPD during 1990–2017 in China and high SDI countries. The solid lines represent the age-standardised incidence rate and the dashed lines represent the age-standardised mortality rate. COPD, chronic obstructive pulmonary disease; SDI, socio-demographic index.
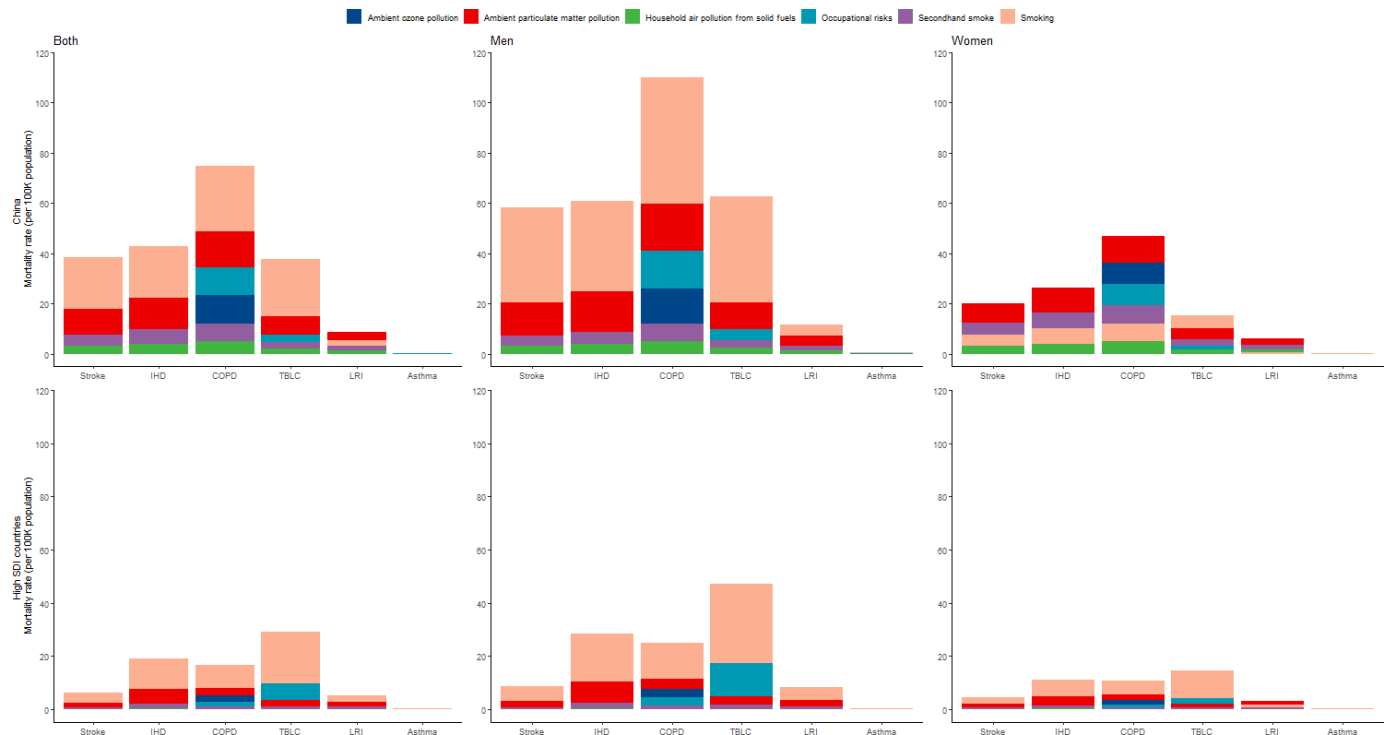
Figure 2 Attributable risk factors to age-standardised mortality rate of COPD and several commonly encountered competing risks of asthma, IHD, stroke, TBLC, LRIs and asthma in China and high SDI countries in 2017. COPD, chronic obstructive pulmonary disease; IHD, ischaemic heart disease; LRIs, lower respiratory infections; SDI, socio-demographic index; TBLC, tracheal, bronchus and lung cancer.

the change point for COPD was 5 years later in China than that in high SDI countries, and that for asthma was 10 years later. In contrast, the change point for IHD was 10 years earlier in China than that in high SDI countries with the same change points for stroke and TBLC (online supplemental figure S4).

Differences in change points in age-specific mortality rates of COPD and competing risks between China and high SDI countries

Figure 4 shows the age-specific mortality rates for COPD and several commonly encountered competing risks in China and high SDI countries in 2017 with the age-specific leading causes of death. Notably, the mortality patterns from COPD and competing risks between China and high SDI countries were different, especially among people aged 75+ years. In China, stroke and IHD were the leading causes of death among those aged 15+ years, followed by COPD. The age-specific mortality rates for TBLC, LRIs and asthma among those aged 75+ years were relatively low compared with those for stroke, IHD and COPD. The change points of age-specific mortality rates for COPD, IHD, stroke, TBLC and asthma were ~80 years, ~80 years, ~75 years, ~65 years and ~80 years. However, in high SDI countries, IHD was the leading cause of death among those aged 20+ years, followed by stroke, especially among those aged 80+ years. The corresponding change points for COPD, IHD, stroke, TBLC and asthma were ~80 years, ~55 years, ~85 years, ~65 years and ~85 years. Sensitivity

analysis yielded the identical results, expect for IHD in China and stroke in high SDI countries, as shown in online supplemental figures S5,S6.

Notably, change points for COPD and TBLC were the same in men in both countries. For men, the change point for IHD was 15 years later in China than that in high SDI countries, but that for stroke was 10 years later in China than that in high SDI countries (online supplemental figure S7). For women, the change points for IHD and TBLC were 20 years and 5 years later in China than that in high SDI countries, respectively, whereas that for stroke was 5 years earlier in China than that in high SDI countries (online supplemental figure S8). Furthermore, the change point of COPD was the same for women in both countries.

DISCUSSION
Principle findings

This study showed that age-standardised incidence and mortality rates for COPD in China and high SDI countries converged gradually during the period 1990–2017. However, differences existed, especially for the age-standardised mortality rate. As expected, tobacco smoke and air pollution were the main attributable risk factors for COPD mortality overall and among men in both countries, but occupational risks were more relevant in China than high SDI countries, especially among Chinese women. Compared with women

Table 1 Estimations of change points of age-specific incidence and mortality rates for COPD, IHD, stroke, TBLC, LRIs and asthma across sex in China and high SDI countries

Diseases	China				High SDI countries			
	Trend	Difference in trend	Change point (years)	P for Davies test	Trend	Difference in trend	Change point (years)	P for Davies test
Incidence rate								
Both								
COPD	1.32 (1.27 to 1.37)	0.48 (0.42 to 0.54)	65 to 69	2.85E-04	1.53 (1.53 to 1.53)	0.44 (0.44 to 0.44)	60 to 64	9.73E-05
IHD	1.51 (1.39 to 1.64)	0.46 (0.39 to 0.53)	70 to 74	3.71E-04	1.66 (1.48 to 1.88)	0.52 (0.45 to 0.60)	65 to 69	2.82E-04
Stroke	1.51 (1.47 to 1.54)	0.29 (0.25 to 0.33)	70 to 74	3.42E-03	1.44 (1.40 to 1.48)	0.46 (0.40 to 0.54)	70 to 74	4.04E-03
TBLC	1.66 (1.52 to 1.81)	0.35 (0.30 to 0.42)	65 to 69	1.54E-03	1.76 (1.60 to 1.94)	0.38 (0.33 to 0.44)	65 to 69	1.22E-03
LRIs	0.65 (0.52 to 0.81)	1.49 (1.19 to 1.87)	20 to 24	2.65E-01	1.02 (1.00 to 1.04)	0.34 (0.19 to 0.62)	85 to 89	2.45E-01
Asthma	0.88 (0.80 to 0.97)	0.44 (0.01 to 22.16)	80 to 84	8.94E-01	0.91 (0.84 to 0.99)	0.60 (0.15 to 2.35)	75 to 79	8.63E-01
Men								
COPD	1.51 (1.51 to 1.51)	0.31 (0.31 to 0.31)	65 to 69	7.64E-05	1.55 (1.55 to 1.55)	0.38 (0.38 to 0.38)	65 to 69	1.44E-04
IHD	1.51 (1.39 to 1.65)	0.43 (0.36 to 0.51)	65 to 69	4.08E-04	1.65 (1.48 to 1.85)	0.48 (0.41 to 0.55)	65 to 69	3.30E-04
Stroke	1.53 (1.49 to 1.56)	0.25 (0.22 to 0.29)	70 to 74	2.26E-03	1.48 (1.44 to 1.52)	0.44 (0.39 to 0.49)	70 to 74	2.63E-03
TBLC	1.69 (1.54 to 1.84)	0.33 (0.28 to 0.40)	65 to 69	1.87E-03	1.81 (1.62 to 2.02)	0.36 (0.31 to 0.42)	65 to 69	1.52E-03
LRIs	0.64 (0.51 to 0.80)	1.51 (1.20 to 1.90)	20 to 24	2.16E-01	1.02 (1.00 to 1.03)	0.28 (0.15 to 0.52)	85 to 89	3.54E-01
Asthma	0.87 (0.79 to 0.96)	0.37 (0.00 to 61.95)	80 to 84	8.10E-01	0.88 (0.81 to 0.96)	0.49 (0.02 to 13.05)	80 to 84	8.25E-01
Women								
COPD	1.28 (1.22 to 1.33)	0.52 (0.45 to 0.59)	65 to 69	3.13E-04	1.53 (1.53 to 1.53)	0.50 (0.49 to 0.50)	60 to 64	7.61E-05
IHD	1.51 (1.38 to 1.65)	0.48 (0.42 to 0.56)	70 to 74	3.82E-04	1.48 (1.40 to 1.56)	0.49 (0.43 to 0.56)	80 to 84	4.82E-04
Stroke	1.48 (1.45 to 1.52)	0.32 (0.27 to 0.37)	75 to 79	7.25E-03	1.41 (1.37 to 1.44)	0.44 (0.36 to 0.55)	75 to 79	8.30E-03
TBLC	1.60 (1.47 to 1.74)	0.39 (0.34 to 0.46)	65 to 69	9.69E-04	1.70 (1.56 to 1.84)	0.42 (0.37 to 0.48)	65 to 69	8.33E-04
LRIs	0.66 (0.52 to 0.82)	1.47 (1.17 to 1.84)	20 to 24	3.39E-01	1.02 (1.00 to 1.04)	0.39 (0.22 to 0.68)	90 to 94	1.41E-01
Asthma	0.89 (0.82 to 0.97)	0.48 (0.02 to 11.15)	80 to 84	9.84E-01	0.94 (0.88 to 1.00)	0.61 (0.21 to 1.77)	70 to 74	5.07E-01
Mortality rate								
Both								
COPD	1.73 (0.38 to 7.74)	0.31 (N.A.)	80 to 84	4.54E-03	1.58 (1.49 to 1.67)	0.37 (0.30 to 0.46)	80 to 84	1.74E-03
IHD	1.61 (1.57 to 1.66)	0.32 (0.27 to 0.38)	80 to 84	3.70E-04	2.14 (2.09 to 2.20)	0.56 (0.54 to 0.58)	55 to 59	2.32E-04
Stroke	1.69 (1.65 to 1.73)	0.24 (0.19 to 0.29)	75 to 79	2.92E-03	1.63 (1.59 to 1.67)	0.40 (0.27 to 0.58)	85 to 89	3.08E-02
TBLC	2.04 (1.98 to 2.11)	0.22 (0.20 to 0.24)	65 to 69	1.03E-03	2.46 (2.40 to 2.51)	0.28 (0.27 to 0.29)	65 to 69	1.02E-03
LRIs	0.33 (0.28 to 0.38)	4.14 (3.57 to 4.81)	10 to 14	2.41E-02	0.39 (0.33 to 0.46)	3.81 (3.24 to 4.48)	5 to 9	4.34E-02
Asthma	1.47 (1.45 to 1.48)	0.21 (0.19 to 0.24)	80 to 84	2.20E-03	1.27 (1.27 to 1.28)	0.44 (0.40 to 0.48)	85 to 89	6.53E-03
Men								
COPD	1.70 (0.45 to 6.51)	0.27 (N.A.)	80 to 84	4.28E-03	1.58 (1.49 to 1.68)	0.31 (0.24 to 0.40)	80 to 84	2.29E-03
IHD	1.57 (1.52 to 1.62)	0.27 (0.22 to 0.33)	75 to 79	3.37E-04	2.11 (2.05 to 2.17)	0.48 (0.46 to 0.50)	55 to 59	2.80E-04

Table 1 Continued

Diseases	China				High SDI countries			
	Trend	Difference in trend	Change point (years)	P for Davies test	Trend	Difference in trend	Change point (years)	P for Davies test
Stroke	1.68 (1.64 to 1.72)	0.20 (0.16 to 0.24)	75 to 79	1.36E-03	1.47 (0.74 to 2.94)	0.35 (N.A.)	85 to 89	1.51E-03
TBLC	2.09 (2.02 to 2.16)	0.20 (0.18 to 0.22)	65 to 69	1.24E-03	2.53 (2.46 to 2.60)	0.25 (0.24 to 0.27)	65 to 69	1.19E-03
LRIs	0.33 (0.27 to 0.40)	4.05 (3.34 to 4.91)	10 to 14	4.65E-02	0.37 (0.29 to 0.49)	3.98 (3.05 to 5.20)	5 to 9	1.18E-01
Asthma	1.47 (1.45 to 1.49)	0.16 (0.14 to 0.19)	80 to 84	2.32E-03	1.24 (1.23 to 1.24)	0.32 (0.29 to 0.35)	85 to 89	6.48E-03
Women								
COPD	1.77 (0.70 to 4.45)	0.34 (N.A.)	80 to 84	5.99E-03	1.58 (1.49 to 1.67)	0.44 (0.36 to 0.52)	80 to 84	1.26E-03
IHD	1.69 (1.65 to 1.73)	0.34 (0.30 to 0.39)	80 to 84	8.31E-04	2.00 (1.94 to 2.06)	0.69 (0.65 to 0.72)	60 to 64	1.78E-04
Stroke	1.70 (1.65 to 1.74)	0.27 (0.21 to 0.34)	80 to 84	2.04E-02	1.62 (1.59 to 1.66)	0.38 (0.21 to 0.69)	85 to 89	2.36E-01
TBLC	1.95 (1.88 to 2.02)	0.27 (0.24 to 0.30)	65 to 69	6.97E-04	2.37 (2.32 to 2.42)	0.32 (0.31 to 0.33)	60 to 64	8.28E-04
LRIs	0.33 (0.29 to 0.37)	4.28 (3.77 to 4.86)	15 to 19	1.11E-02	0.42 (0.38 to 0.46)	3.61 (3.27 to 4.00)	ten to 14	1.10E-02
Asthma	1.47 (1.45 to 1.48)	0.25 (0.23 to 0.28)	85 to 89	2.81E-03	1.30 (1.30 to 1.31)	0.47 (0.40 to 0.55)	90 to 94	6.90E-03

N.A.: the CIs are not available due to the limited number of data points before or after the change point.
COPD, chronic obstructive pulmonary disease; IHD, ischaemic heart disease; LRIs, lower respiratory infections; SDI, socio-demographic index; TBLC, tracheal, bronchus and lung cancer.

in high SDI countries with smoking as the main risk factor, Chinese women were more likely to be exposed to ambient particulate matter and ozone pollution, and occupational risks. Our findings show that the change point for the age-specific mortality rates for COPD was the same in China and high SDI countries, but the change point for age-specific incidence rate was 5 years later in China than in high SDI countries. The change point for incidence and mortality rates for competing risks (including IHD and stroke) also varied between the settings. Taken together, our study suggests that differences in the well-established risk factors as well as varying mortality patterns from other causes between China and high SDI countries might partially explain differences particularly in COPD mortality rates.

Comparison with other studies

Previous studies have extensively compared country-specific COPD burdens.[30 32 44–46] Of these, differences in the prevalence of risk factors, such as smoking, second-hand smoke exposure, ambient particulate matter pollution and occupational risks, were considered the primary drivers for disparities across countries or regions. For instance, in 2015, age-standardised smoking prevalence was 37.5% for Chinese men and 2.2% for Chinese women, whereas those in the USA were 14.4% and 11.7%, and in Germany were 25.2% and 19.4%. Furthermore, smoking cessation and supplemental oxygen have been shown to reduce COPD progression and mortality,[47 48] which might partly be reflected in our results showing the same change points for COPD age-specific mortality rates in both China and high SDI countries. Previous studies also showed that patients with COPD often have comorbidities, such as IHD, heart failure, lung cancer, depression and diabetes.[38 46 49] Our results suggest that competing risks, including these COPD comorbidities, might affect mortality patterns at the population level in both China and high SDI countries.

Possible explanations

Several possible explanations might be responsible for the difference in COPD patterns between China and high SDI countries. First, the varying prevalence of attributable risk factors has a role in shaping the difference in COPD patterns between China and high SDI countries, including the higher prevalence of smoking and secondhand smoke in high SDI countries, and more serious ambient air pollution, occupational risks and more common use of solid fuels exists in China. Second, treatments for COPD and its comorbidities might also contribute to the difference in COPD mortality in both settings, with the relative contribution depending on the implementations and compliance of the recommended treatments. Third, population ageing might be another attributable factor for the difference in age-specific incidence/mortality patterns in COPD between China and high SDI countries, although it cannot explain the trends in age-standardised incidence/mortality rates of COPD, which account for changes in age structure. Fourth,
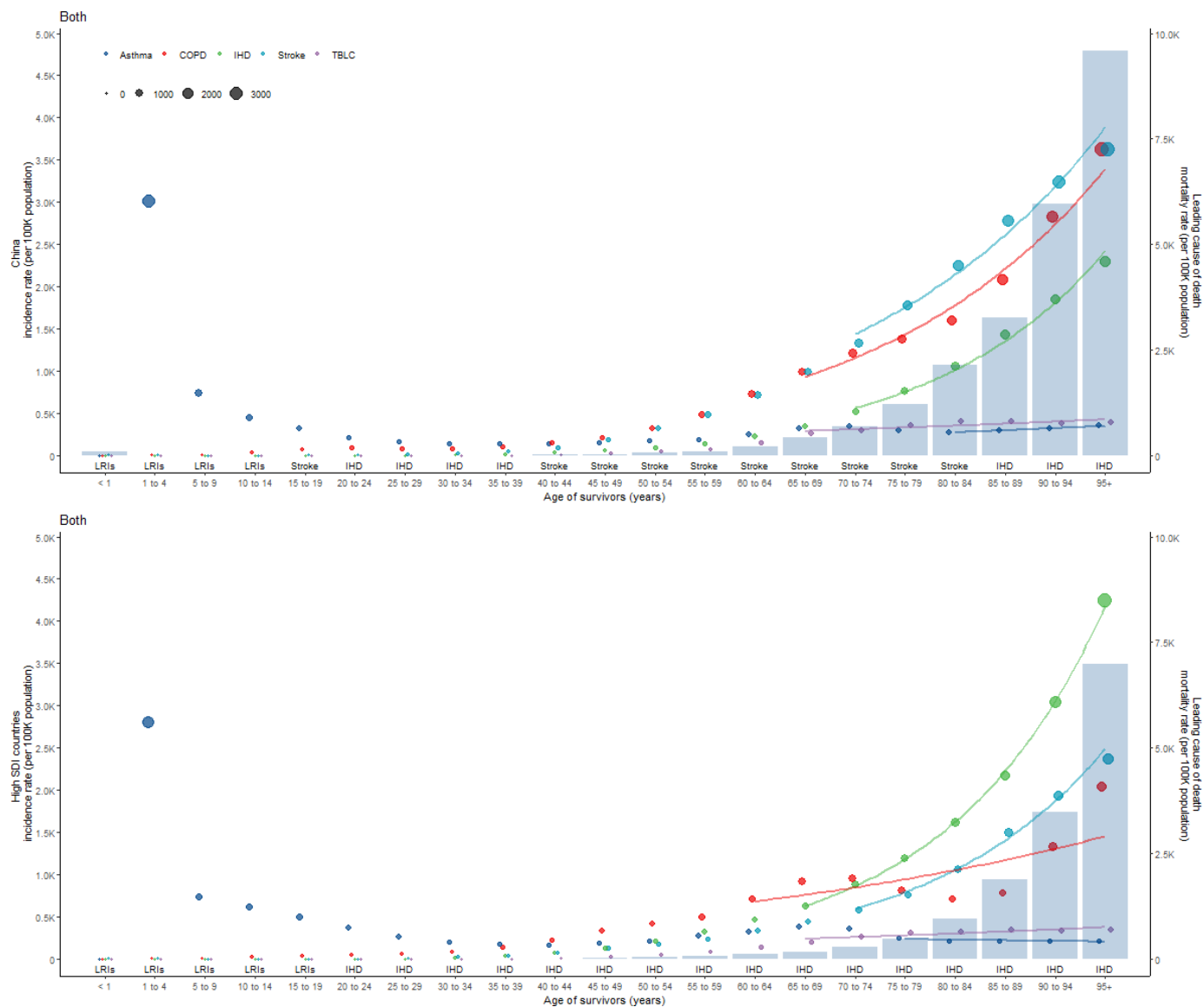
Figure 3 Age-specific incidence rates of COPD and several commonly encountered competing risks of asthma, IHD, stroke, TBLC and asthma in China and high SDI countries in 2017. The dots represent the age-specific incidence rate, the bars represent the age-specific leading cause of death and the curves are fitted by the segmented negative-binominal regression models with change points being the start of the curves. COPD, chronic obstructive pulmonary disease; IHD, ischaemic heart disease; SDI, socio-demographic index; TBLC, tracheal, bronchus and lung cancer.

differences in mortality patterns due to competing events at the population level might also shape the differences in COPD patterns, as reflected in the different change points for age-specific incidence and mortality rates for IHD, stroke, TBLC, LRIs and asthma, because people may have several comorbidities but only die once. For example, at the population level, people in China largely die from COPD after surviving LRIs during adolescence and IHD and stroke during adulthood, because LRIs and IHD/stroke are, respectively, the leading causes of death for infants/teenagers and adults in China. In contrast, people in high SDI countries largely die from COPD only after surviving IHD/stroke during adulthood, which crucially is stronger force of death prior to age 85 years in high SDI countries than in China.

Strengths and limitations

The current study estimates and compares change points of the age-specific incidence/mortality rates for COPD and several commonly encountered competing risks between China and high SDI countries. We found that beyond the differences in risk factors, varying mortality patterns due to competing risks during individual's whole life might also contribute to the discrepancy by affecting the survival of the underlying population.

However, limitations are noted in this study. First, varying implementation and compliance of treatments for COPD and competing risks might contribute to differences in COPD patterns between China and high SDI countries. However, no data on treatment are available to evaluate its relative contribution. Here, we used the
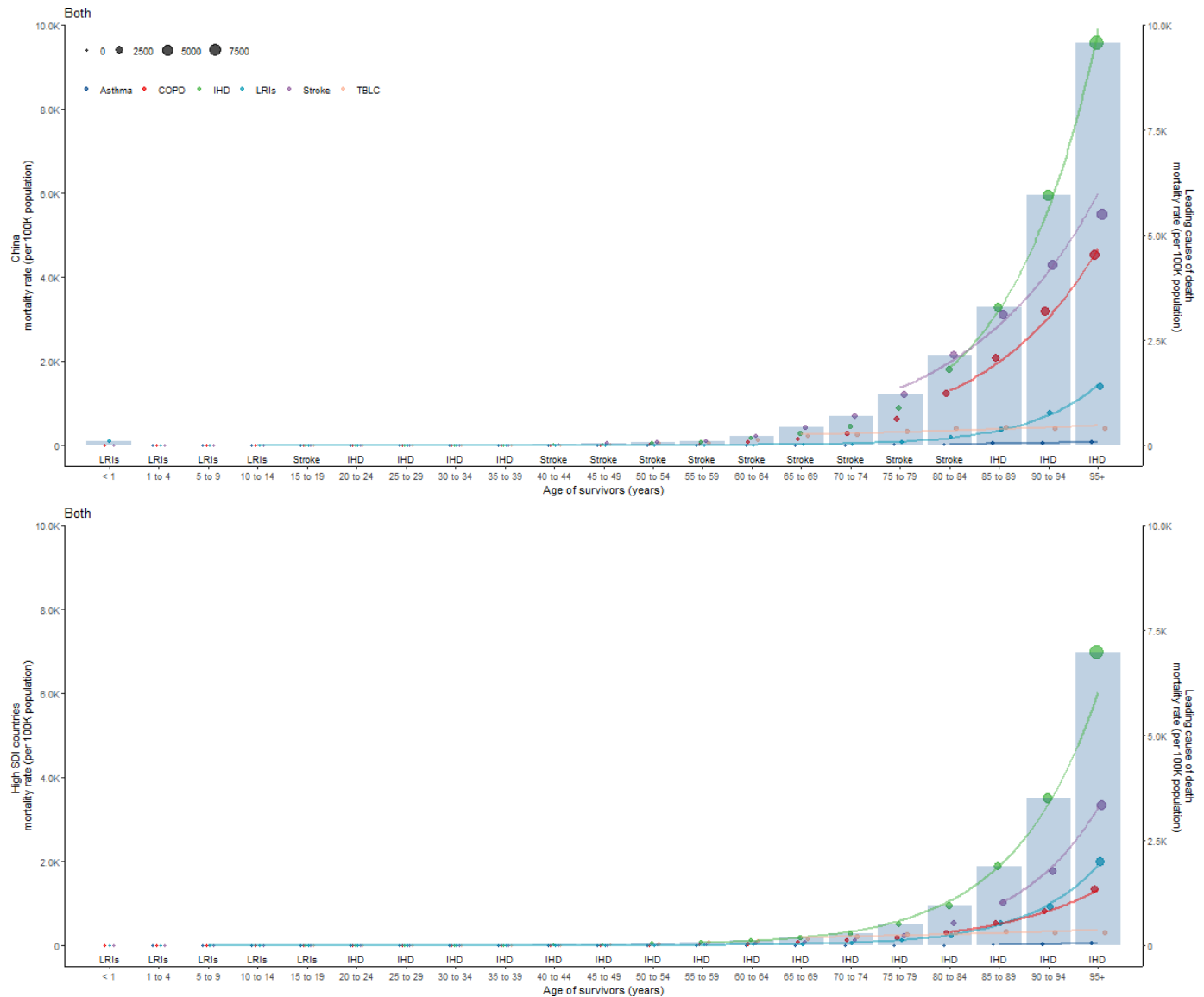
Figure 4 Age-specific mortality rates of COPD and several commonly encountered competing risks of asthma, IHD, stroke, TBLC, LRIs and asthma in China and high SDI countries, 2017. The dots represent the age-specific incidence rate. The bars represent the age-specific leading cause of death. The curves are fitted by the segmented negative-binominal regression models, with change points being the start of the curves. COPD, chronic obstructive pulmonary disease; IHD, ischaemic heart disease; LRIs, lower respiratory infections; SDI, socio-demographic index; TBLC, tracheal, bronchus and lung cancer.

change points of the age-specific mortality rates, which might also indicate the potential contribution of any treatments (including competing risks), although we acknowledge that such measures cannot distinguish between treatments and population ageing nor their magnitudes. Second, prevention against modifiable risk factors, such as tobacco control and Healthy China 2030, would also affect the age-standardised mortality rate for COPD between China and high SDI countries. For example, Europe initiated the action plan for tobacco-free during 1987–2001. It then proposed the European Strategy for tobacco control in 2002, whereas China released the first Beijing smoking-free law (not nationally) in 2015. The risk of chronic respiratory diseases falls over decades after cessation before approaching that of non-smokers,[50] and thus its impact on age-standardised mortality rate for

COPD in high SDI countries could be larger than that in China. However, the magnitude of such an effect cannot be assessed. Third, no data on attributable risk factors for COPD age-standardised incidence are available. We cannot assess the effects of risk factors on COPD incidence directly. Furthermore, the estimates for COPD in China from the GBD Study 2017 were obtained using incidence and death distribution models based on the data from censuses and the Disease Surveillance Point System that covers fewer counties and districts in remote and poorer provinces of China.[51] Particularly, only around 60% of the mortality data was certified by Death Registration in China. Thus, the lack of reliable incident and mortality data may result in wide uncertainty of our estimates. Nevertheless, our results still provide additional information for developing appropriate policies for COPD

prevention in China. Fourth, the difference in socioeconomic status, reflecting by SDI values, between China and high SDI countries may also partially explain the discrepancy in COPD patterns. However, its impact appeared to be limited, as indicated by the same change point for COPD mortality rates in China and high SDI countries. Fifth, the use of a segmented negative-binominal regression model may not fully capture any non-linearity of age-specific incidence/mortality rates of COPD, especially among those aged 65+ years in high SDI countries. More detailed age-specific rates with a spline function might yield more refined estimates of the change points. Sixth, our study is descriptive. Thus, the proposed explanations might be speculated, and open to alternative interpretations. However, our findings provide potential directions for explaining the difference in COPD mortality patterns between China and high SDI countries.

Public health implication

Though the societal burden of COPD in China remains high, improvements, particularly for mortality rates since the 1990s, are encouraging. Nevertheless, instead of over-emphasising COPD prevention solely as previously, developing more comprehensive prevention strategies for COPD, together with other competing risks (eg, IHD, stroke and lung cancer), are needed. In addition, further studies investigating the potential effects of treatment and management on COPD patterns and potential risk factors when data are available can help guide appropriate policies in China and other developing and developed countries.

CONCLUSION

Despite similarities in COPD incidence rates, COPD mortality rates differ between China and high SDI countries which may be partially explained by the varying prevalence of well-established risk factors (ie, tobacco smoke, air pollution and occupational risks) as well as by differences in mortality patterns due to competing events (eg, IHD, stroke, TBLC, LRIs and asthma). Comparisons of cause-specific mortality rates may need to be informed by mortality patterns for major causes of prior deaths.

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