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Mortality and years of life lost of cardiovascular diseases in China, 2005–2020: Empirical evidence from national mortality surveillance system

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A R T I C L E I N F O

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A B S T R A C T

Objectives: Cardiovascular disease (CVD) is leading cause of death in China. We aimed to provide national and subnational estimates and its change of premature mortality burden of CVD during 2005–2020.

Methods: Data from multi-source on the basis of national mortality surveillance system (NMSS) was used to estimate mortality and years of life lost (YLL) of total CVD and its subcategories in Chinese population across 31 provinces during 2005–2020.

Results: Estimated CVD deaths increased from 3.09 million in 2005 to 4.58 million in 2020; the age-standardized mortality rate (ASMR) decreased from 286.85 per 100,000 in 2005 to 245.39 per 100,000 in 2020. A substantial reduction of 19.27% of CVD premature mortality burden, as measured by age-standardized YLL rate, was observed. Ischemic heart disease (IHD), hemorrhagic stroke (HS) and ischemic stroke (IS) were leading 3 causes of CVD death. Marked differences were observed in geographical patterns for total CVD and its subcategories, and it appeared to be lower in areas with higher economic development. Population ageing was dominant driver contributed to CVD deaths increase, followed by population growth. And, age-specific mortality shifts contributed largely to CVD deaths decline in most provinces.

Conclusion: Substantial discrepancies were demonstrated in CVD premature mortality burden across China. Targeted considerations were needed to integrate primary care with clinical care through intensifying further strategies for reducing CVD mortality among specific subcategories, high risk population and regions with inadequate healthcare resources.

1. Introduction

Cardiovascular disease (CVD) is the largest single contributor to global mortality [1] and the leading cause of death in China that accounts for 40% of total deaths [2]. In recent years, the State Council subsequently endorsed series of important documents in CVD prognosis improvement, risk factors intervention, health promotion and universal health coverage to promote CVD health, such as Health China 2030 Guidelines, 13th Five-Year Plan for Hygiene and Health, and Medium- to Long-Term Plan for the Prevention and Treatment of Chronic Disease (2017–2025). Correspondingly, clarifying the CVD burden in different periods, regions and population will help to consolidate targeted health policies and government-dominant strategies to reduce the risk of CVD [3].

Abbreviations: CVD, cardiovascular diseases; NMSS, National Mortality Surveillance System; China CDC, Chinese Center for Disease Control and Prevention; PLAD, provincial-level administrative division; COD, cause-of-death; U5MR, under-5 mortality rate; MCHS, Maternal and Child Health Surveillance System; URR, under-reporting rate; $_5q_0$, probability of death among children aged under 5 years; $_{45}q_{15}$, probability of death among adults aged 15–60 years; MLTFS, model life table system with flexible standard; YLL, years of life lost; ASMR, age-standardized mortality rate; ARC, annual rate of reduction; RHD, rheumatic heart disease; HHD, hypertensive heart disease; IHD, ischemic heart disease; HS, hemorrhagic stroke; SH, subarachnoid hemorrhage; IH, intracerebral hemorrhage; IS, ischemic stroke; MMD, myocarditis and myocardia disease; AA, aortic aneurysm.

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However, the fundamental knowledge of decision making for national and subnational burden of CVD premature mortality remained inadequate [3]. Despite previous systematic analysis of cause-specific CVD burden over time across China, published studies were either of limited scope in CVD mortality patterns and burden of premature mortality, or lack analysis of drivers of CVD mortality change over time [3]. Explicit evaluation of them is needed to appropriately guide efforts to potentially fill remaining knowledge gaps [3,4].

In this study, by using data from a national and subnational representativeness mortality surveillance in China, we provided estimates of cause-specific mortality and premature mortality for CVD during 2005–2020, with special attention paid to describe temporal trends and geographical variations of CVD mortality pattern, sex difference and dominant drivers of its change. It will further facilitate development of locality responses that could support the health care system to improving CVD health of Chinese population.

2. Materials and methods

2.1. Ethical approval and informed consent

Not required.

2.2. Data source

Mortality data were derived from National Mortality Surveillance System (NMSS) housed in Chinese Center for Disease Control and Prevention (CDC). NMSS covers over 300 million individuals from 605 surveillance points in 31 provincial-level administrative divisions (PLAD, excluding Hong Kong Special Administrative Region, Macau Special Administrative Region and Taiwan province) that accounted for 24% of China's population, and routinely collects individual details of death information in real time through an internet-based approach [5]. Detailed descriptions of NMSS have been reported elsewhere [5]. Data for under-reporting adjustment were obtained from under-reporting field surveys for national mortality surveillance conducted in 2009, 2012, 2015 and 2018 separately, which collected under-reporting data from 2006 to 2017. Under-5 Mortality Rate (U5MR) at county level were extracted from a combination estimation of data derived from census, national surveys, Intra-Census Surveys, Maternal and Child Health Surveillance System (MCHS) and NMSS in main analysis [6]. Data for surveillance population and socio-economic covariates were all from National Bureau of Statistics [7]. Data for rate standardization were acquired from 2010 population census [7].

2.3. CVD mortality estimation and projection

2.3.1. All-cause mortality estimation

(i) Under-reporting rate calculation: We calculated under-reporting rate (URR) annually for each age-sex stratum among all surveillance points during 2006–2017 as the proportion of missed deaths among the total number of deaths identified in under-reporting surveys. We used splines regression to predict URR in each stratum in 2005 and 2018. Details of URR at national level on average for every 3 years during 2006–2017 were reported in Supplemental Materials Online Table S1. (ii) Adjusted all-cause mortality rate calculation: We derived under-reporting-adjusted all-cause mortality rate by age-sex for all points by dividing reported number of deaths by (1-URR). We used log-linear model to predict U5MR between 2013 and 2018 using 1996–2012 results. We used locally weighted regression by time and space to handle the discontinuity for each surveillance point after quality control. (iii) ${}_5q_0$ and ${}_{45}q_{15}$ estimation: We produced age-sex all-cause mortality rate at provincial level by weighting population counts in each point during 2005–2018, and subsequently generate probability of death among children aged under 5 years (${}_5q_0$) and adults aged 15–60 years (${}_{45}q_{15}$). We adopted univariate analysis and collinearity diagnosis to examine significant socioeconomic covariates at provincial level in relation to ${}_{45}q_{15}$, including urbanization rate (%), average years of education attainment, beds of medical institutions per 1000, non-agricultural population (10,000 person) and per capita gross regional product (yuan/person). We used non-linear mixed effect model to acquire sex-specific ${}_{45}q_{15}$ estimation at provincial level during 2005–2018. (iv) Age-specific mortality rate estimation: We used a new relational model life table system with flexible standard (MLTFS) based on two parameters of ${}_5q_0$ and ${}_{45}q_{15}$ to generate a full set of age-specific mortality rate for 31 provinces during 2005–2018 [8,9].

2.3.2. CVD mortality estimation

(i) Cause-of-death identification: Cause-of-death (COD) is the most important, direct or actual cause, or last event or act that occurred before the chain of events leading to death. We used International Classification of Diseases 10th Edition (ICD-10) for cause-of-death (COD) identification for CVD. Details of ICD codes for CVD deaths were reported in Supplemental Materials Online Table S2. (ii) Garbage code redistribution: Garbage codes were defined as deaths with non-specific codes, deaths that could not be underlying causes of death, or deaths assigned to intermediate but not underlying COD. In this study, we redistributed them by location-year-sex-age to the most likely COD by applying methods used for this redistribution that developed by Naghavi and colleagues have been reported elsewhere [10]. Details of garbage codes definition, identification and redistribution for CVD deaths were also reported in Supplementary Materials Online Table S3. (iii) Proportion of COD calculation: We calculated the COD proportion for all reported cases followed by reweighting the proportion of each cause based on the fraction of in-hospital/non-hospital death and urban/rural death from NMSS by each location-year-sex-age in order to reduce the potential bias caused by unequally distributed of in-hospital/non-hospital and urban/rural deaths [11]. (iv) CVD mortality estimation: CVD mortality rate by location-year-sex-age group was calculated by multiplying by all-cause mortality rate generated previously and proportion of COD. We used splines regression to adapt its trends to fit CVD mortality rate within the same rubric after data quality control. (v) CVD mortality projection: We projected the result for CVD mortality in 2019 and 2020 by using 2005–2018 results under the same rubric. (vi) Cause aggregation and central rescale: We used a top-down hierarchical format containing 5 levels for all-cause and cause-specific number of CVD deaths during 2005–2020 [12].

2.3.3. YLL computation

Years of life lost (YLL) is a metric of premature mortality calculated as the sum of each death multiplied by the standard life expectancy at each age [12]. We used a theoretical minimum risk reference life table in YLL computation for CVD and its subcategories during 2005–2020 [12], and it was presented in Supplementary Materials Online Table S4.

2.4. Statistical analysis

2.4.1. ARC calculation

To describe the CVD premature mortality burden over time, we calculated Annual Rate of Change (ARC) developed by Preston SH and colleagues through using the logarithm of time period difference for CVD age-standardized YLL rate between 2005 and 2020, divided by number of study period, and then, depicted the result by adding an ARC heatmap [13,14].

2.4.2. Decomposition of changes for CVD deaths

To explore the drivers of change in the number of CVD deaths in China and its provinces, by using methods developed in demographic research from Das Gupta, we decomposed change from 2005 to 2020 into three explanatory components: as growths of the total population; as shifts in population structure by age or sex; or as changes for age-sex-specific mortality rate [9,12,15]. This method of standardization and decomposition integrates interactions between component effects, including population growth, population ageing and mortality patterns transition, into the additive main effects [16]. Details of decomposition have been reported elsewhere [12,15].

In this study, all analysis were performed in SAS version 9.4 (SAS Institute Inc., Cary, North Carolina USA), StataMP version 14.1 (Stata Cooperation College Station, Texas, USA) and R version 4.0.4 (The R foundation for Statistical Computing).

3. Results

3.1. National and subnational premature mortality burden of CVD and its subcategories

Overall, the estimated number of total CVD deaths increased from 3.09 million in 2005 to 4.58 million in 2020 in China (Table 1). The largest relative growth was aortic aneurysm (AA), followed by hypertensive heart disease (HHD), ischemic stroke (IS), ischemic heart disease (IHD) and myocarditis and myocardia disease (MMD). Number of rheumatic heart disease (RHD) and hemorrhagic stroke (HS) deaths remained stable during 2005–2020. The age-standardized mortality rate (ASMR) of total CVD decreased from 286.85 per 100,000 in 2005 to 245.39 per 100,000 in 2020. During which, a substantial reduction was observed in RHD, IHD, HS, MMD, an upward trend was seen in HHD and IHD, while IS shown subtle fluctuations. The age-standardized YLL rate of total CVD fell by 19.27% between 2005 and 2020, IHD, HS and IS were leading 3 causes of CVD death in 2020, with age-standardized YLL rate 1901.99 per 100,000, 995.09 per 100,000 and 990.63 per 100,000, respectively. And, higher mortality among men than women was observed for total CVD and all of its subcategories. At subnational level, in 2020, the top 3 provinces with highest ASMR were Tibet (416.07 per 100,000), Heilongjiang (346.56 per 100,000), Henan (331.38 per 100,000), and the last 3 were Shanghai (137.10 per 100,000), Zhejiang (144.40 per 100,000), Jiangsu (148.11 per 100,000). Despite in the condition of general reduction for CVD mortality in China, provinces like Anhui, Shanxi and Tibet experienced an upward trend of ASMR for total CVD.

3.2. Distribution of YLLs for CVD and its subcategories

Fig. 1 shown the distribution of CVD premature mortality burden by selected characteristics through using of YLL as the main metric. Among which, with the relative premature mortality burden increased in IHD, IS and HHD, YLLs decreased slightly in HS, RHD, including a small fraction being stable for MMD and AA, and the burden was nearly equal distributed in both genders (Fig. 1A). In 2020, IHD occupied 50–60% on average of CVD premature mortality burden among those who aged 15–50 years with a gradual shrink to around 30–40% after 50 years; HS accounted for 30–40% of YLLs among 10–60 years aged labor population, and decreased among those aged 60 years and above; whereas the proportion of IS burden increased with age, reaching its peak at age group 75–79 years. Sex differences existed obviously for IHD, HS, IS and MMD among children aged 0–14 years, with IHD higher in girls and HS, IS, MMD higher in boys (Fig. 1B). Correspondingly in Fig. 1C, over a half of CVD premature mortality occurred at an older age (53.77% among 75 years and older). HHD and IS were subcategories having most YLLs at older ages, while AA and HS mostly occurred at a younger age on average, nearly 30% of MMD premature mortality burden came from population aged 30 years and younger. Overall, compared with men, women were inclined to experience CVD death at an older age. When referring to geographical variations of premature mortality burden among CVD subcategories in 2020 presented in Fig. 1D, Beijing (61.92%), Tianjin (58.71%) and Shandong (55.04%) were top 3 provinces holding the highest YLLs proportion of IHD, Tibet (48.83%), Qinghai (40.27%) and Sichuan (37.25%) with highest proportion of HS, Jiangsu (34.05%), Shanghai (33.78%) and Zhejiang (29.28%) with highest proportion of IS. Besides, HHD appeared comparatively higher in Tibet, Jiangxi and Hunan. Besides, a relative premature mortality burden reduction of total CVD in youngsters aged 0–14 years was higher than other age groups, varied from 1.48% in Jiangsu to 19.17% in Jiangxi with national level of 9.48%, whereas the elderly aged 75 years with an increased ARC of 0.02% on average (Fig. 2).

3.3. Decomposition of changes for CVD deaths

Fig. 3 shown the relative contributions of population growth, population ageing and age-sex-specific CVD morality rate change for total CVD deaths in China and its provinces between 2005 and 2020. Overall, there was a 48.06% increase in total CVD deaths. Population ageing contributed the largest fraction to increase CVD deaths across the country, accounted for 64.11% of total change, followed by 8.48% for population growth, and − 24.53% for age-sex-specific CVD mortality rate. Referring to different regions, the top 3 provinces holding largest contributions of population growth increasing total CVD deaths were Tianjin (52.52%), Beijing (44.24%) and Shanghai (39.39%), while the smallest ones were Guizhou (−7.20%), Sichuan (−4.01%) and Heilongjiang (−1.72%). Besides, the top 3 provinces holding largest contributions of population ageing increasing total CVD deaths were Heilongjiang (100.73%), Jilin (91.50%) and Ningxia (89.70%), while the smallest ones were Guangxi (27.89%), Xizang (33.20%) and Fujian (38.90%). Additionally, the top 3 provinces holding largest contributions of age-sex-specific CVD mortality rate decreasing total CVD deaths were Tianjin (75.89%), Beijing (72.88%) and Inner Mongolia (57.16%), while the smallest ones were Qinghai (0.81%), Henan (5.08%) and Gansu (7.47%).

4. Discussion

By using data from multi-source on the basis of NMSS, we described temporal trends and geographical variations of premature mortality burden for CVD during 2005–2020 in China and its provinces. Comparatively, although there was a decline in CVD premature mortality burden, the absolute increase of CVD deaths due to population ageing could not be ignored. IHD, HS and IS were leading causes of CVD death, and the elderly were high risk population. Substantial geographical variations of premature mortality burden for CVD were observed across the country.

During 2005–2020, the overall CVD premature mortality burden nationwide was higher than global average, far exceeded upper-income countries (such as USA) and was higher than those of upper-middle-income countries (such as UK, Australia, Japan and France) as well, located in the middle of G20 [17]. While in comparison with aforementioned countries, China now has similar rates of heart diseases deaths, but much higher rates of death from stroke [17]. The decline of ASMR and age-standardized YLL rate of total CVD were mostly due to improved medical care and public health environment, including upgraded medical technology, effective treatment of physiological risk factors, proper diagnosis and treatment of acute CVDs, as well as the post-hospital care. For example, through using combined data from the EPICOR (Long-tErm follow-uP of antithrombotic management patterns In Acute CORonary Syndrome patients) and EPICOR Asia across 8 geographical regions and 20 countries covering Europe, American and Asia, previous studies had confirmed that there were substantial geographical variations exist worldwide regarding to patient profiles, in-hospital management and post-discharge mortality among patients with non-ST-segment clavation acute coronary syndromes (NSTE-ACS) and ST-segment elevation myocardial infarction (STEMI) [18,19]. Among which, Latin America was the leading region with highest post-discharge mortality rates, while China located in the middle of the selected countries, followed by North Europe and South Korea, Hong Kong & Singapore with the lowest value [18,19]. This disparity may be partly explained by differences in the following four factors: (i) Differences in

Table 1
Estimated deaths and age-standardized mortality rate, estimated YLLs and age-standardized YLL rate of CVD and its subcategories in China, 2005, 2010, 2015 and 2020.

	Subgroups	2005			2010			2015			2020		
		Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	CVD total	309.11	161.68	147.42	347.93	183.27	164.66	384.33	204.54	179.79	457.66	240.77	216.89
	Rheumatic heart disease	7.84	3.05	4.79	7.46	3.00	4.46	6.93	2.93	4.00	7.02	3.09	3.94
	Hypertensive heart disease	20.73	10.00	10.73	26.16	12.61	13.56	31.93	15.44	16.50	41.31	19.51	21.80
	Ischemic heart disease	119.66	62.01	57.65	137.80	71.44	66.36	156.18	81.35	74.82	192.21	98.19	94.02
	Hemorrhagic stroke	91.76	50.97	40.78	91.22	51.37	39.84	86.19	49.41	36.78	84.54	48.86	35.69
	Ischemic stroke	64.33	33.18	31.15	76.79	40.39	36.40	89.92	48.44	41.48	112.59	60.76	51.83
	Myocarditis and myocardia disease	0.67	0.33	0.34	0.67	0.33	0.34	0.67	0.33	0.35	0.71	0.33	0.38
Estimated deaths	Aortic aneurysm	0.24	0.17	0.06	0.39	0.28	0.10	0.58	0.43	0.15	0.89	0.64	0.25
(10 thousands)	Other cardiovascular and circulatory diseases	3.88	1.96	1.91	7.45	3.85	3.60	11.93	6.22	5.71	18.39	9.39	9.00
	CVD total	286.85	326.54	248.10	273.79	313.35	235.05	259.72	299.91	220.46	245.39	287.66	205.60
	Rheumatic heart disease	7.03	5.76	8.11	5.84	5.00	6.56	4.72	4.28	5.10	3.78	3.69	3.83
	Hypertensive heart disease	19.47	20.81	18.00	20.64	22.01	19.14	21.43	22.85	19.88	21.86	23.38	20.27
	Ischemic heart disease	111.22	125.35	96.86	108.47	122.33	94.38	105.41	119.42	91.25	103.16	117.97	88.70
	Hemorrhagic stroke	84.43	100.73	68.95	71.58	86.16	57.58	58.68	71.63	46.19	46.07	57.91	34.95
	Ischemic stroke	60.27	68.91	52.30	60.56	70.19	51.64	60.56	71.48	50.45	59.81	72.35	48.72
	Myocarditis and myocardia disease	0.60	0.64	0.56	0.52	0.55	0.49	0.46	0.48	0.43	0.40	0.42	0.37
Age- standardized mortality rate	Aortic aneurysm	0.21	0.32	0.11	0.30	0.46	0.15	0.40	0.62	0.20	0.50	0.77	0.25
(per 100,000)	Other cardiovascular and circulatory diseases	3.62	4.03	3.21	5.87	6.65	5.12	8.05	9.15	6.97	9.81	11.18	8.52
	CVD total	6228.23	3563.14	2665.09	6702.17	3863.48	2838.69	7111.20	4143.12	2968.08	8136.34	4711.77	3424.57
	Rheumatic heart disease	214.37	88.75	125.61	182.51	76.61	105.90	148.20	64.34	83.87	129.58	58.94	70.64
	Hypertensive heart disease	373.36	196.50	176.86	446.70	235.36	211.35	523.11	276.23	246.88	657.16	339.59	317.58
	Ischemic heart disease	2434.15	1407.67	1026.47	2671.89	1543.96	1127.93	2902.62	1682.83	1219.78	3402.42	1942.01	1460.41
	Hemorrhagic stroke	1962.14	1180.51	781.63	1920.20	1171.85	748.35	1798.16	1118.41	679.75	1752.15	1104.69	647.47
	Ischemic stroke	1140.68	631.49	509.20	1316.58	741.49	575.09	1497.17	861.08	636.08	1840.48	1064.36	776.12
	Myocarditis and myocardia disease	21.66	11.59	10.07	18.83	10.11	8.72	17.74	9.67	8.08	16.27	9.05	7.23
Estimated YLLs	Aortic aneurysm	7.12	5.33	1.78	10.23	7.93	2.30	14.56	11.39	3.17	21.14	16.34	4.80
(10 thousands)	Other cardiovascular and circulatory diseases	74.76	41.30	33.45	135.23	76.17	59.06	209.64	119.16	90.48	317.13	176.80	140.33
	CVD total	5588.01	6654.56	4516.17	5236.78	6311.70	4157.92	4875.70	5965.12	3785.65	4511.04	5642.49	3407.04
	Rheumatic heart disease	182.49	151.77	211.61	141.26	121.05	160.38	103.13	92.53	113.09	72.71	70.70	74.41
	Hypertensive heart disease	340.19	380.29	298.12	350.12	393.74	304.39	355.17	401.71	306.48	354.70	403.97	304.37
	Ischemic heart disease	2179.15	2611.44	1734.57	2087.85	2518.37	1646.67	1992.59	2426.77	1549.90	1901.99	2353.52	1451.32
	Hemorrhagic stroke	1752.42	2173.41	1334.82	1496.91	1884.32	1111.47	1240.67	1593.09	889.55	995.09	1323.96	673.22
	Ischemic stroke	1042.45	1230.99	861.35	1032.43	1240.21	832.65	1018.33	1249.07	796.96	990.63	1249.21	752.01
	Myocarditis and myocardia disease	17.66	18.99	16.27	14.34	15.50	13.10	12.51	13.73	11.16	10.35	12.08	8.40
Age- standardized YLL rate	Aortic aneurysm	6.01	9.10	2.94	7.93	12.44	3.46	10.17	16.15	4.24	12.55	20.13	5.18
(per 100,000)	Other cardiovascular and circulatory diseases	67.64	78.56	56.48	105.93	126.07	85.81	143.12	172.07	114.26	173.02	208.91	138.12

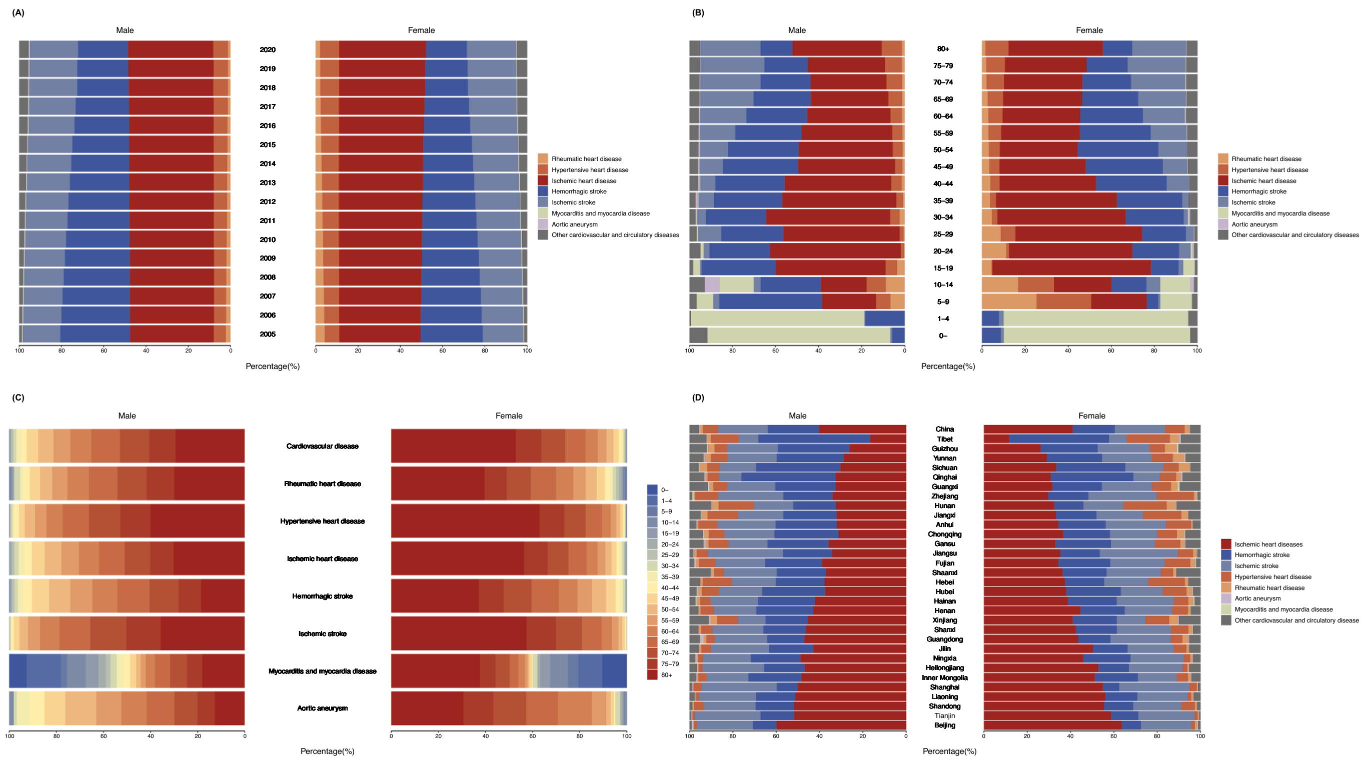

Fig. 1. Percentage of YLLs for CVD by selected characteristics.
(A) Percentage of YLLs for CVD and its subcategories in China, by subcategories and sex, 2005–2020;
(B) Percentage of YLLs for age-specific CVD in China, by subcategories and sex, 2020;
(C) Percentage of YLLs for CVD and its subcategories in China, by age and sex, 2020;
(D) Percentage of YLLs for CVD in China and its provinces, by subcategories and sex, 2020.

	All ages	0–14 years	15–29 years	30–44 years	45–59 years	60–74 years	75+ years
China	−1.43	−9.48	−0.64	−0.86	−1.92	−2.4	0.02
Beijing	−2.52	−8.37	0.71	−3.05	−1.76	−3.45	−1.9
Tianjin	−3.07	−9.11	−1.23	−2.98	−3.85	−4.61	−1.45
Hebei	−0.82	−15.8	1.85	−0.27	−0.22	−1.44	−0.05
Shanxi	0.11	−2.17	0.85	0.42	−0.83	−0.96	1.84
Inner Mongolia	−2.76	−8.09	−3.48	−2.89	−3.39	−3.59	−0.95
Liaoning	−1.55	−8.34	0.12	−1.28	−1.9	−2.49	−0.03
Jilin	−1.34	−8.34	0.45	−1.09	−1.44	−1.84	−0.26
Heilongjiang	−0.89	−6.59	1.94	−0.49	−0.75	−1.27	−0.18
Shanghai	−0.16	−10.14	−19.77	−6.42	−1.81	−2.27	2.3
Jiangsu	−2.42	−1.48	−1.62	0.28	−2	−3.8	−1.48
Zhejiang	−2.2	−5.6	−2.1	−0.59	−3.04	−4.4	−0.36
Anhui	0.25	−11.23	−0.59	2.71	−0.31	−1.08	1.87
Fujian	−1.79	−1.63	1.97	−1.82	−2.79	−3.9	−0.16
Jiangxi	−2.58	−19.17	−4.88	−0.17	−3.64	−4.24	−0.46
Shandong	−0.43	−8.67	1.14	0.91	0.19	−0.92	0.24
Henan	−0.56	2.14	2.68	0.17	−1.35	−1.83	0.92
Hubei	−1.47	−7	−4.08	−1.72	−3.73	−3.41	1.58
Hunan	−2.32	−12.29	−0.19	0.46	−2.44	−3.32	−1.22
Guangdong	−1.9	−12.21	−3	−0.82	−2.09	−3.13	−0.66
Guangxi	−0.92	−13.01	−1.87	−2.06	−0.71	−1.48	0.2
Hainan	−0.94	−8.26	0.9	0.98	−2.71	−1.66	0.43
Chongqing	−2.45	−18.91	−3.16	−3.84	−3.79	−3.47	−0.55
Sichuan	−2.06	−8.54	−3.06	−0.2	−2.78	−2.8	−0.83
Guizhou	−3.18	−16.38	−4.43	−3.61	−4.88	−4.13	−0.58
Yunnan	−1.12	−14.69	−0.95	−0.44	−1.35	−1.68	0.06
Tibet	−0.16	−17.97	−1.38	−0.81	−0.59	−0.29	1.36
Shaanxi	−1.96	−10.3	−2.11	−2.57	−3.8	−3.17	0.17
Gansu	−0.72	−9.86	1.31	0.26	−3	−1.39	1.22
Qinghai	−0.44	−12.6	−2.77	−0.25	−1.85	0.33	0.95
Ningxia	−1.29	−19.16	−2.85	−0.49	−2.12	−2.97	0.63
Xinjiang	−1.17	−5.73	−2.65	−1.58	−1.77	−1.09	−0.61

Annual Rate of Change(%)
5
0
−5
−10
−15
−20

Fig. 2. ARC heatmap of age-specific YLL rate for total CVD in China and its provinces, 2005–2020.

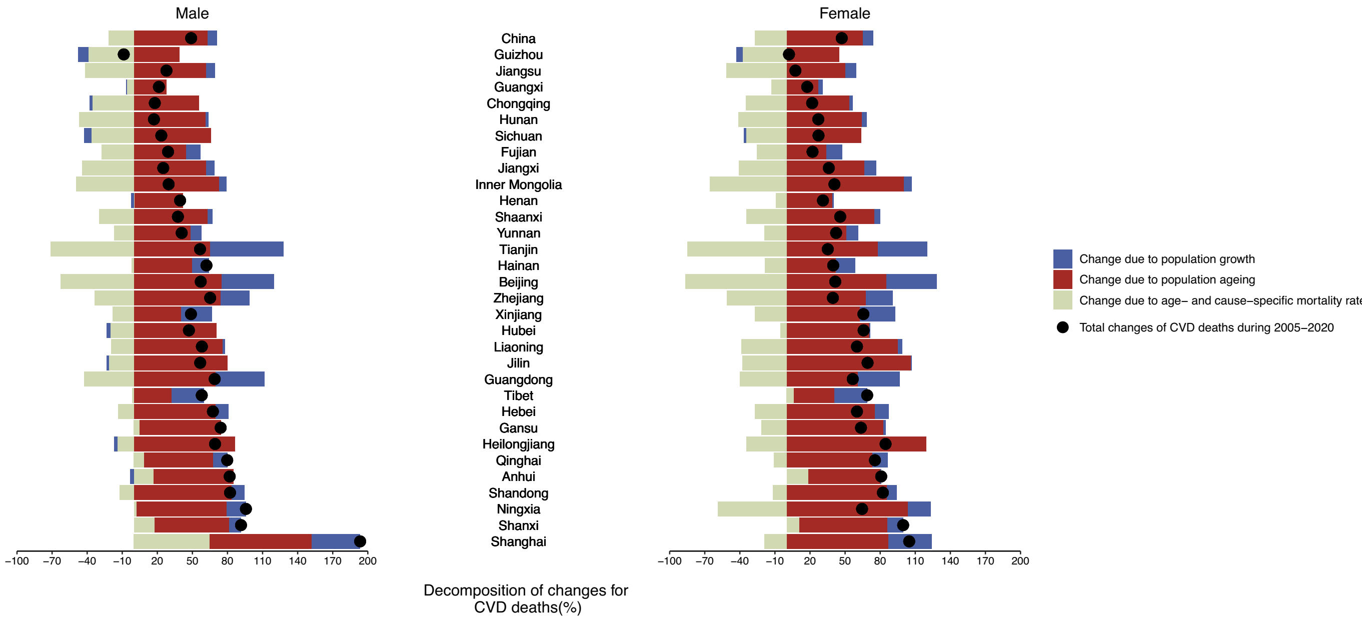

Fig. 3. Decomposition of changes for total CVD deaths in China and its provinces, by sex, 2005–2020.

patients' cardiovascular risk factors, which may be explained by disparate ethnic and regional backgrounds, encompassing both genetic and cultural contexts [20]. (ii) Differences in individual and regional socioeconomic status, either within [21] or between countries [22]; (iii) Differences in performance of national or regional healthcare systems and hospital characteristics [23]; (iv) Differences in local standard clinical practice in terms of the therapies, invasive strategies and post-discharge medication [18,19]. Therefore, suggestions concluded from those studies could also be generalized extensively to reduce CVD premature mortality burden locally.

As for CVD subcategories, in clinical settings, IHD and IS has been increasingly been recognized as a single type of atherosclerotic CVD (ASCVD) both in China and international guidelines on the prevention and treatment because of shared pathologies in the arteries, shared risk factors, and shared strategies for primary and secondary prevention [24,25]. Although previous studies had reported a substantial increase of ASCVD burden [26], a slightly decline ASMR of IHD and a stable trend of IS were observed in this study, but with a moderate increase of fraction among total CVD premature mortality burden. Therefore, classifying ASCVD as a combined type of CVD for the purposes of developing, implementing and evaluation general prevention strategies was reasonable, but separate information on IHD and IS was also helpful because of different management strategies during acute period and different rehabilitation needs for IHD and IS [26]. For example, a high rate of out-of-hospital deaths from IHD, such as acute coronary heart disease (CHD), with insufficient prehospital care like low rate of cardiopulmonary resuscitation still remained a widespread problem with little improvement, especially in rural areas [26–28]. Efforts are needed to improve the provision of prehospital care such as the introduction and practice of chest-pain centers across the country [26,29]. During 2005–2020, being as the second leading CVD cause, an around 40% premature mortality burden reduction for HS was observed, which was similar to previous studies [2,30]. The reason might be attributed to a decline in HS case fatality rate as a result of improved medical treatment in the precondition of stable HS incidence [26,30]. Nevertheless, China remained one of the countries with the highest burden of HS in a study involved in 110 countries, HS mortality were nearly twice as the global average [30]. For RHD, although a decline was observed in this study that similar to a research which stated the reduction occurred at almost entirely in high- and upper-middle-income countries, the premature mortality burden of China still higher than global average [31]. Supports pledged from the American Heart Association (AHA) were imperative for RHD prevention, including professional healthcare work education, technical support for implementation of evidence-based strategies, access to essential medications and treatment, advocacy to increase population awareness, resources and capacity [32,33]. HHD and AA were only 2 subcategories with moderate trends of increase, which might be attributed to shared metabolic risk factors, such as elevated blood pressure along with atherosclerosis [34]. Initiatives to improve public awareness and management of behavior and metabolic risk factors, especially for vulnerable population who at high risk, were necessary [34].

Sex and age-specific disparities of CVD premature mortality burden were presented substantially among its subcategories. Compared with men, women experienced less severe burden of CVD premature mortality, and more likely to occur CVD death at an older age. One plausible reason was men were inclined to be frequent exposed to CVD risk factors, such as unhealthy lifestyles, mental pressure, inadequate medical treatment and health management. Among total CVD and majority of its subcategories, the elderly aged 75 years and above contributed over 50% of premature mortality burden overall. Based on the decomposition of death change, even though population ageing was the dominant driver of considerate increase for total CVD deaths, it seldom reported in most of the cases as it was regarded as an unmodifiable risk factor [26]. Actually, ageing CVD patients exerted challenges beyond merely a large number of older individuals. Notably, much of the evidence for primary and secondary prevention and emergency care strategies were derived from randomized controlled trails (RCT) that including only or most participants aged younger than 75 years, and, most ageing patients with CVD had multimorbidity [35,36]. Since inadequate guidelines have clear recommendations for ageing group, understanding the effects of ageing on premature mortality burden of CVD in China was imperative to identify major issues to be addressed in further research and to develop effective strategies to deal with [26]. Additionally, an evident decline in age-specific mortality of total CVD has made a great contribution to minimize deaths, for younger age group reduced significantly while the older age group remained stable or even increased. This decline in the mortality of infants, children and young teenager in most provinces may be related to the enforcement of life-saving health policies and interventions, rapid development of medical standards and essential treatment, as well as maternal education [2,3,6]. Different from other types of mortality patterns, higher fraction of MMD deaths occurred in younger age were partly due to disease characteristics and specific reasons like genetic, infectious, metabolic or endocrine factors, and targeted approaches should be strengthened for high risk population [37].

Distribution of CVD premature mortality burden and its change over time demonstrated substantial geographical variations across the country. CVD mortality of developed provinces such as Shanghai, Zhejiang and Jiangsu had approached or even exceeded the level of developed countries, the western and northeastern regions were generally lower than the national average, and the situation in such provinces like Tibet, Inner Mongolia and Heilongjiang were still not optimistic. Fortunately, most underdeveloped provinces were catching up at a growth rate much higher than that of developed provinces, especially in Guizhou and Inner Mongolia, where total CVD age-standardized YLL rate had decreased more than 30% during past 16 years. However, a few provinces in non-eastern regions having a positive change for CVD mortality, such as Anhui and Shanxi. Herein, for shifts and geographical variations at provincial level for total and cause-specific CVD mortality, it might be largely due to unequally distributed of CVD risk factors and healthcare services [3,4,26,38]. Therefore, it is necessary to further eradicate the health inequity of regional development, intensify supportive policies to under-developed regions, and attach importance to rationalize healthcare resource allocation. At the same time, attentions should be paid to those areas that affected largely by population ageing, such as Heilongjiang, Jilin and Shandong, the transformation of lifestyles and the popularization of health care knowledge among high risk population should be actively promoted to maintain health and reduce CVD premature mortality burden [26].

Nationwide, population ageing was the dominant driver of increase total CVD deaths, shifts in age-sex-specific CVD mortality rate contributed to decrease total CVD deaths substantially, and population growth exerted both positive and negative effects on total CVD deaths change. The magnitude and trends of CVD epidemic in China are directly affected by population ageing, levels of risk factors, quality of medical care and inequity of healthcare resources, however, these parts are deeply rooted in large-scale socioeconomic and lifestyle changes in whole population [26]. Therefore, CVD epidemic nationwide posed a number of major challenges for healthcare system in various areas, not only for primary care but also for clinical care [17]. Currently, CVD risk factors still remained prevalent among community settings, such as smoking, drinking, physical inactivity, high body mass index (BMI), elevated blood pressure, especially on the condition of population ageing. Nonetheless, being as intermediate diseases for CVD development and mortality, the inadequate rates of awareness, treatment, control for hypertension, hyperlipoidemia or diabetes have profound and complex underlying contributions towards CVD epidemic [3]. While in clinical settings, the availability and affordability of medications, the quality of medical care, the adherence to treatment among patients, and the proper handling for secondary prevention after discharge provided by professionals, might all exert influences on the issue. Fortunately, the challenges in China also create opportunities [17,26,39,40]. One of which that has been arisen in the political realization, for the whole-of-government and whole-of-society policy should be regarded as the priority to guide actions against CVD. Besides, the healthcare system needed to be reformed to adapt the concurrent pressure from CVD epidemic along with population ageing, it should be able to provide continuous life-long services in combination with three levels of CVD prevention rather than discontinuous and fragmented services. Additionally, the rationality of healthcare resource allocation was urgently needed to address substantial health inequity. Furthermore, researches needed to be strengthened to develop evidence-based, low-cost, practical and scalable interventions for CVD patients [17,26,39,40].

To our knowledge, this study was one of the limited researches that provided a comprehensive and explicit estimates of premature mortality burden caused by CVD in China. By using high quality data from NMSS, we demonstrated comparable results by selected characteristics over time across the country. However, this study limited to several limitations. First, the classification of COD varied among different studies in community and clinical settings, and we failed to categorize CVD types to even detailed ones, which may lead to the underestimate or overestimate for existing subcategories. Second, ascertainment bias caused by reporting accuracy of COD may attenuating the quantity and quality of CVD mortality estimation, but we worked to through garbage code redistribution for implausible diagnostic [12]. Third, we failed to present the result by urban/rural, since we roughly defined counties as rural areas and districts as urban areas, the vague classification may improperly interpret urban/rural disparities in guiding policies [5,41].

5. Conclusion

Overall, the CVD premature mortality burden in China remained high from 2005 to 2020, especially due to the rapidly population ageing and growing, its absolute increase could not be ignored. Marked heterogeneity was observed in sex-age-specific characteristics and geographical patterns for total CVD and its subcategories over time. Targeted considerations were needed to integrate primary care with clinical care through intensifying further strategies for reducing CVD mortality among specific subcategories, high risk population and regions with inadequate healthcare resources [3].

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2021.08.034.

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