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Cause of death decomposition among Chinese population in 1991-2019 by Gini coefficient and Mortality-Rate-Difference methods

Feiling Ai, MMed; Xia Wan, PhD

Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences &

School of Basic Medicine, Peking Union Medical College

#5 Dong Dan San Tiao, Dongcheng District, Beijing, China, 100005

Corresponding author: Xia Wan, E-mail: xiawan@ibms.pumc.edu.cn, Telephone: +86 010 6523 3870

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Abstract

Objectives As disease surveillance points systems (DSPs) improved, death causes among Chinese population become clearer. We therefore aim to present variations and drivers of multiple causes of death.

Design A cross-sectional surveillance design.

Setting Original data in 1991 and 2000, and secondary data in 2010 and 2019 were collected from DSPs.

Participants We collected standardized mortality rates (SMR) and crude mortality rates (CMR) among Chinese population derived from DSPs, in 1991, 2000, 2010, and 2019.

Main outcome measures Changes of Gini coefficient were decomposed into reranking (R) and proportionality (P) by using SMR, to identify variations of communicable, maternal, neonatal, and nutritional diseases (CMNN), non-communicable diseases (NCD), and injury. Then, the CMR difference was partitioned into demographic structure (DS) and non-demographic factors (NDFs) by mortality-rate-difference (MRD) method to better understand the drivers of changes in CMR over the past 30 years.

Results In 1991-2019, overall CMR has increased from 591.327/100,000 to 674.505/100,000, while SMR has always decreased. NCD had a larger concentration, as Gini index increased from 0.4429 to 0.5601 over time. Ranks of injury varied most (R=0.1735) in 1991-2019, in comparison with CMNN (R=0.0540) and NCD (R=0.0368). Specifically, the ranks of diabetes, falls, and road traffic accidents increased notably. The decreased SMR of NCD (P=-0.0127) was mainly caused by low-rank causes (i.e., endocrine disorders), while for CMNN (P=0.0030) and injury (P=0.1307), they were high-rank causes. The all-cause CMR rose by 14.07% in 1991-2019, resulting from higher contributions of DS (68.46%) than NDFs (-54.40%). DS accounted for a greater CMR increase in males (70.52%) and urban settings (75.58%).

Conclusions Prevention and control measures targeted NCD and certain causes have become imperative as the population ages, especially for males and rural populations. China must uphold its momentum to improve equitable and accessible health services, environmental quality, as well as health education.

Strengths and limitations of this study

- We introduced two new methods in this study. Firstly, Gini coefficients were used to quantify the variations of 160 death causes, and to reveal the changing trends and the relative importance of each cause. Secondly, the percentage of demographic and non-demographic factors contributing to the difference of crude mortality rate (CMR) was identified.
- We found that causes of death among Chinese population were increasingly centralized on non-communicable diseases, especially neoplasms and cardiovascular diseases over time. Moreover, the ranks of diabetes, road traffic accidents, and falls have increased dramatically in 1990-2019. These findings inform that strategies to prevent and control non-communicable diseases, particularly neoplasm and cardiovascular diseases, should be prioritized.
- We also found that the all-cause CMR rose by 14.07% in 1991-2019, which was mainly caused by the changes in demographic structure (68.46%), specifically, population aging, which showed that population aging will be the most influential factor of Chinese mortality in the coming future.
- There might be some discrepancy between original data and secondary data, however, these can be minimized through a standardized data clean process by health authorities.
- The CMR differences are too general, further exploration of non-demographic factors is needed.

Introduction

Over the past 30 years, China has gradually shifted from the periods of demographic dividend to demographic burden, with slower population growth, faster aging, and severer sub-replacement fertility[1]. The latest national population census showed that population aged 65 and above reached 190.64 million by 2020[2]. Along with the economic boom, people's living standards and medical services have improved significantly. Moreover, continuous attainments in health literacy, lower behavioral and environmental risks, were obtained, benefiting from the implementation of comprehensive disease prevention and control strategies[3]. In this case, there has been a marked shift in cause of death among Chinese population. The Global Burden of Disease Study (GBD) 2017 showed that non-communicable diseases (NCD), such as stroke, ischemic heart disease (IHD), lung cancer, and diabetes, were major causes of premature death, while the mortality rates of infectious diseases, maternal and infant diseases and nutritional deficiency diseases were declining in China[3]. The Chinese provincial disease burden report of cardiovascular disease (CVD) showed that CVD is a leading cause of death from 1990 to 2016, with nearly 1.5 million increased deaths from 1990[4]. By reviewing cancer registries in China, He Jie et al.[5] found that cancer death rose from 10.1% in 1973-1975 to 24.2% in 2015.

Presenting the changes of causes of death quantitatively is pivotal for policy marking, and health resource allocations. However, as prominent improvement in death causes registration has taken place, following increasing variations in causes of death, the mortality patterns are more unpredictable[6]. Previous studies focused on high-rank causes and presented information selectively. To date, the diversity of death causes and their relative importance is less discussed due to various classifications. In resemble studies, researchers introduced a modified Gini coefficient[7], to quantitatively evaluate whether changes in overall rates are disproportionately centralized to high-rank diseases. For example, analyzing the contribution of GBD to the total number of disability adjusted life years (DALYs)[8 9] and assessing changes of continuous indicators, such as obesity rates by body mass index (BMI) and waist circumference (WC)[10]. In our study, we performed a Gini coefficient decomposition method to quantify the variations and the relative importance of death causes among Chinese population over the past three decades. We further decomposed the crude mortality rate (CMR) difference in three periods to estimate the underlying determinants.

Methods

Data source

Data were collected from nationally representative disease surveillance points system (DSPs), with 605 points, covering over 300 million individuals at present[11]. Original data from 1991-2000, and secondary data from National Disease Surveillance System Death Monitoring Dataset in 2010 and 2019[11 12] were analyzed. The CMR was standardized by the census data from the National Bureau of Statistics of China in 2000[13]. We calculated the overall and cause-specific CMR, standardized mortality rates (SMR), as well as sex-specific, rural- and urban-specific mortality rates. Causes of death coded by ICD9 or ICD10 were grouped into three levels according to GBD 2010[14]. The first level contains communicable, maternal, neonatal, and nutritional diseases (CMNN), NCD and injury. The second level consists of main systems amongst primary categories: CMNN includes infectious and parasitic diseases, some infections, and nutritional deficiencies; NCD involves neoplasms, hematopoietic organs and immune diseases, endocrine and nutritional and metabolic diseases; and injury contains self-inflicted injuries, road traffic

accidents and drownings. Lastly, the secondary systems were further divided into specific causes, with two leading causes of NCD, malignant neoplasms and CVD.

Statistical methods

Firstly, we described overall and three categorical mortality rates, in three periods, 1991-2000, 2000-2010, and 2020-2019. Secondly, all-cause and cause-specific SMR were used to calculate Gini coefficient, then the overall variations of causes were presented by using Gini coefficient method[7]. Further, we divided CMR difference into demographic structure (DS) and non-demographic factors (NDFs) by using Mortality-Rate-Difference (MRD) method[15].

Gini coefficient decomposition

Gini coefficient (G), which is bounded between 0 and 1, indicates greater difference of various components with a larger value, which also means overall indicators are more concentrated to the major causes. The graphical representation of Gini coefficient is the Lorenz curve, with X-axis representing the cumulative share of death causes ranked from lowest to highest and Y-axis manifesting the cumulative share of total SMR. The closer the overall Gini coefficient curve to the diagonal represents more equal shares of each component (figure s1). The formula among different years can be expressed as[9]:

$$\Delta G = G_1 - G_0 \equiv R - P \quad (1)$$

$$R = G_1 - G_1^{(0)} \quad (2)$$

$$P = G_0 - G_1^{(0)} \quad (3)$$

G_1 and G_0 represent Gini coefficients in the 0th year and the 1st year, respectively. $G_1^{(0)}$ is the Gini coefficient in the 1st year based on the ranks in the 0th year. $G_1^{(0)}$ was also called the concentration coefficient. ΔG is the difference of Gini coefficient in different years, which can be decomposed into reranking (R) and proportionality (P) indicators. R represents the importance of Gini coefficient change attributing to reranking of causes, therefore, it shows the mobility of death causes. The higher R means greater rank changes, and the lower R denotes smaller changes. R varies between 0 and $2G_1$. When the rank is constant, R=0, and when the rank is completely reversed, R=$2G_1$. P indicates the change of Gini coefficient accounting for the proportion. P shows the change of Gini coefficient when ranking had been held constant at their original distribution, which means P is an indicator of the progressivity of death causes. The relationships among P values, aggregate rate and death causes are summarized in table s1.

Mortality-Rate-Difference

In MRD method, CMR was decomposed into DS and NDFs. DS refers to age distribution, and NDFs include socio-economic, health services, environmental and behavioral factors[16]. The basic principle is that CMR difference is equal to the sum of age structure difference (weighted by mean mortality rate) and mortality difference (weighted by age structure). Taking the mortality rates in 1991 and 2019 for example, the calculation steps are as follows[15]:

Step 1: Determine the population proportion and mortality rate by age group (5-year-old for one group) in 1991 and 2019.

Step 2: Calculate the difference of population proportion by age: $C_x^{2019} - C_x^{1991}$.

Step 3: Calculate weight 1: $(M_x^{2019} + M_x^{1991})/2$.

Step 4: Calculate the effect of age structure difference: $\sum_0^\infty (C_x^{2019} - C_x^{1991}) \times \frac{M_x^{2019} + M_x^{1991}}{2}$.

Step 5: Calculate age-specific mortality difference between 1991 and 2019: $M_x^{2019} - M_x^{1991}$.

Step 6: Calculate weight 2: $(C_x^{2019} + C_x^{1991})/2$.

Step 7: Calculate the effect of mortality difference: $\sum_0^\infty (M_x^{2019} - M_x^{1991}) \times \frac{C_x^{2019} + C_x^{1991}}{2}$.

All the analyses were conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and Python Jupyter.

Results

Overall trends

The total CMRs of were 591.327/100,000, 588.693/100,000, 575.385/100,000, and 674.505/100,000 in 1991, 2000, 2010, and 2019, separately. The CMR increment of males was more than three times of females, and urban CMR was prominently higher than that of rural in 1991-2019, while the all-cause SMR decreased from 637.29/100,000 to 376.78/100,000. The all-cause SMR in males and rural populations declined more slowly in 2000-2010 than in other decades. The SMRs of CMNN, NCD, and injury have been fallen in each decade. The SMRs in males were higher than that of females, and they had a similar decline trend. In rural settings, the decreasing tendency of SMR was close in 1991-2000 and 2010-2019, and they were fluctuated in 2000-2010, with a faster decline in NCD, and a comparatively steady change in CMNN and injury (figure s2). The overall Gini coefficients (G) were 0.4429, 0.5024, 0.5407, and 0.5601 in 1990, 2000, 2010 and 2019, respectively. The continuing increase of G values indicates the expanding difference of the SMR's proportion among three categories. The trends in males, females, and rural residents were consistent with the overall changes, and the gap in urban residents peaked in 2000. Specifically, death causes were more concentrated on NCD, with its proportion increasing from 75% in 1991 to 90% in 2019. Accordingly, CMNN and injury accounted for a much smaller proportion falling from 13% and 12% to 3% and 7%, respectively (figure 1). The MRD decomposition showed that DS has increased CMR, while NDFs have reduced CMR in each decade. In 1991-2019, DS had a greater positive impact on all-cause CMR (68.46%) than the negative impact from NDFs (-54.40%). As a result, the all-cause CMR increased 83.187/100,000 (14.07%). In 2010-2019, the contribution of DS reached maximum with an increasing CMR (46.54%). The proportion of male DS contributed to a higher CMR increase (70.52%) than that of females (67.02%), and the CMR proportion accounting for DS in urban (75.58%) was higher than that of rural (66.49%) over the past three decades (table 1).

Variations of NCD

In NCD, the G continued to augment from 1991 to 2019, with values of 0.7396, 0.7542, 0.7827, and 0.7890, respectively. R value was 0.0368, with increased ranks of neoplasms, neuro-psychiatric conditions, diabetes, musculoskeletal and connective tissue diseases, skin diseases, and non-malignant neoplasms, and decreased ranks of respiratory disease, digestive diseases, genitourinary diseases, congenital anomalies, and sensor organ diseases. In 1991, CVD (44.73%) and respiratory diseases (31.55%) were two major causes. In 2019, CVD (53.22%) still ranked first, following by neoplasms (27.23%), while respiratory diseases (9.95%) dropped to the third place. It's worth noting that, the rank of diabetes increased from 8th to 4th, while congenital anomalies dropped from 6th to 11th. In 1991-2019, P value of NCD was negative (-0.0127), in combination with the falling SMR, which showed that the decline of NCD's SMR was caused by the low-rank causes (endocrine disorders, musculoskeletal, and connective tissue diseases, sensor organ diseases, skin diseases, oral diseases, and non-malignant neoplasms) (table s1). Ranks of NCD varied most in 1991-2000, and they have stabilized since 2000, with R values being 0.0057, 0.0018, and 0.0003 in 1991-2000, 2000-2010, and 2010-2019. The corresponding P values were always negative (-0.0089, -0.0267, and -0.0060). Similarly, low-rank causes were the main drivers among each decade. Male's rank had major changes in 1991-2000 (R=0.0098), while that of female's occurred in 2000-2010 (R=0.0140). P was negative in females and males, both ascribed to low-rank causes. According to the variation of G, rural mortality difference was expanding

over time. Similarly, both rural and urban settings have been driven by the decline of low-rank causes (table 2 & table s2). MRD analysis indicated that DS has increased the CMR, while NDFs have decreased the CMR over time. Both contributions have peaked in 2010-2019. Overall, the CMR of NCD increased by 183.829/100,000 (44.53%), mainly due to DS (85.79%) in 1991-2019. The fall of CMR difference in males (222.753/100,000) was markedly higher than that of females (144.013/100,000). Specifically, the contribution of DS to CMR in males (88.54%) was slightly higher than that of females (83.72%). By contrast, the absolute values of NDFs were higher in females (-44.97%) than that of males (-39.30%). Rural settings had higher DS contributions (87.24%) than that of urban (80.29%); while urban settings had higher NDFs (-50.75%) contributions than that of rural (-36.10%) (table 3). Among NCD, CVD and neoplasms were two leading systems. In terms of CVD, the top three causes were cerebrovascular disease, ischemic heart disease (IHD), and hypertensive heart disease (HHD). The proportion of IHD rose from 15.41% to 40.45%, while HHD dropped from 14.58% to 7.25%, and there were always more females than males from 1991 to 2019. P was negative invariably in 1991-2019, denoting that low-rank causes (HHD, rheumatic heart disease, and other cardiovascular diseases) were major determinants. Neoplasms' rank mainly changed in 1991-2000 (R=0.0065). By 2019, trachea, bronchus, and lung cancers (29.22%) ranked first, followed by liver cancer (15.04%) and gastric cancer (12.05%). It was the decline of high-rank causes (gastric cancer, liver cancer, esophageal cancer, leukemia, mouth, and oropharynx cancers) that resulted in overall decline of neoplasms' SMR (P=0.0800) in 1991-2019 (table s3, table s4). DS has continuously increased CMR of CVD and NCD, while NDFs have increased their CMR before 2010, and then decreased their CMR. Generally, NDFs made little influence on neoplasms (-4.51%) and CVD (-4.41%) in 1991-2019, with similar changes between different sex. In urban settings, NDFs contributed negatively to neoplasms (-34.65%) and CVD (-35.36%) in 1991-2019, while in rural settings, NDFs have represented positive impacts before 2010 (table s5).

Variations of CMNN

The changes of Gini coefficients in CMNN showed that the cause-specific difference increased in 1991-2010 and decreased in 2010-2019. CMNN was always dominated by infectious, parasitic diseases (30-40%), and respiratory infections (35-55%). The major rank changes were the increase of respiratory infections and the decrease of infectious and parasitic diseases. The fall of high-rank (P=0.0030) death causes (infectious and parasitic diseases) resulted in decreased SMR of CMNN. Over the past 30 years, the cause-specific difference (G=0.5091, R=0.0304) in males was higher than that of in females (G=0.4649, R=0). The fall of male SMR was predominantly caused by high-rank causes (infectious and parasitic diseases) (P=0.0180), and in females, they were caused by low-rank causes (pregnancy, childbirth, and puerperal complications) (P=-0.0743). In 1991-2019, there were not any special changes of CMNN in rural and urban settings, and the variations in urban settings were greater than those in rural areas (table 2 & table s2). In the past 30 years, CMNN's CMR has decreased 51.458/100,000, with major contributions of NDFs (90.17%), and DS represented positive contributions since 2000. In 1991-2019, males and females had similar contributions. DS contributed a higher share to urban CMR increase (60.80%) than rural (15.51%). By comparison, NDFs had higher contributions in rural (91.04%) than in urban settings (79.40%). Nevertheless, DS made a decreased CMR in rural settings in 1991-2000, and NDFs made an increased CMR in urban settings in 2000-2010 (table 3).

Variations of Injury

In 1991-2019, overall Gini coefficient of injury remained stable, with 0.51-0.56. Particularly, the rank of falls rose from 6th in 1991 to 2nd in 2019, and the rank of road traffic accidents increased from 3rd to 1st. By contrast, self-inflicted injuries fell from 1st to 3rd. In urban settings, R was smaller (0.0348),

indicating tiny rank changes of specific causes. The leading causes of injury have shifted from self-inflicted injuries (32.33%), road traffic accidents (14.78%), and drownings (14.63%) in 1991 to road traffic accidents (31.14%), falls (27.09%), and self-inflicted injuries (13.35%) in 2019. The decreases in the proportion of high-rank causes (self-inflicted injuries and drownings) led to the SMR decrease of injury (P=0.1307) in 1991-2019 (table 2 & table s2). Injury's CMR decreased constantly, presenting the highest decline in 1991-2000 with 10.925/100,000 and predominately caused by negative impact of NDFs. The highest contributive proportion was presented in 2010-2019. Males (23.08%) and females (24.91%) had similar DS contributions in 1991-2019. Differently, NDFs had higher contributions in females (65.05%) than in males (45.87%). In 1991-2019, DS contributions were higher in urban (37.81%) than that of rural settings (22.67%), while NDFs contributions in rural settings (53.89%) were higher than that of in urban settings (36.13%). Particularly, overall CMR increased by 0.600/100,000 in 1991-2019 caused by higher DS contributions (37.81%), and urban CMR increased by 1.692/100,000 in 2000-2010, and NDFs represented positive contributions (0.49%) (table 3).

Discussion

Overall findings and causes

Generally, China has made notable progress in reducing mortality since 1990s, as the SMR keeping falling. These achievements ascribe to the improvement of healthcare and medical services, such as increasing the coverage of universal health insurance, utilizing artificial intelligence in clinical scenarios, et al[17]. Specifically, NCD's proportion has increased and the cause-specific difference has expanded constantly since 1991. However, CMNN has some fluctuations over time, which has decreased since 2010. As for injury, major changes occurred among males and urban populations. The low-rank causes were the paramount contributors to the decreasing SMR of NCD. By contrast, the high-rank causes resulted in the fall of SMR in CMNN and injury. In 1991-2019, DS led to an increasing CMR, while NDFs caused a decreasing CMR, with the greatest contributions in 2010. As the population ages, the DS explanation percentage for the increased CMR in urban and male populations has becoming larger.

Over time, Chinese mortality are more centralized on NCD, which is in accordance with previous studies, showing an escalating health loss doubled from over 40% in 1991 to 85% in 2019[3]. Of note, the cause-specific differences of CVD and neoplasms were expanding over time. To fight with NCD, serial national policies have been implemented since 1990, such as Guidelines for Chronic Disease Prevention and Treatment, National Healthy Lifestyle Initiative[18], Healthy China 2030 Plan[19], China's Medium- and Long-Term Plan for the Prevention and Control of Chronic Diseases (2017-2025)[20] and National Nutrition Plan (2017-2030)[21]. Beyond that, abundant health promotion programs were performed. In 1991-2019, NDFs have led to the fall of NCD, females declined more than males, and urban settings fell more than rural settings. Absolute contributing value of NDFs was higher in females than that of males, which might pertain to unbalanced risk distribution, for instance, higher smoking rates in males (about 50%) than that of females (around 3%)[22], and higher alcohol consumption rates in males (53.8%) than that of females (12.2%)[23]. In urban and rural settings, NDFs had a lower effect on rural populations, indicating that health strategies in rural areas are underdeveloped. Studies have shown that high prevalence of NCD is closely related to tobacco, harmful alcohol use, unhealthy diet, physical inactivity, obesity, and environmental pollution, et al[24 25]. Environmental pollution, tobacco use, and unhealthy diet are nowadays the most crucial factors in China. Firstly, outdoor (PM2.5 exposure) and indoor (coal burning and second-hand smoke exposure) air pollutions are of great concern. To tackle this, the Chinese government increased policy and financial support, such as National Action Plan for the Prevention and

Control of Air Pollution (2013-2017)[26] and Prime Minister's Fund, which resulted in remarkable environmental improvement[27 28]. According to the latest released Global Air Quality Guidance (2021) (AQG)[29], there are still gaps. Moreover, due to the cumulative and lagging effects of environmental pollution[30], more plans are warranted. Secondly, water pollution was under the spotlight all the time, the state has taken several measures, such as Interim Regulations on the Prevention and Control of Water Pollution in the Huaihe River Basin[31]. As a result, digestive neoplasms mortality was lowering. So far, tobacco use is still a tough problem in China. Although there is some progress in tobacco control, such as legislation[32 33], protecting approximate 195 million individuals (13.5%)[34], the smoking rates were still high in China. The goal of reducing smoking rates to 24.5% and 20%, increasing smoke-free legislation coverage to 30% and 80%, by 2022 and 2030 are still unreached[35], indicating that more stringent measures (i.e., national smoke-free legislation) are warranted. In diet, Chinese have a favor of pickled, smoked, or fried food, nevertheless, intake of fruit, whole grains, and nuts are insufficient, which leads to diets with high levels of fat, protein, calory and low level of fibrin[36]. What's worse, people used to eat hot, brown food, and eat too fast. These unhealthy eating habits pose great risks to digestive system. In addition, we found that both mortality rates and ranks of diabetes increased dramatically during the past 30 years. Diabetes is a crucial disease that we should attach more importance on, as a country with the largest number of diabetics around the world (about 129.8 million)[37], while there are various patients undiagnosed yet. Diabetes is a metabolic disease, and which is mainly related to unhealthy diet, physical inactivity, and alcohol consumption, et al[38]. Remarkably, other than behavioral factors, prediabetes and high blood pressure are also unfavorable causes[38]. Comprehensive measures targeted at diabetes prevention, diagnosis, and treatment are imperative. Moreover, our study identified that NDFs had little effect on neoplasms and CVD, revealing that disease management and control were insufficient. Hence, national strategies, comprehensive community interventions and other measures should continue to intensify[18]. Besides, the development of basic innovation research and breakthrough therapy should be highlighted to reduce mortality in the clinical stage.

In CMNN, we found its proportion has fallen significantly from 1991 to 2019. Special actions targeted meningitis, tetanus, measles, diarrhea, et al have made notable progress[25]. Besides, the direct reporting network system of communicable diseases has been established to help authorities obtain the latest information. In the 1990s, due to the uneven development of rural and urban settings, there was large mortality difference. As primary care and public health services improved, and plans toward extreme poverty-stricken area carried out, healthcare accessibility is expanding to mitigate the gaps[39]. Communicable disease prevention and control, however, are still challenges, for instance, the ongoing COVID-19 pandemic.

There was a dramatic reduction in self-inflicted mortality among injuries over time, especially in rural populations and females. By contrast, falls and road traffic accidents had a notable rise. In the 1990s, the Chinese suicide rate was 23.2/100,000, and the rate in rural is over three times higher than that of urban[40]. Due to the fast-growing economy, urbanization, and increasing social concern, the overall suicide rate has been rapidly declined[41], however, they are transitioning to elderly predominance[42]. Recently, falls have become the leading death cause among the elderly, which mainly occurred in leisure activities, household chores, and other daily activities[43]. In addition, vehicles increased sharply in China, causing large amounts of pedestrians (42%), motorcyclists (25%), and vehicle passengers (17%) died from road traffic accidents[44]. In order to lower the injury rate, it calls for integrated solutions. To precent suicide, we can set helplines, limit pesticide supply and concern mental health. To reduce fall injury, we

should endeavor to create safer environments for the elderly. Additionally, urban planning, road infrastructure construction, and legislation should be strengthened due to frequent road traffic accidents.

We also found that the contributing proportion of DS to CMR was a dominating factor and they are increasing over time. In 2020, there is 13.50% population aged 65 and over in China, far above the international aging standard of 7%[2], which reveals that China has entered into speeding aging society. In the past 30 years, Chinese life expectancy has been increased by 10 years[45]. Hence, long-term care setting to meet the needs of elderly is still impreative[46]. Simultaneously, the fertility rate has declined from 6.71 in 1950 to 1.70 in 2019[1]. To tackle the situation, Chinese government has liberalized the childbearing policy gradually[47 48]. However, there is still a long way to go.

Strengths and limitations

In this study, we used two methods to quantify the diversity and changing trend of death causes among Chinese population in 1991-2019. At first, we presented the validity of Gini decomposition approach as a way of identifying variations for multiple death causes. It offers a statistical description on the rising or falling concentration among leading causes, and reveals whether the significant reranking has taken place. Moreover, according to proportionality combined with a changing general rate, the predominant causes leading to falling rates of systematical death causes are becoming more important relative to higher- or lower-ranked causes. Meanwhile, the CMR differences were decomposed into DS and NDFs by MRD method, which implies the degree of age structure shift and other combined factors contributing to mortality increase or decrease. According to these two approaches, we depicted the overall profile of death causes, and our findings highlight the need for strengthening strategies targeted to the most imperative health issues. Moreover, as we have known the mortality distribution, we can estimate disease burden in future research.

Our study had some limitations. Firstly, some underlying discrepancies might exist between the original and secondary data, however, which can be minimized by standardized operation procedures of data clean and quality control. Secondly, while Gini index and its indicators reranking and proportionality are useful to identify the variations of death causes, its implications are abstract, further interpretations as shown in our study are needed. Thirdly, two components maybe not depict a clear picture of actual determinants of CMR fluctuations, hence, further explorations are warranted.

Conclusion

In summary, our study helps policymakers to decide whether resources need to be reoriented to meet the changing public health challenge by introducing two methods to present the variations of death causes. We found that NCD, especially neoplasm and cardiovascular diseases should be prioritized. Moreover, targeted strategies toward causes with a surging number of deaths (diabetes, road traffic accidents, and falls et al.) should be strengthened. As population ages, China must hold its momentum to improve equitable and accessible health services, environmental quality, and health education, especially for males and rural populations.

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Contributors

Wan Xia designed the study concept and obtained the original data. Ai Feiling managed data, implemented methods, wrote the first draft of the paper. Wan Xia and Ai Feiling contributed to the revision and finalization of the paper, and had full access to all data used in this study, both checked and

verified the data used in the analysis. The corresponding author was responsible for submitting the article for publication.

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Disclaimer

The funders of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report.

Competing interests

The authors declare no competing interests.

Patient and Public involvement

No patient or public were involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not required.

Ethics approval

The research is based on open-source data, so there are no ethical issues and other conflicts of interest.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

The death data in 1991-2000 were not publicly available but are available from the corresponding author on reasonable request. The data in 2010 and 2019 were public accessible to all through published book National Disease surveillance system cause-of-death surveillance dataset.

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Table 1: Decomposition of overall crude mortality rate difference, in 1991-2019

	Mortality Difference	Demographic Structure	Non-demographic Factors
Total			
1991-2000	-2.634	15.37%	-15.82%
2000-2010	-13.308	8.90%	-11.16%
2010-2019	99.120	46.54%	-29.31%
1991-2019	83.178	68.46%	-54.40%
Male			
1991-2000	11.552	16.21%	-14.41%
2000-2010	12.580	10.09%	-8.17%
2010-2019	101.845	43.69%	-28.44%
1991-2019	125.977	70.52%	-50.94%
Female			
1991-2000	-13.470	14.53%	-17.04%
2000-2010	-43.257	7.14%	-15.42%
2010-2019	97.202	51.68%	-31.40%
1991-2019	40.475	67.02%	-59.47%
Urban			
1991-2000	50.544	22.99%	-13.47%
2000-2010	-40.520	13.27%	-20.24%
2010-2019	92.106	39.18%	-22.14%
1991-2019	102.130	75.58%	-56.33%
Rural			
1991-2000	-16.376	13.31%	-15.99%
2000-2010	3.942	4.13%	-3.46%
2010-2019	99.590	52.28%	-35.58%
1991-2019	87.156	66.49%	-52.18%

Table 2: Gini coefficients, reranking, and proportionality of secondary causes, in 1991-2019

	Both	Male	Female	Urban	Rural
CMNN					
Gini index					
G1991	0.4396	0.4967	0.3905	0.4645	0.4435
G2000	0.4523	0.4693	0.4367	0.4874	0.4504
G2010	0.5058	0.5206	0.4897	0.5578	0.4731
G2019	0.4906	0.5091	0.4649	0.5393	0.4623
Reranking					
R1991-2000	0.0702	0.0501	0.0180	0.0868	0.0658
R2000-2010	0.0000	0.0000	0.0430	0.0000	0.0000
R2010-2019	0.0000	0.0000	0.0000	0.0000	0.0000
R1991-2019	0.0540	0.0304	0.0000	0.1321	0.0208
Proportionality					
P1991-2000	0.0575	0.0774	-0.0282	0.0639	0.0589
P2000-2010	-0.0534	-0.0512	-0.0100	-0.0704	-0.0227
P2010-2019	0.0152	0.0114	0.0248	0.0185	0.0108
P1991-2019	0.0030	0.0180	-0.0743	0.0573	0.0019
NCD					
Gini index					
G1991	0.7396	0.7390	0.7413	0.7469	0.7420
G2000	0.7542	0.7569	0.7522	0.7564	0.7553

G2010	0.7827	0.7849	0.7800	0.7758	0.7871
G2019	0.7890	0.7902	0.7887	0.7824	0.7922
Reranking					
R1991-2000	0.0057	0.0098	0.0022	0.0020	0.0021
R2000-2010	0.0018	0.0006	0.0140	0.0000	0.0133
R2010-2019	0.0003	0.0000	0.0003	0.0011	0.0001
R1991-2019	0.0368	0.0367	0.0382	0.0057	0.0368
Proportionality					
P1991-2000	-0.0089	-0.0082	-0.0087	-0.0075	-0.0112
P2000-2010	-0.0267	-0.0273	-0.0138	-0.0194	-0.0185
P2010-2019	-0.0060	-0.0053	-0.0084	-0.0056	-0.0050
P1991-2019	-0.0127	-0.0145	-0.0092	-0.0298	-0.0134
Injury					
Gini index					
G1991	0.5153	0.4883	0.5613	0.4337	0.5356
G2000	0.5210	0.5189	0.5557	0.4976	0.5405
G2010	0.5582	0.5681	0.5506	0.5636	0.5604
G2019	0.5582	0.5675	0.5453	0.5652	0.5565
Reranking					
R1991-2000	0.0260	0.0449	0.0440	0.0218	0.0216
R2000-2010	0.0290	0.0270	0.0423	0.0312	0.0668
R2010-2019	0.0172	0.0162	0.0136	0.0010	0.0308
R1991-2019	0.1735	0.1829	0.1643	0.0348	0.1665
Proportionality					
P1991-2000	0.0203	0.0142	0.0496	-0.0420	0.0167
P2000-2010	-0.0081	-0.0222	0.0474	-0.0348	0.0469
P2010-2019	0.0172	0.0168	0.0189	-0.0007	0.0347
P1991-2019	0.1307	0.1036	0.1803	-0.0966	0.1456

CMNN=communicable, maternal, neonatal, and nutritional diseases; NCD=non-communicable diseases.

Table 3: Decomposition of secondary crude mortality rate difference, in 1991-2019

	Mortality Difference	Demographic Structure	Non-demographic Factors
CMNN			
Both			
1991-2000	-37.851	-7.80%	-43.31%
2000-2010	-11.752	12.09%	-44.54%
2010-2019	-1.855	40.32%	-47.90%
1991-2019	-51.458	20.69%	-90.17%
Male			
1991-2000	-37.970	-7.24%	-42.32%
2000-2010	-10.724	12.52%	-40.27%
2010-2019	-1.623	37.87%	-43.69%
1991-2019	-50.317	22.23%	-87.91%
Female			
1991-2000	-34.403	-9.52%	-39.42%
2000-2010	-15.038	12.80%	-54.68%
2010-2019	-2.060	44.88%	-54.76%
1991-2019	-51.501	19.45%	-92.70%
Urban			

1991-2000	-12.337	13.50%	-53.14%
2000-2010	6.253	12.14%	21.15%
2010-2019	0.294	44.66%	-43.49%
1991-2019	-5.790	60.80%	-79.40%
Rural			
1991-2000	-43.209	-8.95%	-40.93%
2000-2010	-19.303	10.82%	-55.28%
2010-2019	-2.914	36.51%	-48.60%
1991-2019	-65.426	15.51%	-91.04%
NCD			
Both			
1991-2000	57.724	20.90%	-6.92%
2000-2010	20.313	9.85%	-5.53%
2010-2019	105.792	49.15%	-27.60%
1991-2019	183.829	85.79%	-41.26%
Male			
1991-2000	70.298	21.92%	-6.38%
2000-2010	38.546	11.02%	-3.65%
2010-2019	113.908	47.28%	-26.98%
1991-2019	222.753	88.54%	-39.30%
Female			
1991-2000	45.035	20.13%	-8.01%
2000-2010	0.877	7.91%	-7.70%
2010-2019	98.101	52.88%	-29.39%
1991-2019	144.013	83.72%	-44.97%
Urban			
1991-2000	53.215	24.01%	-11.73%
2000-2010	-17.682	14.72%	-18.35%
2010-2019	92.399	40.04%	-20.33%
1991-2019	127.932	80.29%	-50.75%
Rural			
1991-2000	58.201	19.52%	-5.22%
2000-2010	39.192	4.21%	4.21%
2010-2019	110.719	56.15%	-34.20%
1991-2019	208.112	87.24%	-36.10%
Injury			
Both			
1991-2000	-10.925	4.40%	-20.96%
2000-2010	-3.877	5.83%	-12.87%
2010-2019	-4.942	19.08%	-28.73%
1991-2019	-19.743	23.70%	-53.62%
Male			
1991-2000	-7.927	4.89%	-15.16%
2000-2010	0.988	6.68%	-5.25%
2010-2019	-10.642	14.36%	-29.52%
1991-2019	-17.581	23.08%	-45.87%

Female			
1991-2000	-13.746	3.64%	-28.95%
2000-2010	-9.183	4.44%	-27.07%
2010-2019	1.127	30.27%	-26.68%
1991-2019	-21.802	24.91%	-65.05%
Urban			
1991-2000	-0.756	9.78%	-11.90%
2000-2010	1.692	4.35%	0.49%
2010-2019	-0.336	17.86%	-18.77%
1991-2019	0.600	37.81%	-36.13%
Rural			
1991-2000	-12.987	3.64%	-21.02%
2000-2010	-1.699	5.29%	-8.04%
2010-2019	-8.647	20.99%	-35.39%
1991-2019	-23.334	22.67%	-53.89%

CMNN=communicable, maternal, neonatal, and nutritional diseases; NCD=non-communicable diseases.

Legends for figures

Figure 1. CMR and Gini coefficient of total, CMNN, NCD and injury in 1991, 2000, 2010 and 2019. **(A).** Male & Female. **(B).** Urban & Rural.

Figure S1. Lorenz curve for secondary system of SMR ranked from lowest to highest by contribution to the total SMR in non-communicable disease.

Figure S2. SMR of total, CMNN, NCD and Injury in 1991, 2000, 2010 and 2019.

Table S1: Association between proportionality index and attributable causes

Aggregate Rate	Proportionality index	Causes responsible for growth/decline
Growing	+P	Low-rank
	-P	High-rank
Declining	+P	High-rank
	-P	Low-rank

Table S2: Ranks and proportion of secondary causes, in 1991-2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	1	36.00%	2	29.09%	2	32.45%	2	31.14%
Respiratory infections	2	36.22%	1	48.63%	1	49.63%	1	54.31%
Conditions arising during the perinatal period	3	22.64%	3	17.72%	3	13.22%	3	5.66%
Nutritional deficiencies	4	2.96%	4	3.35%	4	3.93%	4	8.58%
Pregnancy, childbirth and puerperal complications	5	2.17%	5	1.21%	5	0.78%	5	0.31%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	44.73%	1	54.47%	1	48.51%	1	53.22%
Respiratory diseases	2	31.55%	2	28.59%	3	14.42%	3	9.95%
Malignant neoplasms	3	7.65%	4	2.95%	2	27.92%	2	27.23%
Digestive diseases	4	7.16%	3	5.21%	4	2.68%	5	2.46%
Genito-urinary diseases	5	2.14%	5	2.58%	7	1.44%	7	1.18%
Congenital anomalies	6	1.74%	8	0.96%	8	0.48%	11	0.22%
Neuro-psychiatric conditions	7	1.68%	6	2.08%	6	1.54%	6	1.90%
Diabetes mellitus	8	1.06%	7	2.01%	5	2.09%	4	2.79%
Endocrine disorders	9	0.67%	9	0.34%	10	0.26%	9	0.33%
Musculoskeletal and connective tissue diseases	10	0.64%	11	0.26%	9	0.31%	8	0.37%
Non-malignant neoplasms	11	0.35%	10	0.29%	11	0.25%	10	0.27%
Sense organ diseases	12	0.30%	13	0.12%	14	0.00%	13	0.01%
Skin diseases	13	0.21%	12	0.14%	12	0.09%	12	0.08%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	32.33%	2	27.16%	2	16.45%	3	13.35%
Other unintentional injuries	2	18.32%	3	14.85%	4	13.26%	4	13.28%
Road traffic accidents	3	14.78%	1	27.22%	1	38.55%	1	31.14%
Drownings	4	14.63%	4	11.14%	5	8.07%	5	6.98%
Poisonings	5	6.62%	6	6.40%	6	6.03%	6	5.97%
Falls	6	6.28%	5	6.56%	3	14.43%	2	27.09%
Violence	7	4.03%	7	4.38%	7	1.84%	8	0.74%
Fires	8	2.31%	8	1.90%	8	1.27%	7	1.36%
Other intentional injuries	9	0.66%	9	0.40%	9	0.10%	9	0.09%
War	10	0.04%	10	0.00%	10	0.00%	10	0.00%
Male								
CMNN								

total		100%		100%		100%		100%
Infectious and parasitic diseases	1	40.83%	2	33.61%	2	37.76%	2	36.87%
Respiratory infections	2	34.24%	1	45.98%	1	45.54%	1	51.14%
Conditions arising during the perinatal period	3	22.97%	3	17.18%	3	13.51%	3	5.86%
Nutritional deficiencies	4	1.97%	4	3.24%	4	3.19%	4	6.13%
Pregnancy, childbirth and puerperal complications	5	0.00%	5	0.00%	5	0.00%	5	0.00%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	35.69%	1	54.14%	1	46.13%	1	50.00%
Respiratory diseases	2	25.59%	2	27.94%	3	14.17%	3	10.33%
Malignant neoplasms	3	25.04%	4	3.31%	2	31.08%	2	30.67%
Digestive diseases	4	6.51%	3	6.10%	4	2.99%	4	2.72%
Genito-urinary diseases	5	1.98%	5	2.76%	6	1.41%	7	1.22%
Congenital anomalies	6	1.40%	8	1.02%	8	0.47%	11	0.21%
Neuro-psychiatric conditions	7	1.37%	6	2.03%	7	1.37%	6	1.66%
Diabetes mellitus	8	0.74%	7	1.66%	5	1.63%	5	2.33%
Endocrine disorders	10	0.37%	10	0.26%	9	0.24%	8	0.29%
Musculoskeletal and connective tissue diseases	9	0.48%	11	0.20%	11	0.21%	9	0.26%
Non-malignant neoplasms	11	0.30%	9	0.28%	10	0.24%	10	0.25%
Sense organ diseases	12	0.25%	12	0.20%	14	0.00%	13	0.00%
Skin diseases	13	0.20%	13	0.10%	12	0.06%	12	0.06%
Oral conditions	14	0.08%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	24.41%	2	21.53%	3	13.12%	4	12.16%
Other unintentional injuries	2	21.77%	3	16.88%	2	14.28%	3	13.39%
Road traffic accidents	3	18.14%	1	30.36%	1	42.09%	1	34.72%
Drownings	4	16.08%	4	11.38%	5	7.91%	5	6.75%
Poisonings	5	6.51%	5	6.81%	6	6.29%	6	6.62%
Falls	6	5.44%	6	6.35%	4	13.10%	2	24.21%
Violence	7	4.31%	7	4.48%	7	1.85%	8	0.63%
Fires	8	2.26%	8	1.60%	8	1.20%	7	1.40%
Other intentional injuries	9	1.04%	9	0.62%	9	0.14%	9	0.12%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%
Female								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	2	30.95%	3	24.15%	2	24.99%	2	22.88%
Respiratory infections	1	39.08%	1	51.57%	1	55.30%	1	58.97%
Conditions arising during the perinatal period	3	22.67%	2	18.22%	3	12.81%	3	5.38%

Nutritional deficiencies	4	4.14%	4	3.49%	4	4.99%	4	12.08%
Pregnancy, childbirth and puerperal complications	5	4.50%	5	2.56%	5	1.92%	5	0.69%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	40.59%	1	54.87%	1	51.84%	1	57.56%
Respiratory diseases	2	28.10%	2	29.34%	3	14.79%	3	9.44%
Malignant neoplasms	3	17.85%	4	2.53%	2	23.50%	2	22.58%
Digestive diseases	4	5.48%	3	4.16%	5	2.26%	6	2.12%
Genito-urinary diseases	5	1.60%	6	2.35%	7	1.48%	7	1.14%
Congenital anomalies	6	1.56%	8	0.89%	8	0.49%	11	0.23%
Neuro-psychiatric conditions	7	1.49%	7	2.15%	6	1.78%	5	2.23%
Diabetes mellitus	8	1.10%	5	2.43%	4	2.72%	4	3.41%
Endocrine disorders	9	0.81%	9	0.43%	10	0.29%	9	0.38%
Musculoskeletal and connective tissue diseases	10	0.60%	10	0.34%	9	0.45%	8	0.51%
Non-malignant neoplasms	11	0.30%	11	0.30%	11	0.27%	10	0.30%
Sense organ diseases	12	0.25%	13	0.03%	14	0.00%	13	0.01%
Skin diseases	13	0.15%	12	0.18%	12	0.14%	12	0.10%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	43.93%	1	37.17%	2	24.14%	3	15.58%
Other unintentional injuries	2	13.35%	3	11.27%	4	10.89%	4	13.09%
Road traffic accidents	3	12.52%	4	10.72%	5	8.44%	5	7.42%
Drownings	4	9.76%	2	21.70%	1	30.33%	2	24.39%
Poisonings	5	7.50%	5	6.94%	3	17.53%	1	32.52%
Falls	6	6.79%	6	5.68%	6	5.45%	6	4.75%
Violence	7	3.61%	7	4.08%	7	1.77%	8	0.96%
Fires	8	2.38%	8	2.44%	8	1.45%	7	1.30%
Other intentional injuries	9	0.10%	9	0.00%	9	0.00%	9	0.00%
War	10	0.06%	10	0.00%	10	0.00%	10	0.00%
Urban								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	43.91%	2	30.71%	2	26.69%	2	25.31%
Respiratory infections	2	36.56%	1	54.21%	1	60.97%	1	63.13%
Conditions arising during the perinatal period	3	17.81%	3	11.51%	3	7.43%	3	4.54%
Nutritional deficiencies	4	0.63%	4	2.56%	4	4.43%	4	6.79%
Pregnancy, childbirth and puerperal complications	5	1.09%	5	1.02%	5	0.48%	5	0.24%
NCD								
total		100.00%		100.00%		100.00%		100%

Cardiovascular diseases	1	55.57%	1	61.91%	1	46.65%	1	51.38%
Respiratory diseases	2	22.51%	2	19.19%	3	12.05%	3	8.81%
Digestive diseases	3	6.17%	3	4.65%	5	2.84%	5	2.67%
Malignant neoplasms	4	4.22%	7	1.62%	2	30.97%	2	29.06%
Neuro-psychiatric conditions	5	2.75%	5	3.24%	6	1.71%	6	2.05%
Genito-urinary diseases	6	2.70%	6	2.89%	7	1.39%	7	1.18%
Diabetes mellitus	7	2.54%	4	4.10%	4	2.85%	4	3.38%
Congenital anomalies	8	1.44%	8	1.09%	8	0.41%	11	0.21%
Endocrine disorders	9	0.87%	9	0.43%	10	0.35%	9	0.41%
Musculoskeletal and connective tissue diseases	10	0.51%	11	0.34%	11	0.31%	8	0.43%
Non-malignant neoplasms	11	0.42%	10	0.36%	9	0.36%	10	0.33%
Skin diseases	12	0.23%	12	0.14%	12	0.11%	12	0.07%
Sense organ diseases	13	0.06%	13	0.03%	13	0.00%	13	0.01%
Oral conditions	14	0.00%	14	0.00%	14	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Road traffic accidents	1	23.53%	1	33.96%	1	37.65%	2	29.35%
Self-inflicted injuries	2	20.68%	2	16.51%	3	15.04%	4	11.72%
Falls	3	14.23%	3	14.02%	2	18.44%	1	31.39%
Other unintentional injuries	4	14.04%	4	10.75%	4	12.79%	3	14.20%
Violence	5	8.73%	6	7.48%	7	2.09%	8	0.73%
Drownings	6	8.73%	7	4.98%	6	6.28%	5	6.25%
Poisonings	7	8.16%	5	10.59%	5	6.37%	6	4.99%
Fires	8	0.95%	8	1.09%	8	1.14%	7	1.23%
Other intentional injuries	9	0.76%	9	0.62%	9	0.19%	9	0.14%
War	10	0.19%	10	0.00%	10	0.00%	10	0.00%
Rural								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	35.18%	2	28.84%	2	36.08%	2	30.53%
Respiratory infections	2	36.18%	1	47.85%	1	42.43%	1	42.97%
Conditions arising during the perinatal period	3	23.14%	3	18.61%	3	16.88%	4	5.60%
Nutritional deficiencies	4	3.20%	4	3.47%	4	3.61%	3	8.50%
Pregnancy, childbirth and puerperal complications	5	2.29%	5	1.24%	5	1.00%	5	0.29%
NCD								
total		100.00%		100.00%		100.00%		100%
Cardiovascular diseases	1	41.89%	1	52.15%	1	49.57%	1	54.09%
Respiratory diseases	2	33.92%	2	31.53%	3	15.77%	3	10.49%
Malignant neoplasms	3	8.54%	4	3.36%	2	26.19%	2	26.36%
Digestive diseases	4	7.42%	3	5.38%	4	2.59%	5	2.37%
Genito-urinary diseases	5	1.99%	5	2.48%	6	1.46%	7	1.19%

Congenital anomalies	6	1.82%	8	0.92%	8	0.52%	11	0.22%
Neuro-psychiatric conditions	7	1.40%	6	1.72%	7	1.44%	6	1.83%
Musculoskeletal and connective tissue diseases	8	0.68%	11	0.24%	9	0.31%	8	0.33%
Diabetes mellitus	9	0.68%	7	1.36%	5	1.66%	4	2.51%
Endocrine disorders	10	0.62%	9	0.30%	10	0.21%	9	0.29%
Sense organ diseases	11	0.36%	12	0.15%	14	0.00%	13	0.00%
Non-malignant neoplasms	12	0.34%	10	0.27%	11	0.19%	10	0.25%
Skin diseases	13	0.21%	13	0.14%	12	0.08%	12	0.08%
Oral conditions	14	0.14%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Self-inflicted injuries	1	33.71%	1	29.08%	2	16.96%	3	13.95%
Other unintentional injuries	2	18.83%	3	15.58%	3	13.43%	4	12.95%
Drownings	3	15.33%	4	12.25%	5	8.72%	5	7.24%
Road traffic accidents	4	13.74%	2	26.01%	1	38.90%	1	31.77%
Poisonings	5	6.44%	5	5.65%	6	5.91%	6	6.33%
Falls	6	5.33%	6	5.21%	4	12.96%	2	25.52%
Violence	7	3.47%	7	3.82%	7	1.74%	8	0.77%
Fires	8	2.47%	8	2.05%	8	1.32%	7	1.42%
Other intentional injuries	9	0.65%	9	0.35%	9	0.07%	9	0.06%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%

CMNN=communicable, maternal, neonatal, and nutritional diseases; NCD=non-communicable diseases.

*1 represents the highest rank.

Table S3: Ranks and Proportion of neoplasms and CVD, in 1991-2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	14.88%	3	12.05%
Liver cancer	2	19.12%	2	20.35%	2	18.09%	2	15.04%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	26.34%	1	29.22%
Esophagus cancer	4	12.66%	4	10.43%	5	8.79%	6	7.39%
Other malignant neoplasms	5	7.21%	5	7.99%	4	9.36%	4	10.15%
Colon and rectum cancers	6	5.50%	6	4.91%	6	6.04%	5	7.52%
Leukemia	7	4.01%	7	3.51%	8	2.65%	9	2.33%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.76%	11	1.85%
Breast cancer	9	1.85%	10	1.90%	9	2.39%	8	2.41%
Pancreas cancer	10	1.84%	9	2.10%	7	2.69%	7	3.69%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	11	1.67%	10	2.18%
Cervix uteri cancer	12	1.37%	13	1.18%	14	1.04%	12	1.64%
Bladder cancer	13	1.15%	11	1.39%	13	1.05%	13	1.27%
Corpus uteri cancer	14	0.77%	14	0.86%	12	1.37%	16	0.76%
Melanoma and other skin cancers	15	0.51%	15	0.53%	17	0.39%	17	0.48%
Ovary cancer	16	0.39%	17	0.34%	16	0.68%	15	0.87%
Prostate cancer	17	0.24%	16	0.38%	15	0.80%	14	1.16%
CVD								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	51.45%	1	56.07%	1	55.28%	1	47.17%
Ischemic heart disease	2	15.42%	2	20.69%	2	34.25%	2	40.45%
Hypertensive heart disease	3	14.58%	4	9.53%	3	5.04%	3	7.25%
Other cardiovascular diseases	4	12.22%	3	10.41%	4	4.00%	4	3.84%
Rheumatic heart disease	5	6.33%	5	3.29%	5	1.43%	5	1.29%
Male								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.98%	3	19.91%	3	15.79%	3	12.87%
Liver cancer	2	21.82%	2	22.53%	2	20.76%	2	17.14%
Trachea, bronchus and lung cancers	3	20.06%	1	23.78%	1	28.43%	1	31.72%
Esophagus cancer	4	13.59%	4	9.89%	4	9.89%	5	8.57%
Other malignant neoplasms	5	6.30%	5	7.15%	5	8.44%	4	9.34%
Colon and rectum cancers	6	4.81%	6	4.35%	6	5.44%	6	6.98%
Leukemia	7	3.29%	7	3.09%	8	2.39%	9	2.10%
Mouth and oropharynx cancers	8	2.57%	8	2.18%	9	1.90%	8	2.12%
Pancreas cancer	9	1.87%	9	1.88%	7	2.45%	7	3.27%
Lymphomas and multiple myeloma	10	1.53%	11	1.22%	10	1.62%	10	2.07%
Bladder cancer	11	1.17%	10	1.75%	12	1.19%	12	1.55%

Melanoma and other skin cancers	12	0.48%	13	0.45%	13	0.34%	13	0.41%
Prostate cancer	13	0.38%	12	0.59%	11	1.24%	11	1.79%
Breast cancer	14	0.11%	14	0.13%	14	0.12%	14	0.06%
Ovary cancer	15	0.02%	17	0.00%	17	0.00%	16	0.00%
Cervix uteri cancer	16	0.00%	15	0.00%	16	0.00%	15	0.00%
Corpus uteri cancer	17	0.00%	16	0.00%	15	0.00%	17	0.00%
CVD								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	52.54%	1	57.77%	1	56.66%	1	49.00%
Ischemic heart disease	2	16.25%	2	20.86%	2	33.49%	2	39.33%
Hypertensive heart disease	3	14.22%	4	9.30%	3	4.69%	3	6.52%
Other cardiovascular diseases	4	11.85%	3	9.61%	4	4.11%	4	4.11%
Rheumatic heart disease	5	5.14%	5	2.46%	5	1.05%	5	1.03%
Female								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	19.95%	2	17.49%	2	13.18%	4	10.53%
Trachea, bronchus and lung cancers	2	15.15%	1	17.81%	1	22.49%	1	24.65%
Liver cancer	3	14.33%	3	16.36%	3	13.16%	3	11.20%
Esophagus cancer	4	11.00%	6	6.77%	6	6.77%	7	5.23%
Other malignant neoplasms	5	8.79%	5	9.49%	4	11.08%	2	11.63%
Colon and rectum cancers	6	6.74%	6	5.91%	5	7.13%	5	8.49%
Leukemia	7	5.31%	8	4.24%	9	3.14%	10	2.74%
Breast cancer	8	4.90%	7	5.08%	7	6.58%	6	6.73%
Cervix uteri cancer	9	3.80%	9	3.32%	11	2.95%	8	4.63%
Corpus uteri cancer	10	2.15%	11	2.40%	8	3.91%	13	2.16%
Mouth and oropharynx cancers	11	2.02%	12	2.00%	14	1.50%	14	1.36%
Pancreas cancer	12	1.80%	10	2.50%	10	3.13%	9	4.46%
Lymphomas and multiple myeloma	13	1.34%	13	1.31%	13	1.77%	12	2.38%
Bladder cancer	14	1.12%	15	0.72%	15	0.78%	15	0.76%
Ovary cancer	15	1.05%	14	0.94%	12	1.95%	11	2.46%
Melanoma and other skin cancers	16	0.55%	16	0.69%	16	0.49%	16	0.60%
Prostate cancer	17	0.00%	17	0.00%	17	0.00%	17	0.00%
CVD								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	54.14%	1	53.55%	1	45.03%
Ischemic heart disease	2	14.46%	2	20.43%	2	35.20%	2	41.76%
Other cardiovascular diseases	4	12.64%	3	11.34%	4	3.87%	4	3.52%
Hypertensive heart disease	3	15.00%	4	9.83%	3	5.48%	3	8.11%
Rheumatic heart disease	5	7.65%	5	4.27%	5	1.91%	5	1.59%
Urban								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Trachea, bronchus and lung cancers	1	26.27%	1	29.62%	1	28.73%	1	30.09%

Liver cancer	2	16.04%	2	16.93%	2	14.86%	2	13.16%
Stomach cancer	3	14.54%	3	13.07%	3	12.79%	3	10.84%
Other malignant neoplasms	4	10.71%	4	8.99%	4	10.59%	4	10.48%
Esophagus cancer	5	7.59%	6	5.23%	6	5.94%	6	6.15%
Colon and rectum cancers	6	6.76%	5	6.55%	5	7.60%	5	8.85%
Leukemia	7	3.87%	8	3.38%	9	2.50%	10	2.28%
Pancreas cancer	8	3.08%	7	3.41%	7	3.72%	7	4.38%
Breast cancer	9	2.73%	9	2.96%	8	3.06%	8	2.89%
Mouth and oropharynx cancers	10	2.17%	10	2.68%	11	1.88%	11	1.79%
Lymphomas and multiple myeloma	11	1.42%	12	1.57%	10	2.18%	9	2.43%
Bladder cancer	12	1.22%	11	1.95%	12	1.36%	14	1.44%
Corpus uteri cancer	13	0.99%	15	0.84%	16	1.03%	16	0.69%
Cervix uteri cancer	14	0.95%	13	1.08%	15	1.10%	13	1.47%
Ovary cancer	15	0.83%	14	0.98%	14	1.13%	15	1.11%
Melanoma and other skin cancers	16	0.51%	17	0.28%	17	0.38%	17	0.44%
Prostate cancer	17	0.32%	16	0.49%	13	1.15%	12	1.51%
CVD								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	54.91%	1	53.06%	1	49.38%	1	45.16%
Ischemic heart disease	2	21.71%	2	27.05%	2	38.69%	2	42.62%
Hypertensive heart disease	3	10.44%	4	7.75%	4	5.02%	3	6.62%
Other cardiovascular diseases	4	9.00%	3	9.98%	3	5.67%	4	4.37%
Rheumatic heart disease	5	3.95%	5	2.16%	5	1.24%	5	1.24%
Rural								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	16.27%	3	12.67%
Liver cancer	2	19.12%	2	20.35%	2	20.25%	2	16.02%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	24.74%	1	28.78%
esophagus cancer	4	12.66%	4	10.43%	4	10.70%	5	8.04%
Other malignant neoplasms	5	7.21%	5	7.99%	5	8.55%	4	9.98%
Colon and rectum cancers	6	5.50%	6	4.91%	6	4.99%	6	6.81%
Leukemia	7	4.01%	7	3.51%	7	2.75%	8	2.35%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.68%	11	1.88%
Breast cancer	9	1.85%	10	1.90%	9	1.94%	9	2.16%
Pancreas cancer	10	1.84%	9	2.10%	8	2.00%	7	3.34%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	12	1.34%	10	2.05%
Cervix uteri cancer	12	1.37%	13	1.18%	13	0.99%	12	1.73%
Bladder cancer	13	1.15%	11	1.39%	14	0.84%	13	1.18%
Corpus uteri cancer	14	0.77%	14	0.86%	11	1.60%	15	0.80%
Melanoma and other skin cancers	15	0.51%	15	0.53%	16	0.41%	17	0.50%
Ovary cancer	16	0.39%	17	0.34%	17	0.38%	16	0.74%
Prostate cancer	17	0.24%	16	0.38%	15	0.58%	14	0.97%
CVD								

total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	57.19%	1	58.41%	1	48.08%
Hypertensive heart disease	2	16.02%	4	10.20%	3	5.05%	3	7.54%
Other cardiovascular diseases	3	13.34%	3	10.58%	4	3.11%	4	3.60%
Ischemic heart disease	4	13.24%	2	18.33%	2	31.89%	2	39.47%
Rheumatic heart disease	5	7.16%	5	3.71%	5	1.54%	5	1.31%

CMNN=communicable, maternal, neonatal, and nutritional diseases; NCD=non-communicable diseases; CVD=cardiovascular disease. *1 represents the highest rank.

Table S4: **Gini coefficients, reranking, and proportionality of neoplasms and CVD, in 1991-2019**

	Both	Male	Female	Urban	Rural
Neoplasms					
Gini index					
G1991	0.5989	0.6577	0.5233	0.5824	0.6218
G2000	0.6023	0.6640	0.5249	0.5866	0.6218
G2010	0.5884	0.6589	0.5055	0.5649	0.6098
G2019	0.5685	0.6077	0.4922	0.5564	0.5757
Reranking					
R1991-2000	0.0065	0.0098	0.0031	0.0028	0.0090
R2000-2010	0.0050	0.0012	0.0035	0.0028	0.0182
R2010-2019	0.0042	0.0299	0.0157	0.0011	0.0075
R1991-2019	0.0504	0.0735	0.0559	0.0102	0.0720
Proportionality					
P1991-2000	0.0032	0.0035	0.0014	-0.0015	0.0090
P2000-2010	0.0189	0.0064	0.0230	0.0244	0.0302
P2010-2019	0.0241	0.0811	0.0290	0.0096	0.0416
P1991-2019	0.0808	0.1235	0.0869	0.0362	0.1181
CVD					
Gini index					
G1991	0.3741	0.3963	0.3498	0.3838	0.3563
G2000	0.4681	0.4894	0.4404	0.3928	0.4616
G2010	0.5474	0.5574	0.5348	0.4150	0.5663
G2019	0.5140	0.5229	0.5029	0.3933	0.5185
Reranking					
R1991-2000	0.0025	0.0010	0.0462	0.0107	0.0337
R2000-2010	0.0038	0.0024	0.0057	0.0000	0.0075
R2010-2019	0.0000	0.0000	0.0000	0.0047	0.0000
R1991-2019	0.0000	0.0000	0.1326	0.0000	0.1275
Proportionality					
P1991-2000	-0.0915	-0.0922	-0.0444	0.0017	-0.0716
P2000-2010	-0.0755	-0.0655	-0.0888	-0.0222	-0.0972
P2010-2019	0.0333	0.0345	0.0318	0.0264	0.0478
P1991-2019	-0.1399	-0.1266	-0.0205	-0.0095	-0.0346

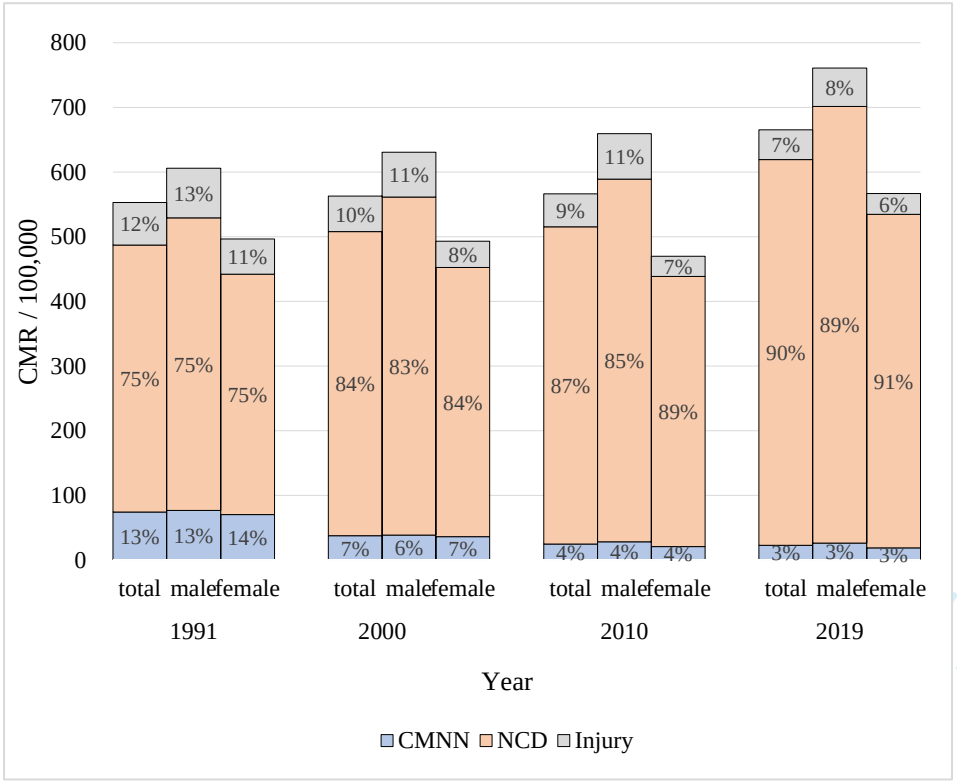
CVD=cardiovascular disease.

Table S5: Decomposition of neoplasm and CVD's crude mortality rate difference, in 1991-2019

	Mortality Difference	Demographic Structure	Non-demographic Factors
Neoplasms			
Both			
1991-2000	22.745	17.56%	7.65%
2000-2010	24.081	18.30%	3.02%
2010-2019	25.410	35.40%	-16.86%
1991-2019	72.235	84.58%	-4.51%
Male			
1991-2000	29.505	18.60%	7.44%
2000-2010	31.627	18.28%	3.87%
2010-2019	32.626	36.06%	-17.35%
1991-2019	93.758	87.22%	-4.46%
Female			
1991-2000	15.702	16.76%	6.92%
2000-2010	16.123	17.62%	2.03%
2010-2019	18.328	35.65%	-16.97%
1991-2019	50.153	82.04%	-6.40%
Urban			
1991-2000	14.468	19.47%	-7.71%
2000-2010	7.612	17.24%	-11.71%
2010-2019	17.914	26.63%	-14.29%
1991-2019	39.993	67.14%	-34.65%
Rural			
1991-2000	24.026	16.29%	13.47%
2000-2010	27.341	15.40%	10.70%
2010-2019	30.033	41.97%	-19.23%
1991-2019	81.400	91.35%	9.48%
CVD			
Both			
1991-2000	44.582	24.76%	3.78%
2000-2010	37.284	7.60%	10.96%
2010-2019	79.416	56.81%	-23.46%
1991-2019	161.282	107.63%	-4.41%
Male			
1991-2000	51.266	26.31%	5.45%
2000-2010	46.201	9.09%	12.63%
2010-2019	78.670	53.82%	-23.43%
1991-2019	176.138	111.18%	-2.08%
Female			
1991-2000	37.431	23.44%	1.35%
2000-2010	28.051	5.53%	9.36%
2010-2019	80.390	61.30%	-24.17%
1991-2019	145.872	104.75%	-8.14%

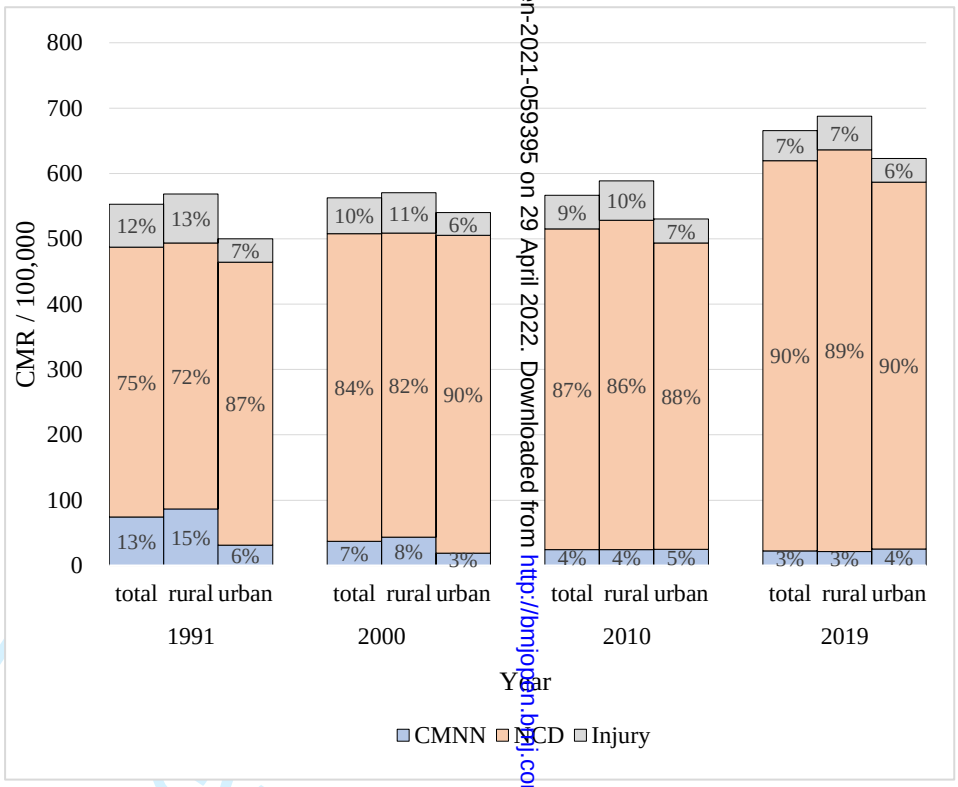
Urban			
1991-2000	39.771	27.36%	-5.23%
2000-2010	-0.889	14.29%	-14.69%
2010-2019	69.701	47.72%	-15.84%
1991-2019	108.582	95.77%	-35.36%
Rural			
1991-2000	45.046	23.43%	6.72%
2000-2010	55.518	0.58%	27.97%
2010-2019	82.682	64.00%	-30.93%
1991-2019	183.246	111.89%	10.74%

CVD=cardiovascular disease.



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.4429	0.5024	0.5407	0.5601
Male	0.4543	0.5059	0.5353	0.5535
Female	0.4405	0.4906	0.5530	0.5726

(A) Male & Female



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.4429	0.5024	0.5407	0.5601
Urban	0.5311	0.5700	0.5454	0.5614
Rural	0.4223	0.4853	0.5410	0.5597

(B) Urban & Rural

Figure 1 CMR and Gini coefficient of total, CMNN, NCD and injury in 1991, 2000, 2010 and 2019

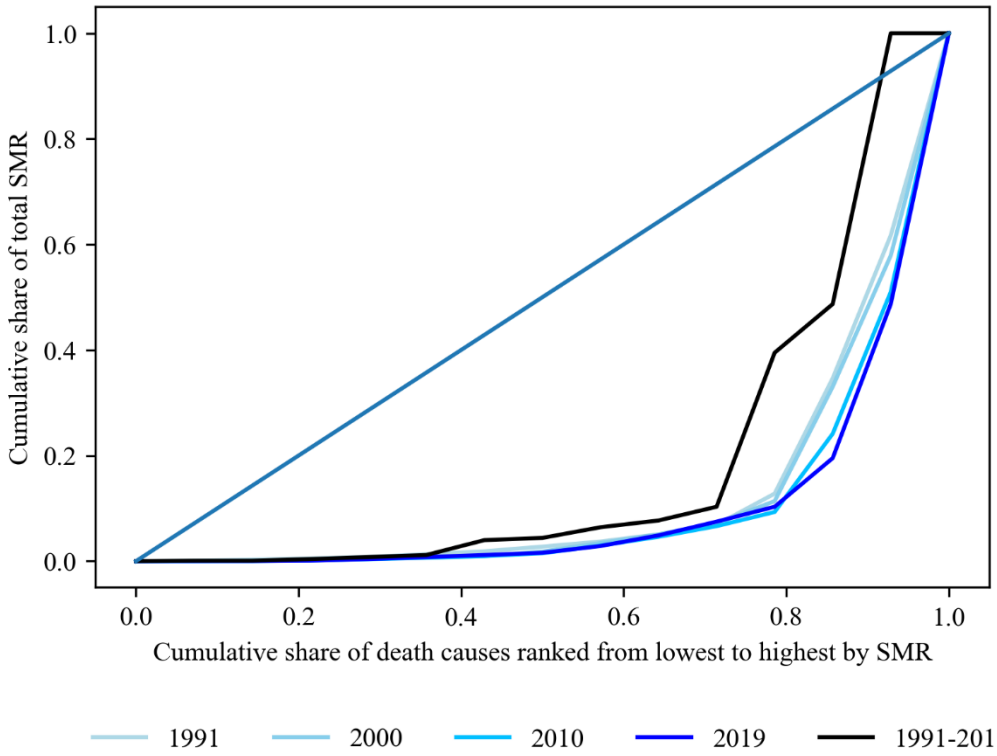
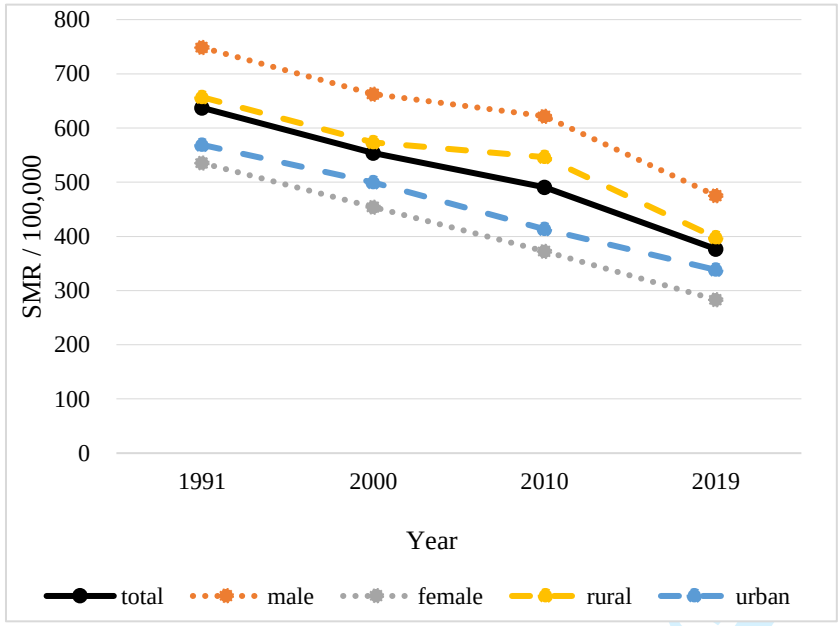
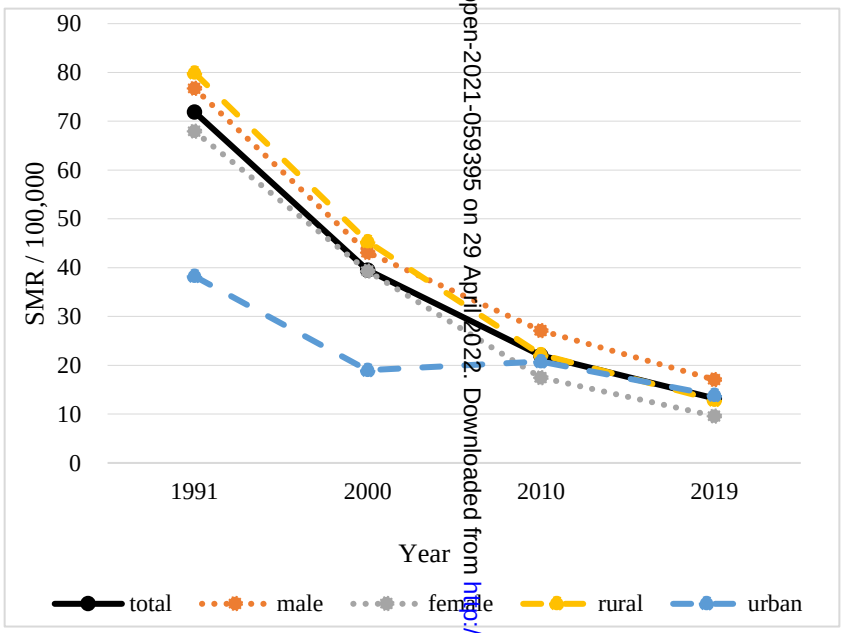


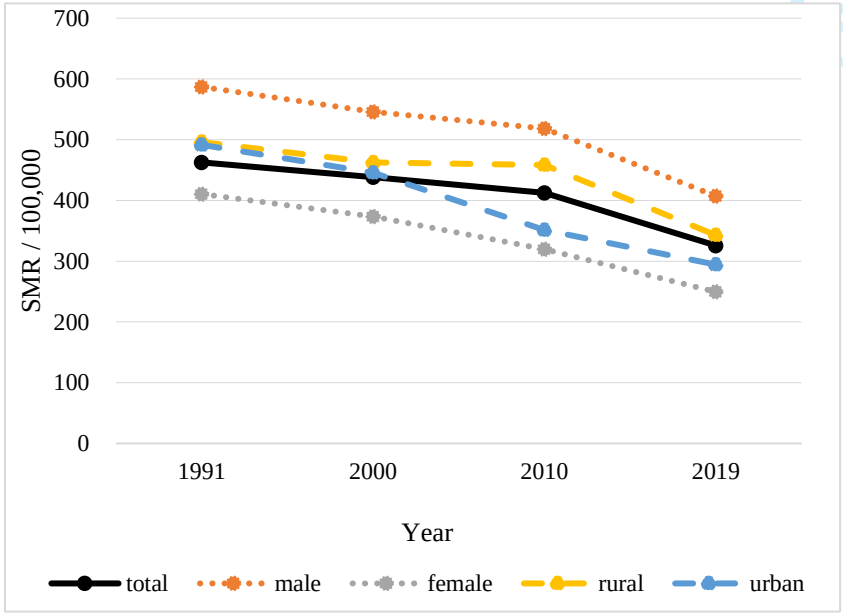
Figure. S1 Lorenz curve for secondary system of SMR ranked from lowest to highest by contribution to the total SMR in non-communicable diseases



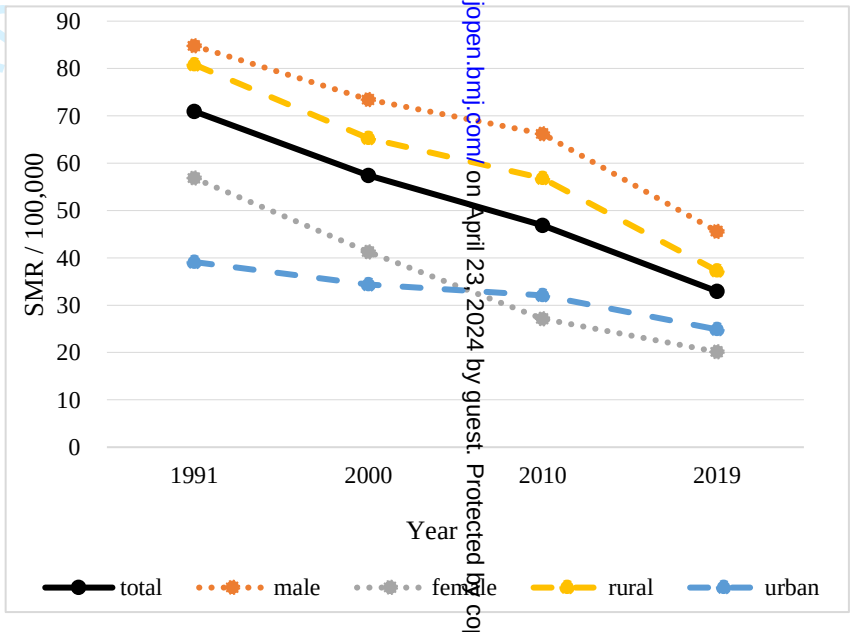
(A) Total



(B) CMNN



(C)NCD



(D) Injury

Figure. S2 SMR of total, CMNN, NCD and Injury in 1991, 2000, 2010, and 2019

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	--
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	--
		(*e*) Describe any sensitivity analyses	--
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	--
		(b) Give reasons for non-participation at each stage	--
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-8
		(b) Indicate number of participants with missing data for each variable of interest	--
Outcome data	15*	Report numbers of outcome events or summary measures	--
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	--

		(*b*) Report category boundaries when continuous variables were categorized	--
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	--
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-8
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Gini coefficient decomposition- and mortality-rate-difference-based description of mortality causes in the Chinese population from 1991 to 2019: Analysis of surveillance data

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Gini coefficient decomposition- and mortality-rate-difference-based description of mortality causes in the Chinese population from 1991 to 2019: Analysis of surveillance data

Feiling Ai, MMed; Xia Wan, PhD

Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences &

School of Basic Medicine, Peking Union Medical College

#5 Dong Dan San Tiao, Dongcheng District, Beijing, China, 100005

Corresponding author: Xia Wan, E-mail: xiawan@ibms.pumc.edu.cn, Telephone: +86 010 6523 3870

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ABSTRACT

Objectives Improved national Disease Surveillance Points systems (DSPs) in China have clarified the mortality causes in the Chinese population. We investigated the variations and drivers of multiple mortality causes.

Design This was a retrospective cross-sectional surveillance study.

Setting Original data in 1991 and 2000, and secondary data in 2010 and 2019 were collected from DSPs across nationwide locations in China.

Participants Standardized mortality rates (SMR) and crude mortality rates (CMR) of the Chinese population in 1991, 2000, 2010, and 2019 were ascertained.

Main outcome measures Changes in Gini coefficients (*G*) computed using SMR, were decomposed into reranking (*R*) and proportionality (*P*) to identify variations in communicable, maternal, neonatal, and nutritional diseases (CMNN), non-communicable diseases (NCD), and injury. The CMR difference (in %) was partitioned into demographic structure and non-demographic factors using the mortality-rate-difference method.

Results From 1991 to 2019, the overall CMR increased from 591.327/100,000 to 674.505/100,000, whereas the SMR continually decreased. An increasing concentration of NCD contributed to the increased all-cause *G* from 0.443 to 0.560 during 1991-2019. Between 1991 and 2019, compared with CMNN (*R*=0.054) and NCD (*R*=0.037), the ranking of injury changed the most (*R*=0.173). The ranking of diabetes, falls, and road traffic accidents markedly increased over time. The decreased SMR of NCD (*P*=-0.013) was mainly due to low-ranking causes, whereas changes in CMNN (*P*=0.0030) and injury (*P*=0.131) were due to high-ranking causes. All-cause CMR increased by 14.07% from 1991 to 2019due to greater contributions from demographic structure (68.46%) than from non-demographic factors (-54.40%). Demographic structural changes accounted more for CMR increases in males (70.52%) and in urban populations (75.58%).

Conclusions Prevention and control measures targeting NCD and specific causes are imperatively needed, and should be strengthened as the population ages, especially for males and rural populations.

Strengths and limitations of this study

- Our study described the transitions of mortality causes in China by analyzing data from the nationally representative Disease Surveillance Points systems (DSPs).
- Our study quantified the variations and relative importance of various mortality causes from 1991 to 2019 in China using the Gini coefficient decomposition method.
- Our study presents the percentage of demographic and non-demographic factors that contributed to changes in the crude mortality rate (CMR) from 1991 to 2019 among the Chinese population.
- Despite some discrepancy between the original and secondary data, the heterogeneity can be minimized by a standardized data collection and analysis process with stringent quality control procedures.
- A potential limitation of the study was that the decomposition of CMR differences was too crude, especially for non-demographic factors.

INTRODUCTION

In the past 30 years, China has gradually transitioned from demographic dividend to demographic burden, with slower population growth, faster aging, and more severe sub-replacement fertility.[1] The national census in 2020 showed that individuals aged 65 and above constituted 190.64 million of the national population.[2] Living standards and access to medical services have improved significantly with the economic boom and health literacy, and behavioral and environmental risks were obtained through comprehensive disease prevention and control programs.[3] Accordingly, a marked shift occurred in the mortality causes among the Chinese population; the Global Burden of Disease Study (GBD) 2017 showed that non-communicable diseases (NCD), such as stroke, ischemic heart disease, lung cancer, and diabetes, are the major causes of premature death, whilst mortality rates due to infectious diseases, maternal and infant factors, and nutritional deficiencies decreased.[3] The Chinese provincial disease burden report indicated that cardiovascular disease was the leading cause of death from 1990 to 2016, with a nearly 1.5 million increase in the number of deaths since 1990.[4] He et al.[5] reviewed cancer registries in China and found that cancer mortality increased from 10.1% during 1973-1975 to 24.2% in 2015.

Changes in mortality and associated drivers clearly are pivotal for policy making, and health resource allocation for aging and health transition. The marked improvement in the registration of mortality causes as well as the accessibility of insight into variations in mortality causes have generated more unpredictable mortality patterns in the Chinese population.[6] Earlier studies focused on high-ranking causes that implicitly obscured the complex picture of varying mortality causes and changes in their relative importance over time.[7] Despite stable rates, certain mortality causes increased in rank due to the decline in other causes. Increasing uncertainties, including the coronavirus disease pandemic, have increased the diversity of the mortality causes, engendering concerns about prioritization of resource reallocation. Thus, researchers introduced the modified Gini coefficient (G)[7-10] to quantitatively evaluate whether changes in overall rates including disability adjusted life years rates and obesity rates, are disproportionately centralized toward high-ranking causes.[7,9] The continuing increasing availability of data sources whereby the changes between the crude mortality rates (CMRs) can be interpreted in terms of the components attributable to various factors, provide an epidemiological perspective.[11,12] It is important to quantify the contributions of population aging and other risk factors to CMR, which can be obtained by the mortality-rate-difference method, a widely used technique in demography.[13]

This study was conducted to decompose G differences to quantify the variations and the relative importance of multiple mortality causes in the Chinese population from 1991 to 2019. Based on the demographic structure and non-demographic factors, we split the difference in the CMR during three periods.

METHODS

Data source

Data were collected from the Disease Surveillance Points system (DSPs) established by the Chinese Centre for Disease Control and Prevention, with nationwide locations selected by multiple-stratified random sampling. From administrative departments, we inferred that the DSPs underwent three major adjustments: the number of monitoring points increased from 145 in 1990 (covering 10 million) to 161 in 2005 (covering 78 million), and to 605 points (covering 300 million) in 2013derived from administrative departments.[14] Through a stringent sampling design, implementation, completeness

accuracy, and comparative validation, the DSP data could reflect the mortality level of Chinese population. Original data from 1991 and 2000, and secondary data from 2010 and 2019 in the National Disease Surveillance System Death Monitoring Dataset[14,18] were analyzed. All CMRs were standardized using 5-year census data from the National Bureau of Statistics of China in 2000.[19] The overall and cause-specific, as well as sex-specific, rural-, and urban-specific CMR, and standardized mortality rates (SMR) were calculated.

Mortality causes were ascertained from medical certificates and the underlying causes were identified through verbal autopsy procedures, encoded by the International Classification of Diseases (ICD)-9 or ICD-10 (before or since 2000), and, according to the GBD classifications in 2010,[20] the causes were grouped into three levels: first, comprising communicable, maternal, neonatal, and nutritional diseases (CMNN), NCD, and injury; second, comprising the main systems among three primary categories – CMNN, including infectious and parasitic diseases, some infections, and nutritional deficiencies; NCD, including neoplasms, hematopoietic organs and immune diseases; endocrine, nutritional and metabolic diseases; and injury, comprising self-inflicted injuries, road traffic accidents and drownings; and third, the secondary systems were further divided into specific causes. Thus, we analyzed causes of malignant neoplasms and cardiovascular disease among the two leading systems.

Statistical analysis

First, we described the all-cause and three categorical CMR and SMR, in three periods: 1991-2000, 2000-2010, and 2010-2019. Second, we used all-cause and cause-specific SMRs to calculate the *G*. Overall variations of causes are presented by decomposing the difference in *G* between two timepoints.[8] Third, using the mortality-rate-difference method, the CMR difference was split into demographic structure and non-demographic factors.[11,13]

***G* decomposition method**

The *G* (G: 0-1) indicates greater difference among various large-value components, whereby the overall indicators are more concentrated among the major causes, and this is depicted by the Lorenz curve: the x-axis and y-axis represent the cumulative shares of mortality causes, ranked from lowest to highest, and the total SMR, respectively. An overall *G* curve that is closer to the diagonal represents more equal shares of each component (Supplementary Figure S1).

In the decomposition of *G* changes (Supplementary Part A),[7] the *G* difference (ΔG) in studied periods (1991-2000, 2000-2010, 2010-2019, and 1991-2019) is decomposed into reranking (*R*) and proportionality (*P*): *R* represents the importance of the *G* changes from reranking of causes and indicates the mobility of causes; *P* indicates the *G* changes that account for the proportion when ranking is held constant at the original distribution and indicates the progressivity of causes (Supplementary Table S1).

Mortality-rate-difference method

In the mortality-rate-difference method, the CMR difference is decomposed into demographic structure including age distribution, and non-demographic factors, including risk factors (smoking, alcohol consumption, physical activities, and air/water pollution), socio-economic development, healthcare facilities etc.[21] The CMR difference equates to the sum of the age-structure difference weighted by the mean mortality rate as well as to the mortality difference weighted by the age structure (Supplementary Part A).[11,13] We calculated CMR differences in periods: 1991-2000, 2000-2010, 2010-2019, and 1991-2019.

All analyses were conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and Python Jupyter Notebook 6.0.3 (https://jupyter.org/).

RESULTS

Overall changes in CMR and all-cause SMR

Figure 1 shows the total and sex-, urban, and rural-specific CMRs of CMNN, NCD, and injury during 1991-2019. The total CMRs of were 591.327/100,000, 588.693/100,000, 575.385/100,000, and 674.505/100,000 in 1991, 2000, 2010, and 2019respectively; male CMRs were higher every year. The rural CMR remained higher than urban CMR. All-cause SMR decreased from 637.29/100,000 in 1991 to 376.78/100,000 in 2019, with slower decline trends in males and in rural populations during 2000-2010 than in other decades (Figure 2). SMRs of CMNN, NCD, and injury decreased in every decade, and were higher in males albeit with a declining trend. The decreasing tendency of rural SMR was close during 1991-2000 and 2010-2019, but fluctuated during 2000-2010, with a faster decline in NCD and a comparatively steady change in CMNN and injury (Figure 2).

Figure 1 depicts *G* and the percentage of CMRs for CMNN, NCD, and injury: the overall *Gs* were 0.443, 0.502, 0.541, and 0.560 in 1990, 2000, 2010, and 2019, respectively. The increase in *G* values was due to disproportionate falls of SMRs among the three categories. Mortality causes were more concentrated on NCD and, in 1991 and 2019, increased from 75% to 90%, whereas CMNN and injury comprised smaller proportions, and decreased from 13% and 12% to 3% and 7%, respectively. Proportional changes in males, females, and rural residents mimicked the overall trends, and the gap in urban residents peaked in 2000.

Table 1 represents CMR changes between two timepoints (1991-2019) and the year- and sex-specific contributory proportions of all-cause demographic and non-demographic factors. Males had a threefold CMR increase (125.977/100,000) compared to females (40.475/100,000); the CMR increase was prominently higher in urban (102.130/100,000) than in rural areas (87.156/100,000). Per decade, the demographic structure and non-demographic factors, respectively, increased and decreased the all-cause CMR. During 1991-2019, demographic structure had a greater positive impact on all-cause CMR (68.46%) than the negative impact of non-demographic factors (-54.40%). Thus, all-cause CMR increased by 83.187/100,000 (14.07%). Male demographic structure induced a higher CMR increase (70.52%) than that of females (67.02%), and the CMR proportion for demographic structure in urban areas (75.58%) was higher than that in rural areas (66.49%). Over the past three decades, all absolute contributions of demographic structure and non-demographic factors peaked, with an increasing CMR between 2010 and 2019.

Variations of NCD

Table 2 shows *G* and their decompositions across 30 years in China for 14 causes in NCD. The G augmented from 0.740 in 1991 to 0.789 in 2019 The *R* value was 0.037 between 1991 and 2019, with increased ranks of neoplasms, neuro-psychiatric conditions, diabetes, musculoskeletal and connective tissue diseases, skin diseases, and non-malignant neoplasms, whereas the ranking of respiratory disease, digestive diseases, genitourinary diseases, congenital anomalies, and sensory organ diseases decreased (Table S2). In 1991, cardiovascular (44.73%) and respiratory (31.55%) diseases were two major causes; however, in 2019, cardiovascular disease (53.22%) ranked first, whereas neoplasms (27.23%) and respiratory diseases (9.95%) held second and third ranks, respectively. Diabetes increased from the 8th to 4th rank, whereas congenital anomalies dropped from the 6th to 11th rank. NCD had a negative *P*-value (-0.013) between 1991 and 2019, in combination with the falling SMR, indicating that the fall of low-ranking causes (endocrine disorders, musculoskeletal, and connective tissue diseases, sensory organ diseases, skin diseases, oral diseases, and non-malignant neoplasms) were mainly responsible for the

decline in the SMR of NCDs. Among the studied periods, the ranking of NCD subcategories varied most during 1991-2000, and stabilized since 2000 (*R*-value: 0.006, 0.002, 0 (0.003) with negative *P*-values: -0.009, -0.027, and -0.006 during 1991-2000, 2000-2010, and 2010-2019, respectively. Similarly, low-ranking causes remained the main drivers in each decade. Ranking in males and females underwent major changes during 1991-2000 (*R*=0.010), and 2000-2010 (*R*=0.014), respectively, whereas negative *P* in both was ascribed to low-ranking causes. *G*-variation-related rural mortality differences expanded over time, but changes in rural and urban settings were mainly caused by the decline of low-ranking causes (Table 2 and Table S2).

Table 3 presents CMR changes between years (1991-2019) and the year- and sex-specific contributory percentage of demographic and non-demographic factors in three categories.

In NCD, consistent with all-cause CMR, demographic structure and non-demographic factors increased and decreased the CMR over time, respectively, and the changes peaked in 2010-2019. Overall, the NCD-CMR increased by 183.829/100,000 (44.53%), mainly due to the demographic structure (85.79%) from 1991 to 2019. Between the sexes, the NCD-CMR difference in males (222.753/100,000) was markedly higher than that in females (144.013/100,000), with a slightly higher contribution of demographic structure to CMR in males (88.54%) than that in females (83.72%). In contrast, the absolute values of non-demographic factors were higher in females (-44.97%) than in males (-39.30%). Rural settings had higher demographic-structure contributions (87.24%) than urban settings (80.29%), whereas urban settings had higher non-demographic factors (-50.75%) absolute contributions than rural settings (-36.10%) (Table 3).

Variations of neoplasms and cardiovascular diseases

Further analysis of Gini decomposition and mortality-rate-difference based on neoplasms and cardiovascular diseases ─ two leading NCD systems ─ is shown in Table S3-S5.

Between 1991 and 2019, *G* decreased by subcategories of neoplasms and their ranks mainly changed in 1991-2000 (*R*=0.006). In 2019, trachea, bronchus, and lung cancers (29.22%) ranked first, followed by liver (15.04%) and gastric (12.05%) cancers. The decline in high-ranking causes (gastric cancer, liver cancer, esophageal cancer, leukemia, oral, and oropharyngeal cancers) induced an overall decline of SMR-neoplasms (*P*=0.080) from 1991 to 2019. Unlike neoplasms, between 1991 and 2019, the G of cardiovascular diseases based on subcategories increased over time; the top three causes were cerebrovascular, ischemic, and hypertensive heart diseases: ischemic heart disease increased from 15.41% to 40.45%, whereas hypertensive heart disease decreased from 14.58% to 7.25%, but was always higher in women than in men. *P*-value remained invariably negative from 1991 to 2019, indicating that low-ranking causes (hypertensive heart disease, rheumatic heart disease, and other cardiovascular diseases) were major determinants (Tables S3 and S4).

Demographic structure continuously increased the CMR of neoplasms and cardiovascular diseases, whereas before 2010, non-demographic factors increased and decreased their CMR, respectively, and, from 1991 to 2019, generally made small contributions to neoplasms (-4.51%) and cardiovascular diseases (-4.41%), with similar sex-stratified changes. In urban settings, non-demographic factors contributed negatively to neoplasms (-34.65%) and cardiovascular diseases (-35.36%) from 1991 to 2019, whereas in rural settings, non-demographic factors positively affected their CMRs before 2010 (Table S5).

Variations of CMNN

The underlying *G*-changes in CMNN (Table 2) showed that the cause-specific difference among CMNN increased from 1991 to 2019: *G*-values increased during 1991-2010 and decreased during 2010-2019.

CMNN was dominated by infectious, parasitic (30-40%) and respiratory (35-55%) infections. The major ranking changes indicated increased respiratory infections and decreased infectious, parasitic diseases. The fall of high-ranking (P=0.003) mortality causes (infectious and parasitic diseases) decreased the CMNN-SMR during 1991-2019. In the past 30 years, the cause-specific difference (G=0.509, R=0.030) was higher in males than in females (G=0.465, R=0). The male-SMR decrease was predominantly caused by high-ranking causes (infectious and parasitic diseases; P=0.018), whereas the female-SMR decrease was caused by low-ranking causes (pregnancy, childbirth, and puerperal complications; P=-0.074). SMR variations in urban settings were greater than those in rural areas from 1991 to 2019 (Table 2 and Table S2).

The CMR-CMNN decreased by 51.458/100,000 between 1991 and 2019, with major contributions from non-demographic factors (-90.17%). Effects of demographic structure were negative during 1991-2000, but turned positive during 2000-2010 and 2010-2019. Males and females showed similar changes in overall trends. Demographic structure contributed more to urban CMR increase (60.80%) than to the rural CMR (15.51%), whereas, non-demographic factors had higher contributions in rural (91.04%) than in urban settings (79.40%). In contrast to overall changes, demographic structure decreased CMR in rural settings during 1991-2000 (-8.95%), but non-demographic factors increased CMR in urban settings during 2000-2010 (21.15%) (Table 3).

Variations of injury

The overall G of injury increased from 1991 to 2019 (Table 2). In particular, the ranking of falls increased from the 6th in 1991 to 2nd rank in 2019, whereas the ranking of road traffic accidents increased from 3rd to 1st. In contrast, self-inflicted injuries decreased from 1st to 3rd. In urban settings, R was smaller (0.035), indicating small ranking changes in specific causes. The leading causes of injury shifted from self-inflicted injuries (32.33%), road traffic accidents (14.78%), and drowning (14.63%) in 1991 to road traffic accidents (31.14%), falls (27.09%), and self-inflicted injuries (13.35%) in 2019. The decreased proportion of high-ranking causes (self-inflicted injuries and drownings) decrease the SMR of injury (P=0.131) from 1991 to 2019 (Table 2and Table S2).

The CMR of injury decreased constantly, representing the highest decline during 1991-2000 (10.925/100,000), predominately caused by the negative impact of non-demographic factors (Table 3). The highest contributory proportion was noted during 2010-2019. Males (23.08%) and females (24.91%) had similar demographic-structure contributions from 1991 to 2019. In contrast, non-demographic factors had higher contributions in females (65.05%) than in males (45.87%). From 1991 to 2019, demographic-structure contributions were higher in urban (37.81%) than in rural settings (22.67%), whereas non-demographic-factor contributions in rural settings (53.89%) were higher than those in urban settings (36.13%). The overall CMR increased by 0.600/100,000 from 1991 to 2019 due to higher demographic-structure contributions (37.81%), urban CMR increased by 1.692/100,000 from 2000 to 2010, and non-demographic factors represented positive contributions (0.49%; Table 3 and Table S2).

DISCUSSION

Main findings

Based on the decomposition of G and CMR difference, we quantitatively represented variations in mortality causes across broad groups and subcategories in the Chinese population – from 1991 to 2019. G variations indicated that mortality causes have disproportionately favoured low-ranking causes among NCD since 1991, with higher components for neoplasms and cardiovascular diseases. In CMNN and injury, mortality causes were unequally concentrated in high-ranking causes during 1991-2019, thereby

decreasing their SMRs. Moreover, for injuries, major changes occurred in male and urban populations. Mortality-rate-difference analysis, showed that, from 1991 to 2019, demographic structure and non-demographic factors increased and decreased CMR, respectively, with the maximum contributions in 2010. With population aging, the explanatory share of demographic structure for the increased CMR in urban and male populations increased. Specifically, from 1991 to 2019, non-demographic factors decreased the CMR of NCDs, which declined more in females than in males, and in urban than in rural settings. Of note, cause-specific differences in neoplasms and cardiovascular disease expanded over time.

Strengths and limitations

We identified the overall profile of mortality causes and associated drivers in the Chinese population from 1991 to 2019 to highlight the most imperative health issues. First, we validated the Gini decomposition approach for identifying variations in multiple mortality causes that statistically describes the rising or falling concentration of leading causes to reveal the occurrence of significant reranking. By combining proportionality with a changing general rate, the predominant causes that decrease the rate of systematic mortality causes gain importance, relative to higher- or lower-ranked causes. CMR differences were decomposed into demographic structure and non-demographic factors, offering quick, simple clues about the contributions of age-structure shift and other combined factors to changes in mortality rates. Furthermore, the results facilitate the evaluation of the effects of aging and disease-prevention and control strategies.

Despite the well-depicted overall profiling and drivers of mortality causes of the Chinese population, several study limitations exist. First, discrepancies between the original and secondary data possibly exist, and can be minimized by standardized protocol for data cleaning, analysis, and quality control. Second, the Gini index and its indicators reranking and proportionality facilitate the identification of variations in mortality causes, but the relatively abstract implications, are difficult to follow. Third, data derived from DSPs, with continuing increase in population size, might introduce inconsistencies; however, previous studies proved the national representativeness of the DSPs.[15-17] Although the SMR stemming from the United Nations Population Division was slightly higher than that from the Chinese national census, the overall trend is consistent (results not shown), which further confirms the robustness of our findings. Last, we split the CMR difference into two components, whereby non-demographic factors constitute a general classification, that may not clearly depict the actual determinants of CMR fluctuations besides demographic structures.

Significance and implications of this study

Knowing the variations and determinants of mortality causes is important for policymakers to address the increasing health needs of older adults. Compared with studies that visualize the changes in high-ranking causes in different years by colorful lattices or crossed lines,[3] we depicted a clear picture of distributions and relative importance of various mortality causes including distributions and relative importance with quantitative values. Besides, some studies analyzed the provincial inequality including maternal mortality and malignant tumors in China. However, as we know, this is the first study interpreted the proportion of population aging and non-demographic factors contributing to CMR changes in China, with national and all-cause perspective.[23,24]Transitions of mortality causes and non-demographic factors

Changes in cause-specific NCD

NCD plays an increasingly major role among mortality causes, with an escalating health loss doubled from over 40% in 1991 to 85% in 2019,[3] that is closely related to non-demographic factors, including environmental pollution (air/water pollution), tobacco use, harmful alcohol use, unhealthy diet, physical

inactivity, and obesity in China.[17,25] Since 1990, China's progress in fight with NCDs relied on serial national policies coupled with comprehensive health promotion programs including Guidelines for Chronic Disease Prevention and Treatment, National Healthy Lifestyle Initiative, Healthy China 2030 Plan, China's Medium- and Long-Term Plan for the Prevention and Control of Chronic Diseases (2017-2025) and National Nutrition Plan (2017-2030).[26-29] Moreover, the Chinese government increased policy and financial support to reduce risk factors, including the National Action Plan for the Prevention and Control of Air Pollution (2013-2017),[30] smoke-free legislation in more than 20 cities and the Law on the Protection of Minors for tobacco control,[31,32] etc. with remarkable improvement indicated by increased absolute values of non-demographic factors. However, awareness of the increasing number of NCD-mortality caused by cumulative and lagging effects of environmental pollution,[33] high smoking rates,[34] longstanding unhealthy eating habits,[35] insufficient physical activity-participation,[36] and continuing increasing obesity rate should be noted in China.[37] There were less contributions from non-demographic factors in rural populations, as inequality between rural and urban settings, including health services utilization, family income, education level, etc., prevailed,[38,39] which warned us that more efforts are needed to facilitate equality between rural and urban areas.

Changes in cause-specific CMNN

The CMNN proportion decreased significantly from 1991 to 2019, due to the establishment of a direct reporting network system of communicable diseases, that facilitated the collection of updated information and implementations of several special interventions targeting meningitis, tetanus, measles, diarrhea, etc..[25] From 1991 to 2019, the uneven development of rural and urban settings induced a more than 10 times mortality difference between rural and urban areas in CMNN, with higher demographic and non-demographic contributions in urban and rural areas is narrowing with improved primary care and public health services, and plans implemented in extreme poverty-stricken areas.[49] Communicable disease prevention and control, however, are great challenges, for instance, the ongoing coronavirus disease pandemic.

Changes in cause-specific injury

A dramatic reduction in self-inflicted mortality among injuries occurred over time, especially in rural and female populations. In the 1990s, the suicide rate in China was 23.2/100,000, and was more than three times higher in rural than in urban areas.[50] The fast-growing economy, urbanization, and increasing social concern have rapidly decreased the overall suicide rate over time,[51] which has transitioned to predominance among older adults.[52] In contrast, falls and road traffic accidents increased notably. Fall injury, usually during leisure activities, household chores, and other daily activities, is the leading cause among older adults.[53] The continuing increase in vehicles numbers in China, has resulted in the high mortality of pedestrians (42%), motorcyclists (25%), and vehicle passengers (17%) in road traffic accidents.[54]

Demographic shift

Demographic structure, as a dominated CMR contributor, strikingly increased over time. In 2020, individuals aged ≥65 years comprised 13.50% of the population in China and this rate is far higher than the international aging standard of 7%;[2] thus China has transitioned into rapidly aging society. In the past 30 years, life expectancy increased by 10 years in China.[55] Simultaneously, the fertility rate declined from 6.71 in 1950 to 1.70 in 2019.[1] Accordingly, the Chinese government has gradually modified the childbearing policy.[57,58]

Suggestions and future research

In summary, China's notable progress in reducing mortality since the 1990s is ascribed to improved healthcare and medical services.[22] However, integrated efforts are needed to lessen the mortality rate. First, national policies, strategies, and special interventions are needed to create a supportive environment and to reduce poverty and inequality between rural and urban areas. For example, interventions for strengthening urban planning, road infrastructure, and legislation are needed to avert road traffic accidents. Second, stringent measures for tobacco control, alcohol restriction, and mitigation of other risk factors are warranted. Third, comprehensive measures for prevention, diagnosis, and treatment of prioritized diseases should be intensified.[26] With population aging, the establishment of long-term care settings to fulfil the needs of older adults is imperative.[56] Based on the distribution and priority of diverse mortality causes depicted on this study, in the future, more accurate estimation of disease burden could be realized in combination with incidence and prevalence of diseases. In addition, more studies are needed to further evaluate the non-demographic factors.

CONCLUSIONS

NCD, especially neoplasms and cardiovascular diseases, remains a major public health concern among the mortality causes in China, with population aging increasingly threatening to worsen the situation. Despite several achievements, there is insufficient implementation of strategies to control non-demographic factors in China. Laws mandating control of risk factors are needed, as is attention toward improving equitable access to health services, environmental quality, and health education, especially for older, male and rural populations.

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Contributors

Wan Xia designed the study concept and obtained the original data. Ai Feiling managed data, implemented methods, wrote the first draft of the paper. Wan Xia and Ai Feiling contributed to the revision and finalization of the paper, and had full access to all data used in this study, both checked and verified the data used in the analysis. The corresponding author was responsible for submitting the article for publication.

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Disclaimer

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Competing interests

All of the authors declare that they have no potential or actual conflicts of interest.

Patient and Public involvement

No patient or public were involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

The research is based on open-source data, so there are no ethical issues and other conflicts of interest.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

The data used in our study were collected from the Disease Surveillance Points system (DSPs) established by the Chinese Centre for Disease Control and Prevention. The data from 1991 to 2000 were not publicly available but are available from the corresponding author on reasonable request. The data in 2010 and 2019 were public accessible to all through published book National Disease surveillance system cause-of-death surveillance dataset (http://ncncd.chinacdc.cn/jcysj/siyinjcx/syfxbg/202101/t20210118_223798.htm).

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Table 1. Changes in the contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific all-cause crude mortality differences, from 1991 to 2019

Periods	Mortality Difference	Demographic Structure	Non-demographic Factors
Total			
1991-2000	-2.634	15.37%	-15.82%
2000-2010	-13.308	8.90%	-11.16%
2010-2019	99.120	46.54%	-29.31%
1991-2019	83.178	68.46%	-54.40%
Male			
1991-2000	11.552	16.21%	-14.41%
2000-2010	12.580	10.09%	-8.17%
2010-2019	101.845	43.69%	-28.44%
1991-2019	125.977	70.52%	-50.94%
Female			
1991-2000	-13.470	14.53%	-17.04%
2000-2010	-43.257	7.14%	-15.42%
2010-2019	97.202	51.68%	-31.40%
1991-2019	40.475	67.02%	-59.47%
Urban			
1991-2000	50.544	22.99%	-13.47%
2000-2010	-40.520	13.27%	-20.24%
2010-2019	92.106	39.18%	-22.14%
1991-2019	102.130	75.58%	-56.33%
Rural			
1991-2000	-16.376	13.31%	-15.99%
2000-2010	3.942	4.13%	-3.46%
2010-2019	99.590	52.28%	-35.58%
1991-2019	87.156	66.49%	-52.18%

Table 2. Changes in Gini coefficients, reranking, and proportionality of secondary causes for the combined and, male, female, rural, and urban categories, from 1991 to 2019

Periods	Both	Male	Female	Urban	Rural
CMNN					
Gini index					
1991	0.440	0.497	0.391	0.464	0.444
2000	0.452	0.469	0.437	0.487	0.450
2010	0.506	0.521	0.490	0.558	0.473
2019	0.491	0.509	0.465	0.539	0.462
Reranking					
1991-2000	0.070	0.050	0.018	0.087	0.066
2000-2010	0.000	0.000	0.043	0.000	0.000
2010-2019	0.000	0.000	0.000	0.000	0.000
1991-2019	0.054	0.030	0.000	0.132	0.021
Proportionality					
1991-2000	0.058	0.077	-0.028	0.064	0.059
2000-2010	-0.053	-0.051	-0.010	-0.070	-0.023
2010-2019	0.015	0.011	0.025	0.019	0.011
1991-2019	0.003	0.018	-0.074	0.057	0.002

NCD					
Gini index					
1991	0.740	0.739	0.741	0.747	0.742
2000	0.754	0.757	0.752	0.756	0.755
2010	0.783	0.785	0.780	0.776	0.787
2019	0.789	0.790	0.789	0.782	0.792
Reranking					
1991-2000	0.006	0.010	0.002	0.002	0.002
2000-2010	0.002	0.001	0.014	0.000	0.013
2010-2019	0.000	0.000	0.000	0.001	0.000
1991-2019	0.037	0.037	0.038	0.006	0.037
Proportionality					
1991-2000	-0.009	-0.008	-0.009	-0.008	-0.011
2000-2010	-0.027	-0.027	-0.014	-0.019	-0.019
2010-2019	-0.006	-0.005	-0.008	-0.006	-0.005
1991-2019	-0.013	-0.015	-0.009	-0.030	-0.013
Injury					
Gini index					
1991	0.515	0.488	0.561	0.434	0.536
2000	0.521	0.519	0.556	0.498	0.541
2010	0.558	0.568	0.551	0.564	0.560
2019	0.558	0.567	0.545	0.565	0.557
Reranking					
1991-2000	0.026	0.045	0.044	0.022	0.022
2000-2010	0.029	0.027	0.042	0.031	0.067
2010-2019	0.017	0.016	0.014	0.001	0.031
1991-2019	0.174	0.183	0.164	0.035	0.167
Proportionality					
1991-2000	0.020	0.014	0.050	-0.042	0.017
2000-2010	-0.008	-0.022	0.047	-0.035	0.047
2010-2019	0.017	0.017	0.019	-0.001	0.035
1991-2019	0.131	0.104	0.180	-0.097	0.146

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

Table 3. Changes in the contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific secondary-cause crude mortality difference, from 1991 to 2019

Periods	Mortality Difference	Demographic Structure	Non-demographic Factors
CMNN			
Both			
1991-2000	-37.851	-7.80%	-43.31%
2000-2010	-11.752	12.09%	-44.54%
2010-2019	-1.855	40.32%	-47.90%
1991-2019	-51.458	20.69%	-90.17%
Male			
1991-2000	-37.970	-7.24%	-42.32%
2000-2010	-10.724	12.52%	-40.27%
2010-2019	-1.623	37.87%	-43.69%
1991-2019	-50.317	22.23%	-87.91%

Female			
1991-2000	-34.403	-9.52%	-39.42%
2000-2010	-15.038	12.80%	-54.68%
2010-2019	-2.060	44.88%	-54.76%
1991-2019	-51.501	19.45%	-92.70%
Urban			
1991-2000	-12.337	13.50%	-53.14%
2000-2010	6.253	12.14%	21.15%
2010-2019	0.294	44.66%	-43.49%
1991-2019	-5.790	60.80%	-79.40%
Rural			
1991-2000	-43.209	-8.95%	-40.93%
2000-2010	-19.303	10.82%	-55.28%
2010-2019	-2.914	36.51%	-48.60%
1991-2019	-65.426	15.51%	-91.04%
NCD			
Both			
1991-2000	57.724	20.90%	-6.92%
2000-2010	20.313	9.85%	-5.53%
2010-2019	105.792	49.15%	-27.60%
1991-2019	183.829	85.79%	-41.26%
Male			
1991-2000	70.298	21.92%	-6.38%
2000-2010	38.546	11.02%	-3.65%
2010-2019	113.908	47.28%	-26.98%
1991-2019	222.753	88.54%	-39.30%
Female			
1991-2000	45.035	20.13%	-8.01%
2000-2010	0.877	7.91%	-7.70%
2010-2019	98.101	52.88%	-29.39%
1991-2019	144.013	83.72%	-44.97%
Urban			
1991-2000	53.215	24.01%	-11.73%
2000-2010	-17.682	14.72%	-18.35%
2010-2019	92.399	40.04%	-20.33%
1991-2019	127.932	80.29%	-50.75%
Rural			
1991-2000	58.201	19.52%	-5.22%
2000-2010	39.192	4.21%	4.21%
2010-2019	110.719	56.15%	-34.20%
1991-2019	208.112	87.24%	-36.10%
Injury			
Both			
1991-2000	-10.925	4.40%	-20.96%
2000-2010	-3.877	5.83%	-12.87%
2010-2019	-4.942	19.08%	-28.73%

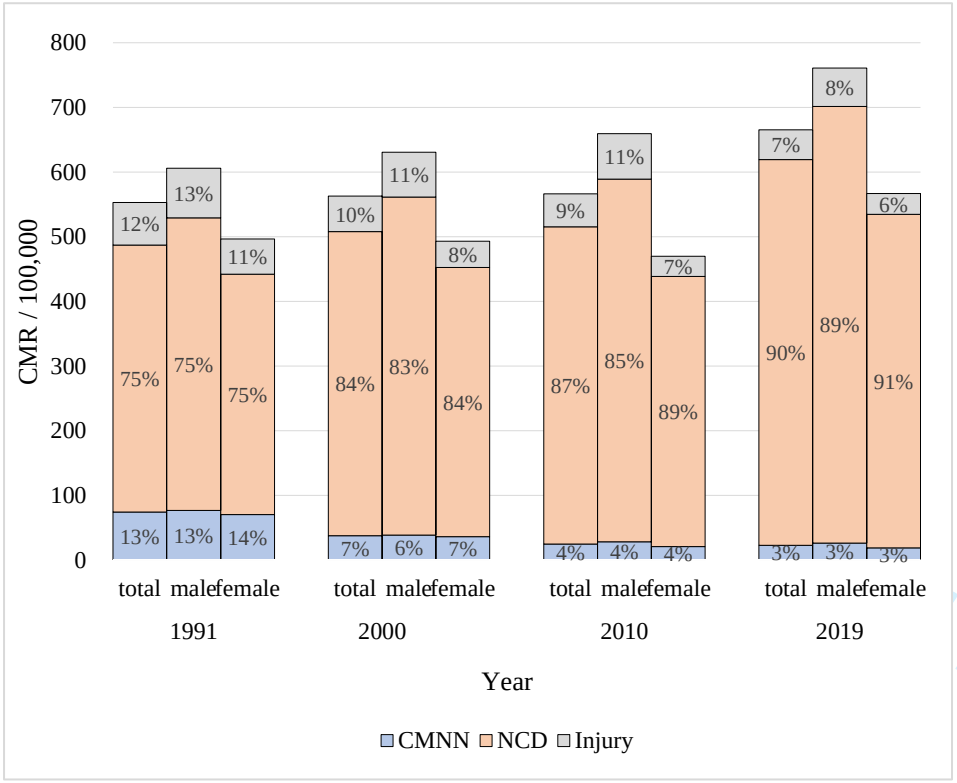
1991-2019	-19.743	23.70%	-53.62%
Male			
1991-2000	-7.927	4.89%	-15.16%
2000-2010	0.988	6.68%	-5.25%
2010-2019	-10.642	14.36%	-29.52%
1991-2019	-17.581	23.08%	-45.87%
Female			
1991-2000	-13.746	3.64%	-28.95%
2000-2010	-9.183	4.44%	-27.07%
2010-2019	1.127	30.27%	-26.68%
1991-2019	-21.802	24.91%	-65.05%
Urban			
1991-2000	-0.756	9.78%	-11.90%
2000-2010	1.692	4.35%	0.49%
2010-2019	-0.336	17.86%	-18.77%
1991-2019	0.600	37.81%	-36.13%
Rural			
1991-2000	-12.987	3.64%	-21.02%
2000-2010	-1.699	5.29%	-8.04%
2010-2019	-8.647	20.99%	-35.39%
1991-2019	-23.334	22.67%	-53.89%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

Legends for figures

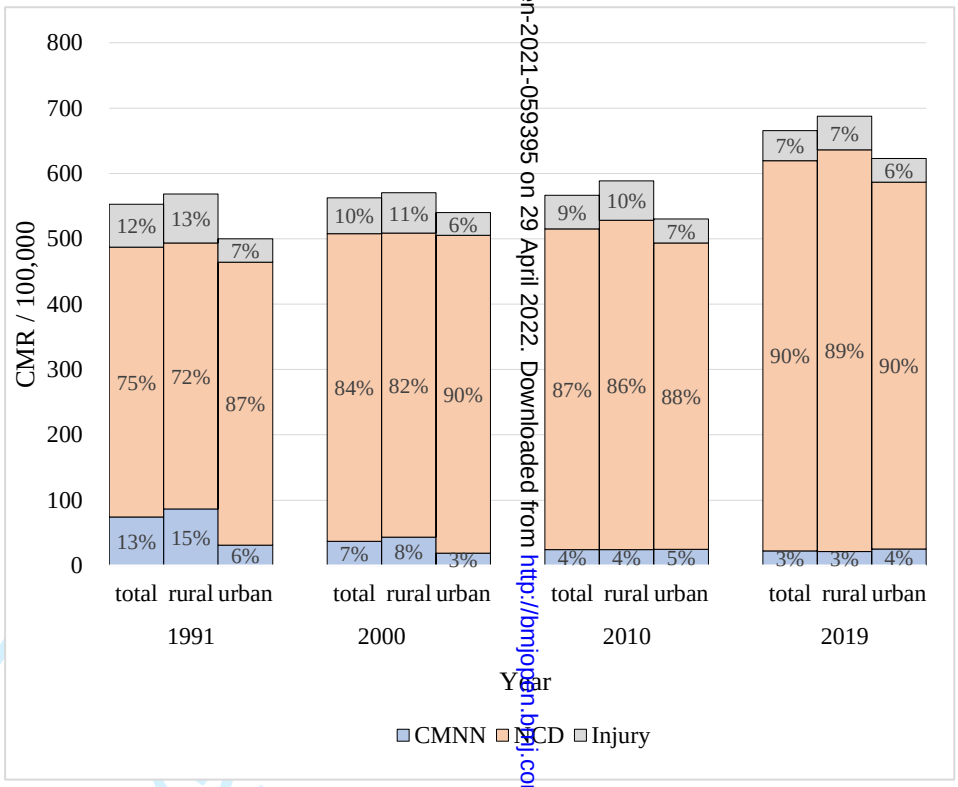
Figure 1. CMR and Gini coefficient of all-cause, CMNN, NCD, and injury in 1991, 2000, 2010, and 2019. (A). Both, male and female. (B). Both, urban and rural. **(A)** Male and female; **(B)** Urban and rural. (CMR: crude mortality rate; CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.)

Figure 2. SMR per 100,000 persons of all-cause and three major categories (CMNN, NCD, and injury) in China, 1991-2019. **(A)** Total; **(B)** CMNN; **(C)** NCD; **(D)** Injury. (SMR: standardized mortality rate; CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.)



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.443	0.502	0.541	0.560
Male	0.454	0.506	0.535	0.553
Female	0.440	0.491	0.553	0.573

(A) Male and female



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.443	0.502	0.541	0.560
Urban	0.531	0.570	0.545	0.561
Rural	0.422	0.485	0.541	0.560

(B) Urban and rural

Figure 1. CMR and Gini coefficient of all-cause, CMNN, NCD, and injury in 1991, 2000, 2010, and 2019

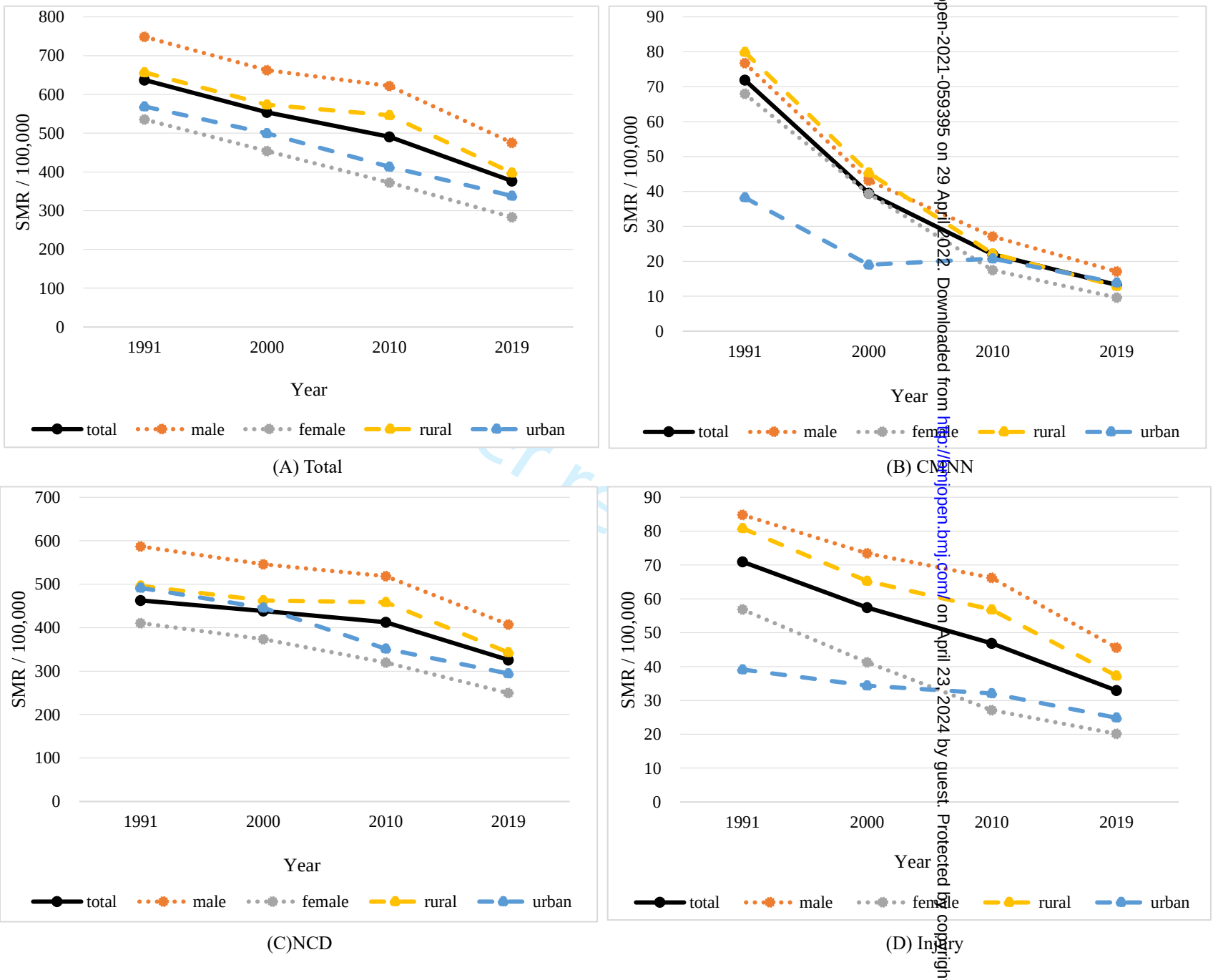


Figure 2. SMR per 100,000 persons of all-cause and three major categories (CMNN, NCD, and injury) in China, 1991-2019

Supplementary Materials

Contents

Part A: calculation formulas

1.Gini decomposition method

The Gini decomposition formulas are as follows:

$$\Delta G = G_1 - G_0 \equiv R - P \quad (1)$$

$$R = G_1 - G_1^{(0)} \quad (2)$$

$$P = G_0 - G_1^{(0)} \quad (3)$$

Where G_1 and G_0 represent *G* in the 0th and the 1st years, respectively. $G_1^{(0)}$ also known as the concentration coefficient, is the *G* in the 1st year based on the ranks in the 0th year. ΔG is the difference in the *G* in different years, and can be decomposed into reranking (*R*) and proportionality (*P*). R represents the importance of the *G* change from reranking of causes and indicates the mobility of mortality causes. A higher and lower indicates greater and smaller rank changes, respectively. At a constant rank, *R*=0, and, when the rank is completely reversed, *R*=2G_1. *P* indicates the change in the *G* that accounts for the proportion, when ranking is held constant at the original distribution; thus, *P* indicates the progressivity of mortality causes. Table S1 presents relationships among *P*-values, aggregate rates, and mortality causes.

2.Mortality-rate-difference method

The crude mortality rate (CMR) difference equates to the sum of the age structure difference (weighted by the mean mortality rate) and mortality difference (weighted by the age structure). Assume that we have two comparison 1991 and 2019 for which we have the CMR and populations data by age groups. We use M to express the CMR, C to express the age structure, and x to express age groups. In this study, we use 5-year age groups. Thus, the CMR difference between 1991 and 2019 can be calculated using the following steps.[1,2]

Step 1: Determine the population proportion and mortality rate by age group (5-year-old for one group) in 1991 and 2019.

Step 2: Calculate the difference of population proportion by age: $C_x^{2019} - C_x^{1991}$.

Step 3: Calculate weight 1: $(M_x^{2019} + M_x^{1991})/2$.

Step 4: Calculate the effect of age structure difference: $\sum_0^\infty (C_x^{2019} - C_x^{1991}) \times \frac{M_x^{2019} + M_x^{1991}}{2}$.

Step 5: Calculate age-specific mortality difference between 1991 and 2019: $M_x^{2019} - M_x^{1991}$.

Step 6: Calculate weight 2: $(C_x^{2019} + C_x^{1991})/2$.

Step 7: Calculate the effect of mortality difference: $\sum_0^\infty (M_x^{2019} - M_x^{1991}) \times \frac{C_x^{2019} + C_x^{1991}}{2}$.

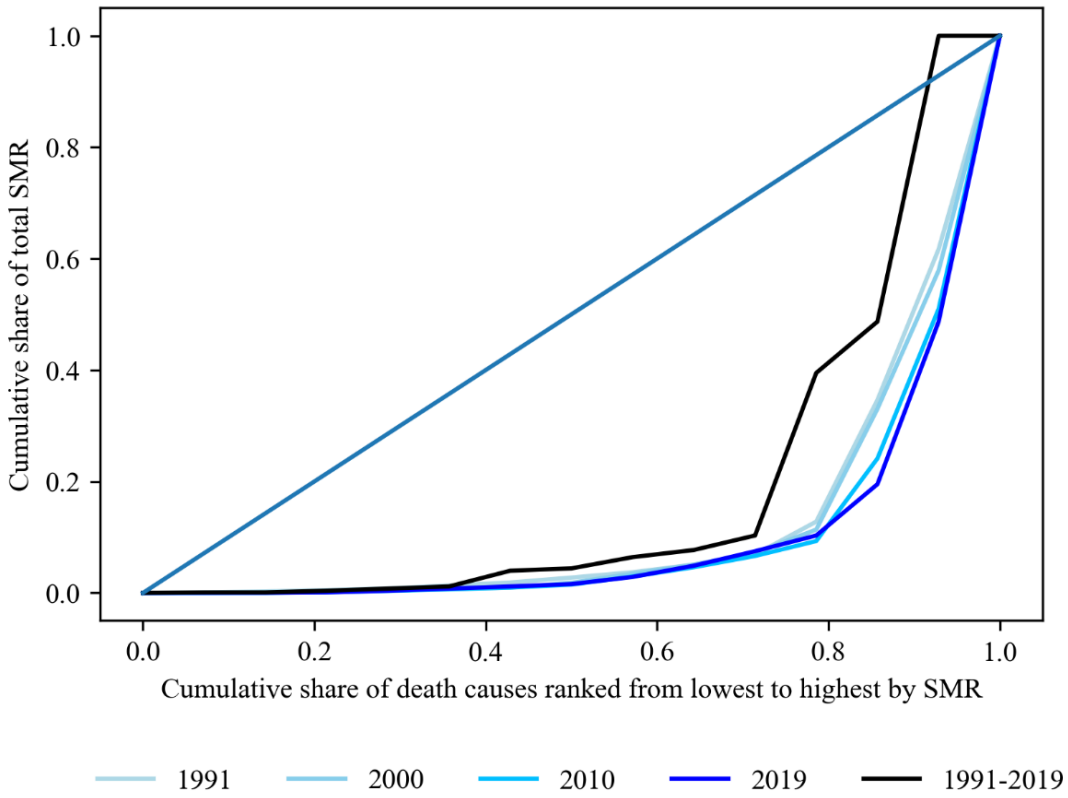
The CMR difference is expressed as values and percentages.

[1] Kitagawa, E.Y. Components of a difference between two rates. JASA 1955;50(272): 1168-1194.

[2] Zhai Z, Lu L, Luo M, et al. Modern population analysis techniques: China Renmin University Press 1989.

Part B: supplementary figure

Figure S1. Lorenz curve for secondary-cause standardized mortality rates ranked from lowest to highest by contribution to the all-cause standardized mortality rates of non-communicable diseases, from 1991 to 2019.



SMR: standardized mortality rate.

Part C: supplementary tables

Table S1. Association between proportionality index and attributable causes

Aggregate Rate	Proportionality (*P*)	Causes responsible for growth/decline
Growing	+*P*	Low-ranking
	-*P*	High-ranking
Declining	+*P*	High-ranking
	-*P*	Low-ranking

Table S2. Changes in ranks and proportion of secondary causes for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	1	36.00%	2	29.09%	2	32.45%	2	31.14%
Respiratory infections	2	36.22%	1	48.63%	1	49.63%	1	54.31%
Conditions arising during the perinatal period	3	22.64%	3	17.72%	3	13.22%	3	5.66%
Nutritional deficiencies	4	2.96%	4	3.35%	4	3.93%	4	8.58%
Pregnancy, childbirth and puerperal complications	5	2.17%	5	1.21%	5	0.78%	5	0.31%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	44.73%	1	54.47%	1	48.51%	1	53.22%
Respiratory diseases	2	31.55%	2	28.59%	3	14.42%	3	9.95%
Malignant neoplasms	3	7.65%	4	2.95%	2	27.92%	2	27.23%
Digestive diseases	4	7.16%	3	5.21%	4	2.68%	5	2.46%
Genito-urinary diseases	5	2.14%	5	2.58%	7	1.44%	7	1.18%
Congenital anomalies	6	1.74%	8	0.96%	8	0.48%	11	0.22%
Neuro-psychiatric conditions	7	1.68%	6	2.08%	6	1.54%	6	1.90%
Diabetes mellitus	8	1.06%	7	2.01%	5	2.09%	4	2.79%
Endocrine disorders	9	0.67%	9	0.34%	10	0.26%	9	0.33%
Musculoskeletal and connective tissue diseases	10	0.64%	11	0.26%	9	0.31%	8	0.37%
Non-malignant neoplasms	11	0.35%	10	0.29%	11	0.25%	10	0.27%
Sensory organ diseases	12	0.30%	13	0.12%	14	0.00%	13	0.01%
Skin diseases	13	0.21%	12	0.14%	12	0.09%	12	0.08%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	32.33%	2	27.16%	2	16.45%	3	13.35%
Other unintentional injuries	2	18.32%	3	14.85%	4	13.26%	4	13.28%
Road traffic accidents	3	14.78%	1	27.22%	1	38.55%	1	31.14%
Drownings	4	14.63%	4	11.14%	5	8.07%	5	6.98%
Poisonings	5	6.62%	6	6.40%	6	6.03%	6	5.97%
Falls	6	6.28%	5	6.56%	3	14.43%	2	27.09%
Violence	7	4.03%	7	4.38%	7	1.84%	8	0.74%

Fires	8	2.31%	8	1.90%	8	1.27%	7	1.36%
Other intentional injuries	9	0.66%	9	0.40%	9	0.10%	9	0.09%
War	10	0.04%	10	0.00%	10	0.00%	10	0.00%
Male								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	1	40.83%	2	33.61%	2	37.76%	2	36.87%
Respiratory infections	2	34.24%	1	45.98%	1	45.54%	1	51.14%
Conditions arising during the perinatal period	3	22.97%	3	17.18%	3	13.51%	3	5.86%
Nutritional deficiencies	4	1.97%	4	3.24%	4	3.19%	4	6.13%
Pregnancy, childbirth and puerperal complications	5	0.00%	5	0.00%	5	0.00%	5	0.00%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	35.69%	1	54.14%	1	46.13%	1	50.00%
Respiratory diseases	2	25.59%	2	27.94%	3	14.17%	3	10.33%
Malignant neoplasms	3	25.04%	4	3.31%	2	31.08%	2	30.67%
Digestive diseases	4	6.51%	3	6.10%	4	2.99%	4	2.72%
Genito-urinary diseases	5	1.98%	5	2.76%	6	1.41%	7	1.22%
Congenital anomalies	6	1.40%	8	1.02%	8	0.47%	11	0.21%
Neuro-psychiatric conditions	7	1.37%	6	2.03%	7	1.37%	6	1.66%
Diabetes mellitus	8	0.74%	7	1.66%	5	1.63%	5	2.33%
Endocrine disorders	10	0.37%	10	0.26%	9	0.24%	8	0.29%
Musculoskeletal and connective tissue diseases	9	0.48%	11	0.20%	11	0.21%	9	0.26%
Non-malignant neoplasms	11	0.30%	9	0.28%	10	0.24%	10	0.25%
Sensory organ diseases	12	0.25%	12	0.20%	14	0.00%	13	0.00%
Skin diseases	13	0.20%	13	0.10%	12	0.06%	12	0.06%
Oral conditions	14	0.08%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	24.41%	2	21.53%	3	13.12%	4	12.16%
Other unintentional injuries	2	21.77%	3	16.88%	2	14.28%	3	13.39%
Road traffic accidents	3	18.14%	1	30.36%	1	42.09%	1	34.72%
Drownings	4	16.08%	4	11.38%	5	7.91%	5	6.75%
Poisonings	5	6.51%	5	6.81%	6	6.29%	6	6.62%
Falls	6	5.44%	6	6.35%	4	13.10%	2	24.21%
Violence	7	4.31%	7	4.48%	7	1.85%	8	0.63%
Fires	8	2.26%	8	1.60%	8	1.20%	7	1.40%

Other intentional injuries	9	1.04%	9	0.62%	9	0.14%	9	0.12%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%
Female								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	2	30.95%	3	24.15%	2	24.99%	2	22.88%
Respiratory infections	1	39.08%	1	51.57%	1	55.30%	1	58.97%
Conditions arising during the perinatal period	3	22.67%	2	18.22%	3	12.81%	3	5.38%
Nutritional deficiencies	4	4.14%	4	3.49%	4	4.99%	4	12.08%
Pregnancy, childbirth and puerperal complications	5	4.50%	5	2.56%	5	1.92%	5	0.69%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	40.59%	1	54.87%	1	51.84%	1	57.56%
Respiratory diseases	2	28.10%	2	29.34%	3	14.79%	3	9.44%
Malignant neoplasms	3	17.85%	4	2.53%	2	23.50%	2	22.58%
Digestive diseases	4	5.48%	3	4.16%	5	2.26%	6	2.12%
Genito-urinary diseases	5	1.60%	6	2.35%	7	1.48%	7	1.14%
Congenital anomalies	6	1.56%	8	0.89%	8	0.49%	11	0.23%
Neuro-psychiatric conditions	7	1.49%	7	2.15%	6	1.78%	5	2.23%
Diabetes mellitus	8	1.10%	5	2.43%	4	2.72%	4	3.41%
Endocrine disorders	9	0.81%	9	0.43%	10	0.29%	9	0.38%
Musculoskeletal and connective tissue diseases	10	0.60%	10	0.34%	9	0.45%	8	0.51%
Non-malignant neoplasms	11	0.30%	11	0.30%	11	0.27%	10	0.30%
Sensory organ diseases	12	0.25%	13	0.03%	14	0.00%	13	0.01%
Skin diseases	13	0.15%	12	0.18%	12	0.14%	12	0.10%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	43.93%	1	37.17%	2	24.14%	3	15.58%
Other unintentional injuries	2	13.35%	3	11.27%	4	10.89%	4	13.09%
Road traffic accidents	3	12.52%	4	10.72%	5	8.44%	5	7.42%
Drownings	4	9.76%	2	21.70%	1	30.33%	2	24.39%
Poisonings	5	7.50%	5	6.94%	3	17.53%	1	32.52%
Falls	6	6.79%	6	5.68%	6	5.45%	6	4.75%
Violence	7	3.61%	7	4.08%	7	1.77%	8	0.96%
Fires	8	2.38%	8	2.44%	8	1.45%	7	1.30%
Other intentional injuries	9	0.10%	9	0.00%	9	0.00%	9	0.00%

War	10	0.06%	10	0.00%	10	0.00%	10	0.00%
Urban								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	43.91%	2	30.71%	2	26.69%	2	25.31%
Respiratory infections	2	36.56%	1	54.21%	1	60.97%	1	63.13%
Conditions arising during the perinatal period	3	17.81%	3	11.51%	3	7.43%	3	4.54%
Nutritional deficiencies	4	0.63%	4	2.56%	4	4.43%	4	6.79%
Pregnancy, childbirth and puerperal complications	5	1.09%	5	1.02%	5	0.48%	5	0.24%
NCD								
total		100.00%		100.00%		100.00%		100%
Cardiovascular diseases	1	55.57%	1	61.91%	1	46.65%	1	51.38%
Respiratory diseases	2	22.51%	2	19.19%	3	12.05%	3	8.81%
Digestive diseases	3	6.17%	3	4.65%	5	2.84%	5	2.67%
Malignant neoplasms	4	4.22%	7	1.62%	2	30.97%	2	29.06%
Neuro-psychiatric conditions	5	2.75%	5	3.24%	6	1.71%	6	2.05%
Genito-urinary diseases	6	2.70%	6	2.89%	7	1.39%	7	1.18%
Diabetes mellitus	7	2.54%	4	4.10%	4	2.85%	4	3.38%
Congenital anomalies	8	1.44%	8	1.09%	8	0.41%	11	0.21%
Endocrine disorders	9	0.87%	9	0.43%	10	0.35%	9	0.41%
Musculoskeletal and connective tissue diseases	10	0.51%	11	0.34%	11	0.31%	8	0.43%
Non-malignant neoplasms	11	0.42%	10	0.36%	9	0.36%	10	0.33%
Skin diseases	12	0.23%	12	0.14%	12	0.11%	12	0.07%
Sensory organ diseases	13	0.06%	13	0.03%	13	0.00%	13	0.01%
Oral conditions	14	0.00%	14	0.00%	14	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Road traffic accidents	1	23.53%	1	33.96%	1	37.65%	2	29.35%
Self-inflicted injuries	2	20.68%	2	16.51%	3	15.04%	4	11.72%
Falls	3	14.23%	3	14.02%	2	18.44%	1	31.39%
Other unintentional injuries	4	14.04%	4	10.75%	4	12.79%	3	14.20%
Violence	5	8.73%	6	7.48%	7	2.09%	8	0.73%
Drownings	6	8.73%	7	4.98%	6	6.28%	5	6.25%
Poisonings	7	8.16%	5	10.59%	5	6.37%	6	4.99%
Fires	8	0.95%	8	1.09%	8	1.14%	7	1.23%
Other intentional injuries	9	0.76%	9	0.62%	9	0.19%	9	0.14%
War	10	0.19%	10	0.00%	10	0.00%	10	0.00%

Rural								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	35.18%	2	28.84%	2	36.08%	2	30.53%
Respiratory infections	2	36.18%	1	47.85%	1	42.43%	1	42.97%
Conditions arising during the perinatal period	3	23.14%	3	18.61%	3	16.88%	4	5.60%
Nutritional deficiencies	4	3.20%	4	3.47%	4	3.61%	3	8.50%
Pregnancy, childbirth and puerperal complications	5	2.29%	5	1.24%	5	1.00%	5	0.29%
NCD								
total		100.00%		100.00%		100.00%		100%
Cardiovascular diseases	1	41.89%	1	52.15%	1	49.57%	1	54.09%
Respiratory diseases	2	33.92%	2	31.53%	3	15.77%	3	10.49%
Malignant neoplasms	3	8.54%	4	3.36%	2	26.19%	2	26.36%
Digestive diseases	4	7.42%	3	5.38%	4	2.59%	5	2.37%
Genito-urinary diseases	5	1.99%	5	2.48%	6	1.46%	7	1.19%
Congenital anomalies	6	1.82%	8	0.92%	8	0.52%	11	0.22%
Neuro-psychiatric conditions	7	1.40%	6	1.72%	7	1.44%	6	1.83%
Musculoskeletal and connective tissue diseases	8	0.68%	11	0.24%	9	0.31%	8	0.33%
Diabetes mellitus	9	0.68%	7	1.36%	5	1.66%	4	2.51%
Endocrine disorders	10	0.62%	9	0.30%	10	0.21%	9	0.29%
Sensory organ diseases	11	0.36%	12	0.15%	14	0.00%	13	0.00%
Non-malignant neoplasms	12	0.34%	10	0.27%	11	0.19%	10	0.25%
Skin diseases	13	0.21%	13	0.14%	12	0.08%	12	0.08%
Oral conditions	14	0.14%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Self-inflicted injuries	1	33.71%	1	29.08%	2	16.96%	3	13.95%
Other unintentional injuries	2	18.83%	3	15.58%	3	13.43%	4	12.95%
Drownings	3	15.33%	4	12.25%	5	8.72%	5	7.24%
Road traffic accidents	4	13.74%	2	26.01%	1	38.90%	1	31.77%
Poisonings	5	6.44%	5	5.65%	6	5.91%	6	6.33%
Falls	6	5.33%	6	5.21%	4	12.96%	2	25.52%
Violence	7	3.47%	7	3.82%	7	1.74%	8	0.77%
Fires	8	2.47%	8	2.05%	8	1.32%	7	1.42%
Other intentional injuries	9	0.65%	9	0.35%	9	0.07%	9	0.06%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases. *1 represents the highest rank.

Table S3. Changes in ranks and proportion of neoplasms and cardiovascular diseases for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	14.88%	3	12.05%
Liver cancer	2	19.12%	2	20.35%	2	18.09%	2	15.04%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	26.34%	1	29.22%
Esophagus cancer	4	12.66%	4	10.43%	5	8.79%	6	7.39%
Other malignant neoplasms	5	7.21%	5	7.99%	4	9.36%	4	10.15%
Colon and rectum cancers	6	5.50%	6	4.91%	6	6.04%	5	7.52%
Leukemia	7	4.01%	7	3.51%	8	2.65%	9	2.33%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.76%	11	1.85%
Breast cancer	9	1.85%	10	1.90%	9	2.39%	8	2.41%
Pancreas cancer	10	1.84%	9	2.10%	7	2.69%	7	3.69%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	11	1.67%	10	2.18%
Cervix uteri cancer	12	1.37%	13	1.18%	14	1.04%	12	1.64%
Bladder cancer	13	1.15%	11	1.39%	13	1.05%	13	1.27%
Corpus uteri cancer	14	0.77%	14	0.86%	12	1.37%	16	0.76%
Melanoma and other skin cancers	15	0.51%	15	0.53%	17	0.39%	17	0.48%
Ovary cancer	16	0.39%	17	0.34%	16	0.68%	15	0.87%
Prostate cancer	17	0.24%	16	0.38%	15	0.80%	14	1.16%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	51.45%	1	56.07%	1	55.28%	1	47.17%
Ischemic heart disease	2	15.42%	2	20.69%	2	34.25%	2	40.45%
Hypertensive heart disease	3	14.58%	4	9.53%	3	5.04%	3	7.25%
Other cardiovascular diseases	4	12.22%	3	10.41%	4	4.00%	4	3.84%
Rheumatic heart disease	5	6.33%	5	3.29%	5	1.43%	5	1.29%
Male								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.98%	3	19.91%	3	15.79%	3	12.87%
Liver cancer	2	21.82%	2	22.53%	2	20.76%	2	17.14%
Trachea, bronchus and lung cancers	3	20.06%	1	23.78%	1	28.43%	1	31.72%

Esophagus cancer	4	13.59%	4	9.89%	4	9.89%	5	8.57%
Other malignant neoplasms	5	6.30%	5	7.15%	5	8.44%	4	9.34%
Colon and rectum cancers	6	4.81%	6	4.35%	6	5.44%	6	6.98%
Leukemia	7	3.29%	7	3.09%	8	2.39%	9	2.10%
Mouth and oropharynx cancers	8	2.57%	8	2.18%	9	1.90%	8	2.12%
Pancreas cancer	9	1.87%	9	1.88%	7	2.45%	7	3.27%
Lymphomas and multiple myeloma	10	1.53%	11	1.22%	10	1.62%	10	2.07%
Bladder cancer	11	1.17%	10	1.75%	12	1.19%	12	1.55%
Melanoma and other skin cancers	12	0.48%	13	0.45%	13	0.34%	13	0.41%
Prostate cancer	13	0.38%	12	0.59%	11	1.24%	11	1.79%
Breast cancer	14	0.11%	14	0.13%	14	0.12%	14	0.06%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	52.54%	1	57.77%	1	56.66%	1	49.00%
Ischemic heart disease	2	16.25%	2	20.86%	2	33.49%	2	39.33%
Hypertensive heart disease	3	14.22%	4	9.30%	3	4.69%	3	6.52%
Other cardiovascular diseases	4	11.85%	3	9.61%	4	4.11%	4	4.11%
Rheumatic heart disease	5	5.14%	5	2.46%	5	1.05%	5	1.03%
Female								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	19.95%	2	17.49%	2	13.18%	4	10.53%
Trachea, bronchus and lung cancers	2	15.15%	1	17.81%	1	22.49%	1	24.65%
Liver cancer	3	14.33%	3	16.36%	3	13.16%	3	11.20%
Esophagus cancer	4	11.00%	6	6.77%	6	6.77%	7	5.23%
Other malignant neoplasms	5	8.79%	5	9.49%	4	11.08%	2	11.63%
Colon and rectum cancers	6	6.74%	6	5.91%	5	7.13%	5	8.49%
Leukemia	7	5.31%	8	4.24%	9	3.14%	10	2.74%
Breast cancer	8	4.90%	7	5.08%	7	6.58%	6	6.73%
Cervix uteri cancer	9	3.80%	9	3.32%	11	2.95%	8	4.63%
Corpus uteri cancer	10	2.15%	11	2.40%	8	3.91%	13	2.16%
Mouth and oropharynx cancers	11	2.02%	12	2.00%	14	1.50%	14	1.36%
Pancreas cancer	12	1.80%	10	2.50%	10	3.13%	9	4.46%
Lymphomas and multiple myeloma	13	1.34%	13	1.31%	13	1.77%	12	2.38%
Bladder cancer	14	1.12%	15	0.72%	15	0.78%	15	0.76%

Ovary cancer	15	1.05%	14	0.94%	12	1.95%	11	2.46%
Melanoma and other skin cancers	16	0.55%	16	0.69%	16	0.49%	16	0.60%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	54.14%	1	53.55%	1	45.03%
Ischemic heart disease	2	14.46%	2	20.43%	2	35.20%	2	41.76%
Other cardiovascular diseases	4	12.64%	3	11.34%	4	3.87%	4	3.52%
Hypertensive heart disease	3	15.00%	4	9.83%	3	5.48%	3	8.11%
Rheumatic heart disease	5	7.65%	5	4.27%	5	1.91%	5	1.59%
Urban								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Trachea, bronchus and lung cancers	1	26.27%	1	29.62%	1	28.73%	1	30.09%
Liver cancer	2	16.04%	2	16.93%	2	14.86%	2	13.16%
Stomach cancer	3	14.54%	3	13.07%	3	12.79%	3	10.84%
Other malignant neoplasms	4	10.71%	4	8.99%	4	10.59%	4	10.48%
Esophagus cancer	5	7.59%	6	5.23%	6	5.94%	6	6.15%
Colon and rectum cancers	6	6.76%	5	6.55%	5	7.60%	5	8.85%
Leukemia	7	3.87%	8	3.38%	9	2.50%	10	2.28%
Pancreas cancer	8	3.08%	7	3.41%	7	3.72%	7	4.38%
Breast cancer	9	2.73%	9	2.96%	8	3.06%	8	2.89%
Mouth and oropharynx cancers	10	2.17%	10	2.68%	11	1.88%	11	1.79%
Lymphomas and multiple myeloma	11	1.42%	12	1.57%	10	2.18%	9	2.43%
Bladder cancer	12	1.22%	11	1.95%	12	1.36%	14	1.44%
Corpus uteri cancer	13	0.99%	15	0.84%	16	1.03%	16	0.69%
Cervix uteri cancer	14	0.95%	13	1.08%	15	1.10%	13	1.47%
Ovary cancer	15	0.83%	14	0.98%	14	1.13%	15	1.11%
Melanoma and other skin cancers	16	0.51%	17	0.28%	17	0.38%	17	0.44%
Prostate cancer	17	0.32%	16	0.49%	13	1.15%	12	1.51%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	54.91%	1	53.06%	1	49.38%	1	45.16%
Ischemic heart disease	2	21.71%	2	27.05%	2	38.69%	2	42.62%
Hypertensive heart disease	3	10.44%	4	7.75%	4	5.02%	3	6.62%
Other cardiovascular diseases	4	9.00%	3	9.98%	3	5.67%	4	4.37%
Rheumatic heart disease	5	3.95%	5	2.16%	5	1.24%	5	1.24%

Rural								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	16.27%	3	12.67%
Liver cancer	2	19.12%	2	20.35%	2	20.25%	2	16.02%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	24.74%	1	28.78%
esophagus cancer	4	12.66%	4	10.43%	4	10.70%	5	8.04%
Other malignant neoplasms	5	7.21%	5	7.99%	5	8.55%	4	9.98%
Colon and rectum cancers	6	5.50%	6	4.91%	6	4.99%	6	6.81%
Leukemia	7	4.01%	7	3.51%	7	2.75%	8	2.35%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.68%	11	1.88%
Breast cancer	9	1.85%	10	1.90%	9	1.94%	9	2.16%
Pancreas cancer	10	1.84%	9	2.10%	8	2.00%	7	3.34%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	12	1.34%	10	2.05%
Cervix uteri cancer	12	1.37%	13	1.18%	13	0.99%	12	1.73%
Bladder cancer	13	1.15%	11	1.39%	14	0.84%	13	1.18%
Corpus uteri cancer	14	0.77%	14	0.86%	11	1.60%	15	0.80%
Melanoma and other skin cancers	15	0.51%	15	0.53%	16	0.41%	17	0.50%
Ovary cancer	16	0.39%	17	0.34%	17	0.38%	16	0.74%
Prostate cancer	17	0.24%	16	0.38%	15	0.58%	14	0.97%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	57.19%	1	58.41%	1	48.08%
Hypertensive heart disease	2	16.02%	4	10.20%	3	5.05%	3	7.54%
Other cardiovascular diseases	3	13.34%	3	10.58%	4	3.11%	4	3.60%
Ischemic heart disease	4	13.24%	2	18.33%	2	31.89%	2	39.47%
Rheumatic heart disease	5	7.16%	5	3.71%	5	1.54%	5	1.31%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

*1 represents the highest rank.

Table S4. Changes in Gini coefficients, reranking, and proportionality of neoplasms and cardiovascular diseases for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	Both	Male	Female	Urban	Rural
Neoplasms					
Gini index					
1991	0.599	0.658	0.523	0.582	0.622
2000	0.602	0.664	0.525	0.587	0.622
2010	0.588	0.659	0.506	0.565	0.610
2019	0.569	0.608	0.492	0.556	0.576
Reranking					
1991-2000	0.007	0.010	0.003	0.003	0.009
2000-2010	0.005	0.001	0.004	0.003	0.018
2010-2019	0.004	0.030	0.016	0.001	0.007
1991-2019	0.050	0.073	0.056	0.010	0.072
Proportionality					
1991-2000	0.003	0.004	0.001	-0.001	0.009
2000-2010	0.019	0.006	0.023	0.024	0.030
2010-2019	0.024	0.081	0.029	0.010	0.042
1991-2019	0.081	0.124	0.087	0.036	0.118
Cardiovascular diseases					
Gini index					
1991	0.374	0.396	0.350	0.384	0.356
2000	0.468	0.489	0.440	0.393	0.462
2010	0.547	0.557	0.535	0.415	0.566
2019	0.514	0.523	0.503	0.393	0.519
Reranking					
1991-2000	0.002	0.001	0.046	0.011	0.034
2000-2010	0.004	0.002	0.006	0.000	0.007
2010-2019	0.000	0.000	0.000	0.005	0.000
1991-2019	0.000	0.000	0.133	0.000	0.128
Proportionality					
1991-2000	-0.092	-0.092	-0.044	0.002	-0.072
2000-2010	-0.076	-0.066	-0.089	-0.022	-0.097
2010-2019	0.033	0.034	0.032	0.026	0.048
1991-2019	-0.140	-0.127	-0.020	-0.009	-0.035

Table S5. Changes in contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific crude mortality difference of neoplasm and cardiovascular diseases, from 1991 to 2019

	Mortality Difference	Demographic Structure	Non-demographic Factors
Neoplasms			
Both			
1991-2000	22.745	17.56%	7.65%
2000-2010	24.081	18.30%	3.02%
2010-2019	25.410	35.40%	-16.86%
1991-2019	72.235	84.58%	-4.51%
Male			
1991-2000	29.505	18.60%	7.44%
2000-2010	31.627	18.28%	3.87%
2010-2019	32.626	36.06%	-17.35%
1991-2019	93.758	87.22%	-4.46%
Female			
1991-2000	15.702	16.76%	6.92%
2000-2010	16.123	17.62%	2.03%
2010-2019	18.328	35.65%	-16.97%
1991-2019	50.153	82.04%	-6.40%
Urban			
1991-2000	14.468	19.47%	-7.71%
2000-2010	7.612	17.24%	-11.71%
2010-2019	17.914	26.63%	-14.29%
1991-2019	39.993	67.14%	-34.65%
Rural			
1991-2000	24.026	16.29%	13.47%
2000-2010	27.341	15.40%	10.70%
2010-2019	30.033	41.97%	-19.23%
1991-2019	81.400	91.35%	9.48%
Cardiovascular diseases			
Both			
1991-2000	44.582	24.76%	3.78%
2000-2010	37.284	7.60%	10.96%
2010-2019	79.416	56.81%	-23.46%
1991-2019	161.282	107.63%	-4.41%
Male			
1991-2000	51.266	26.31%	5.45%
2000-2010	46.201	9.09%	12.63%
2010-2019	78.670	53.82%	-23.43%
1991-2019	176.138	111.18%	-2.08%
Female			

1991-2000	37.431	23.44%	1.35%
2000-2010	28.051	5.53%	9.36%
2010-2019	80.390	61.30%	-24.17%
1991-2019	145.872	104.75%	-8.14%
Urban			
1991-2000	39.771	27.36%	-5.23%
2000-2010	-0.889	14.29%	-14.69%
2010-2019	69.701	47.72%	-15.84%
1991-2019	108.582	95.77%	-35.36%
Rural			
1991-2000	45.046	23.43%	6.72%
2000-2010	55.518	0.58%	27.97%
2010-2019	82.682	64.00%	-30.93%
1991-2019	183.246	111.89%	10.74%

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	--
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	--
		(*e*) Describe any sensitivity analyses	--
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	--
		(b) Give reasons for non-participation at each stage	--
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-8
		(b) Indicate number of participants with missing data for each variable of interest	--
Outcome data	15*	Report numbers of outcome events or summary measures	--
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	--

		(*b*) Report category boundaries when continuous variables were categorized	--
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	--
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-8
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Gini coefficient decomposition- and mortality-rate-difference-based description of mortality causes in the Chinese population from 1991 to 2019: A retrospective cross-sectional surveillance study

Feiling Ai, MMed; Xia Wan, PhD

Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences &

School of Basic Medicine, Peking Union Medical College

#5 Dong Dan San Tiao, Dongcheng District, Beijing, China, 100005

Corresponding author: Xia Wan, E-mail: xiawan@ibms.pumc.edu.cn, Telephone: +86 010 6523 3870

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ABSTRACT

Objectives Improved national Disease Surveillance Points systems (DSPs) in China have clarified mortality causes in the Chinese population. This study aimed to investigate the variations and drivers of multiple mortality causes.

Design This was a retrospective cross-sectional surveillance study.

Setting Original data in 1991 and 2000, and secondary data in 2010 and 2019 were collected from DSPs across China.

Participants Standardized mortality rates (SMR) and crude mortality rates (CMR) of the Chinese population in 1991, 2000, 2010, and 2019 were ascertained.

Main outcome measures Changes in the Gini coefficients (*G*), computed using SMR, were decomposed into reranking (*R*) and proportionality (*P*) to identify variations in communicable, maternal, neonatal, and nutritional diseases (CMNN); non-communicable diseases (NCD); and injury. The CMR difference (in %) was partitioned into the demographic structure and non-demographic factors using the mortality-rate-difference method.

Results From 1991 to 2019, the overall CMR increased from 591.327/100,000 to 674.505/100,000, whereas the SMR continually decreased. An increasing concentration of NCD contributed to the increased all-cause *G* from 0.443 to 0.560 during 1991-2019. Between 1991 and 2019, compared with CMNN (*R*=0.054) and NCD (*R*=0.037), the ranking of injury changed the most (*R*=0.173). The ranking of diabetes, falls, and road traffic accidents increased markedly over time. The decreased SMR of NCD (*P*=-0.013) was mainly due to low-ranking causes, whereas changes in CMNN (*P*=0.0030) and injury (*P*=0.131) were due to high-ranking causes. All-cause CMR increased by 14.07% from 1991 to 2019 due to greater contributions from the demographic structure (68.46%) than the non-demographic factors (-54.40%). Demographic structural changes accounted more for CMR increases in males (70.52%) and urban populations (75.58%).

Conclusions Prevention and control measures targeting NCD and specific causes are imperatively needed, and should be strengthened as the population ages, especially for males and rural populations.

Strengths and limitations of this study

- Our study described the transitions of mortality causes in China by analyzing data from the nationally representative Disease Surveillance Points systems (DSPs).
- Our study quantified the variations and relative importance of various mortality causes from 1991 to 2019 in China using the Gini coefficient decomposition method.
- Our study presents the percentage of demographic and non-demographic factors that contributed to changes in the crude mortality rate (CMR) from 1991 to 2019 in the Chinese population.
- Despite discrepancies between the original and secondary data, heterogeneity can be minimized by a standardized data collection and analysis process with stringent quality control procedures.
- A potential limitation of the study is that the decomposition of CMR differences was very crude, especially for non-demographic factors.

INTRODUCTION

Over the past 30 years, China has gradually transitioned from demographic dividend to demographic burden, with slower population growth, faster aging, and more severe sub-replacement fertility.[1] The 2020 national census showed that individuals aged 65 and above constituted 190.64 million of the national population.[2] Living standards and access to medical services have improved significantly with the economic boom and health literacy, and behavioral and environmental risks were curbed through comprehensive disease prevention and control programs.[3] Accordingly, a marked shift occurred in mortality causes in the Chinese population; the Global Burden of Disease Study (GBD) 2017 showed that non-communicable diseases (NCD), such as stroke, ischemic heart disease, lung cancer, and diabetes, were the major causes of premature death, whilst mortality rates due to infectious diseases, maternal and infant factors, and nutritional deficiencies decreased.[3] The Chinese provincial disease burden report indicated that cardiovascular disease was the leading cause of death from 1990 to 2016, with a nearly 1.5 million increase in deaths since 1990.[4] He et al.[5] reviewed cancer registries in China and found that cancer mortality increased from 10.1% during 1973-1975 to 24.2% in 2015.

Changes in mortality and associated drivers are pivotal for policymaking, and health resource allocation for aging and health transition. The marked improvement in the registration of mortality causes and the accessibility of insight into variations in mortality causes have generated more unpredictable mortality patterns in the Chinese population.[6] Previous studies have focused on high-ranking causes that implicitly obscured the complex picture of varying mortality causes and changes in their relative importance over time.[7] Despite stable rates, certain mortality causes increased in rank due to the decline of other causes. Increasing uncertainties, including the coronavirus disease pandemic, have increased the diversity of the mortality causes, engendering concerns about the prioritization of resource reallocation. Thus, researchers introduced the modified Gini coefficient (G)[7-10] to quantitatively evaluate whether changes in overall rates including disability-adjusted life years and obesity rates, are disproportionately centralized toward high-ranking causes.[7,9] The continuing increasing availability of data sources, whereby the changes between the crude mortality rates (CMRs) can be interpreted in terms of the components attributable to various factors, provides an epidemiological perspective.[11,12] It is important to quantify the contributions of population aging and other risk factors to CMR, which can be obtained by the mortality-rate-difference method, a widely used technique in demography.[13]

This study was conducted to decompose G differences to quantify the variations and the relative importance of multiple mortality causes in the Chinese population from 1991 to 2019. The difference in the CMR was split based on the demographic structure and non-demographic factors.

METHODS

Data source

Data were collected from the Disease Surveillance Points system (DSPs), the only national representative death surveillance system established by the Chinese Centre for Disease Control and Prevention, with nationwide locations selected by multiple-stratified random sampling. From administrative departments, we inferred that the DSPs underwent three major adjustments: the number of monitoring points increased from 145 in 1990 (covering 10 million) to 161 in 2005 (covering 78 million) and to 605 points (covering 300 million) in 2013 derived from administrative departments.[14] Through a stringent sampling design, implementation, completeness accuracy, and comparative validation, the DSPs data could reflect the mortality level in the Chinese population.[15-17] Original data from 1991 and 2000,[18] and secondary data

from 2010 and 2019 in the National Disease Surveillance System Death Monitoring Dataset[14,19] were analyzed. All CMRs were standardized using the 5-year age census data from the National Bureau of Statistics of China in 2000.[20] The overall and cause-specific, as well as sex-specific, rural- and urban-specific CMR, and standardized mortality rates (SMR) were calculated.

Mortality causes were ascertained from medical certificates and the underlying causes were identified through verbal autopsy procedures, encoded by the International Classification of Diseases (ICD)-9 or ICD-10 (before or since 2000). According to the GBD classifications in 2010,[21] the causes were grouped into three levels: first, comprising communicable, maternal, neonatal, and nutritional diseases (CMNN), NCD, and injury; second, comprising the main systems among the three primary categories – CMNN, including infectious and parasitic diseases, some infections, and nutritional deficiencies; NCD, including neoplasms, hematopoietic organs and immune diseases, endocrine, nutritional and metabolic diseases; and injury, comprising self-inflicted injuries, road traffic accidents, and drownings; and third, the secondary systems were further divided into specific causes. Then, we analyzed the causes of malignant neoplasms and cardiovascular disease among the two leading systems.

Statistical analysis

First, we described the all-cause and three categorical CMR and SMR, in three periods: 1991-2000, 2000-2010, and 2010-2019. Second, we used all-cause and cause-specific SMRs to calculate the *G*. Overall variations of causes are presented by decomposing the difference in *G* between two timepoints.[8] Third, using the mortality-rate-difference method, the CMR difference was split into the demographic structure and non-demographic factors.[11,13]

***G* decomposition method**

The *G* (G: 0-1) indicates a greater difference among various large-value components, whereby the overall indicators are more concentrated among the major causes, and this is depicted by the Lorenz curve: the x-axis and y-axis represent the cumulative shares of mortality causes, ranked from lowest to highest, and the total SMR, respectively. An overall *G* curve closer to the diagonal represents more equal shares of each component (Supplementary Figure S1).

In the decomposition of *G* changes (Supplementary Part A),[7] the *G* difference (ΔG) in the studied periods (1991-2000, 2000-2010, 2010-2019, and 1991-2019) is decomposed into reranking (*R*) and proportionality (*P*). *R* represents the importance of the *G* changes from reranking of causes and indicates the mobility of causes; *P* indicates the *G* changes that account for the proportion when ranking is held constant at the original distribution and indicates the progressivity of causes (Supplementary Table S1).

Mortality-rate-difference method

In the mortality-rate-difference method, the CMR difference is decomposed into the demographic structure including age distribution, and non-demographic factors, including risk factors (such as smoking, alcohol consumption, physical activities, and air/water pollution), socio-economic development, and healthcare facilities[22] The CMR difference equates to the sum of the age-structure difference weighted by the mean mortality rate and to the mortality difference weighted by the age structure (Supplementary Part A).[11,13] We calculated CMR differences in the periods: 1991-2000, 2000-2010, 2010-2019, and 1991-2019.

All analyses were conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and Python Jupyter Notebook 6.0.3 (https://jupyter.org/).

RESULTS

Overall changes in CMR and all-cause SMR

Figure 1 shows the total and sex-, urban-, and rural-specific CMRs of CMNN, NCD, and injury during 1991-2019. The total CMRs were 591.327/100,000, 588.693/100,000, 575.385/100,000, and 674.505/100,000 in 1991, 2000, 2010, and 2019, respectively; male CMRs were higher every year. The rural CMRs remained higher than urban CMRs. All-cause SMR decreased from 637.29/100,000 in 1991 to 376.78/100,000 in 2019, with slower decline trends in males and in rural populations during 2000-2010 than in other decades (Figure 2). The SMRs of CMNN, NCD, and injury decreased every decade, and were higher in males, albeit with a declining trend. The decreasing tendency of rural SMR was close during 1991-2000 and 2010-2019 but fluctuated during 2000-2010, with a faster decline in NCD and a comparatively steady change in CMNN and injury (Figure 2).

Figure 1 depicts *G* and the percentage of CMRs for CMNN, NCD, and injury: the overall *Gs* were 0.443, 0.502, 0.541, and 0.560 in 1990, 2000, 2010, and 2019, respectively. The increase in *G* values was due to disproportionate falls of SMRs among the three categories. Mortality causes were more concentrated on NCD and, in 1991 and 2019, increased from 75% to 90%, whereas CMNN and injury comprised smaller proportions and decreased from 13% and 12% to 3% and 7%, respectively. Proportional changes in males, females, and rural residents mimicked the overall trends, and the gap in urban residents peaked in 2000.

Table 1 represents CMR changes between two timepoints (1991 and 2019) and the year- and sex-specific contributory proportions of all-cause demographic and non-demographic factors. Males had a threefold CMR increase (125.977/100,000) compared to females (40.475/100,000); the CMR increase was prominently higher in urban (102.130/100,000) than in rural areas (87.156/100,000). The demographic structure and non-demographic factors increased and decreased the all-cause CMR, respectively, per decade. During 1991-2019, the demographic structure had a greater positive impact on all-cause CMR (68.46%) than the negative impact of non-demographic factors (-54.40%). Thus, all-cause CMR increased by 83.187/100,000 (14.07%). Male demographic structure induced a higher CMR increase (70.52%) than females (67.02%), and the CMR proportion for demographic structure in urban areas (75.58%) was higher in rural areas (66.49%). Over the past three decades, all absolute contributions of demographic structure and non-demographic factors peaked, with an increasing CMR between 2010 and 2019.

Variations of NCD

Table 2 shows *G* and their decompositions across 30 years in China for 14 causes of NCD. The *G* augmented from 0.740 in 1991 to 0.789 in 2019. The *R* was 0.037 between 1991 and 2019, with increased ranks of neoplasms, neuro-psychiatric conditions, diabetes, musculoskeletal and connective tissue diseases, skin diseases, and non-malignant neoplasms, whereas the ranking of respiratory disease, digestive diseases, genitourinary diseases, congenital anomalies, and sensory organ diseases decreased (Table S2). In 1991, cardiovascular (44.73%) and respiratory (31.55%) diseases were two major causes; however, in 2019, cardiovascular disease (53.22%) ranked first, whereas neoplasms (27.23%) and respiratory diseases (9.95%) held the second and third ranks, respectively. Diabetes increased from the 8th to 4th rank, whereas congenital anomalies dropped from the 6th to 11th rank. NCD had a negative *P*-value (-0.013) between 1991 and 2019, in combination with the falling SMR, indicating that the fall of low-ranking causes (endocrine disorders, musculoskeletal, and connective tissue diseases, sensory organ diseases, skin diseases, oral diseases, and non-malignant neoplasms) was mainly responsible for the decline in the SMR of NCDs. Among the studied periods, the ranking of NCD subcategories varied the most during 1991-2000, and has stabilized since 2000 (*R*-value: 0.006, 0.002, 0.0003) with negative *P*-values: -0.009, -0.027, and -0.006 during 1991-2000, 2000-2010, and 2010-2019, respectively. Similarly,

low-ranking causes remained the main drivers in each decade. Ranking in males and females underwent major changes during 1991-2000 (R=0.010) and 2000-2010 (R=0.014), respectively, whereas negative P was ascribed to low-ranking causes in both. G-variation-related rural mortality differences expanded over time, but changes in rural and urban settings were mainly caused by the decline of low-ranking causes (Table 2 and Table S2).

Table 3 presents CMR changes between 1991 and 2019 and the year- and sex-specific contributory percentage of demographic and non-demographic factors in three categories. In NCD, consistent with all-cause CMR, demographic structure and non-demographic factors increased and decreased the CMR over time, respectively, and the changes peaked in 2010-2019. Overall, the NCD-CMR increased by 183.829/100,000 (44.53%), mainly due to the demographic structure (85.79%) from 1991 to 2019. The NCD-CMR difference in males (222.753/100,000) was markedly higher than females (144.013/100,000), with a slightly higher contribution of demographic structure to CMR in males (88.54%) than females (83.72%). In contrast, the absolute values of non-demographic factors were higher in females (-44.97%) than in males (-39.30%). Rural settings had higher demographic-structure contributions (87.24%) than urban settings (80.29%), whereas urban settings had higher non-demographic factors (-50.75%) absolute contributions than rural settings (-36.10%) (Table 3).

Variations of neoplasms and cardiovascular diseases

Further analysis of Gini decomposition and mortality-rate-difference based on neoplasms and cardiovascular diseases — two leading NCD systems — is shown in Table S3-S5.

Between 1991 and 2019, G decreased in neoplasms subcategories of neoplasms and their ranks mainly changed from 1991 to 2000 (R=0.006). In 2019, trachea, bronchus, and lung cancers (29.22%) ranked first, followed by liver (15.04%) and gastric (12.05%) cancers. The decline in high-ranking causes (gastric cancer, liver cancer, esophageal cancer, leukemia, oral, and oropharyngeal cancers) induced an overall decline of SMR-neoplasms (P=0.080) from 1991 to 2019. Unlike neoplasms, between 1991 and 2019, the G of cardiovascular diseases based on subcategories increased over time; the top three causes were cerebrovascular, ischemic, and hypertensive heart diseases. Ischemic heart disease increased from 15.41% to 40.45%, whereas hypertensive heart disease decreased from 14.58% to 7.25%, but was always higher in women than in men. P-value remained invariably negative from 1991 to 2019, indicating that low-ranking causes (hypertensive heart disease, rheumatic heart disease, and other cardiovascular diseases) were major determinants (Tables S3 and S4).

Demographic structure continuously increased the CMR of neoplasms and cardiovascular diseases, whereas before 2010, non-demographic factors increased and decreased their CMR, respectively. From 1991 to 2019, non-demographic factors generally made small contributions to neoplasms (-4.51%) and cardiovascular diseases (-4.41%), with similar sex-stratified changes. In urban settings, non-demographic factors contributed negatively to neoplasms (-34.65%) and cardiovascular diseases (-35.36%) from 1991 to 2019, whereas in rural settings, non-demographic factors positively affected their CMRs before 2010 (Table S5).

Variations of CMNN

The underlying G-changes in CMNN (Table 2) showed that the cause-specific difference among CMNN increased from 1991 to 2019: G-values increased during 1991-2010 and decreased during 2010-2019. CMNN was dominated by infectious, parasitic (30-40%) and respiratory (35-55%) infections. The major ranking changes indicated increased respiratory infections and decreased infectious, parasitic diseases. The fall of high-ranking (P=0.003) mortality causes (infectious and parasitic diseases) decreased the CMNN-SMR during 1991-2019. In the past 30 years, the cause-specific difference (G=0.509, R=0.030)

was higher in males than in females (G=0.465, R=0). The male-SMR decrease was predominantly caused by high-ranking causes (infectious and parasitic diseases; P=0.018), whereas the female-SMR decrease was caused by low-ranking causes (pregnancy, childbirth, and puerperal complications; P=-0.074). SMR variations in urban settings were greater than in rural areas from 1991 to 2019 (Table 2 and Table S2).

The CMR-CMNN decreased by 51.458/100,000 between 1991 and 2019, with major contributions from non-demographic factors (-90.17%). Effects of the demographic structure were negative during 1991-2000, but turned positive during 2000-2010 and 2010-2019. Males and females showed similar changes in overall trends. Demographic structure contributed more to urban CMR increase (60.80%) than rural CMR (15.51%), whereas, non-demographic factors had higher contributions in rural (91.04%) than in urban settings (79.40%). In contrast to overall changes, demographic structure decreased CMR in rural settings during 1991-2000 (-8.95%), but non-demographic factors increased CMR in urban settings during 2000-2010 (21.15%) (Table 3).

Variations of injury

The overall G of injury increased from 1991 to 2019 (Table 2). In particular, the ranking of falls increased from the 6th in 1991 to 2nd rank in 2019, whereas the ranking of road traffic accidents increased from 3rd to 1st. In contrast, self-inflicted injuries decreased from 1st to 3rd. In urban settings, R was smaller (0.035), indicating small ranking changes in specific causes. The leading causes of injury shifted from self-inflicted injuries (32.33%), road traffic accidents (14.78%), and drowning (14.63%) in 1991 to road traffic accidents (31.14%), falls (27.09%), and self-inflicted injuries (13.35%) in 2019. The decreased proportion of high-ranking causes (self-inflicted injuries and drownings) decreased the SMR of injury (P=0.131) from 1991 to 2019 (Table 2 and Table S2).

The CMR of injury decreased constantly, representing the highest decline during 1991-2000 (10.925/100,000), predominately caused by the negative impact of non-demographic factors (Table 3). The highest contributory proportion was noted during 2010-2019. Males (23.08%) and females (24.91%) had similar demographic-structure contributions from 1991 to 2019. In contrast, non-demographic factors had higher contributions in females (65.05%) than males (45.87%). From 1991 to 2019, demographic-structure contributions were higher in urban (37.81%) than in rural settings (22.67%), whereas non-demographic-factor contributions in rural settings (53.89%) were higher than those in urban settings (36.13%). The overall CMR increased by 0.600/100,000 from 1991 to 2019 due to higher demographic-structure contributions (37.81%), urban CMR increased by 1.692/100,000 from 2000 to 2010, and non-demographic factors represented positive contributions (0.49%; Table 3 and Table S2).

DISCUSSION

Main findings

Based on the decomposition of G and CMR differences, we quantitatively represented variations in mortality causes across broad groups and subcategories in the Chinese population – from 1991 to 2019. G variations indicated that mortality causes have disproportionately favored low-ranking causes among NCD since 1991, with higher components for neoplasms and cardiovascular diseases. For CMNN and injury, mortality causes were unequally concentrated in high-ranking causes during 1991-2019, thereby decreasing their SMRs. Moreover, for injuries, major changes occurred in male and urban populations. Mortality-rate-difference analysis showed that from 1991 to 2019, demographic structure and non-demographic factors increased and decreased CMR, respectively, with the maximum contributions in 2010. The explanatory share of demographic structure for the increased CMR in urban and male populations increased with population aging. Specifically, from 1991 to 2019, non-demographic factors

decreased the CMR of NCDs, which declined more in females than males, and in urban than rural settings. Of note, cause-specific differences in neoplasms and cardiovascular disease expanded over time.

Strengths and limitations

We identified the overall profile of mortality causes and associated drivers in the Chinese population from 1991 to 2019 to highlight the most imperative health issues. First, we validated the Gini decomposition approach for identifying variations in multiple mortality causes that statistically describe the rising or falling concentration of leading causes to reveal the occurrence of significant reranking. By combining proportionality with a changing general rate, the predominant causes that decrease the rate of systematic mortality causes gain importance, relative to higher- or lower-ranked causes. CMR differences were decomposed into the demographic structure and non-demographic factors, offering quick, simple clues about the contributions of age-structure shift and other combined factors to changes in mortality rates. Furthermore, the results facilitate the evaluation of the effects of aging and disease prevention and control strategies.

Despite the well-depicted overall profiling and drivers of mortality causes of the Chinese population, several study limitations exist. First, discrepancies between the original and secondary data possibly exist but can be minimized by a standardized protocol for data cleaning, analysis, and quality control. Second, the Gini index and its indicators reranking and proportionality facilitate the identification of variations in mortality causes, but the relatively abstract implications, are difficult to follow. Third, data derived from DSPs, with the increase in population size, might introduce inconsistencies; however, previous studies illustrated the national representativeness of the DSPs.[15-17] Sensitivity analysis showed that the SMR stemming from the United Nations Population Division was higher than the Chinese national census, however, the overall trend is consistent (results not shown), which further confirms our findings. Last, we split the CMR difference into two components, whereby non-demographic factors constitute a general classification, that may not clearly depict the actual determinants of CMR fluctuations besides demographic structures.

Significance and implications of this study

Knowing the variations and determinants of mortality causes is important for policymakers to address the increasing health needs of older adults. Compared with studies that visualize the changes in high-ranking causes in different years by colorful lattices or crossed lines,[3] we depicted a clear picture of distributions and relative importance of various mortality causes including distributions and relative importance with quantitative values. Some studies analyzed provincial inequality including maternal mortality and malignant tumors in China. However, to the best of our knowledge, this is the first study that interpreted the proportion of population aging and non-demographic factors contributing to CMR changes in China, with national and all-cause perspectives.[23,24]

Transitions of mortality causes and non-demographic factors

Changes in cause-specific NCD

NCD plays an increasingly major role among mortality causes, with an escalating health loss doubled from over 40% in 1991 to 85% in 2019,[3] that is closely related to non-demographic factors, including environmental pollution (air/water pollution), tobacco use, harmful alcohol use, unhealthy diet, physical inactivity, and obesity in China.[17,25] Since 1990, China's progress in the fight against NCDs relied on serial national policies coupled with comprehensive health promotion programs including Guidelines for Chronic Disease Prevention and Treatment, National Healthy Lifestyle Initiative, Healthy China 2030 Plan, China's Medium- and Long-Term Plan for the Prevention and Control of Chronic Diseases (2017-2025) and National Nutrition Plan (2017-2030).[26-29] Moreover, the Chinese government increased

policy and financial support to reduce risk factors, including the National Action Plan for the Prevention and Control of Air Pollution (2013-2017),[30] smoke-free legislation in more than 20 cities and the Law on the Protection of Minors for tobacco control,[31,32] etc. with remarkable improvement indicated by increased absolute values of non-demographic factors. However, awareness of the increasing number of NCD-mortality caused by cumulative and lagging effects of environmental pollution,[33] high smoking rates,[34] longstanding unhealthy eating habits,[35] insufficient physical activity-participation,[36] and continuing increasing obesity rate should be noted in China.[37] There were fewer contributions from non-demographic factors in rural populations, as inequality between rural and urban settings, including health services utilization, family income, education level, etc., prevailed,[38,39] which warned us that more efforts are needed to facilitate equality between rural and urban areas.

Changes in cause-specific CMNN

The CMNN proportion decreased significantly from 1991 to 2019, due to the establishment of a direct reporting network system of communicable diseases, which facilitated the collection of updated information and implementation of several special interventions targeting meningitis, tetanus, measles, diarrhea, etc.[25] From 1991 to 2019, the uneven development of rural and urban settings induced a more than 10 times mortality difference between rural and urban areas in CMNN, with higher demographic and non-demographic contributions in urban and rural areas is narrowing with improved primary care and public health services, and plans implemented in extreme poverty-stricken areas.[40] Communicable disease prevention and control, however, are great challenges, for instance, the ongoing coronavirus disease pandemic.

Changes in cause-specific injury

A dramatic reduction in self-inflicted mortality among injuries occurred over time, especially in rural and female populations. In the 1990s, the suicide rate in China was 23.2/100,000, and was more than three times higher in rural than urban areas.[41] The fast-growing economy, urbanization, and increasing social concern have rapidly decreased the overall suicide rate over time,[42] which has transitioned to predominance among older adults.[43] In contrast, falls and road traffic accidents increased notably. Fall injury, usually during leisure activities, household chores, and other daily activities, is the leading cause among older adults.[44] The continuing increase in vehicles numbers in China has resulted in the high mortality of pedestrians (42%), motorcyclists (25%), and vehicle passengers (17%) in road traffic accidents.[45]

Demographic shift

Demographic structure, as a dominated CMR contributor, strikingly increased over time. In 2020, individuals aged ≥65 years comprised 13.50% of the population in China and this rate is far higher than the international aging standard of 7%;[2] thus China has transitioned into rapidly aging society. In the past 30 years, life expectancy increased by 10 years in China.[46] Simultaneously, the fertility rate declined from 6.71% in 1950 to 1.70% in 2019.[1] Accordingly, the Chinese government has gradually modified the childbearing policy.[47,48]

Suggestions and future research

In summary, China's notable progress in reducing mortality since the 1990s is ascribed to improved healthcare and medical services.[49] However, integrated efforts are needed to lessen the mortality rate. First, national policies, strategies, and special interventions are needed to create a supportive environment and reduce poverty and inequality between rural and urban areas. For example, interventions for strengthening urban planning, road infrastructure, and legislation are needed to avert road traffic accidents. Second, stringent measures for tobacco control, alcohol restriction, and mitigation of other

risk factors are warranted. Third, comprehensive measures for prevention, diagnosis, and treatment of prioritized diseases should be intensified.[26] With the population aging, the establishment of long-term care settings to fulfill the needs of older adults is imperative.[50] Based on the distribution and priority of diverse mortality causes depicted in this study, in the future, a more accurate estimation of disease burden could be realized in combination with the incidence and prevalence of diseases. In addition, more studies are needed to further evaluate the non-demographic factors.

CONCLUSIONS

The *G* and mortality-rate-difference decomposition methods are useful for quantifying the changes of multiple mortality causes. The findings show that NCD, especially neoplasms and cardiovascular diseases, remains a major public health concern among the mortality causes in China, with population aging increasingly threatening to worsen the situation. Despite several achievements, there is insufficient implementation of strategies to control non-demographic factors in China. Laws mandating control of risk factors are needed, as is attention toward improving equitable access to health services, environmental quality, and health education, especially for older, male and rural populations.

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Contributors

Wan Xia designed the study concept and obtained the original data. Ai Feiling managed data, implemented methods, wrote the first draft of the paper. Wan Xia and Ai Feiling contributed to the revision and finalization of the paper, and had full access to all data used in this study, both checked and verified the data used in the analysis. The corresponding author was responsible for submitting the article for publication.

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Disclaimer

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Competing interests

All of the authors declare that they have no potential or actual conflicts of interest.

Patient and Public involvement

No patient or public were involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

The research is based on open-source data, so there are no ethical issues and other conflicts of interest.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

The data used in our study were collected from the Disease Surveillance Points system (DSPs) established by the Chinese Centre for Disease Control and Prevention. The data from 1991 to 2000 were not publicly available but are available from the corresponding author on reasonable request. The data in 2010 and 2019 were public accessible to all through published book National Disease surveillance system cause-of-death surveillance dataset (http://ncncd.chinacdc.cn/jcysj/siyinjcx/syfxbg/202101/t20210118_223798.htm).

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Table 1. Changes in the contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific all-cause crude mortality differences, from 1991 to 2019

Periods	Mortality Difference	Demographic Structure	Non-demographic Factors
Total			
1991-2000	-2.634	15.37%	-15.82%
2000-2010	-13.308	8.90%	-11.16%
2010-2019	99.120	46.54%	-29.31%
1991-2019	83.178	68.46%	-54.40%
Male			
1991-2000	11.552	16.21%	-14.41%
2000-2010	12.580	10.09%	-8.17%
2010-2019	101.845	43.69%	-28.44%
1991-2019	125.977	70.52%	-50.94%
Female			
1991-2000	-13.470	14.53%	-17.04%
2000-2010	-43.257	7.14%	-15.42%
2010-2019	97.202	51.68%	-31.40%
1991-2019	40.475	67.02%	-59.47%
Urban			
1991-2000	50.544	22.99%	-13.47%
2000-2010	-40.520	13.27%	-20.24%
2010-2019	92.106	39.18%	-22.14%
1991-2019	102.130	75.58%	-56.33%
Rural			
1991-2000	-16.376	13.31%	-15.99%
2000-2010	3.942	4.13%	-3.46%
2010-2019	99.590	52.28%	-35.58%
1991-2019	87.156	66.49%	-52.18%

Table 2. Changes in Gini coefficients, reranking, and proportionality of secondary causes for the combined and, male, female, rural, and urban categories, from 1991 to 2019

Periods	Both	Male	Female	Urban	Rural
CMNN					
Gini index					
1991	0.440	0.497	0.391	0.464	0.444
2000	0.452	0.469	0.437	0.487	0.450
2010	0.506	0.521	0.490	0.558	0.473
2019	0.491	0.509	0.465	0.539	0.462
Reranking					
1991-2000	0.070	0.050	0.018	0.087	0.066
2000-2010	0.000	0.000	0.043	0.000	0.000
2010-2019	0.000	0.000	0.000	0.000	0.000
1991-2019	0.054	0.030	0.000	0.132	0.021
Proportionality					
1991-2000	0.058	0.077	-0.028	0.064	0.059
2000-2010	-0.053	-0.051	-0.010	-0.070	-0.023
2010-2019	0.015	0.011	0.025	0.019	0.011
1991-2019	0.003	0.018	-0.074	0.057	0.002

NCD					
Gini index					
1991	0.740	0.739	0.741	0.747	0.742
2000	0.754	0.757	0.752	0.756	0.755
2010	0.783	0.785	0.780	0.776	0.787
2019	0.789	0.790	0.789	0.782	0.792
Reranking					
1991-2000	0.006	0.010	0.002	0.002	0.002
2000-2010	0.002	0.001	0.014	0.000	0.013
2010-2019	0.000	0.000	0.000	0.001	0.000
1991-2019	0.037	0.037	0.038	0.006	0.037
Proportionality					
1991-2000	-0.009	-0.008	-0.009	-0.008	-0.011
2000-2010	-0.027	-0.027	-0.014	-0.019	-0.019
2010-2019	-0.006	-0.005	-0.008	-0.006	-0.005
1991-2019	-0.013	-0.015	-0.009	-0.030	-0.013
Injury					
Gini index					
1991	0.515	0.488	0.561	0.434	0.536
2000	0.521	0.519	0.556	0.498	0.541
2010	0.558	0.568	0.551	0.564	0.560
2019	0.558	0.567	0.545	0.565	0.557
Reranking					
1991-2000	0.026	0.045	0.044	0.022	0.022
2000-2010	0.029	0.027	0.042	0.031	0.067
2010-2019	0.017	0.016	0.014	0.001	0.031
1991-2019	0.174	0.183	0.164	0.035	0.167
Proportionality					
1991-2000	0.020	0.014	0.050	-0.042	0.017
2000-2010	-0.008	-0.022	0.047	-0.035	0.047
2010-2019	0.017	0.017	0.019	-0.001	0.035
1991-2019	0.131	0.104	0.180	-0.097	0.146

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

Table 3. Changes in the contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific secondary-cause crude mortality difference, from 1991 to 2019

Periods	Mortality Difference	Demographic Structure	Non-demographic Factors
CMNN			
Both			
1991-2000	-37.851	-7.80%	-43.31%
2000-2010	-11.752	12.09%	-44.54%
2010-2019	-1.855	40.32%	-47.90%
1991-2019	-51.458	20.69%	-90.17%
Male			
1991-2000	-37.970	-7.24%	-42.32%
2000-2010	-10.724	12.52%	-40.27%
2010-2019	-1.623	37.87%	-43.69%
1991-2019	-50.317	22.23%	-87.91%

Female			
1991-2000	-34.403	-9.52%	-39.42%
2000-2010	-15.038	12.80%	-54.68%
2010-2019	-2.060	44.88%	-54.76%
1991-2019	-51.501	19.45%	-92.70%
Urban			
1991-2000	-12.337	13.50%	-53.14%
2000-2010	6.253	12.14%	21.15%
2010-2019	0.294	44.66%	-43.49%
1991-2019	-5.790	60.80%	-79.40%
Rural			
1991-2000	-43.209	-8.95%	-40.93%
2000-2010	-19.303	10.82%	-55.28%
2010-2019	-2.914	36.51%	-48.60%
1991-2019	-65.426	15.51%	-91.04%
NCD			
Both			
1991-2000	57.724	20.90%	-6.92%
2000-2010	20.313	9.85%	-5.53%
2010-2019	105.792	49.15%	-27.60%
1991-2019	183.829	85.79%	-41.26%
Male			
1991-2000	70.298	21.92%	-6.38%
2000-2010	38.546	11.02%	-3.65%
2010-2019	113.908	47.28%	-26.98%
1991-2019	222.753	88.54%	-39.30%
Female			
1991-2000	45.035	20.13%	-8.01%
2000-2010	0.877	7.91%	-7.70%
2010-2019	98.101	52.88%	-29.39%
1991-2019	144.013	83.72%	-44.97%
Urban			
1991-2000	53.215	24.01%	-11.73%
2000-2010	-17.682	14.72%	-18.35%
2010-2019	92.399	40.04%	-20.33%
1991-2019	127.932	80.29%	-50.75%
Rural			
1991-2000	58.201	19.52%	-5.22%
2000-2010	39.192	4.21%	4.21%
2010-2019	110.719	56.15%	-34.20%
1991-2019	208.112	87.24%	-36.10%
Injury			
Both			
1991-2000	-10.925	4.40%	-20.96%
2000-2010	-3.877	5.83%	-12.87%
2010-2019	-4.942	19.08%	-28.73%

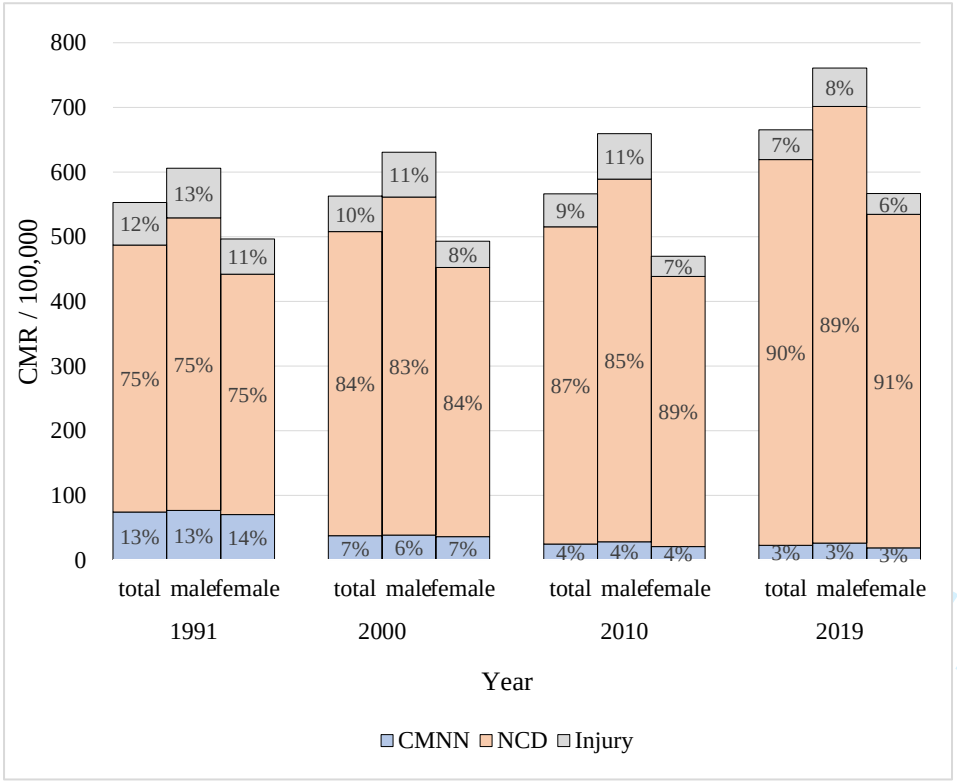
1991-2019	-19.743	23.70%	-53.62%
Male			
1991-2000	-7.927	4.89%	-15.16%
2000-2010	0.988	6.68%	-5.25%
2010-2019	-10.642	14.36%	-29.52%
1991-2019	-17.581	23.08%	-45.87%
Female			
1991-2000	-13.746	3.64%	-28.95%
2000-2010	-9.183	4.44%	-27.07%
2010-2019	1.127	30.27%	-26.68%
1991-2019	-21.802	24.91%	-65.05%
Urban			
1991-2000	-0.756	9.78%	-11.90%
2000-2010	1.692	4.35%	0.49%
2010-2019	-0.336	17.86%	-18.77%
1991-2019	0.600	37.81%	-36.13%
Rural			
1991-2000	-12.987	3.64%	-21.02%
2000-2010	-1.699	5.29%	-8.04%
2010-2019	-8.647	20.99%	-35.39%
1991-2019	-23.334	22.67%	-53.89%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

Legends for figures

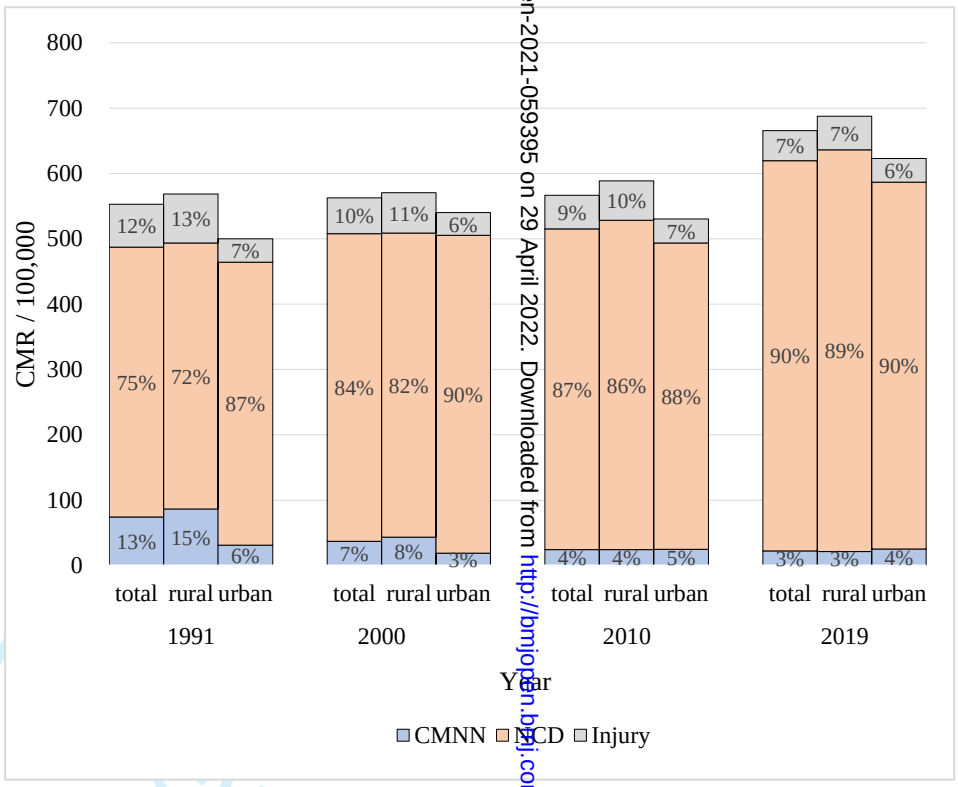
Figure 1. CMR and Gini coefficient of all-cause, CMNN, NCD, and injury in 1991, 2000, 2010, and 2019. (A). Both, male and female. (B). Both, urban and rural. **(A)** Male and female; **(B)** Urban and rural. (CMR: crude mortality rate; CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.)

Figure 2. SMR per 100,000 persons of all-cause and three major categories (CMNN, NCD, and injury) in China, 1991-2019. **(A)** Total; **(B)** CMNN; **(C)** NCD; **(D)** Injury. (SMR: standardized mortality rate; CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.)



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.443	0.502	0.541	0.560
Male	0.454	0.506	0.535	0.553
Female	0.440	0.491	0.553	0.573

(A) Male and female



Gini coefficient				
	1991	**2000**	**2010**	**2019**
Both	0.443	0.502	0.541	0.560
Urban	0.531	0.570	0.545	0.561
Rural	0.422	0.485	0.541	0.560

(B) Urban and rural

Figure 1. CMR and Gini coefficient of all-cause, CMNN, NCD, and injury in 1991, 2000, 2010, and 2019

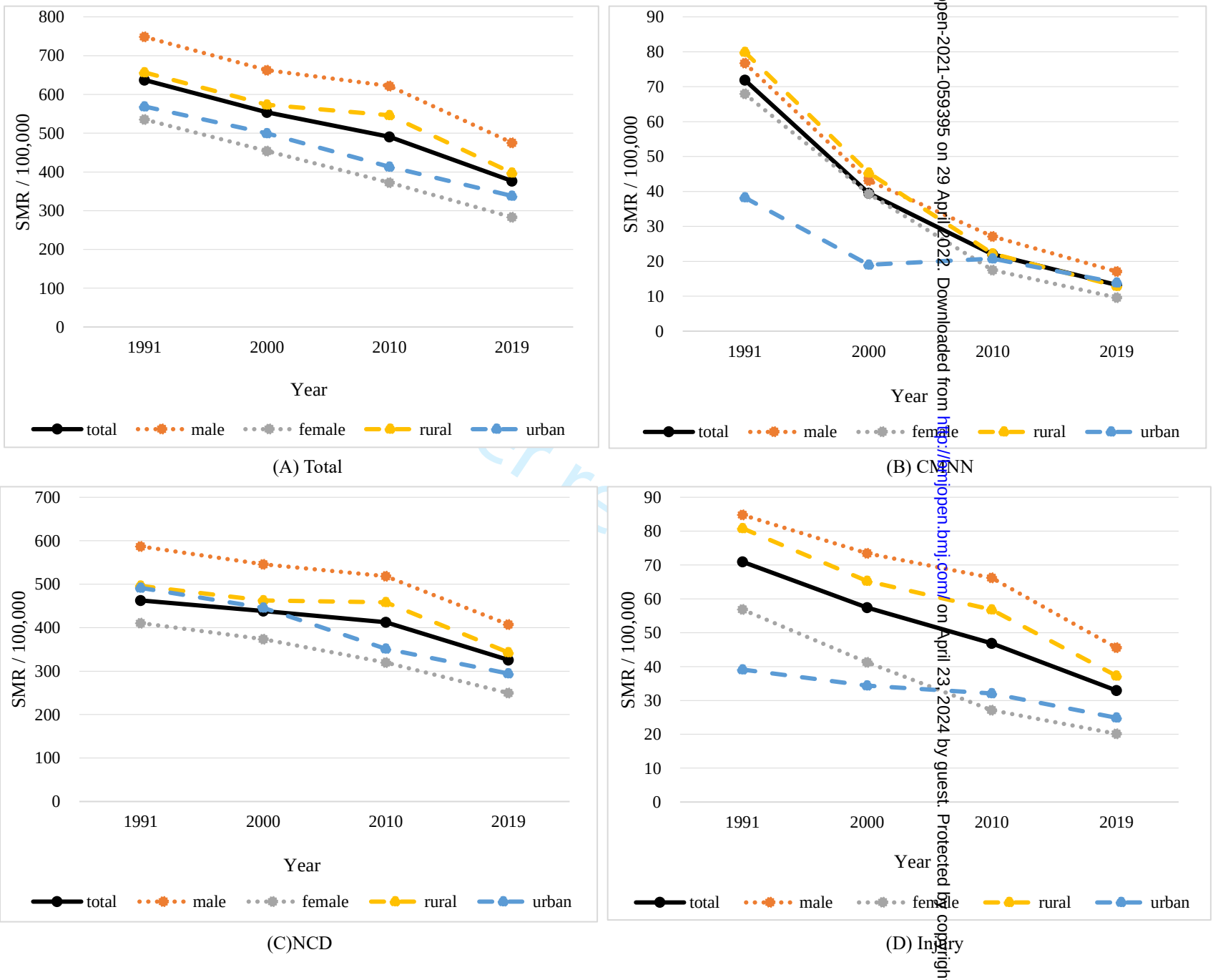


Figure 2. SMR per 100,000 persons of all-cause and three major categories (CMNN, NCD, and injury) in China, 1991-2019

Supplementary Materials

Contents

Part A: calculation formulas

1.Gini decomposition method

The Gini decomposition formulas are as follows:

$$\Delta G = G_1 - G_0 \equiv R - P \quad (1)$$

$$R = G_1 - G_1^{(0)} \quad (2)$$

$$P = G_0 - G_1^{(0)} \quad (3)$$

Where G_1 and G_0 represent *G* in the 0th and the 1st years, respectively. $G_1^{(0)}$ also known as the concentration coefficient, is the *G* in the 1st year based on the ranks in the 0th year. ΔG is the difference in the *G* in different years, and can be decomposed into reranking (*R*) and proportionality (*P*). R represents the importance of the *G* change from reranking of causes and indicates the mobility of mortality causes. A higher and lower indicates greater and smaller rank changes, respectively. At a constant rank, *R*=0, and, when the rank is completely reversed, *R*=2G_1. *P* indicates the change in the *G* that accounts for the proportion, when ranking is held constant at the original distribution; thus, *P* indicates the progressivity of mortality causes. Table S1 presents relationships among *P*-values, aggregate rates, and mortality causes.

2.Mortality-rate-difference method

The crude mortality rate (CMR) difference equates to the sum of the age structure difference (weighted by the mean mortality rate) and mortality difference (weighted by the age structure). Assume that we have two comparison 1991 and 2019 for which we have the CMR and populations data by age groups. We use M to express the CMR, C to express the age structure, and x to express age groups. In this study, we use 5-year age groups. Thus, the CMR difference between 1991 and 2019 can be calculated using the following steps.[1,2]

Step 1: Determine the population proportion and mortality rate by age group (5-year-old for one group) in 1991 and 2019.

Step 2: Calculate the difference of population proportion by age: $C_x^{2019} - C_x^{1991}$.

Step 3: Calculate weight 1: $(M_x^{2019} + M_x^{1991})/2$.

Step 4: Calculate the effect of age structure difference: $\sum_0^\infty (C_x^{2019} - C_x^{1991}) \times \frac{M_x^{2019} + M_x^{1991}}{2}$.

Step 5: Calculate age-specific mortality difference between 1991 and 2019: $M_x^{2019} - M_x^{1991}$.

Step 6: Calculate weight 2: $(C_x^{2019} + C_x^{1991})/2$.

Step 7: Calculate the effect of mortality difference: $\sum_0^\infty (M_x^{2019} - M_x^{1991}) \times \frac{C_x^{2019} + C_x^{1991}}{2}$.

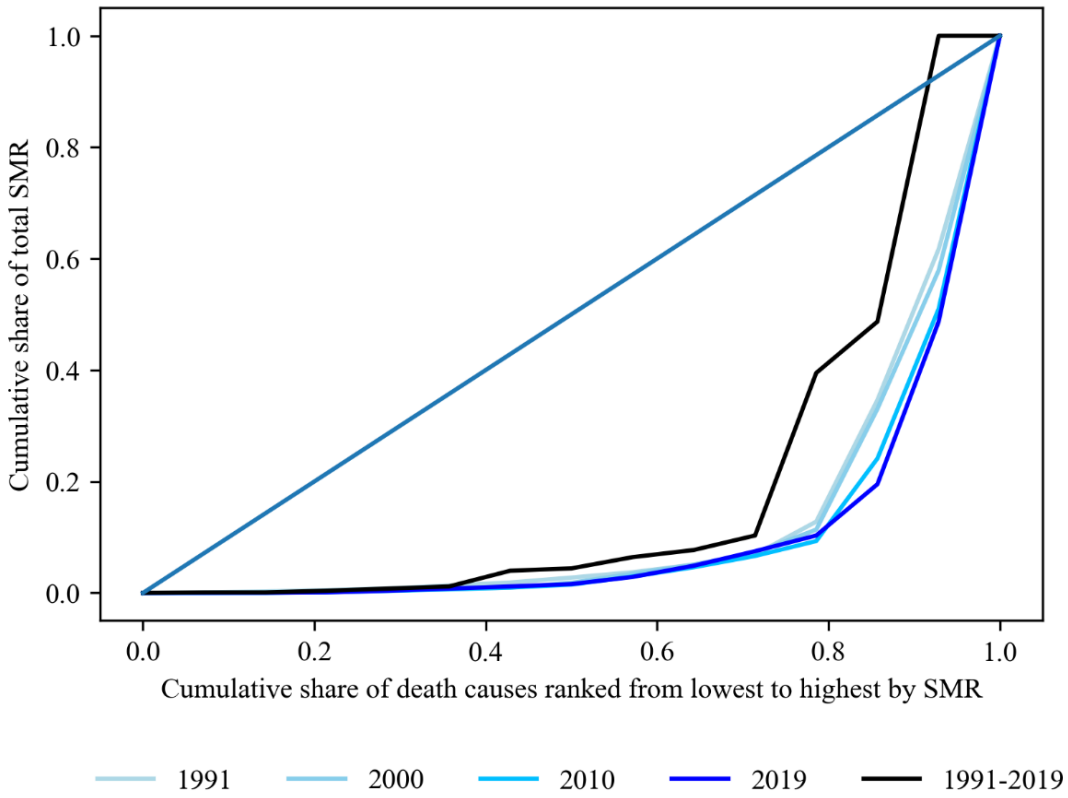
The CMR difference is expressed as values and percentages.

[1] Kitagawa, E.Y. Components of a difference between two rates. JASA 1955;50(272): 1168-1194.

[2] Zhai Z, Lu L, Luo M, et al. Modern population analysis techniques: China Renmin University Press 1989.

Part B: supplementary figure

Figure S1. Lorenz curve for secondary-cause standardized mortality rates ranked from lowest to highest by contribution to the all-cause standardized mortality rates of non-communicable diseases, from 1991 to 2019.



SMR: standardized mortality rate.

Part C: supplementary tables

Table S1. Association between proportionality index and attributable causes

Aggregate Rate	Proportionality (*P*)	Causes responsible for growth/decline
Growing	+*P*	Low-ranking
	-*P*	High-ranking
Declining	+*P*	High-ranking
	-*P*	Low-ranking

Table S2. Changes in ranks and proportion of secondary causes for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	1	36.00%	2	29.09%	2	32.45%	2	31.14%
Respiratory infections	2	36.22%	1	48.63%	1	49.63%	1	54.31%
Conditions arising during the perinatal period	3	22.64%	3	17.72%	3	13.22%	3	5.66%
Nutritional deficiencies	4	2.96%	4	3.35%	4	3.93%	4	8.58%
Pregnancy, childbirth and puerperal complications	5	2.17%	5	1.21%	5	0.78%	5	0.31%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	44.73%	1	54.47%	1	48.51%	1	53.22%
Respiratory diseases	2	31.55%	2	28.59%	3	14.42%	3	9.95%
Malignant neoplasms	3	7.65%	4	2.95%	2	27.92%	2	27.23%
Digestive diseases	4	7.16%	3	5.21%	4	2.68%	5	2.46%
Genito-urinary diseases	5	2.14%	5	2.58%	7	1.44%	7	1.18%
Congenital anomalies	6	1.74%	8	0.96%	8	0.48%	11	0.22%
Neuro-psychiatric conditions	7	1.68%	6	2.08%	6	1.54%	6	1.90%
Diabetes mellitus	8	1.06%	7	2.01%	5	2.09%	4	2.79%
Endocrine disorders	9	0.67%	9	0.34%	10	0.26%	9	0.33%
Musculoskeletal and connective tissue diseases	10	0.64%	11	0.26%	9	0.31%	8	0.37%
Non-malignant neoplasms	11	0.35%	10	0.29%	11	0.25%	10	0.27%
Sensory organ diseases	12	0.30%	13	0.12%	14	0.00%	13	0.01%
Skin diseases	13	0.21%	12	0.14%	12	0.09%	12	0.08%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	32.33%	2	27.16%	2	16.45%	3	13.35%
Other unintentional injuries	2	18.32%	3	14.85%	4	13.26%	4	13.28%
Road traffic accidents	3	14.78%	1	27.22%	1	38.55%	1	31.14%
Drownings	4	14.63%	4	11.14%	5	8.07%	5	6.98%
Poisonings	5	6.62%	6	6.40%	6	6.03%	6	5.97%
Falls	6	6.28%	5	6.56%	3	14.43%	2	27.09%
Violence	7	4.03%	7	4.38%	7	1.84%	8	0.74%

Fires	8	2.31%	8	1.90%	8	1.27%	7	1.36%
Other intentional injuries	9	0.66%	9	0.40%	9	0.10%	9	0.09%
War	10	0.04%	10	0.00%	10	0.00%	10	0.00%
Male								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	1	40.83%	2	33.61%	2	37.76%	2	36.87%
Respiratory infections	2	34.24%	1	45.98%	1	45.54%	1	51.14%
Conditions arising during the perinatal period	3	22.97%	3	17.18%	3	13.51%	3	5.86%
Nutritional deficiencies	4	1.97%	4	3.24%	4	3.19%	4	6.13%
Pregnancy, childbirth and puerperal complications	5	0.00%	5	0.00%	5	0.00%	5	0.00%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	35.69%	1	54.14%	1	46.13%	1	50.00%
Respiratory diseases	2	25.59%	2	27.94%	3	14.17%	3	10.33%
Malignant neoplasms	3	25.04%	4	3.31%	2	31.08%	2	30.67%
Digestive diseases	4	6.51%	3	6.10%	4	2.99%	4	2.72%
Genito-urinary diseases	5	1.98%	5	2.76%	6	1.41%	7	1.22%
Congenital anomalies	6	1.40%	8	1.02%	8	0.47%	11	0.21%
Neuro-psychiatric conditions	7	1.37%	6	2.03%	7	1.37%	6	1.66%
Diabetes mellitus	8	0.74%	7	1.66%	5	1.63%	5	2.33%
Endocrine disorders	10	0.37%	10	0.26%	9	0.24%	8	0.29%
Musculoskeletal and connective tissue diseases	9	0.48%	11	0.20%	11	0.21%	9	0.26%
Non-malignant neoplasms	11	0.30%	9	0.28%	10	0.24%	10	0.25%
Sensory organ diseases	12	0.25%	12	0.20%	14	0.00%	13	0.00%
Skin diseases	13	0.20%	13	0.10%	12	0.06%	12	0.06%
Oral conditions	14	0.08%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	24.41%	2	21.53%	3	13.12%	4	12.16%
Other unintentional injuries	2	21.77%	3	16.88%	2	14.28%	3	13.39%
Road traffic accidents	3	18.14%	1	30.36%	1	42.09%	1	34.72%
Drownings	4	16.08%	4	11.38%	5	7.91%	5	6.75%
Poisonings	5	6.51%	5	6.81%	6	6.29%	6	6.62%
Falls	6	5.44%	6	6.35%	4	13.10%	2	24.21%
Violence	7	4.31%	7	4.48%	7	1.85%	8	0.63%
Fires	8	2.26%	8	1.60%	8	1.20%	7	1.40%

Other intentional injuries	9	1.04%	9	0.62%	9	0.14%	9	0.12%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%
Female								
CMNN								
total		100%		100%		100%		100%
Infectious and parasitic diseases	2	30.95%	3	24.15%	2	24.99%	2	22.88%
Respiratory infections	1	39.08%	1	51.57%	1	55.30%	1	58.97%
Conditions arising during the perinatal period	3	22.67%	2	18.22%	3	12.81%	3	5.38%
Nutritional deficiencies	4	4.14%	4	3.49%	4	4.99%	4	12.08%
Pregnancy, childbirth and puerperal complications	5	4.50%	5	2.56%	5	1.92%	5	0.69%
NCD								
total		100%		100%		100%		100%
Cardiovascular diseases	1	40.59%	1	54.87%	1	51.84%	1	57.56%
Respiratory diseases	2	28.10%	2	29.34%	3	14.79%	3	9.44%
Malignant neoplasms	3	17.85%	4	2.53%	2	23.50%	2	22.58%
Digestive diseases	4	5.48%	3	4.16%	5	2.26%	6	2.12%
Genito-urinary diseases	5	1.60%	6	2.35%	7	1.48%	7	1.14%
Congenital anomalies	6	1.56%	8	0.89%	8	0.49%	11	0.23%
Neuro-psychiatric conditions	7	1.49%	7	2.15%	6	1.78%	5	2.23%
Diabetes mellitus	8	1.10%	5	2.43%	4	2.72%	4	3.41%
Endocrine disorders	9	0.81%	9	0.43%	10	0.29%	9	0.38%
Musculoskeletal and connective tissue diseases	10	0.60%	10	0.34%	9	0.45%	8	0.51%
Non-malignant neoplasms	11	0.30%	11	0.30%	11	0.27%	10	0.30%
Sensory organ diseases	12	0.25%	13	0.03%	14	0.00%	13	0.01%
Skin diseases	13	0.15%	12	0.18%	12	0.14%	12	0.10%
Oral conditions	14	0.11%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100%		100%		100%		100%
Self-inflicted injuries	1	43.93%	1	37.17%	2	24.14%	3	15.58%
Other unintentional injuries	2	13.35%	3	11.27%	4	10.89%	4	13.09%
Road traffic accidents	3	12.52%	4	10.72%	5	8.44%	5	7.42%
Drownings	4	9.76%	2	21.70%	1	30.33%	2	24.39%
Poisonings	5	7.50%	5	6.94%	3	17.53%	1	32.52%
Falls	6	6.79%	6	5.68%	6	5.45%	6	4.75%
Violence	7	3.61%	7	4.08%	7	1.77%	8	0.96%
Fires	8	2.38%	8	2.44%	8	1.45%	7	1.30%
Other intentional injuries	9	0.10%	9	0.00%	9	0.00%	9	0.00%

War	10	0.06%	10	0.00%	10	0.00%	10	0.00%
Urban								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	43.91%	2	30.71%	2	26.69%	2	25.31%
Respiratory infections	2	36.56%	1	54.21%	1	60.97%	1	63.13%
Conditions arising during the perinatal period	3	17.81%	3	11.51%	3	7.43%	3	4.54%
Nutritional deficiencies	4	0.63%	4	2.56%	4	4.43%	4	6.79%
Pregnancy, childbirth and puerperal complications	5	1.09%	5	1.02%	5	0.48%	5	0.24%
NCD								
total		100.00%		100.00%		100.00%		100%
Cardiovascular diseases	1	55.57%	1	61.91%	1	46.65%	1	51.38%
Respiratory diseases	2	22.51%	2	19.19%	3	12.05%	3	8.81%
Digestive diseases	3	6.17%	3	4.65%	5	2.84%	5	2.67%
Malignant neoplasms	4	4.22%	7	1.62%	2	30.97%	2	29.06%
Neuro-psychiatric conditions	5	2.75%	5	3.24%	6	1.71%	6	2.05%
Genito-urinary diseases	6	2.70%	6	2.89%	7	1.39%	7	1.18%
Diabetes mellitus	7	2.54%	4	4.10%	4	2.85%	4	3.38%
Congenital anomalies	8	1.44%	8	1.09%	8	0.41%	11	0.21%
Endocrine disorders	9	0.87%	9	0.43%	10	0.35%	9	0.41%
Musculoskeletal and connective tissue diseases	10	0.51%	11	0.34%	11	0.31%	8	0.43%
Non-malignant neoplasms	11	0.42%	10	0.36%	9	0.36%	10	0.33%
Skin diseases	12	0.23%	12	0.14%	12	0.11%	12	0.07%
Sensory organ diseases	13	0.06%	13	0.03%	13	0.00%	13	0.01%
Oral conditions	14	0.00%	14	0.00%	14	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Road traffic accidents	1	23.53%	1	33.96%	1	37.65%	2	29.35%
Self-inflicted injuries	2	20.68%	2	16.51%	3	15.04%	4	11.72%
Falls	3	14.23%	3	14.02%	2	18.44%	1	31.39%
Other unintentional injuries	4	14.04%	4	10.75%	4	12.79%	3	14.20%
Violence	5	8.73%	6	7.48%	7	2.09%	8	0.73%
Drownings	6	8.73%	7	4.98%	6	6.28%	5	6.25%
Poisonings	7	8.16%	5	10.59%	5	6.37%	6	4.99%
Fires	8	0.95%	8	1.09%	8	1.14%	7	1.23%
Other intentional injuries	9	0.76%	9	0.62%	9	0.19%	9	0.14%
War	10	0.19%	10	0.00%	10	0.00%	10	0.00%

Rural								
CMNN								
total		100.00%		100.00%		100.00%		100%
Infectious and parasitic diseases	1	35.18%	2	28.84%	2	36.08%	2	30.53%
Respiratory infections	2	36.18%	1	47.85%	1	42.43%	1	42.97%
Conditions arising during the perinatal period	3	23.14%	3	18.61%	3	16.88%	4	5.60%
Nutritional deficiencies	4	3.20%	4	3.47%	4	3.61%	3	8.50%
Pregnancy, childbirth and puerperal complications	5	2.29%	5	1.24%	5	1.00%	5	0.29%
NCD								
total		100.00%		100.00%		100.00%		100%
Cardiovascular diseases	1	41.89%	1	52.15%	1	49.57%	1	54.09%
Respiratory diseases	2	33.92%	2	31.53%	3	15.77%	3	10.49%
Malignant neoplasms	3	8.54%	4	3.36%	2	26.19%	2	26.36%
Digestive diseases	4	7.42%	3	5.38%	4	2.59%	5	2.37%
Genito-urinary diseases	5	1.99%	5	2.48%	6	1.46%	7	1.19%
Congenital anomalies	6	1.82%	8	0.92%	8	0.52%	11	0.22%
Neuro-psychiatric conditions	7	1.40%	6	1.72%	7	1.44%	6	1.83%
Musculoskeletal and connective tissue diseases	8	0.68%	11	0.24%	9	0.31%	8	0.33%
Diabetes mellitus	9	0.68%	7	1.36%	5	1.66%	4	2.51%
Endocrine disorders	10	0.62%	9	0.30%	10	0.21%	9	0.29%
Sensory organ diseases	11	0.36%	12	0.15%	14	0.00%	13	0.00%
Non-malignant neoplasms	12	0.34%	10	0.27%	11	0.19%	10	0.25%
Skin diseases	13	0.21%	13	0.14%	12	0.08%	12	0.08%
Oral conditions	14	0.14%	14	0.01%	13	0.00%	14	0.00%
Injury								
total		100.00%		100.00%		100.00%		100%
Self-inflicted injuries	1	33.71%	1	29.08%	2	16.96%	3	13.95%
Other unintentional injuries	2	18.83%	3	15.58%	3	13.43%	4	12.95%
Drownings	3	15.33%	4	12.25%	5	8.72%	5	7.24%
Road traffic accidents	4	13.74%	2	26.01%	1	38.90%	1	31.77%
Poisonings	5	6.44%	5	5.65%	6	5.91%	6	6.33%
Falls	6	5.33%	6	5.21%	4	12.96%	2	25.52%
Violence	7	3.47%	7	3.82%	7	1.74%	8	0.77%
Fires	8	2.47%	8	2.05%	8	1.32%	7	1.42%
Other intentional injuries	9	0.65%	9	0.35%	9	0.07%	9	0.06%
War	10	0.03%	10	0.00%	10	0.00%	10	0.00%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases. *1 represents the highest rank.

Table S3. Changes in ranks and proportion of neoplasms and cardiovascular diseases for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	1991		2000		2010		2019	
	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion	Rank*	Proportion
Total								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	14.88%	3	12.05%
Liver cancer	2	19.12%	2	20.35%	2	18.09%	2	15.04%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	26.34%	1	29.22%
Esophagus cancer	4	12.66%	4	10.43%	5	8.79%	6	7.39%
Other malignant neoplasms	5	7.21%	5	7.99%	4	9.36%	4	10.15%
Colon and rectum cancers	6	5.50%	6	4.91%	6	6.04%	5	7.52%
Leukemia	7	4.01%	7	3.51%	8	2.65%	9	2.33%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.76%	11	1.85%
Breast cancer	9	1.85%	10	1.90%	9	2.39%	8	2.41%
Pancreas cancer	10	1.84%	9	2.10%	7	2.69%	7	3.69%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	11	1.67%	10	2.18%
Cervix uteri cancer	12	1.37%	13	1.18%	14	1.04%	12	1.64%
Bladder cancer	13	1.15%	11	1.39%	13	1.05%	13	1.27%
Corpus uteri cancer	14	0.77%	14	0.86%	12	1.37%	16	0.76%
Melanoma and other skin cancers	15	0.51%	15	0.53%	17	0.39%	17	0.48%
Ovary cancer	16	0.39%	17	0.34%	16	0.68%	15	0.87%
Prostate cancer	17	0.24%	16	0.38%	15	0.80%	14	1.16%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	51.45%	1	56.07%	1	55.28%	1	47.17%
Ischemic heart disease	2	15.42%	2	20.69%	2	34.25%	2	40.45%
Hypertensive heart disease	3	14.58%	4	9.53%	3	5.04%	3	7.25%
Other cardiovascular diseases	4	12.22%	3	10.41%	4	4.00%	4	3.84%
Rheumatic heart disease	5	6.33%	5	3.29%	5	1.43%	5	1.29%
Male								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.98%	3	19.91%	3	15.79%	3	12.87%
Liver cancer	2	21.82%	2	22.53%	2	20.76%	2	17.14%
Trachea, bronchus and lung cancers	3	20.06%	1	23.78%	1	28.43%	1	31.72%

Esophagus cancer	4	13.59%	4	9.89%	4	9.89%	5	8.57%
Other malignant neoplasms	5	6.30%	5	7.15%	5	8.44%	4	9.34%
Colon and rectum cancers	6	4.81%	6	4.35%	6	5.44%	6	6.98%
Leukemia	7	3.29%	7	3.09%	8	2.39%	9	2.10%
Mouth and oropharynx cancers	8	2.57%	8	2.18%	9	1.90%	8	2.12%
Pancreas cancer	9	1.87%	9	1.88%	7	2.45%	7	3.27%
Lymphomas and multiple myeloma	10	1.53%	11	1.22%	10	1.62%	10	2.07%
Bladder cancer	11	1.17%	10	1.75%	12	1.19%	12	1.55%
Melanoma and other skin cancers	12	0.48%	13	0.45%	13	0.34%	13	0.41%
Prostate cancer	13	0.38%	12	0.59%	11	1.24%	11	1.79%
Breast cancer	14	0.11%	14	0.13%	14	0.12%	14	0.06%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	52.54%	1	57.77%	1	56.66%	1	49.00%
Ischemic heart disease	2	16.25%	2	20.86%	2	33.49%	2	39.33%
Hypertensive heart disease	3	14.22%	4	9.30%	3	4.69%	3	6.52%
Other cardiovascular diseases	4	11.85%	3	9.61%	4	4.11%	4	4.11%
Rheumatic heart disease	5	5.14%	5	2.46%	5	1.05%	5	1.03%
Female								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	19.95%	2	17.49%	2	13.18%	4	10.53%
Trachea, bronchus and lung cancers	2	15.15%	1	17.81%	1	22.49%	1	24.65%
Liver cancer	3	14.33%	3	16.36%	3	13.16%	3	11.20%
Esophagus cancer	4	11.00%	6	6.77%	6	6.77%	7	5.23%
Other malignant neoplasms	5	8.79%	5	9.49%	4	11.08%	2	11.63%
Colon and rectum cancers	6	6.74%	6	5.91%	5	7.13%	5	8.49%
Leukemia	7	5.31%	8	4.24%	9	3.14%	10	2.74%
Breast cancer	8	4.90%	7	5.08%	7	6.58%	6	6.73%
Cervix uteri cancer	9	3.80%	9	3.32%	11	2.95%	8	4.63%
Corpus uteri cancer	10	2.15%	11	2.40%	8	3.91%	13	2.16%
Mouth and oropharynx cancers	11	2.02%	12	2.00%	14	1.50%	14	1.36%
Pancreas cancer	12	1.80%	10	2.50%	10	3.13%	9	4.46%
Lymphomas and multiple myeloma	13	1.34%	13	1.31%	13	1.77%	12	2.38%
Bladder cancer	14	1.12%	15	0.72%	15	0.78%	15	0.76%

Ovary cancer	15	1.05%	14	0.94%	12	1.95%	11	2.46%
Melanoma and other skin cancers	16	0.55%	16	0.69%	16	0.49%	16	0.60%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	54.14%	1	53.55%	1	45.03%
Ischemic heart disease	2	14.46%	2	20.43%	2	35.20%	2	41.76%
Other cardiovascular diseases	4	12.64%	3	11.34%	4	3.87%	4	3.52%
Hypertensive heart disease	3	15.00%	4	9.83%	3	5.48%	3	8.11%
Rheumatic heart disease	5	7.65%	5	4.27%	5	1.91%	5	1.59%
Urban								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Trachea, bronchus and lung cancers	1	26.27%	1	29.62%	1	28.73%	1	30.09%
Liver cancer	2	16.04%	2	16.93%	2	14.86%	2	13.16%
Stomach cancer	3	14.54%	3	13.07%	3	12.79%	3	10.84%
Other malignant neoplasms	4	10.71%	4	8.99%	4	10.59%	4	10.48%
Esophagus cancer	5	7.59%	6	5.23%	6	5.94%	6	6.15%
Colon and rectum cancers	6	6.76%	5	6.55%	5	7.60%	5	8.85%
Leukemia	7	3.87%	8	3.38%	9	2.50%	10	2.28%
Pancreas cancer	8	3.08%	7	3.41%	7	3.72%	7	4.38%
Breast cancer	9	2.73%	9	2.96%	8	3.06%	8	2.89%
Mouth and oropharynx cancers	10	2.17%	10	2.68%	11	1.88%	11	1.79%
Lymphomas and multiple myeloma	11	1.42%	12	1.57%	10	2.18%	9	2.43%
Bladder cancer	12	1.22%	11	1.95%	12	1.36%	14	1.44%
Corpus uteri cancer	13	0.99%	15	0.84%	16	1.03%	16	0.69%
Cervix uteri cancer	14	0.95%	13	1.08%	15	1.10%	13	1.47%
Ovary cancer	15	0.83%	14	0.98%	14	1.13%	15	1.11%
Melanoma and other skin cancers	16	0.51%	17	0.28%	17	0.38%	17	0.44%
Prostate cancer	17	0.32%	16	0.49%	13	1.15%	12	1.51%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	54.91%	1	53.06%	1	49.38%	1	45.16%
Ischemic heart disease	2	21.71%	2	27.05%	2	38.69%	2	42.62%
Hypertensive heart disease	3	10.44%	4	7.75%	4	5.02%	3	6.62%
Other cardiovascular diseases	4	9.00%	3	9.98%	3	5.67%	4	4.37%
Rheumatic heart disease	5	3.95%	5	2.16%	5	1.24%	5	1.24%

Rural								
Neoplasms								
total		100.00%		100.00%		100.00%		100.00%
Stomach cancer	1	21.25%	3	19.06%	3	16.27%	3	12.67%
Liver cancer	2	19.12%	2	20.35%	2	20.25%	2	16.02%
Trachea, bronchus and lung cancers	3	18.29%	1	21.69%	1	24.74%	1	28.78%
esophagus cancer	4	12.66%	4	10.43%	4	10.70%	5	8.04%
Other malignant neoplasms	5	7.21%	5	7.99%	5	8.55%	4	9.98%
Colon and rectum cancers	6	5.50%	6	4.91%	6	4.99%	6	6.81%
Leukemia	7	4.01%	7	3.51%	7	2.75%	8	2.35%
Mouth and oropharynx cancers	8	2.37%	8	2.13%	10	1.68%	11	1.88%
Breast cancer	9	1.85%	10	1.90%	9	1.94%	9	2.16%
Pancreas cancer	10	1.84%	9	2.10%	8	2.00%	7	3.34%
Lymphomas and multiple myeloma	11	1.46%	12	1.25%	12	1.34%	10	2.05%
Cervix uteri cancer	12	1.37%	13	1.18%	13	0.99%	12	1.73%
Bladder cancer	13	1.15%	11	1.39%	14	0.84%	13	1.18%
Corpus uteri cancer	14	0.77%	14	0.86%	11	1.60%	15	0.80%
Melanoma and other skin cancers	15	0.51%	15	0.53%	16	0.41%	17	0.50%
Ovary cancer	16	0.39%	17	0.34%	17	0.38%	16	0.74%
Prostate cancer	17	0.24%	16	0.38%	15	0.58%	14	0.97%
Cardiovascular diseases								
total		100.00%		100.00%		100.00%		100.00%
Cerebrovascular disease	1	50.25%	1	57.19%	1	58.41%	1	48.08%
Hypertensive heart disease	2	16.02%	4	10.20%	3	5.05%	3	7.54%
Other cardiovascular diseases	3	13.34%	3	10.58%	4	3.11%	4	3.60%
Ischemic heart disease	4	13.24%	2	18.33%	2	31.89%	2	39.47%
Rheumatic heart disease	5	7.16%	5	3.71%	5	1.54%	5	1.31%

CMNN: communicable, maternal, neonatal, and nutritional diseases; NCD: non-communicable diseases.

*1 represents the highest rank.

Table S4. Changes in Gini coefficients, reranking, and proportionality of neoplasms and cardiovascular diseases for the combined and, male, female, rural, and urban categories, from 1991 to 2019

	Both	Male	Female	Urban	Rural
Neoplasms					
Gini index					
1991	0.599	0.658	0.523	0.582	0.622
2000	0.602	0.664	0.525	0.587	0.622
2010	0.588	0.659	0.506	0.565	0.610
2019	0.569	0.608	0.492	0.556	0.576
Reranking					
1991-2000	0.007	0.010	0.003	0.003	0.009
2000-2010	0.005	0.001	0.004	0.003	0.018
2010-2019	0.004	0.030	0.016	0.001	0.007
1991-2019	0.050	0.073	0.056	0.010	0.072
Proportionality					
1991-2000	0.003	0.004	0.001	-0.001	0.009
2000-2010	0.019	0.006	0.023	0.024	0.030
2010-2019	0.024	0.081	0.029	0.010	0.042
1991-2019	0.081	0.124	0.087	0.036	0.118
Cardiovascular diseases					
Gini index					
1991	0.374	0.396	0.350	0.384	0.356
2000	0.468	0.489	0.440	0.393	0.462
2010	0.547	0.557	0.535	0.415	0.566
2019	0.514	0.523	0.503	0.393	0.519
Reranking					
1991-2000	0.002	0.001	0.046	0.011	0.034
2000-2010	0.004	0.002	0.006	0.000	0.007
2010-2019	0.000	0.000	0.000	0.005	0.000
1991-2019	0.000	0.000	0.133	0.000	0.128
Proportionality					
1991-2000	-0.092	-0.092	-0.044	0.002	-0.072
2000-2010	-0.076	-0.066	-0.089	-0.022	-0.097
2010-2019	0.033	0.034	0.032	0.026	0.048
1991-2019	-0.140	-0.127	-0.020	-0.009	-0.035

Table S5. Changes in contributory percentage of the demographic structure and non-demographic factors to the year- and sex-specific crude mortality difference of neoplasm and cardiovascular diseases, from 1991 to 2019

	Mortality Difference	Demographic Structure	Non-demographic Factors
Neoplasms			
Both			
1991-2000	22.745	17.56%	7.65%
2000-2010	24.081	18.30%	3.02%
2010-2019	25.410	35.40%	-16.86%
1991-2019	72.235	84.58%	-4.51%
Male			
1991-2000	29.505	18.60%	7.44%
2000-2010	31.627	18.28%	3.87%
2010-2019	32.626	36.06%	-17.35%
1991-2019	93.758	87.22%	-4.46%
Female			
1991-2000	15.702	16.76%	6.92%
2000-2010	16.123	17.62%	2.03%
2010-2019	18.328	35.65%	-16.97%
1991-2019	50.153	82.04%	-6.40%
Urban			
1991-2000	14.468	19.47%	-7.71%
2000-2010	7.612	17.24%	-11.71%
2010-2019	17.914	26.63%	-14.29%
1991-2019	39.993	67.14%	-34.65%
Rural			
1991-2000	24.026	16.29%	13.47%
2000-2010	27.341	15.40%	10.70%
2010-2019	30.033	41.97%	-19.23%
1991-2019	81.400	91.35%	9.48%
Cardiovascular diseases			
Both			
1991-2000	44.582	24.76%	3.78%
2000-2010	37.284	7.60%	10.96%
2010-2019	79.416	56.81%	-23.46%
1991-2019	161.282	107.63%	-4.41%
Male			
1991-2000	51.266	26.31%	5.45%
2000-2010	46.201	9.09%	12.63%
2010-2019	78.670	53.82%	-23.43%
1991-2019	176.138	111.18%	-2.08%
Female			

1991-2000	37.431	23.44%	1.35%
2000-2010	28.051	5.53%	9.36%
2010-2019	80.390	61.30%	-24.17%
1991-2019	145.872	104.75%	-8.14%
Urban			
1991-2000	39.771	27.36%	-5.23%
2000-2010	-0.889	14.29%	-14.69%
2010-2019	69.701	47.72%	-15.84%
1991-2019	108.582	95.77%	-35.36%
Rural			
1991-2000	45.046	23.43%	6.72%
2000-2010	55.518	0.58%	27.97%
2010-2019	82.682	64.00%	-30.93%
1991-2019	183.246	111.89%	10.74%

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	--
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	--
		(*e*) Describe any sensitivity analyses	--
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	--
		(b) Give reasons for non-participation at each stage	--
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-8
		(b) Indicate number of participants with missing data for each variable of interest	--
Outcome data	15*	Report numbers of outcome events or summary measures	--
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	--

		(*b*) Report category boundaries when continuous variables were categorized	--
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	--
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-8
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.