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

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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 Standardised mortality rates (SMRs) and crude mortality rates (CMRs) 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 (NCDs) 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 NCDs 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 NCDs (R=0.037), the ranking of injury changed the most (R=0.174). The ranking of diabetes, falls and road traffic accidents increased markedly over time. The decreased SMR of NCDs (P=−0.013) was mainly due to low-ranking causes, whereas changes in CMNN (P=0.003) and injury (P=0.131) were due to high-ranking causes. All-cause CMR increased by 14.06% 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 NCDs and specific causes are imperatively needed, and

Strengths and limitations of this study

► Our study described the transitions of mortality causes in China by analysing data from the nationally representative Disease Surveillance Points systems.
► 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 presented the percentage of demographic and non-demographic factors that contributed to changes in the crude mortality rates (CMRs) from 1991 to 2019 in the Chinese population.
► Despite discrepancies between the original and secondary data, heterogeneity can be minimised by a standardised 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.

should be strengthened as the population ages, especially for males and rural populations.

INTRODUCTION

Over the past 30 years, China has gradually transitioned from demographic dividend to demographic burden, with slower population growth, faster ageing and more severe subre-placement 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 behavioural and environmental risks were curbed through comprehensive disease prevention and control programmes.[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 (NCDs), such as stroke, ischaemic heart disease, lung cancer and diabetes, were the major causes of premature death, while 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] Wei *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 policy-making, and health resource allocation for ageing 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 prioritisation 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 centralised 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 ageing and other risk factors to CMRs, 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 CMRs 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.[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 analysed. All CMRs were standardised 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-specific and urban-specific CMRs, and standardised mortality rates (SMRs) 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), NCDs and injury; second, comprising the main systems among the three primary categories—CMNN, including infectious and parasitic diseases, some infections and nutritional deficiencies, etc.; NCDs, including neoplasms, haematopoietic organs and immune diseases, endocrine, nutritional and metabolic diseases, etc.; and injury, comprising self-inflicted injuries, road traffic accidents and drownings, etc.; and third, the secondary systems were further divided into specific causes. Then, we analysed the causes of malignant neoplasms and cardiovascular diseases among the two leading systems.

Statistical analysis
First, we described the all-cause and three categorical CMRs and SMRs, 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 were 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 (online supplemental figure S1).

In the decomposition of *G* changes (online supplemental file 1 part A),[7] the *G* difference (ΔG) in the

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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 (online supplemental 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), socioeconomic 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 (online supplemental file 1 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 V.9.4 (SAS Institute) and Python Jupyter Notebook V.6.0.3 (https://jupyter.org/).

RESULTS
Overall changes in CMRs and all-cause SMRs

Figure 1 shows the total and sex-specific, urban-specific and rural-specific CMRs of CMNN, NCDs 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, NCDs and injury decreased every decade, and were higher in males, although with a declining trend. The decreasing tendency of rural SMRs was close during 1991–2000 and 2010–2019 but fluctuated during 2000–2010, with a faster decline in NCDs and a comparatively steady change in CMNN and injury (figure 2).

Figure 1 depicts G and the percentage of CMRs for CMNN, NCDs 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 NCDs 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-specific and sex-specific contributory proportions of all-cause demographic and non-demographic factors. Males had a threefold CMR increase (125.977/100 000) compared with 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
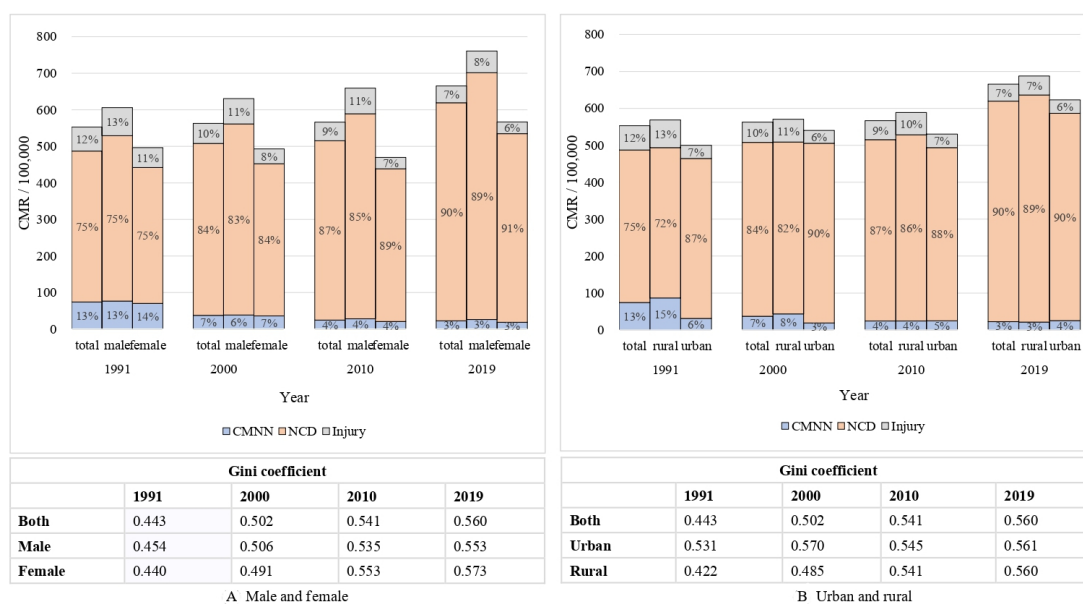
Figure 1 CMR and Gini coefficient of all-cause, CMNN, NCD and injury in 1991, 2000, 2010 and 2019. (A) Both, male and female. (B) Both, urban and rural. CMNN, communicable, maternal, neonatal and nutritional; CMR, crude mortality rate; NCD, non-communicable disease.
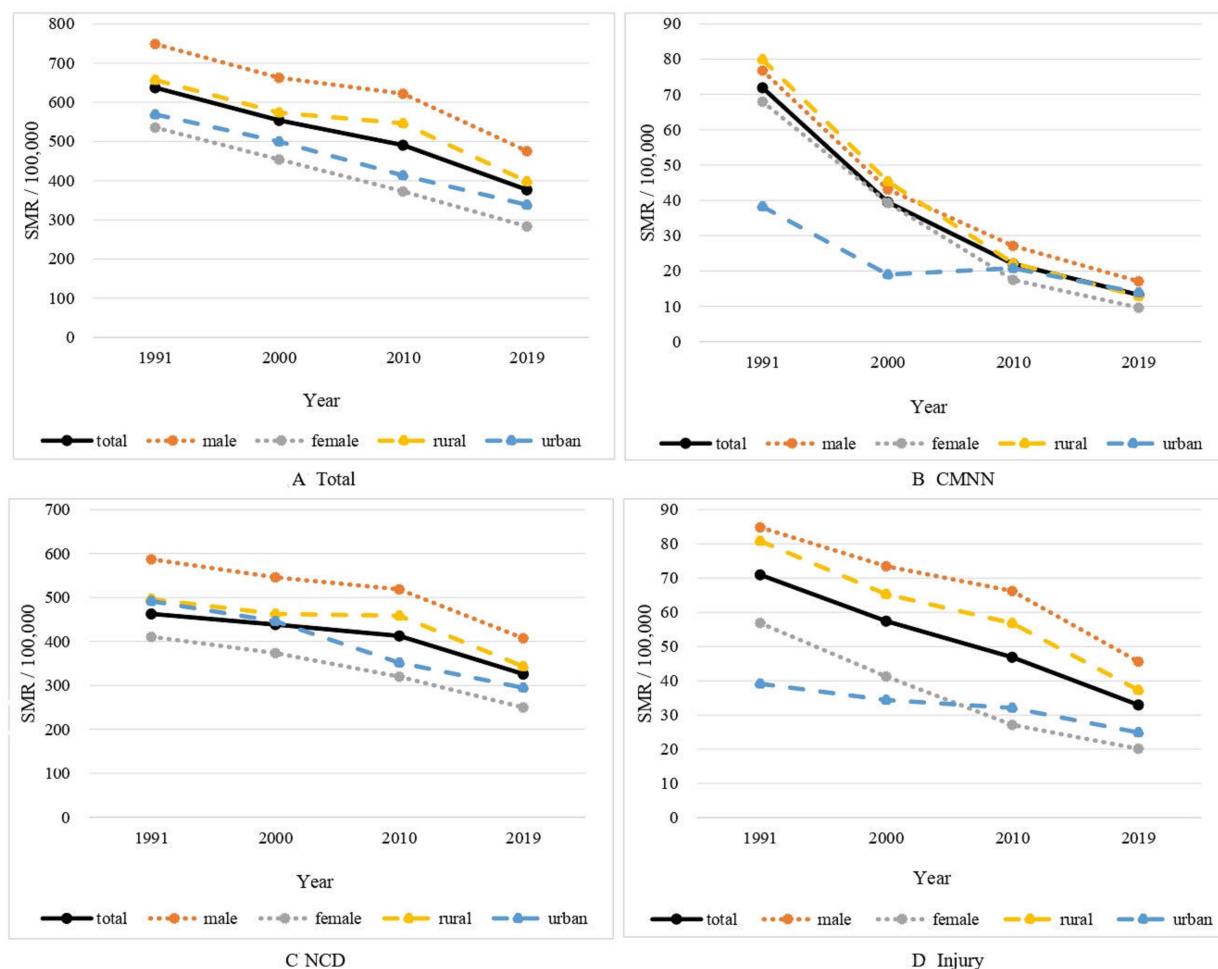
Figure 2 SMR per 100 000 persons of all-cause and three major categories (CMNN, NCD and injury) in China, 1991–2019. (A) total; (B) CMNN; (C) NCD; (D) injury. CMNN, communicable, maternal, neonatal and nutritional diseases; NCD, non-communicable disease; SMR, standardised mortality rate.

impact of non-demographic factors (−54.40%). Thus, all-cause CMR increased by 83.187/100 000 (14.06%). 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 NCDs

Table 2 shows G and their decompositions across 30 years in China for 14 causes of NCDs. 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, neuropsychiatric 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 (online supplemental 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. NCDs 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 NCDs subcategories varied the most during 1991–2000, and has stabilised since 2000 (R values: 0.006, 0.002, 0.0003) with negative P values: −0.009 to −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 value was ascribed to low-ranking causes in both. G-variation-related rural mortality differences expanded over time, but changes in rural and

Table 1 Changes in the contributory percentage of the demographic structure and non-demographic factors to the year-specific 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%

urban settings were mainly caused by the decline of low-ranking causes (table 2 and online supplemental table S2).

Table 3 presents CMRs changes between 1991 and 2019 and the year-specific and sex-specific contributory percentage of demographic and non-demographic factors in three categories. In NCDs, consistent with all-cause CMRs, demographic structure and non-demographic factors increased and decreased the CMRs 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 CMRs 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 NCDs systems is shown in online supplemental table S3–S5.

Between 1991 and 2019, G decreased in neoplasms subcategories of neoplasms and their ranks mainly changed from 1991 to 2000 (R=0.007). 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, oesophageal cancer, leukaemia, oral and oropharyngeal cancers) induced an overall decline of SMR-neoplasms (P=0.081) 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, ischaemic and hypertensive heart diseases. Ischaemic heart disease increased from 15.42% to 40.45%, whereas hypertensive heart disease decreased from 14.58% to 7.25%, but was always higher in women than in men. P values 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 (online supplemental tables S3 and S4).

Demographic structure continuously increased the CMRs of neoplasms and cardiovascular diseases, whereas before 2010, non-demographic factors increased and decreased their CMRs, 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 (online supplemental 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;

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					

Continued

Table 2 Continued

Periods	Both	Male	Female	Urban	Rural
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; NCD, non-communicable disease.

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 online supplemental 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 sixth in 1991 to second rank in 2019, whereas the ranking of road traffic accidents increased from third to first. In contrast, self-inflicted injuries decreased from first to third. 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 online supplemental table S2).

The CMRs 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 urban 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 online supplemental 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 NCDs 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 CMRs, respectively, with the maximum contributions in 2010. The explanatory share of demographic structure for the increased CMRs in urban and male populations increased with population ageing. Specifically, from 1991 to 2019, non-demographic factors decreased the CMRs of NCDs, which declined more in females than males, and in urban than rural settings. Of note, cause-specific differences in neoplasms and cardiovascular diseases 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 described 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 decreased the rate of systematic mortality causes gained importance, relative to higher-ranked or lower-ranked causes. CMR

Table 3 Changes in the contributory percentage of the demographic structure and non-demographic factors to the year-specific 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			

Continued

Table 3 Continued

Periods	Mortality difference	Demographic structure	Non-demographic factors
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; NCD, non-communicable disease.

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 ageing 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 minimised by a standardised 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 SMRs 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 policy-makers to address the increasing health needs of older adults. Compared with studies that visualise the changes in high-ranking causes in different years by colourful 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 analysed provincial inequality including maternal mortality and malignant tumours in China. However, to the best of our knowledge, this is the first study that interpreted the proportion of population ageing 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 NCDs

NCDs 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 programmes including Guidelines for Chronic Disease Prevention and Treatment, National Healthy Lifestyle Initiative, Healthy China 2030 Plan, China's Medium-Term 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] long-standing 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 utilisation, 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 in China, which facilitated the collection of updated information and implementation of several special interventions targeting meningitis, tetanus, measles, diarrhoea, 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, urbanisation 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 ageing standard of 7%;[2] thus, China has transitioned into rapidly ageing 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 prioritised diseases should be intensified.[26] With the population ageing, the establishment of long-term care settings to fulfil 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 realised 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 NCDs, especially neoplasms and cardiovascular diseases, remains a major public health concern among the mortality causes in China, with population ageing 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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Supplementary Materials

Contents

Part A: calculation formulas

1.Gini decomposition method

The Gini decomposition formulas are as follows:

$$\Delta G = G_1 - G_0 \equiv R - P \qquad (1)$$
$$R = G_1 - G_1^{(0)} \qquad (2)$$
$$P = G_0 - G_1^{(0)} \qquad (3)$$

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.

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Part B: supplementary figure

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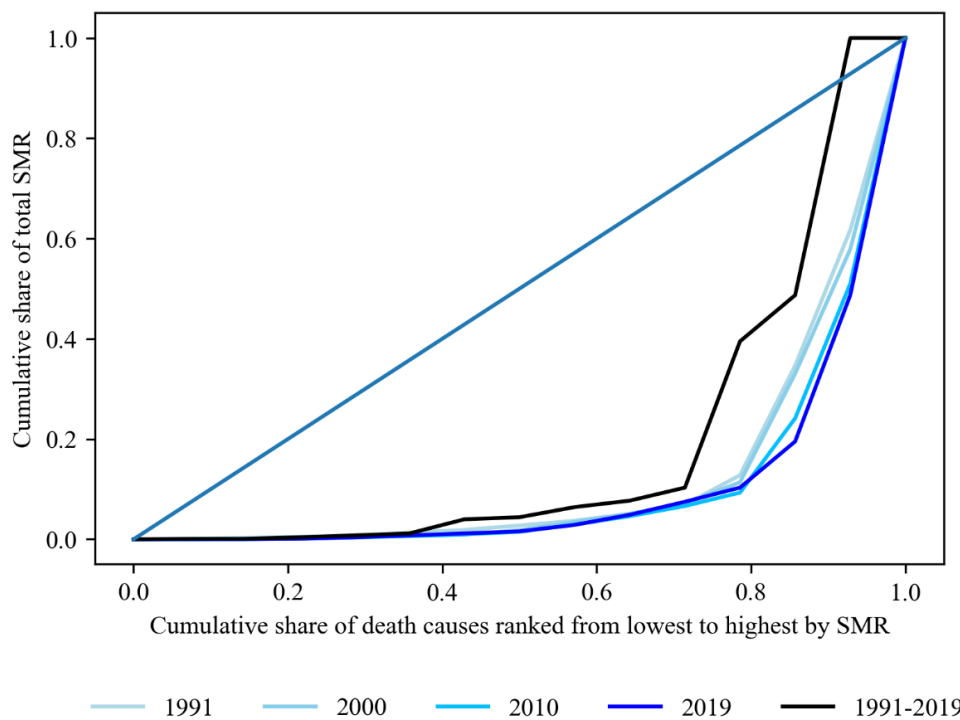
highest by contribution to the all-cause standardized mortality rates of non-communicable diseases, from 1991 to 2019.

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

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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%

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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%

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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%

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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.

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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

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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			

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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%