BMJ Open

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

Feiling Ai, Xia Wan

To cite: Ai F, Wan X. 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. *BMJ Open* 2022;**12**:e059395. doi:10.1136/bmjopen-2021-059395

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-059395).

Received 21 November 2021
Accepted 08 April 2022

Check for updates

Department of Epidemiology and Biostatistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences & School of Basic Medicine, Peking Union Medical College, Beijing, China

Correspondence to
Dr Xia Wan;
xiawan@ibms.pumc.edu.cn

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 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 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.

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 subreplacement 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 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/).

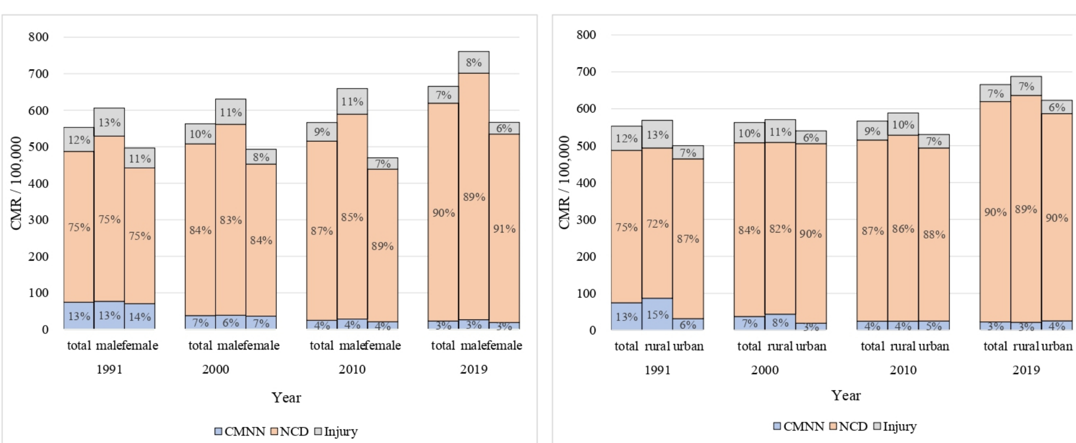
RESULTS

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 *G*s 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



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. (A) Both, male and female. (B) Both, urban and rural. CMNN, communicable, maternal, neonatal and nutritional; CMR, crude mortality rate; NCD, non-communicable disease.

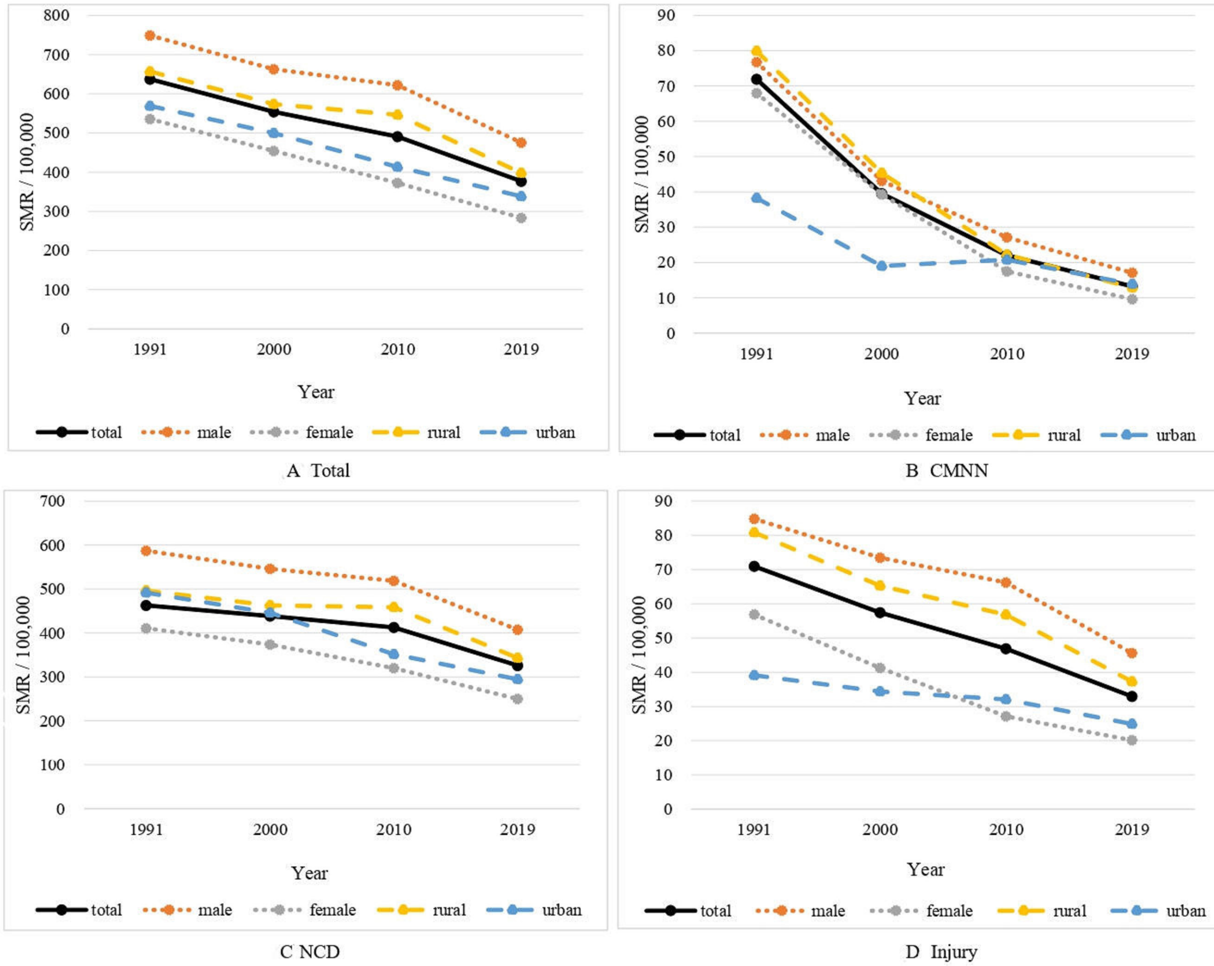


Figure 2 SMR per 100 000 persons of all-cause and three major categories (CMNN, NCD and injury) in China, 1991–2019. (A) total; (B) CMNN; (C) NCD; (D) injury. CMNN, communicable, maternal, neonatal and nutritional diseases; NCD, non-communicable disease; SMR, standardised mortality rate.

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			
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.

Acknowledgements We thank Yunjie Jia for her useful advice on the manuscript translation.

Contributors XW designed the study concept and obtained the original data. FA managed data, implemented methods, wrote the first draft of the paper. XW and FA contributed to the revision and finalisation 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.

Funding This work was funded by CAMS Innovation Fund for Medical Sciences (CIFM) (2016-12 M-3-001), and China Medical Board-Collaborating Programmes (CMB-CP) Grant for the Burden of Diseases in China (12-107, 15-208).

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 None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. 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 in 1991 and 2000 were publicly available in the website of Chinese Centre for Disease Control and Prevention. 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).

ORCID iD

Xia Wan http://orcid.org/0000-0002-0738-5631

REFERENCES

1 Chen H, RH X, Tang T. *Understanding and response of China's demographic transition*. PBC Working Paper, 2021.
2 National Bureau of Statistics. *The main data of the seventh national census*, 2021.
3 Zhou M, Wang H, Zeng X, *et al*. Mortality, morbidity, and risk factors in China and its provinces, 1990-2017: a systematic analysis for the global burden of disease study 2017. *Lancet* 2019;394:1145–58.
4 Liu S, Li Y, Zeng X, *et al*. Burden of cardiovascular diseases in China, 1990-2016: findings from the 2016 global burden of disease study. *JAMA Cardiol* 2019;4:342–52.
5 Wei W, Zeng H, Zheng R, *et al*. Cancer registration in China and its role in cancer prevention and control. *Lancet Oncol* 2020;21:e342–9.
6 Bergeron-Boucher M-P, Aburto JM, van Raalte A. Diversification in causes of death in low-mortality countries: emerging patterns and implications. *BMJ Glob Health* 2020;5:e002414.
7 Dyson H, Van Gestel R, van Doorslaer E, Henry D, Raf VG, vD E. The relative importance and stability of disease burden causes over time: summarizing regional trends on disease burden for 290 causes over 28 years. *Popul Health Metr* 2021;19:30.
8 Jenkins SP, Kerm PV. Trends in income inequality, pro-poor income growth, and income mobility. *Oxf Econ Pap* 2006;58:531–48.
9 Barrenho E, Miraldo M, Smith PC. Does global drug innovation correspond to burden of disease? the neglected diseases in developed and developing countries. *Health Econ* 2019;28:123–43.
10 Nie P, Ding L, Sousa-Poza A, *et al*. Inequality of weight status in urban Cuba: 2001–2010. *Popul Health Metr* 2021;19:24.
11 Kitagawa EY. Components of a difference between two rates. *JASA* 1955;50:1168–94.
12 Bashir S, Estève J. Analysing the difference due to risk and demographic factors for incidence or mortality. *Int J Epidemiol* 2000;29:878–84.
13 Zhai ZW, Lu L, Luo MC. *Modern population analysis techniques*. China Renmin University Press, 1989.[Dataset].
14 Center for Chronic Noncommunicable Diseases, Chinese Center for Disease Control and Prevention; National Health Commission Statistical Information Center. *National disease surveillance system cause-of-death surveillance dataset in 2019*. Beijing: China Science and Technology Press, 2019.
15 Yang G, Hu J, Rao KQ, *et al*. Mortality registration and surveillance in China: history, current situation and challenges. *Popul Health Metr* 2005;3:3.
16 Liu S, Wu X, Lopez AD, *et al*. An integrated national mortality surveillance system for death registration and mortality surveillance, China. *Bull World Health Organ* 2016;94:46–57.

17 Yang G, Kong L, Zhao W, *et al*. Emergence of chronic non-communicable diseases in China. *Lancet* 2008;372:1697–705.
18 Yang GH. Chinese center for disease control and prevention. National disease surveillance system cause-of-death surveillance data from 1991 to 2000. Available: https://www.phsciencedata.cn/Share/ky_sjml.jsp?id=%227253a104-63ac-40f7-a0ac-b04c1096ae52%22
19 Chinese Center for Disease Control and Prevention. *National disease surveillance system cause-of-death surveillance dataset in 2010*. Beijing: Military Science Publishing House, 2010.
20 National Bureau of Statistics. *Population census data in China in 2000*, 2001.
21 Murray CJL, Vos T, Lozano R, *et al*. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010. *The Lancet* 2012;380:2197–223.
22 Yang GH. *Death causes and their risk factors in Chinese population: prevalence, trend and distribution*. Beijing: Peking Union Medical College Press, 2005.
23 Zhang X, Ye Y, Fu C, *et al*. Anatomy of provincial level inequality in maternal mortality in China during 2004–2016: a new decomposition analysis. *BMC Public Health* 2020;20:758.
24 Guo XL, Fu ZT, Sun JD, *et al*. [Trend of mortality and decomposition on malignant tumors in Shandong province, 1970-2013]. *Zhonghua Liu Xing Bing Xue Za Zhi* 2019;40:924–9.
25 Yang G, Wang Y, Zeng Y, *et al*. Rapid health transition in China, 1990–2010: findings from the global burden of disease study 2010. *The Lancet* 2013;381:1987–2015.
26 Sun XD, Lv J, LM L. Prevalence of major risk factors for chronic diseases and development of prevention strategies. *Chin J Prev Contr Chron Dis* 2008;5.
27 Tan X, Liu X, Shao H. Healthy China 2030: a vision for health care. *Value Health Reg Issues* 2017;12:112–4.
28 Office of The State Council of China. *Notice of the General Office of the State Council on printing and distributing China's Medium and Long-term Plan for Prevention and Treatment of Chronic Diseases (2017-2025)*, 2017.
29 Office of The State Council of China. *Notice of the general office of the state Council on printing and distributing national nutrition plan (2017-2030)*, 2017.
30 Office of The State Council of China. *Notice of the general office of the state Council on printing and distributing action plan on air pollution prevention*, 2013.
31 Central People's Government of the People's Republic of China. *Law of the People's Republic of China on the Protection of Minors*, 2020.
32 Think Tank Research Center for Health Development. *A civil society perspective 2019 tobacco control in China*, 2019.
33 Liu L, Wan X, Chen G, *et al*. [Risk Factors of Lung Cancer in Xuanwei, Yunnan Province, China]. *Zhongguo Fei Ai Za Zhi* 2017;20:528–37.
34 Central People's Government of the People's Republic of China. *Healthy China action (2019- 2030*, 2019.
35 Du H, Li L, Bennett D, *et al*. Fresh fruit consumption and major cardiovascular disease in China. *N Engl J Med* 2016;374:1332–43.
36 Zou Q, Wang H, Du W, *et al*. Trends in Leisure-Time Physical Activity Among Chinese Adults - China, 2000-2015. *China CDC Wkly* 2020;2:135–9.
37 Guo Y, Yin X, Wu H, *et al*. Trends in overweight and obesity among children and adolescents in China from 1991 to 2015: a meta-analysis. *Int J Environ Res Public Health* 2019;16:4656.
38 Guo B, Xie X, Wu Q. Inequality in the health services utilization in rural and urban China: a horizontal inequality analysis. *Medicine* 2020;99:e18625.
39 Wang D. Reduction but not elimination: health inequalities among urban, migrant, and rural children in China-the moderating effect of the fathers' education level. *BMC Public Health* 2019;19:1219.
40 Department of Primary Health Care, National Health Commission. *National basic public health service project management platform*, .
41 Phillips MR, Li X, Zhang Y. Suicide rates in China, 1995-99. *Lancet* 2002;359:835–40.
42 Jiang H, Niu L, Hahne J, *et al*. Changing of suicide rates in China, 2002-2015. *J Affect Disord* 2018;240:165–70.
43 Zhong B-L, Chiu HFK, Conwell Y. Elderly suicide trends in the context of transforming China, 1987-2014. *Sci Rep* 2016;6:37724.
44 Lu ZM, Wang Y, Ye PP, ZM L, PP Y, *et al*. [Analysis on epidemiologic characteristics of fall in old people: results from Chinese National Injury Surveillance System, 2015-2018]. *Zhonghua Liu Xing Bing Xue Za Zhi* 2021;42:137–41.
45 Wang L, Ning P, Yin P, *et al*. Road traffic mortality in China: analysis of national surveillance data from 2006 to 2016. *Lancet Public Health* 2019;4:e245–55.
46 GBD 2019 Demographics Collaborators. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950-2019: a comprehensive demographic analysis for the global burden of disease study 2019. *Lancet* 2020;396:1160–203.
47 The State Council of the CPC Central Committee. *The decision on implementing the universal two-child policy reform and improving the management of family planning services*, 2015.
48 The State Council of the CPC Central Committee. *Decision on optimizing birth policy to promote long-term balanced development of population*, 2021.
49 Guo XJ, Zhang R. *One hundred years of medical care*. . China Health Insurance, 2021: 07. 16–21.
50 Cacchione PZ. Innovative care models across settings: providing nursing care to older adults. *Geriatr Nurs* 2020;41:16–20.