SSM - Population Health 24 (2023) 101527

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

The temporal trend of road traffic mortality in China from 2004 to 2020☆

Kehao Ren [1], Lipeng Miao, Juncheng Lyu [*,1]

Weifang Medical University, School of Public Health, China

ARTICLE INFO

Keywords:
China
Joinpoint regression
Mortality
Road traffic injury
Trends

ABSTRACT

Background: Road traffic accidents are one of the critical disasters that cause massive negative influences to the social economy and people's property, health and life safety. The purpose of this study is to analyze the temporal trend of road traffic mortality in China from 2004 to 2020, and further analyze the key factors that the influencing changes in China's road traffic mortality and provides information for the development of targeted interventions to reduce the number of preventable deaths.
Methods: The data were retrieved from the Chinese Death Cause Monitoring Data Set from 2004 to 2020. The road traffic mortality rates were standardized by the Sixth National Population Census (6th NPC) data. Joinpoint regression method was manipulated to analyze temporal trends of standardized road traffic mortality. The study used annual percentage change (APC) and average annual percentage change (AAPC) calculated by the Joinpoint regression model to describe trends in road traffic mortality rates.
Results: The overall age-adjusted road traffic mortality in China showed a declining trend from 2004 to 2020 ($AAPC_{2004\text{-}2020}$ = - 4.2%), from 20.9 to 12.92 per 100,000. Rural road traffic mortality rates were generally higher than the one in urban areas, and males were generally higher than females. There was an overall downward trend of the standardized road traffic mortality in the East and Central regions between 2004 and 2020. It was worth noting that the road traffic mortality rates in the Western region showed an upward trend from 2006 to 2011 ($APC_{2006\text{-}2011}$ = 3.3%) and continued to decline after 2011 ($APC_{2011\text{-}2020}$ = - 6.7%). The road traffic mortality rates of aged 65 years and older was highest, which required focused attention.
Conclusions: From 2004 to 2020, the road traffic mortality rates in China generally declined. At the same time, there was a slow reduction or even an upward trend in road traffic mortality rates among the elderly and in western regions. Rural males are a priority group for road traffic injury prevention.

1. Introduction

At present, the number of Road Traffic Injuries (RTIs) caused by road traffic accidents has dramatically increased. Road traffic accidents are one of the critical disasters that cause massive negative influences to social economy and people's property, health and life safety. At the same time, road traffic participants are always exposed to the risk of RTI_S. (Han et al., 2014; Wang, Ning, et al., 2019) Word Health Organization named the World Health Day on April 7, 2004 as "Road Safety Day", with the theme of a "Road Safety, Preparedness", and called on the world to pay attention to the public health problem of road traffic safety. (India State-Level Disease Burden Initiative Road Injury Collaborators, 2020; Wang & Jiang, 2019) The WHO Global Status Report on Road Safety 2018 highlighted that as many as 1.35 million people die from road traffic accidents every year. Road traffic injuries was a leading killer of people aged 5 to 29, especially in developing countries.

The China Statistical Yearbook-2021 reported 244,674 road traffic accidents in China in 2020, which resulted in 61,703 deaths and 250,723 injuries. (China, 2021) The traffic accident mortality in China was as high as 19.75% percentage of the whole mortality numbers, which was significantly higher than that of developed countries during the same period. (Wang, Liu, et al., 2019) The WHO estimated that one

☆ The research was supported by (1) Natural Science Foundation of Shandong Province: ZR2021MH408. (2) Research Project of China Academic Degree and Graduate Education Association: 2020ZDB44, (3) Shandong Provincial Youth Innovation Team Development Plan of Colleges and Universities: No.2019-6-156, Lu-Jiao, (4) the Overseas Study and Visiting Project of Shandong Provincial Government and (5) 2021 University Level Demonstration Curriculum of Ideological and Political Couse.

* Corresponding author.
E-mail address: lvjuncheng79@163.com (J. Lyu).
[1] Co-frist authors: Juncheng Lyu and Kehao Ren are the co-first authors.

https://doi.org/10.1016/j.ssmph.2023.101527
Received 22 May 2023; Received in revised form 15 September 2023; Accepted 3 October 2023
Available online 5 October 2023

fifth of road traffic deaths occurred in China. (Organization, 2015) As the most populous country in the world, China is particularly vulnerable to road traffic injuries. Efforts to improve road safety in China may be able to significantly reduce global road traffic mortality rates.

A number of previous studies provided some data on temporal trends of road traffic mortality rates in China. Several studies have shown that road traffic mortality rates are generally higher for males than for females, and generally higher in rural areas than in urban areas. (Huang et al., 2013a; Samath et al., 2015; Zhang et al., 2012a, 2014) Road traffic injuries are the leading cause of death in the 15–44 age group in several countries, (Chi Wang et al., 2004) such as China, Vietnam, (Ngo et al., 2012) and the United States. (Wang et al., 2018a) However, with the aging process in Chinese population, the number of elderly road users is gradually increasing. Compared with drivers aged 40–49, drivers aged 65–69 had a 1.29 times higher risk, drivers aged 85+ had a 3.74 times higher risk of a fatal crash. (Preusser et al., 1998) It was speculated that the number of road traffic deaths in China will increase dramatically to 8.4 million by 2020 without better preventive measures. (Murray & Lopez, 1997) It was essential for the implementation and evaluation of preventive strategies to accurate assessment of road safety data. The purpose of this study was to analyze the temporal trend of road traffic mortality in China from 2004 to 2020, and the data were divided according to gender and urban/rural, age group, and geographic location (East, Central, and West) to identify node points. In turn, it analyzed the key factors that influencing changes in China's road traffic mortality and provided information for the development of targeted interventions to reduce the number of preventable deaths.

2. Method

2.1. Data sources

The data were retrieved from *the Chinese Death Cause Monitoring Data Set*, which included information on Road Traffic Mortality Rates (RTMR) of geographic location, age group and urban/rural/sex combination from 2004 to 2020. The National Disease Surveillance System (NDS), was established in 1978, continues to monitor mortality levels and changes in disease patterns in the Chinese population. It had been expanded to 161 sites and began to provide annual cause-of-death surveillance results as a dataset in 2004. (Cheng et al., 2017; Liu et al., 2016) In 2013, the National Health and Family Planning Commission integrated the former Ministry of Health Cause of Death Statistics System and the National Disease Surveillance System, then expanded it to 605 surveillance sites. The research data for this study was obtained from the road traffic mortality data of the "Mortality and Causes of Death of Major Injuries" in the "China Cause of Death Surveillance Dataset". This study used the data of the sixth population census as the standard population, and carried out age standardization processing on the road traffic mortality of all age groups in China from 2004 to 2020. The State Council decided to conduct the sixth national population census in 2010. The standard time point for this census was 0 h on November 1, and the census mainly investigated the basic conditions of the population and households. In addition, age-adjusted mortality rates were calculated separately for each group according to urban and rural areas, different gender and regions. The reason why the sixth population census was used as the standard population was that it was the latest population census to current study.

2.2. Statistical analysis

Excle 2016 was used to collect and sort out the crude traffic mortality data of urban and rural areas, different gender and regions by age from 2004 to 2020 in China. The age-standardized mortality rate (ASMR) is calculated based on a standard population with the following formula:

$$ASMR = \frac{\sum N_i P_i}{\mathrm{N}}$$

In the formula, ***Ni*** is the number of standard population in a particular age group, ***Pi*** is the morbidity/mortality rate in that age group, ***Ni Pi*** is the expected number of morbidity/mortality in a particular age group in the study population, and ***N*** is the total number of standard population. We calculated the standardized road traffic mortality rates for China overall, including different residences, different gender, different regions, and different gender by different regions respectively.

Joinpoint regression method was manipulated to analyze temporal trends of standardized road traffic mortality. According to the type of data, this research should adopt a non-linear data analysis model. (Kim et al., 2000; Zeng, 2019) The number of segmentation points is determined based on the grid search method, and the default maximum number of segmentation points is 3. (Qiu et al., 2009) The change trend of each segment was described by Annual Change Percentage (APC), and the overall change trend of was described by Average Annual Change Percentage (AAPC). The AAPC is a weighted average of the APC from the Joinpoint regression model. The AAPC will coincide with the APC when no connection point is detected. Based on t-distribution and normal distribution, hypothesis test was conducted for the obtained APC and AAPC. The APC and AAPC was calculated by using equation as followed:

$$APC = \{\exp(\beta) - 1\} \times 100$$

$$APC = \left\{ \exp\left(\frac{\sum \beta_i w_i}{\sum w_i}\right) - 1 \right\} \times 100$$

In the formula, β is the regression coefficient, w_i is the width of the interval span (i.e., the number of years included in the interval) for each segmented function, and β_i is the regression coefficient corresponding to each interval.

If APC is positive, it indicates that the mortality rate tends to increase year by year in this time interval and vice versa; if APC=AAPC, it indicates that the mortality rate does not have a significant turning point throughout the study time interval, and shows a monotonous and continuous upward or downward trend; the difference is statistically significant when the Joinpoint regression is set at $P < 0.05$. In addition, hypothesis test was used to test whether the trend of each section or the change of the overall trend were statistically significant, and the confidence interval was calculated. Differences were judged to be significant when the *P*-value was less than 0.05 according to a two-sided test.

3. Results

3.1. General description of the temporal trends

Trend changes of age-adjusted mortality rates for road traffic in China for males and females, urban and rural were illustrated in Fig. 1, which of all different groups decreased from 2004 to 2020. As shown in Fig. 1, the road traffic mortality of males was higher than that of females, and the rural road traffic mortality was higher than that of urban. The greatest decline of RTMR was the rural males group (53.9% decrease). The RTMR of urban males, urban females, rural males and rural females decreased from 25.52 to 10.98, from 9.47 to 4.44, from 40.30 to 18.58, from 12.22 to 7.02 separately.

The change of China's age-adjusted road traffic mortality by region from 2004 to 2020 was illustrated in Fig. 2, which still showed the decreasing tendency. The mortality declined from 23.76 to 10.37 in the eastern region, declined from 21.32 to 11 in the central region, and declined from 22.73 to 11.98 in the western region. The largest decline in mortality was in the eastern region (56.63% decrease).

The variation of China's age-adjusted road traffic mortality by age stage from 2004 to 2020 was clarified in Fig. 3. Road traffic mortality rate declined in all groups during this period. The mortality decreased

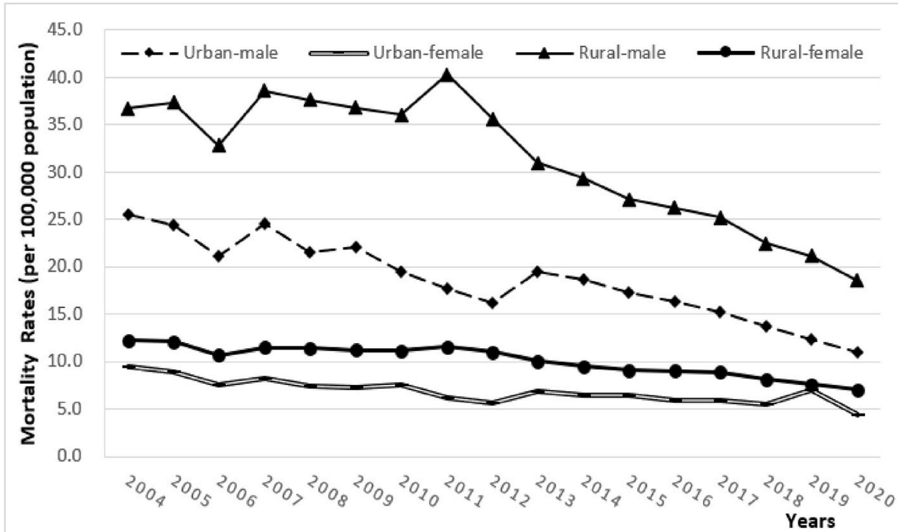

Fig. 1. Age-adjusted mortality rates of China's road traffic by urban and rural areas and gender from 2004 to 2020.

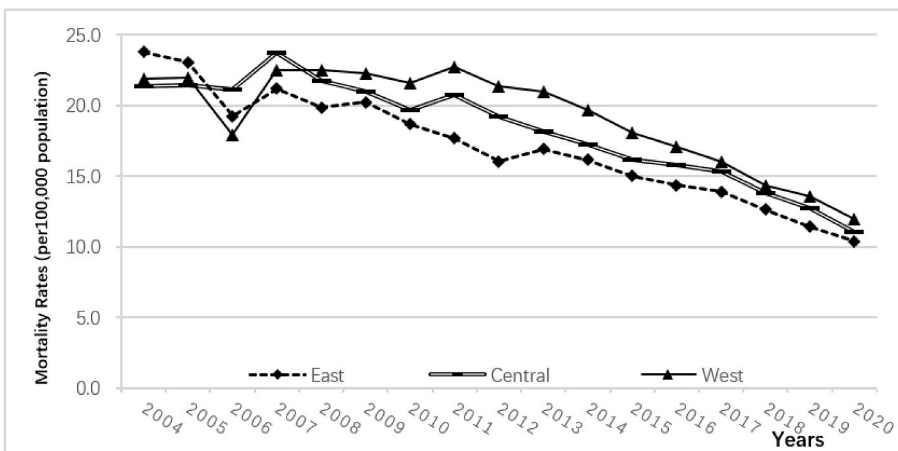

Fig. 2. Age-adjusted mortality rates of China's road traffic by region from 2004 to 2020.

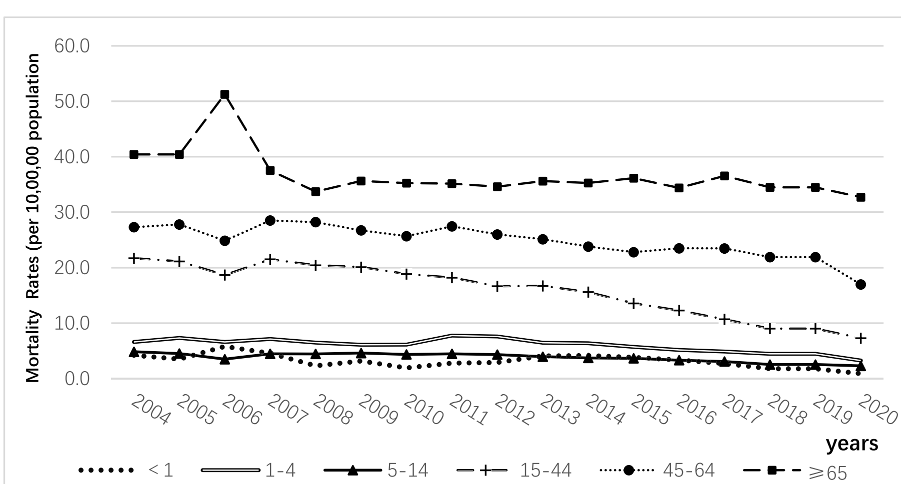

Fig. 3. Age-adjusted mortality rates of China's road traffic by age from 2004 to 2020.

from 4.21 to 0.89 for people aged <1, from 6.6 to 3.25 for people aged 1–4, from 4.84 to 2.29 for people aged 5–14, from 21.71 to 7.29 for people aged 15–44, from 27.3 to 16.98 for people aged 45–64, and from 40.43 to 32.71 for people aged ≥65. The largest decreases were seen in people aged 15–44 (66.42% decrease.) The smallest decreases were seen in people aged ≥65 and did not show a significant downward trend.

3.2. Temporal trends in combined urban/rural/sex road traffic mortality rates

The overall and different gender by different residence temporal trends of China's road traffic standardized mortality rates were presented in Figs. 4 and 5 and Table 1. Joinpoint regression analysis yielded an overall decreasing trend in road traffic mortality rates for each of these groups from 2004 to 2020. In all groups, 2011 and 2012 were vital node points. The downward trend in overall road traffic mortality rates occurred at 2 node points in 2011 and 2017, divided into 2 successive declining bands. The overall road traffic mortality decreased by 4.2% annually on average($P < 0.001$), including 4.6% annually from 2011 to 2017 (APC=-4.6%, P=0.005) and 9.2% annually from 2017 to 2020 (APC=-9.2%, P=0.008). From 2004 to 2011, the road traffic mortality rates of urban males and urban females showed a similar downward trend. From 2015 to 2020, the road traffic mortality of urban females decreased by 9.6% annually on average (APC=-9.6%, $P < 0.001$). From 2011 to 2020, the road traffic mortality of rural males and rural females showed a downward trend.

3.3. Temporal trend of road traffic mortality by different regions

The temporal trends of China's road traffic standardized mortality rates by different regions from 2004 to 2020 were depicted in Fig. 6 and Table 2. Joinpoint regression analysis yielded an overall decreasing trend of road traffic mortality for each of these groups from 2004 to 2020. The western region shifted from an upward trend to a downward trend in 2011. There were 2 joint points in the downward trend in East, Central and West in 2006 and 2017. Among them, the RTMR dropped by 5.1% annually on average in the eastern region ($P < 0.001$), dropped by 3.8% annually in the central region ($P < 0.001$), and dropped by 3.5% annually in the western region ($P < 0.001$). The results showed that the RTMR in the eastern and central regions declined slowly from 2006 to 2007 to 2017, then accelerated from 2017 to 2020. From 2006 to 2011, the western region showed an upward trend, and from 2011 to 2020 (APC=3.3%, P=0.02), which decreased at an average annual rate of 6.7% (APC=-6.7%, $P < 0.001$).

3.4. Temporal trend of road traffic mortality by age group

The temporal trends of road traffic mortality rates by age group in China from 2004 to 2020 were shown in Table 3, which were divided into 6 age groups. The results of the Joinpoint analysis showed a downward trend in road traffic mortality rates in China between 2004 and 2020 for all age groups except for the elderly aged 65 and above. The greatest decline of road traffic mortality rates between 2004 and 2008 was the younger than one year group, with an average annual decrease of 36.8% (APC=-36.8%, P=0.037). The decline trend of road traffic mortality of the 1–4 year group (APC=-8.7%, $P < 0.001$)and 5–14 year group (APC=-7.5%, $P < 0.001$) from 2012 to 2020 was similar. The 15–44 year group from 2014 to 2020 declined significantly, with an average annual decline of 11.5% (APC=-11.5%, $P < 0.001$). From 2008 to 2018, the road traffic mortality of aged 45–64 group decreased slowly (APC=-2%, P=0.008).

4. Discussion

4.1. Main research results

This study mainly investigated the temporal trend of road traffic mortality in China from 2004 to 2020. Unlike most previous studies, we used a combination of gender and urban/rural groupings to make the study population more specific. Previous studies have rarely used geographic grouping, so we adopted a geographic location grouping to understand whether geographic location has an impact on road traffic mortality rates. In order to understand the trend of road traffic mortality rates in different age groups, the researchers conducted a study of age subgroups. The following three main results were drawn from this study. First of all, from 2011 to 2020, the age standardized mortality of Chinese road traffic showed a downward trend. Secondly, there were great differences in road traffic mortality and its change trend among different subgroups. It was worth noting that the RTMR in the Western region showed an upward trend from 2006 to 2011, and continued to decline after 2011. Finally, the road traffic mortality of the elderly over 65 years was the highest and did not show a significant downward trend, which

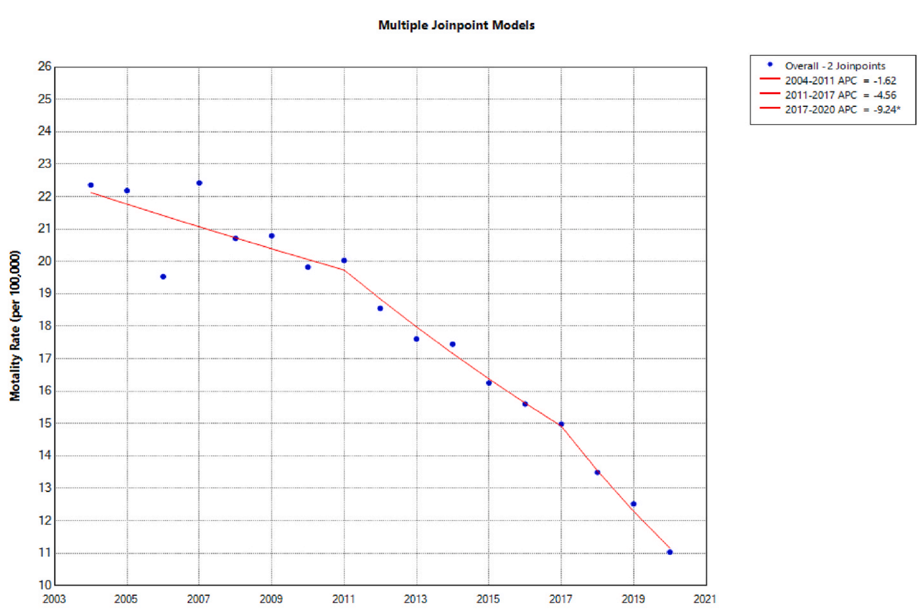

Fig. 4. Age-adjusted mortality rates of China's road traffic, 2004–2020, with line segments from Joinpoint regression models.

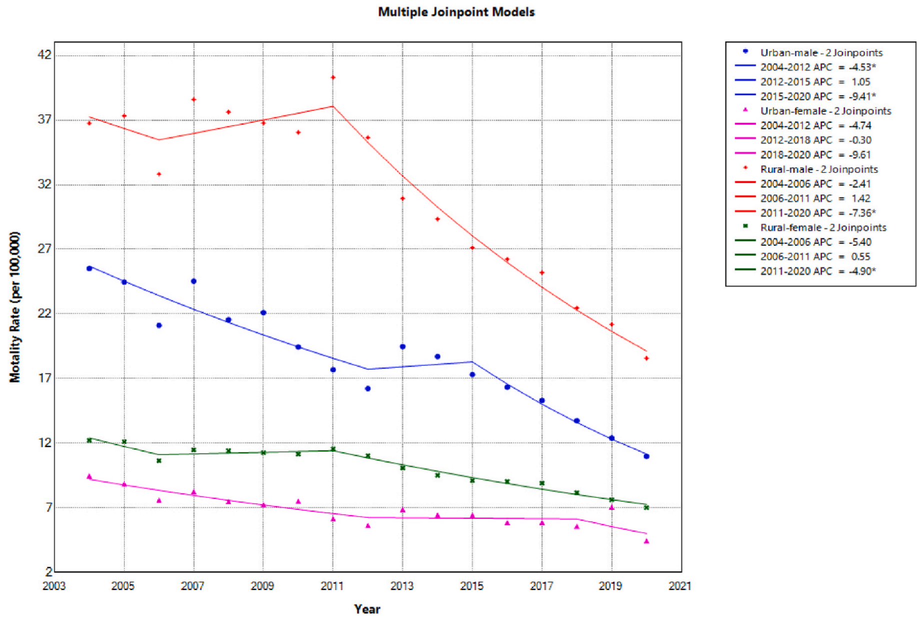

Fig. 5. Age-adjusted mortality rates of China's road traffic by urban、rural and different gender, China, 2004–2020, with line segments from Joinpoint regression models.

Table 1
Summary of the Joinpoint analyses for trends in road traffic mortality rates by urban、rural and gender, China, 2004–2020.

Groups	Period	APC(95%CI)	AAPC(95% CI)	t	P
Overall	2004–2020		-4.2(-5.7, -2.7)	-7.9	**<0.001**
	2004–2011	-1.6(-3.3, 0.1)		-2.2	0.059
	2011–2017	-4.6(-7.3, -1.8)		-3.7	**0.005**
	2017–2020	-9.2(-14.9, -3.2)		-3.4	**0.008**
Urban -Male	2004–2020		-5.1(-8.1, -1.9)	-3.1	**0.002**
	2004–2012	-4.5(-6.4, -2.6)		-5.3	**0.001**
	2012–2015	1.0(-15.8, 21.3)		0.1	0.900
	2015–2020	-9.4(-13.0, -5.6)		-5.5	**< 0.001**
Urban -Female	2004–2020		-3.7(-6.0, -1.4)	-3.2	**0.001**
	2004–2012	-4.7(-6.5, -3.0)		-6.0	**< 0.001**
	2012–2018	-0.3(-4.0, 3.5)		-0.2	0.859
	2018–2020	-9.6(-23.7, 7.0)		-1.4	0.209
Rural -Male	2004–2020		-4.1(-5.4, -2.8)	-6.0	**< 0.001**
	2004–2006	-2.4(-11.2, 7.2)		-0.6	0.571
	2006–2011	1.4(-1.5, 4.5)		1.1	0.310
	2011–2020	-7.4(-8.2, -6.6)		-20.2	**< 0.001**
Rural -Female	2004–2020		-3.3(-4.5, -2.0)	-5.0	**< 0.001**
	2004–2006	-5.4(-13.5, 3.5)		-1.4	0.196
	2006–2011	0.5(-2.3, 3.4)		0.4	0.674
	2011–2020	-4.9(-5.7, -4.1)		-13.9	**< 0.001**

Abbreviations: APC = annual percent change, AAPC = average annual percent change.

required special attention.

4.2. *Interpretation of research results*

4.2.1. *The whole temporal trend of RTMR*

For the overall age-adjusted mortality of Chinese road traffic, the year of 2011 was an important node point. From 2004 to 2011, the age standardized mortality of Chinese road traffic did not show a significant downward trend. But from 2011 to 2020, the age standardized mortality of Chinese road traffic showed a continuous downward trend. Based on previous research, (Wang et al., 2018b) the RTMR in China showed an upward trend from 1992 to 2002. The downward trend from 2004 to 2011 was not significant until 2011, when there was a apparent turnaround. The reason could be that the National People's Congress passed comprehensive road traffic safety legislation. China amended its road safety law in 2011 to specify rules on drink driving, seat belts, speed control, etc. It has made drunk driving as a criminal offence, and has imposed severe punishment on drunk driving, so that people pay more attention to drunken driving. (The Central Government of the People's Republic of China, 2011) Therefore, the reduction of road traffic mortality in China from 2011 to 2020 may be affected by these laws and regulations.

4.2.2. *The combination of rural/urban/sex temporal trend of RTMR*

The study found that even though the road traffic mortality for rural males declined, it was consistently higher than the other three cohorts in fact. Males were more likely to be engaged in high-risk occupations with greater exposure to road traffic injuries than females. The high mortality rate in rural areas may be due to the combination of accelerated motorization, lack of road safety infrastructure, (Zhang et al., 2012b) underdeveloped pre-hospital aids and hospital emergency care, (Hung et al., 2009) irrational use of motor vehicles (Traffic Management Bureau of Ministry of Public Security, 2021), and insufficient prevalence of traffic laws and regulations in rural areas. On the other hand, road traffic fatality rates for urban and rural males have declined faster than for urban and rural females. Rural males had the highest road traffic mortality rate, which was similar to the results of domestic and international studies. (GBD 2019 Disease s and In and juries Collaborators, 2020; Jiang et al., 2011; Murray & Lopez, 1997) This may be related to factors such as increasing penalties for traffic accidents, strictly controlling

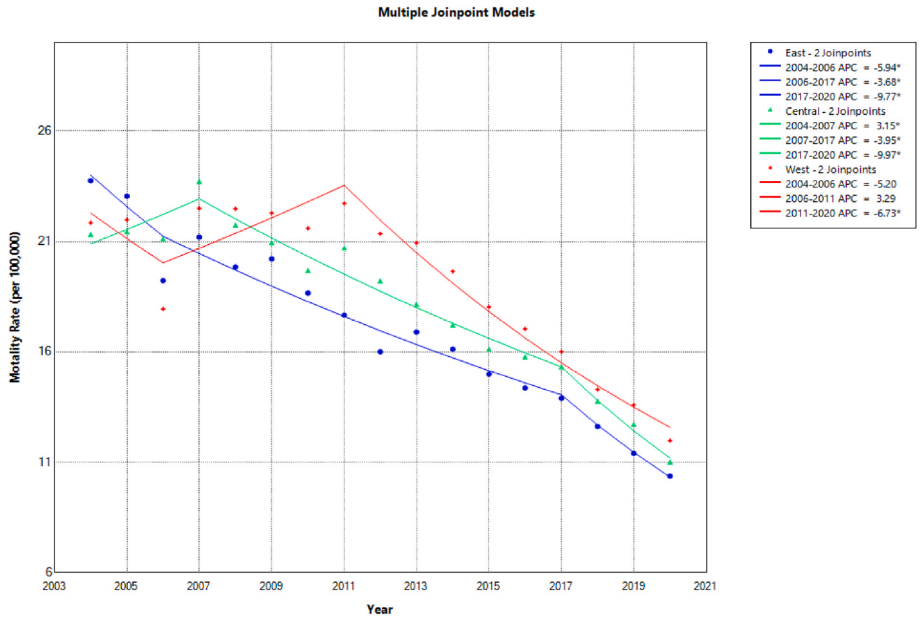

Fig. 6. Age-adjusted mortality rates of China's road traffic by region, China, 2004–2020, with line segments from Joinpoint regression models.

Table 2
Summary of the joinpoint analyses for trends in road traffic mortality rates by region, China, 2004–2020.

Region groups	Period	APC (95% CI)	AAPC (95% CI)	t	*P*
East	2004–2020		-5.1(-6.4, -3.8)	-7.5	< **0.001**
	2004–2006	-5.9(-14.6, 3.6)		-1.4	0.184
	2006–2017	-3.7(-4.4, -3.0)		-11.3	< **0.001**
	2017–2020	-9.8(-14.0, -5.3)		-4.8	**0.001**
Central	2004–2020		-3.8(-4.9, -2.7)	-6.7	< **0.001**
	2004–2007	3.2(-1.4, 7.9)		1.5	0.156
	2007–2017	-4.0(-4.7, -3.2)		-11.0	< **0.001**
	2017–2020	-10.0(-14.0, -5.8)		-5.2	**0.001**
West	2004–2020		-3.5(-4.7, -2.4)	-5.9	< **0.001**
	2004–2006	-5.2(-12.7, 2.9)		-1.5	0.176
	2006–2011	3.3(0.6, 6.0)		2.8	**0.020**
	2011–2020	-6.7(-7.4, -6.0)		-21.0	< **0.001**

Abbreviations: APC = annual percent change, AAPC = average annual percent change.

Table 3
Joinpoint regression analysis of age-specific road mortality rates, China, 2004–2020.

Age groups	Period	APC (95%CI)	AAPC (95%CI)	t	P
Overall					
<1	2004–2008	-36.8(-58.6, -3.5)	-14.7(-26.6, -1.0)	-2.5	**0.037**
	2008–2015	10.0(-12.3, 37.9)		0.9	0.368
	2015–2020	-24.1(-43.8, 2.4)		-2.1	0.067
1–4	2004–2009	-2.3(-7.0, 2.5)	-4.1(-7.7, -0.3)	-1.1	0.302
	2009–2012	6.3(-14.4, 32.1)		0.6	0.540
	2012–2020	-8.7(-10.9, -6.5)		-8.7	< **0.001**
5–14	2004–2006	-10.3(-20.8, 1.6)	-4.5(-6.2, -2.8)	-2.0	0.080
	2006=2011	3.6(-0.4, 7.8)		2.0	0.073
	2011–2020	-7.5(-8.6, -6.5)		-15.5	< **0.001**
15–44	2004–2009	-1.1(-4.7, 2.6)	-6.3, (-8.1, -4.5)	-0.7	0.515
	2009–2014	-5.0(-9.8, 0.1)		-2.2	0.054
	2014–2020	-11.5(-13.9, -9.0)		-10.0	< **0.001**
45–64	2004–2008	0.7(-3.9, 5.5)	-2.6(-4.5, -0.6)	0.3	0.737
	2008–2018	-2.0(-3.3, -0.7)		-3.4	**0.008**
	2018–2020	-11.3(-23.4, 2.8)		-1.8	0.099
≥65	2004–2006	6.9(-2.2, 17.0)	-0.8(-2.6, 1.0)	1.7	0.125
	2006–2009	-8.5(-16.4, 0.1)		-2.2	0.051
	2009–2020	0.0(-0.6, 0.7)		0.2	0.876

Abbreviations: APC = annual percent change, AAPC = average annual percent change.

drunk driving, and raising awareness of road safety. (Burzyńska & Pikala, 2021; Samath et al., 2015) From 2004 to 2020, the age-adjusted mortality rate for rural males and females declined significantly, and the rate of decrease for rural males would be faster (7.4%). It indicated that the state has paid more attention to the problem of road traffic injuries in rural areas, and that the effect of traffic injury prevention and control has already appeared. (Huang et al., 2013b; Liu et al., 2012)

4.2.3. The regional different for temporal trend of RTMR

In terms of geographic differences, the road traffic mortality rates showed the fastest decline trend in the eastern region (5.1%), while the mortality rate in the western region showed an increasing trend from 2006 to 2011 then continued to decline after 2011. It was inferred that the imbalance in regional economic development was an important reason for the regional differences in road traffic mortality rates. (Eun, 2020; Meng et al., 2019) In addition, residents in the western region were less educated than those in the central and eastern regions, and may be less aware of traffic safety, which may also be affected by the higher road traffic mortality rates. It is recommended that differentiated policies and measures could be adopted in the eastern, central, and western regions. Those eastern and central regions with better economic conditions should emphasize the implementation of laws and increase disciplinary actions. For the western region where the level of education is not high and transportation infrastructure is not developed the State should increase the economic investment cost in the western region and strengthen the road traffic safety publicity in the western region to raise people's awareness of traffic safety (Hyder et al., 2012).

Generally speaking, the older people's road traffic injury should be paid more attention. For difference among different age groups, the results of the Joinpoint analysis showed a downward trend in road traffic mortality rates in China between 2004 and 2020 for all age groups except for the elderly aged 65 and above. The rate of decline in road traffic mortality was faster for those younger than 1 year and for those aged 15–44 years. Previous study had shown that higher mortality rates from the elder road users (especially elder females) in motor vehicle accidents were more likely suffering chest injuries, especially chest wall factures. This was mainly due to the fact that both drivers and pedestrians were more vulnerable in the road environment. (Lee et al., 2006) At the same time, some elderly people who move to urban and live with their children are more likely to suffer road traffic injuries. (Zhang et al., 2012a) The ageing of China's population is likely to pose a particular challenge to the reduction of road traffic mortality rates in China, given the high mortality of older people.

The State and the Government can conduct road safety campaigns to make the public aware of the seriousness of traffic accidents. Laws and regulations should continue to be strictly adhered to when dealing with offenders, and penalties should be increased if necessary. Different interventions should be applied to different geographic locations and should not be treated equally. The government should still continue to strengthen the control of road traffic safety in rural areas, supervise the popularization and implementation of rural road traffic laws. On the other hand, the government should raise the awareness of rural residents about traffic safety, improve the road infrastructure in rural areas, and raise the level of medical care in rural and western areas. In addition, traffic police in cities should play a role in helping elderly pedestrians from traffic injuries. Automobile design should be more intelligent and suitable for the elderly. The safety measures for cars should be further increased, such as designing more durable cars with airbags and seat belts.

5. Advantages and limitations

Instead of a traditional urban/rural and gender grouping, the article used a different grouping methodology to combined the two and drew more relevant conclusions. In addition, the article added an analysis of mortality trends in the East, Central and West, which was more comprehensive than previous studies. The data in this article mentioned from *the Chinese Death Cause Monitoring Data Set* of the CDC, which was more authoritative and comprehensive than that of previous studies, and the connected-point regression used in the article was more specialized than traditional analysis methods. The research results analyzed the temporal trend of road traffic mortality in China in recent 16 years. It detected the connection point of the temporal trend of the general population and several subgroups of road traffic mortality in this period, which also summarized the changes of each subgroup more reasonably. We found that although the road traffic mortality in China has been decreasing year by year in recent years, it is still at a high level. The road traffic mortality ranked first among the causes of death due to injuries among residents, and still needed to be addressed.

This study also has few limitations. This study used Joinpoint regression model to test the temporal trend of standardized mortality of major roads in China, and identify the key nodes of mortality changes. Although it can better reveal the characteristics of local data changes tread, exploring the major influencing factors of road traffic injuries among Chinese people would be required in the future. In addition, this paper did not further predict the future development trend of road traffic mortality.

6. Conclusions

In a word, from 2004 to 2020, the road traffic mortality in China generally declined. At the same time, there was a slow reduction or even an upward trend in road traffic mortality rates among the elderly people as well as in western regions. Rural males are a priority group for road traffic injury prevention. Temporal trends in road traffic mortality in China would continually require close attention in the future studies.

Ethical statement

There is no need of Ethical statement for this study.

Declaration of competing interest

The authors declared on conflict of interest with respect to the research, author-ship, and publication of this article.

Data availability

Data will be made available on request.

Acknowledgements

The work presented in this paper is sponsored by the (1) Natural Science Foundation of Shandong Province: ZR2021MH408, (2) Research Project of China Academic Degree and Graduate Education Association: 2020ZDB44, (3) Shandong Provincial Youth Innovation Team Development Plan of Colleges and Universities: No. 2019-6-156, Lu-Jiao, (4) the Overseas Study Project of Shandong Provincial Government and (5) 2021 University Level Demonstration Curriculum of Ideological and Political Couse.

References

Burzyńska, M., & Pikala, M. (2021). Decreasing trends in road traffic mortality in Poland: A twenty-year analysis. *International Journal of Environmental Research and Public Health, 18*(19), Article 10411.

Cheng, P., Yin, P., Ning, P., et al. (2017). Trends in traumatic brain injury mortality in China, 2006-2013: A population-based longitudinal study. *PLoS Medicine, 14*(7), Article e1002332.

China, C. D. C. (2021). *China cause of death surveillance dataset 2021*. Beijing: China Science and Technology Press.

Chi, Guibo, Wang, et al. (2004). Patterns of road traffic injuries in China [J]. *Chinese Journal of Epidemiology*, 52–55, 07.

Eun, S. J. (2020). Trends in mortality from road traffic injuries in South Korea, 1983-2017: Joinpoint regression and age-period-cohort analyses. *Accident Analysis & Prevention, 134*, Article 105325.

GBD 2019 Diseases and Injuries Collaborators. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: A systematic analysis for the global burden of disease study 2019. *Lancet, 396*(10258), 1204–1222.

Han, Yun fei, & Li, Dexi (2014). Progress of epidemiological research on road traffic injuries in China [J]. *Journal of Shenyang Medical College, 16*, 225–228, 04.

Huang, Y., Tian, D., Gao, L., et al. (2013a). Neglected increases in rural road traffic mortality in China: Findings based on health data from 2005 to 2010. *BMC Public Health, 13*, 1111.

Huang, Y., Tian, D., Gao, L., et al. (2013b). Neglected increases in rural road traffic mortality in China: Findings based on health data from 2005 to 2010. *BMC Public Health, 13*, 1111.

Hung, K. K., Cheung, C. S., Rainer, T. H., et al. (2009). EMS systems in China. *Resuscitation, 80*(7), 732–735.

Hyder, A. A., Allen, K. A., Di Pietro, G., et al. (2012). Addressing the implementation gap in global road safety: Exploring features of an effective response and introducing a 10-country program. *American Journal of Public Health, 102*(6), 1061–1067.

India State-Level Disease Burden Initiative Road Injury Collaborators. (2020). Mortality due to road injuries in the states of India: The global burden of disease study 1990-2017. *The Lancet Public Health, 5*(2), e86–e98.

Jiang, G., Choi, B. C., Wang, D., et al. (2011). Leading causes of death from injury and poisoning by age, sex and urban/rural areas in Tianjin, China 1999-2006. *Injury, 42*(5), 501–506.

Kim, H. J., Fay, M. P., Feuer, E. J., et al. (2000). Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine, 19*(3), 335–351.

Lee, W. Y., Cameron, P. A., & Bailey, M. J. (2006). Road traffic injuries in the elderly. *Emergency Medicine Journal, 23*(1), 42–46.

Liu, S., Wu, X., Lopez, A. D., et al. (2016). An integrated national mortality surveillance system for death registration and mortality surveillance, China. *Bulletin of the World Health Organization, 94*(1), 46–57.

Liu, Q., Zhang, L., Li, J., Zuo, D., et al. (2012). The gap in injury mortality rates between urban and rural residents of Hubei Province, China. *BMC Public Health, 12*, 180.

Meng, R., Xu, X., Xu, Y., et al. (2019). Epidemiological characteristics of injury mortality in Guangdong Province, China, 2015. *BMC Public Health, 19*(1), 142.

Murray, C. J., & Lopez, A. D. (1997). Alternative projections of mortality and disability by cause 1990-2020: Global burden of disease study. *Lancet, 349*(9064), 1498–1504.

Ngo, A. D., Rao, C., Hoa, N. P., et al. (2012). Road traffic related mortality in Vietnam: Evidence for policy from a national sample mortality surveillance system. *BMC Public Health, 12*, 561.

Organization, W. H. (2015). Global Status report on road safety 2015. *Injury Prevention, 15*, 286-86.

Preusser, D. F., Williams, A. F., Ferguson, S. A., et al. (1998). Fatal crash risk for older drivers at intersections. *Accident Analysis & Prevention, 30*(2), 151–159.

Qiu, D., Katanoda, K., Marugame, T., et al. (2009). A Joinpoint regression analysis of long-term trends in cancer mortality in Japan (1958-2004). *International Journal of Cancer, 124*(2), 443–448.

Samath, D., Dharmaratne, Upendra, Achala, et al. (2015). *'Road traffic crashes, injury and fatality trends in Sri Lanka: 1938-2013*. Bulletin of the World Health Organization.

The Central Government of the People's Republic of China. (2011). *[Decree of the president of the people's Republic of China No. 47] the standing committee of the national people's congress on the revision of the*. Road Traffic Safety Law of the People's Republic of China. decision',[EB] Central Government Portal. Available at: http://www.gov.cn/flfg/2011-04/25/content_1851694.htm. (Accessed 18 July 2022).

Traffic Management Bureau of Ministry of Public Security. (2021). *Road traffic accident statistics: Annual report of people's Republic of China 2020*. Beijing: Traffic Management Bureau of Ministry of Public Security.

Wang, T., & Jiang, B. (2019). Road traffic mortality in China: Good prospect and arduous undertaking. *The Lancet Public Health, 4*(5), e214–e215.

Wang, D., Liu, Q., Ma, L., et al. (2019). Road traffic accident severity analysis: A census-based study in China. *Journal of Safety Research, 70*, 135–147.

Wang, L., Ning, P., Yin, P., et al. (2019). Road traffic mortality in China: Analysis of national surveillance data from 2006 to 2016. *The Lancet Public Health, 4*(5), e245–e255.

Wang, L., Yu, C., Zhang, G., et al. (2018a). Comparison of secular trends in road injury mortality in China and the United States: An age-period-cohort analysis. *International Journal of Environmental Research and Public Health, 15*(11), 2508.

Wang, L., Yu, C., Zhang, G., et al. (2018b). Comparison of secular trends in road injury mortality in China and the United States: An age-period-cohort analysis. *International Journal of Environmental Research and Public Health, 15*(11), 2508.

Zeng, S. C. (2019). Joinpoint regression modeling and its application in the analysis of infectious disease prevalence trends[J]. *Chinese Journal of Health Statistics, 36*, 787–791, 05.

Zhang, L., Li, Z., Li, X., et al. (2014). Study on the trend and disease burden of injury deaths in Chinese population, 2004-2010. *PLoS One, 9*(1), Article e85319. Jan17.

Zhang, L., Zhou, J. H., Qiu, J., et al. (2012a). Comparative analysis of characteristics and risk factors of traffic injury in aged people from urban and rural areas in Chongqing. *Chinese Journal of Traumatology, 15*(1), 27–31.

Zhang, L., Zhou, J. H., Qiu, J., et al. (2012b). Comparative analysis of characteristics and risk factors of traffic injury in aged people from urban and rural areas in Chongqing. *Chinese Journal of Traumatology, 15*(1), 27–31. PMID: 22300916.