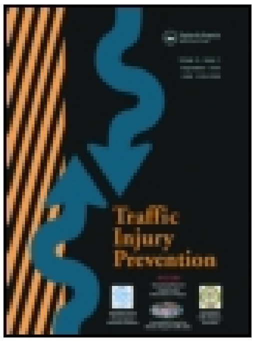

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An analysis of the characteristics of road traffic injuries and a prediction of fatalities in China from 1996 to 2015

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An analysis of the characteristics of road traffic injuries and a prediction of fatalities in China from 1996 to 2015

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ABSTRACT

Objectives: This study analyzed the characteristics and burdens of road traffic injuries (RTIs) from the 3 perspectives of time, space, and population in China and predicted traffic fatalities using 2 models.

Methods: By extracting data from the *China Statistical Yearbooks* and *GBD 2015* (Global Health Data Exchange), we described the change in the time trend of traffic crashes and economic losses associated with the rate of motorization in China from 1996 to 2015; analyzed the geographical distribution of these events by geographic information system; and evaluated the age-, sex-, and cause-specific death rate, disability-adjusted life year (DALY) rate, years of life lost (YLL) rate, and years lost due to disability (YLD) rate lost from RTIs from 1990 to 2015. In addition, we predicted the traffic fatality (per population or vehicles) trend using the log-linear model derived from Smeed's and Borsos' models.

Results: From 1996 to 2015, the motorization rate showed rapid growth, increasing from 0.023 to 0.188. With the growth in the motorization rate, the time trends of traffic crashes and economic losses in China changed, showing a tendency to first increase and then later decrease. The crashes and losses were closely correlated and mainly distributed in some of the economically developed provinces, including Zhejiang, Jiangsu, Anhui, Sichuan, and Guangdong provinces. The health burden of RTIs presented a time trend similar to that of the economic burden, and it was higher among males than females. The death rate among older pedestrians was higher. The DALY rate and YLL rate among young and middle-aged pedestrians were higher. The YLD rate among older motor vehicle drivers was higher. In addition, the fatalities per 10,000 vehicles continued to decline, and Borsos's model was better fitted to the reported traffic fatalities than Smeed's model.

Conclusions: Although the burden of RTIs in China has declined, the burden of RTIs is still heavy. Hence, RTIs remain a universal problem of great public health concern in China, and we need to work hard to reduce them.

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Road traffic injuries; characteristics; burden; predicted traffic fatality

Introduction

The world is undergoing a rapid transition in population health, noncommunicable diseases, and injuries that affect adults (Lozano et al. 2012). Road traffic injury (RTI), one of the most serious among all injuries, occurs when the vehicle strikes or collides with another vehicle, pedestrian, animal, road debris, or other a stationary object, resulting in injury, death, and property damage. In 2010, RTIs were the eighth leading cause of death (Murray et al. 2012) and are projected to rise to the fourth leading cause by 2030 (Mathers and Loncar 2006).

Many studies have shown that RTIs have a huge impact on health and development.

RTIs account for nearly 90% of global road traffic deaths. Since 2007, RTIs have plateaued at 1.25 million lives each year. In low- and middle-income countries, fatality rates are double those of high-income countries (WHO 2015). Given these deaths, it is not unexpected that RTIs are the leading cause of death among travelers to low- and middle-income countries (Stewart et al. 2016). In addition, the presence of RTIs could make the average life expectancy decrease by more than half a year. Globally, disability-adjusted life years (DALYs) from RTIs ranked ninth in 2015. In developing countries, years lost due to disability (YLDs) from RTIs are more than 90% of all YLDs (Kassebaum et al. 2016; Li et al. 2017; Nantulya and Reich 2002). Due to the high morbidity and mortality of RTIs, many families are plunged into poverty by the expense of medical care, the loss of a family's main income, or the added burden of caring for disabled victim of RTIs (Hassani-Mahmooei et al. 2016).

As the most populous developing country in the world, China is particularly vulnerable to the impact of RTIs (Wang et al. 2008). RTIs occupied the top place among all

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injuries in China in 2015 (Vos et al. 2015). In September 2016, the United Nations released the Sustainable Development Goals (SDGs), which used the SDG index scores to evaluate the SDG indicators. The score of the RTI SDG index is below 50 every year (Yu and Wang 2017), which indicates that the need for improvement in RTI rates in China is urgent (Wang et al. 2015). Furthermore, in October 2016, the Chinese government promulgated the *Outline of the Healthy China 2030 Plan*, which calls for the following: "By 2030, deaths caused by RTIs per 10,000 vehicles will decrease by 30%" (Zhuang 2016, p. 34). Therefore, this study was undertaking in order to gain an understanding of the current situation of RTIs in China as soon as possible.

Although RTIs have been a leading cause of mortality for many years, most traffic crashes are both predictable and preventable. There is considerable evidence on interventions that are effective at making roads safer (Banstola and Mytton 2017; Salam et al. 2016). Therefore, what are the characteristics of RTIs in China? Can we accomplish the 2030 goal? This study seeks to evaluate the basic characteristics and burden of RTIs and to predict traffic fatalities to provide a reference for prevention and control of road traffic injuries in China.

Methods

Data sources

Data used in this study were obtained from *China Statistical Yearbooks* (National Bureau of Statistics 2017) and GBD 2015 (Institute for Health Metrics and Evaluation 2016).

China Statistical Yearbooks are owned and maintained by the National Bureau of Statistics of the People's Republic of China and comprehensively reflect the economic and social development of China. For this study, *China Statistical Yearbooks* mainly provided the population, number of motor vehicles, and basic data on traffic accidents, including 4 basic indicators: The number of crashes, fatalities, and nonfatal injuries and losses converted into cash. *Losses converted into cash*, namely, direct property losses, refers to the amount of money that the loss of vehicles or objects could be converted into. *Economic losses* in this study refers to losses converted into cash caused by the traffic accidents.

The World Health Organization's Global Burden of Disease (GBD) study developed DALYs in 1990 as a measurement of the gap between current health status and a full health situation. DALYs for a disease or health condition are calculated as the sum of the years of life lost (YLLs) due to premature mortality in the population and YLDs for people living with the health condition or its consequences. Data on the health burden of RTIs were extracted from *GBD 2015* (Institute for Health Metrics and Evaluation 2016), including the age, sex, vehicle type, specific death rate, DALY rate, YLL rate, and YLD rate due to RTIs.

Data analysis

First, the motorization rate was assessed by the number of vehicles per population; next, a trend analysis of traffic

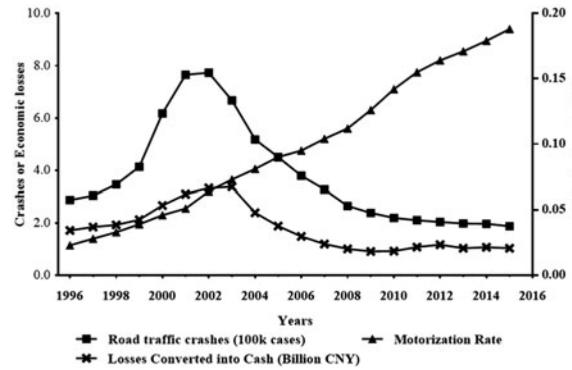

Figure 1. The changes in the crashes and losses with the motorization rate in China, 1996-2015.

crashes and economic losses (that is, the losses converted into cash) in China was carried out using SPSS (Ver. 17.0 for Windows, SPSS Inc., Chicago). Second, a geographic information system was used to reflect the geographical distribution of traffic crashes and economic losses in China. Third, this study evaluated the health burden of RTIs (age-, sex-, and cause-specific death rates and DALY, YLL, and YLD rates). Finally, log-linear regression models (Smeed's (Smeed 1949) and Borsos et al.'s (Borsos et al. 2012)) were used to predict the traffic fatalities per 10,000 vehicles or per 100,000 population.

Smeed's formula was as follows:

$$\ln(D/N) = a - b\ln(N/P), \tag{1}$$

where D is the number of fatalities; N is the number of vehicles; P is the population; a is the slope of the equation; and b is the intercept of the equation.

$$\text{Or } D/N = \exp(a) * (N/P)^{-b} \tag{2}$$

Or

$$D/P = a * (N/P)^{(1-b)} \tag{3}$$

Borsos et al.'s formula was as follows:

$$\ln(D/P) - \ln(N/P) = \ln(a) - b(N/P), \tag{4}$$

where $\ln(a)$ is the slope of the equation and b is the intercept of the equation.

$$\text{Or} D/N = a *^{(1-b)} \tag{5}$$

$$\text{Or} D/P = a * (N/P)e^{-b(N/P)} \tag{6}$$

Results

Time trend of RTIs in China

In China, the motorization rate has grown rapidly, from 0.023 vehicles per person in 1996 to 0.188 vehicles per person in 2015. With the motorization rate growing, the instances of crashes and the economic losses from RTIs converted into cash (Chinese Yuan, CNY) increased first and then decreased.

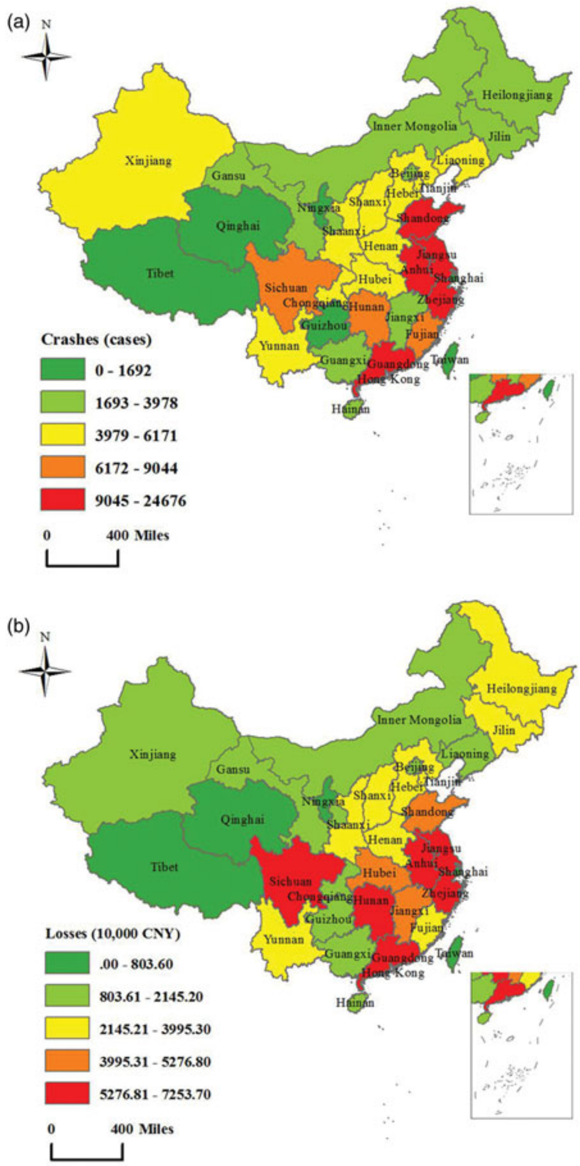

Figure 2. The spatial distribution of the crashes and losses from RTIs in China in 2015. (a: road traffic crashes; b: losses from RTIs converted into cash. The data of Hong Kong, Macao and Taiwan were missing, expressed as zero.)

The highest number of crashes, occurring in 2002, was 773,137. Compared to 1996, the number of crashes in 2015 declined, with a drop of 34.7%. The crashes declined rapidly from 2002 to 2010, and the decline in the rate from 2010 to 2015 was moderate (Figure 1). The crashes displayed a negative correlation with the motorization rate ($r = 0.652$, $P < .01$).

The cumulative economic losses from 1996 to 2015 were over 352 billion yuan. The economic losses declined from 1.85 billion in 1996 to 1.08 billion in 2015, with a 39.6% decrease. The largest loss was 33.69 billion in 2003. The losses began to rapidly decline from 2003 to 2010, but from 2010 to 2015, the economic losses presented a moderate upward trend, up approximately 12% (Figure 1).

Spatial distribution of RTIs in China

In 2015, the accident-prone areas were located mainly in some of the economically developed provinces, including the provinces of Shandong, Anhui, Jiangsu, Zhejiang, Guangdong, Fujian, Hunan, and Sichuan (Figure 2a). The distribution of losses in 2015 was broadly consistent with the crashes. The highest losses occurred in the provinces of Anhui, Jiangsu, Zhejiang, Guangdong, Hunan, and Sichuan, followed by the provinces of Shandong, Hubei, and Jiangxi (Figure 2b). Guangdong province had the most crashes and losses. Tibet, Qinghai Province, and Ningxia had the fewest crashes and losses.

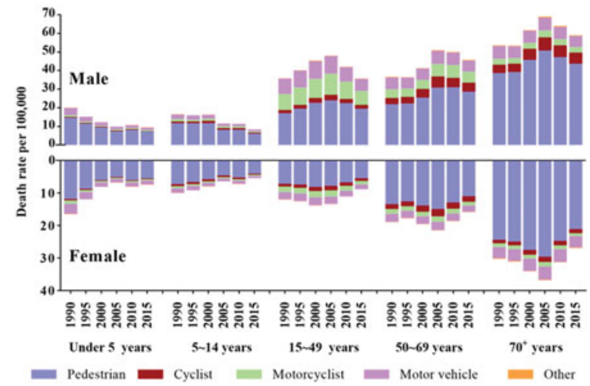

Figure 3. The death rates of RTIs by sex, age and cause in China from 1990 to 2015.

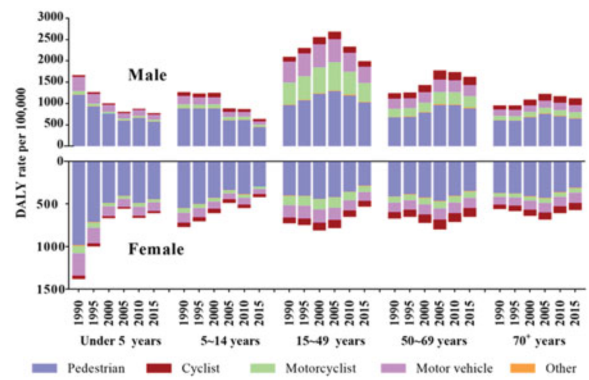

Figure 4. The DALY rates of RTIs by sex, age and cause in China, 1990-2015.

Health burden of RTIs in China

In addition to the economic burden, RTIs incurred a great health burden. We used the death rate, DALY rate, YLL rate, and YLD rate to evaluate the health burden.

The death rate (deaths per 100,000 population) rose from 23.19 in 1990 to 27.72 in 2002 and then fell to 20.44 in 2015, showing a trend similar to that of crashes. From 1990 to 2015, the death rate decreased by 11.9%. From 1990 to 2015, the death rate among males was higher than that among females. During this period, the death rate among males decreased by 4.2%, and that among females decreased by 30.2%. The descending speed of the death rate in males was lower than that in females. The death rate by age had different trends. The death rate in the population aged 70+ years was greater than in the other age groups, followed by the populations aged 50–69 and 15–49 years. The death rate for those over 15 years old had a trend similar to the death rate for all ages. Death rates were highest among pedestrians,

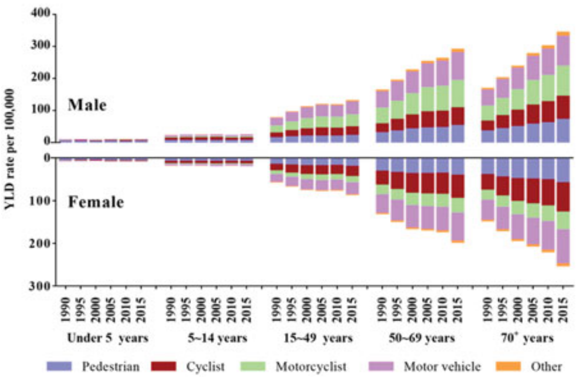

Figure 5. The YLD rates of RTIs by sex, age and cause in China, 1990-2015.

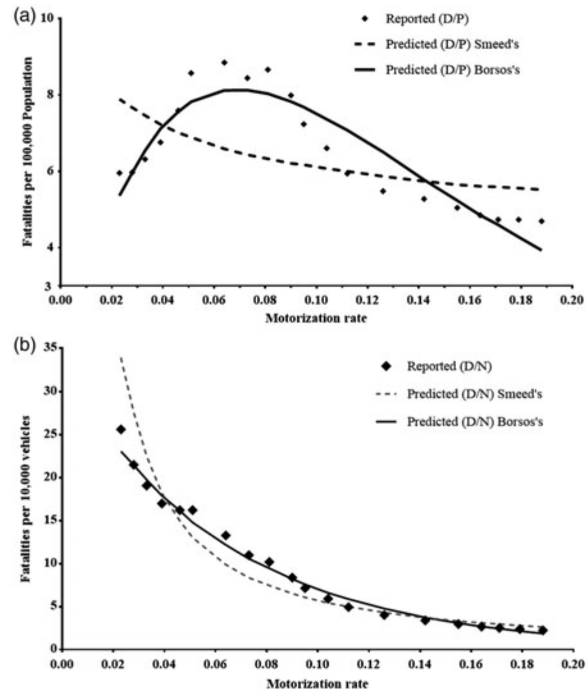

Figure 6. The fatalities predicted by Smeed's model and Borsos' model in China, 1996-2015. (a: the fatalities per 10,000 vehicles; b: the fatalities per 100,000 population)

followed by motor vehicle occupants, motorcyclists, cyclists, and others. The death rate by vehicle type in different age groups and sexes showed slight differences (Figure 3).

The DALY rate (DALYs per 100,000 population) declined from 1,199.54 in 1996 to 1,007.89 in 2015 and declined by 15.98%. The DALY rate showed a trend similar to that of the death rate. The DALY rate among males was higher than that among females. The DALY rate in the population aged 15–49 years was the highest. The DALY rate among pedestrians was the highest, followed by motor vehicle occupants, motorcyclists, cyclists, and other road injuries. In addition, the DALY rate among male motorcyclists was higher than that among cyclists, except in the population aged 70+ years. The DALY rate among female cyclists was higher than that among female motorcyclists (Figure 4).

The YLL rate accounted for almost 90% of the DALY rate and presented a trend similar to that of the DALY rate. The YLD rate presented an upward trend from 1990 to 2015, with an increase of 54.60%. In 2015, the YLL rate was still approximately 7 times higher than the YLD rate.

The YLD rate for males was also higher than that for females, but the age and vehicle type YLD rates were different from the DALY rate and the YLL rate. The YLD rate in the population aged 70+ years was the highest. The motor vehicle YLD rate was the highest in both sexes. However, the vehicle type YLD rate showed only slight differences between males and females. The motorcyclist YLD rate for males was higher than the corresponding rates for male cyclists and pedestrians. The cyclist YLD rate in females was higher than the corresponding rates for female pedestrians and motorcyclists (Figure 5).

Predicted traffic fatalities

Based on the motorization rate in China from 1996 to 2015, we used Smeed's model and Borsos et al.'s model to predict the fatalities per 10,000 vehicles or per 100,000 population in China, respectively.

The result of Smeed's model showed that the estimated value of the slope was -1.227 ($P < .001$) and the estimated value of the intercept was -1.079.

Thus, taking the values of the slope and intercept into Equations (2) and (3):

$$D/N = 0.340 * (D/P)^{-1.227} \tag{7}$$

$$\text{Or } D/P = 0.340 * \left(N/P\right)^{(-0.227)}, \tag{8}$$

The result of Borsos et al.'s model showed that the estimated value of the slope was -14.529 ($P < .001$) and the estimated value of the intercept was 5.773.

Thus, taking the values of the slope and intercept into Equations (5) and (6):

$$D/N = 321.468 * e^{-14.529(N/P)} \tag{9}$$

$$\text{Or} D/P = 321.468 * (N/P) * e^{-14.529(N/P)}. \tag{10}$$

Figure 6a, drawn according to Equations (7) and (9), shows the predicted fatalities per 10,000 vehicles for Smeed's model and Borsos et al.'s model in China from 1996 to 2015. The reported fatalities per 10,000 vehicles showed a steady decline from 25.63 in 1996 to 2.23 in 2015, an approximate decrease of 91%. The R^2 values in the 2 models were greater than 0.70 ($P < .001$), indicating the goodness of fit of the 2 models. In fact, the forecast values of the 2 models was close to the reported value, but the predicted value of Borsos et al.'s model was more in line with the reported value than that of Smeed's model. Figure 6b, drawn according to Equations (8) and (10), shows the predicted fatalities per 100,000 population using Smeed's model and Borsos et al.'s model in China from 1996 to 2015. The reported fatalities per 100,000 population presented an increase first and then showed a decreasing tendency. Similarly, the predicted value of Borsos et al.'s model was better fitted to the reported traffic fatalities per 100,000 population than Smeed's model.

Discussion

We know that there are 2 primary sources of RTI data in China: Police data (from the traffic police) and health data (from the *Chinese Health Statistics Yearbook*). Research has indicated that the health data may be more valid than the police data (Huang et al. 2016). Therefore, this study collected data from the *Chinese Health Statistics Yearbook*.

The rates of traffic crashes and losses showed a tendency to first rise and then fall, with peaks in 2002 and 2003. Since 1996, road traffic laws throughout the country have been continuously improving; for example, new laws include the Administrative Measures on Motor Vehicle Driver's License and Driver Training Schools Regulations in 1996, Regulations on Traffic Violation Procedures in 2000, and the Law of the People's Republic of China on Road Traffic Safety in 2003 (Decree No. 8 of the President of the PRC Hu Jintao 2003). On the one hand, these regulations and laws improve road safety awareness so that people actively obey the traffic rules. On the other hand, the regulations and laws promote the continuous implementation of major traffic safety measures; for example, wearing seat belts, not driving after drinking or doing drugs, and not driving while distracted (Kaufman and Wiebe 2016; Reardon et al. 2017). In addition, dangerous road sections are strictly checked. Several studies have shown that promotion of the Road Traffic Safety Law has helped significantly reduce RTIs (Hu 2003; Karim et al. 2015). Thus, the health burden of RTIs also declined accordingly.

RTIs in China are mainly distributed in some of the economically developed provinces; for example, Zhejiang, Jiangsu, Anhui, Sichuan, and Guangdong provinces. The distribution of civil motor vehicles was also higher in these provinces. In these provinces, industrialization promotes economic development, which significantly influences the demand and supply of motor vehicles (Sharma et al. 2011). The traffic demand and active traffic promoted economic growth in these areas; in turn, economic growth resulted in an increased burden of RTIs (Al-Reesi et al. 2013; Zefreh et al. 2017). At the forefront of the national economy, these provinces had more complete transportation facilities, which resulted in heavy traffic flow and then caused frequent traffic crashes (Sanchez-Vallejo et al. 2015).

The burden of RTIs among males was higher than that among females, largely because most drivers in China are male. According to the Traffic Management Bureau of the Public Security Ministry, the number of male drivers in 2015 reached 240 million, significantly higher than the number of female drivers at 8.4 million (Shen and Zhou 2016). Multiple studies showed that males are more likely to have risky driving behaviors than females, such as speeding, driving under the influence, and being involved in physical fighting (Hanna et al. 2013; Iliescu and Sârbescu 2013; Zhang et al. 2011). This was consistent with a study in India (Dandona et al. 2011). Young females are more likely to ride a bicycle, whereas young males are more interested in motorcycles. In addition, compared to young females, young males are given more freedom and are less restricted by their parents. Therefore, these factors together result in a higher burden of RTIs for males than females.

Pedestrian RTIs had the highest death rate, DALY rate, and YLL rate. As a developing country, walking, in some areas, is essentially its own mode of transportation and, as such, is a necessity (Damsere-Derry et al. 2010). In recent years, Chinese people have responded to the idea of universal health, and more people, especially the elderly, pay greater attention to their health. They walk for pleasure or to improve their health status through this physical activity (Lange-Maia et al. 2015). In addition, some passenger deaths were due to falls from utility vehicles, attributed largely to vehicle overcrowding (Smith and Cummings 2004). Motor vehicles had the highest YLD rate, and pedestrians had the lowest YLD rate. Drivers may be less attentive to pedestrians on national roads, which resulted in pedestrians being more likely to be involved motor vehicle accidents (Hamann et al. 2015). Research showed that reducing the number of motor vehicles had the potential to reduce the total number of transportation fatalities compared with a more high-risk approach (Fuller and Morency 2013).

The death rate and YLD rate among the elderly were the highest. The DALY rate and YLL rate among the population aged 15–49 years were the highest. Many studies showed that age was associated with the severity of the RTI (Borowy 2013; GBD 2013 Mortality and Causes of Death Collaborators 2015). Because of the decreasing physical robustness and comorbidities that occur with age, older people are more vulnerable to injuries and have a higher probability of dying from injuries from which younger people recover (Jiang et al. 2015; Wang et al. 2016).

Borsos et al.'s model appeared to be a better fit than Smeed's model. This is largely because Smeed's model and Borsos et al.'s model both supposed that fatalities increased with the motorization rate, but Borsos et al.'s model accounted for the improved infrastructure (Al-Reesi et al. 2013).

However, the change in traffic fatalities per 10,000 vehicles was moderate in recent years, which suggests that additional road safety efforts are required to mitigate the burden of RTIs in China. The number of fatalities per 100,000 population we counted was lower than the death rate evaluated by the GBD. The number of fatalities per 100,000 population we counted was based on data from the *Chinese Health Statistics Yearbook*, and the death rate per 100,000 population was estimated by the GBD. The GBD standardized the data and estimated the death rate according to the distribution (Wang et al. 2016). Due to a variety of factors related to RTIs, there are many relevant prediction models. We could make forecasts more accurate by incorporating more risk factors in further studies.

There are several major limitations of this study. First, the secondary data could not evaluate the individual factors. Second, we did not explore the temporal analysis of deaths from RTIs. Third, the number of vehicles collected did not include data from Hong Kong, Macao, and Taiwan, which means that the motorization rate was reduced.

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