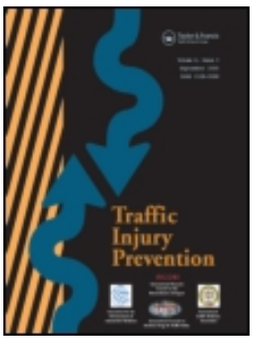

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Road Traffic Injuries in the People's Republic of China, 1951–2008

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Objective*: Road traffic injuries (RTIs) have become the leading cause of injury deaths in China. This article analyzed the trends in all crashes, nonfatal injuries, and fatalities from road traffic crashes from 1951 to 2008 and compared the crash frequency, crash severity, and crash patterns by provinces, types of road, and injured road users.*

Methods*: Road traffic crash data were obtained from the Bureau of Traffic Management at the Ministry of Public Security and National Bureau of Statistics of China. Descriptive statistical analyses were conducted.*

Results*: Over the past 5 decades, road traffic injuries have increased substantially in China. From 1951 to 2008, the total number of road traffic crashes, nonfatal injuries, and fatalities increased by 43-fold, 58-fold, and 85-fold, respectively. Linear regression suggested a significant decline of 30.1 percent (95% confidence interval [CI]: 24.8–35.3) in the mortality rate per 100,000 people during the period 2002 to 2008. From 2004 to 2008, road traffic crash mortality rate per 100,000 people varied greatly in China from the lowest of 3.0 in Henan in 2008 to the highest of 21.7 in Xizang in 2004. RTIs in China disproportionally affected the following populations: males, persons 21 to 50 years of age, pedestrians, and motorcyclists/bicyclists. Adults aged more than 65 years accounted for approximately 10 percent of total road traffic deaths. Road types and RTIs severity were closely related; highways were associated with greater mortality rates.*

Conclusion*: Road traffic injuries have become a burgeoning public health problem in China. Programs need to be developed to prevent nonfatal injuries and fatalities caused by road traffic crashes in this emerging country.*

Keywords Road traffic injuries; Mortality rate; Low- and middle-income countries; High-income countries; China

INTRODUCTION

Road traffic injuries (RTIs) are a major cause of death and disability globally. A disproportionate number of these injuries occur in developing countries (Murray and Lopez 1997). According to estimates, nearly 1.2 million people are killed and between 20 million and 50 million more are injured or disabled in road traffic crashes each year worldwide (Kopits and Cropper 2005; Peden et al. 2004). RTIs account for 2.1 percent of the global mortality and 2.6 percent of all disability-adjusted life years (DALYs) lost (Peden et al. 2004). However, low- and middle-income countries account for about 85 percent of the deaths and for 90 percent of the annual DALYs lost. This number is expected to increase significantly in the next two decades if appropriate measures are not developed to control the problem (Peden et al. 2004). Studies showed that road traffic deaths will decline by about 27 percent in high-income countries but will increase by more than 80 percent in low- and middle-income countries (Kopits and Cropper 2005; Murray and Lopez 1997). RTIs are predicted to be the third leading contributor to the global burden of diseases by 2020 (Peden et al. 2004).

The economic loss of RTIs is enormous. A conservative estimation of global economic loss due to RTIs is US$518 billion per year worldwide and about US$65 billion in low- and middle-income countries (Jacobs et al. 2000). The report showed that RTIs cost low- and middle-income countries between 1 and 1.5 percent of their gross national product (GNP) and high-income countries 2 percent of GNP (Jacobs et al. 2000). Many families are plunged into poverty by the expenses of medical care, loss of family main income, or the added burden of caring for the disabled because of RTIs (Nantulya and Reich 2003).

The lifestyle of the people of the People's Republic of China has changed remarkably during the last 30 years due to economic reforms and modernization. An enormous growth in the number of motor vehicles and the total length of roadway occurred in China. Between 1978 and 2008, the number of registered motor vehicles in China increased at an annual average growth rate of 16.9 percent. In the meantime, the total length of roadway in China increased at an annual average growth rate of 4.9 percent (National Bureau of Statistics of China 2009). In many countries, rapid economic growth allowed significantly more households to own a car or truck and more individuals to drive;

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thus, RTIs become an unwanted consequence of the economic modernization (Kopits and Cropper 2005; Soderlund and Zwi 1995). In China, RTIs caused the loss of 3 million potentially productive life years, with an estimated value of US$3 billion in 1999 (Chi and Wang 2004). In total, 616,971 road crashes were reported in 2000, 754,919 in 2001, and 773,137 in 2002, and about 100,000 people are killed in road traffic crashes each year. RTIs exceeded any other causes of injury death and took first place in China (Wang et al. 2008). In high-income countries, such as Australia, the U.K., and the United States, the problem of RTIs has attracted increasing research and interventions, which in turn resulted in significant reductions in the incidence and impact of these injuries (Peden et al. 2004). In comparison, although China has significantly higher rates of incidence and mortality of RTIs than high-income countries, little has been done to provide road safety statistics and to conduct road safety research.

Using the publicly available national data released by the Bureau of Traffic Management at the China Ministry of Public Security (2009), this article has 2 objectives: (1) to describe quantitatively the trend of mortality caused by RTIs in China from 1951 to 2008 and (2) to compare the crash frequency, crash severity, and crash patterns by various types of roads and provinces. Geographic difference in RTI mortality is expected in China because provinces have significant economic development and modernization level.

METHODS

Study Design and Data Source

This retrospective cross-sectional study was based on official police annual reports of road traffic crashes during the period 1951 to 2008. The information found in the registration database for each crash was based on a standardized Road Traffic Crash Information Collection Form. This form is filled in on-site by the traffic police officer who handles the crash case. This form includes variables descriptive of the crash site and crash circumstances (e.g., cause of crash, time, and place, number of injured people and number of deaths, type of crash, pavement situation, and type of road) as well as of the victim(s)' characteristics. Population denominator data and motor vehicle data were obtained from the *Annual Statistics Communique* released by the National Bureau of Statistics of China in 2009.

Definition of Study Variables

In the China road traffic crash information system, road traffic crashes are defined to include all traffic-related crashes that result in injury or death to road users (drivers, motorcyclists, cyclists, passengers, pedestrians, and others). Road traffic crash injuries are defined to include all traffic-related nonfatal injuries. Road traffic crash fatalities are defined to include all traffic-related deaths that occur within 7 days after the crash event. This is much shorter than the 30 days after the crash event that is used in many countries to monitor road traffic crash deaths.

- Mortality rate per 100,000 people: Relative figure showing ratio of fatalities to population.
- Mortality rate per 10,000 vehicles: Relative figure showing the ratio of fatalities to the number of registered motor vehicles.
- Highways: Roads with a recommended speed of 100 to 120 km/h and with separated lanes and directions.
- Main roads: Roads with a recommended speed of 50 to 80 km/h and with separation of vehicles.
- Secondary main roads, city/branch roads: Roads with a permitted speed of 20 to 40 km/h.

Statistical Analysis

Data were entered into EpiData 3.0 (Odense, Denmark) and analyzed using SAS 9.1 (SAS Institute Inc., USA). First, we examined the annual trend of road traffic injuries in China from 1951 to 2008. All crashes, nonfatal injuries, fatalities, mortality rate per 10,000 registered vehicles, and mortality rate per 100,000 people were calculated. The geographical distribution of mortality rate per 100,000 people from 2004 to 2008 was compared to evaluate geographic patterns of RTIs by provinces. Second, we compared demographic characteristics of nonfatal injuries and fatalities from road traffic crashes by gender and age. Age was divided into 8 groups (1–9, 10–20, 21–30, 31–40, 41–50, 51–60, 61–65, and >65 years) based on the established age classification of official police crash statistics. The fatality trends of road traffic crashes from 2000 to 2008 were compared by types of road users, including auto drivers, passengers, motorcyclists, bicyclists, and pedestrians. Finally, we studied the proportion of road kilometers covered by types of roads and the proportion of all crashes, nonfatal injuries, and fatalities associated with each of them using road traffic crashes per 10,000 kilometer, nonfatal injuries per 10,000 kilometer, and fatalities per 10,000 kilometer.

RESULTS

The annual trend of RTIs in China is presented in Table I. From 1951 to 2008, road traffic injuries in China increased and a significant increase in RTIs was observed after 1980. Over the past 58 years, road traffic crashes have increased 43-fold from 5922 to 265,204, injuries increased 58-fold from 5159 to 304,919, and fatalities increased 85-fold from 852 to 73,484. The mortality rate of RTIs reached the historically highest record (8.8/100,000 people) in 2002 and more than doubled in 1990. Before 2000, the number of fatalities from road traffic crashes more than doubled every 10 years. The death toll of road traffic crashes was more than 100 thousand people for 4 consecutive years during the period of 2001 to 2004. From 2002 to 2008, linear regression suggested a significant decrease of 30.1 percent (95% confidence interval [CI]: 24.8–35.3) in the mortality rate per 100,000 people.

Table II presents the geographical distribution and ranking of mortality rate of road traffic crashes per 100,000 people by province. From 2004 to 2008, the mortality rate of road traffic crashes per 100,000 people varied greatly in China from the

Table I Characteristics of road traffic crashes in China, 1951–2008

Year	Number of crashes	Number of nonfatal injuries	Number of fatalities	Mortality rate/10,000 vehicles	Mortality rate/100,000 people
1951	5922	5159	852	137.6	0.2
1955	9249	5463	955	94.2	0.2
1960	33,634	18,637	5762	257.5	0.9
1965[a]	20,967	11,949	2382	79.5	0.3
1970	55,437	37,128	9654	227.6	1.2
1975	91,606	71,776	16,862	183.9	1.8
1980	116,692	80,824	21,818	104.5	2.2
1985	202,394	13,682	40,906	62.4	3.9
1990	250,297	155,072	49,271	33.4	4.3
1995	271,843	159,308	71,494	22.5	5.9
2000	616,971	418,721	93,853	15.6	7.3
2001	754,919	546,485	105,930	15.2	8.5
2002	773,137	562,074	109,381	13.7	8.8
2003	667,507	494,174	104,372	10.8	8.1
2004	517,889	480,864	107,077	9.9	8.2
2005	450,254	469,911	98,738	7.6	7.6
2006	378,781	431,139	89,455	6.2	6.8
2007	327,209	380,442	81,649	5.1	6.2
2008	265,204	304,919	73,484	4.3	5.6

[a]More missing data in this period.

Table II Geographical distribution and sorting of mortality rate per 100,000 people for road traffic crashes in China, 2004–2008[a]

Area	2004	2005	2006	2007	2008
Beijing	10.9 (9)	13.0 (6)	11.6 (5)	9.9 (6)	8.1 (9)
Tianjin	9.7 (11)	10.4 (10)	9.4 (10)	9.0 (9)	12.8 (2)
Hebei	6.7 (22)	6.0 (23)	5.1 (25)	4.9 (24)	4.2 (24)
Shanxi	12.5 (8)	11.5 (9)	10.2 (8)	9.1 (8)	8.6 (8)
Neimenggu	9.4 (12)	8.8 (14)	7.9 (14)	7.7 (13)	6.7 (13)
Liaoning	7.9 (17)	6.9 (18)	6.2 (18)	5.9 (19)	5.3 (20)
Jilin	9.3 (13)	9.0 (13)	7.9 (13)	6.9 (14)	6.1 (14)
Heilongjiang	6.5 (23)	5.7 (25)	5.7 (22)	5.0 (23)	4.5 (23)
Shanghai	8.9 (14)	10.3 (11)	9.1 (12)	8.6 (11)	8.0 (10)
Jiangsu	10.9 (10)	10.2 (12)	9.2 (11)	7.8 (12)	6.9 (12)
Zhejiang	16.0 (2)	14.6 (3)	13.5 (2)	12.9 (2)	11.6 (3)
Anhui	7.4 (20)	6.7 (20)	6.0 (20)	5.6 (21)	4.5 (22)
Fujian	12.5 (7)	11.8 (8)	11.0 (7)	10.0 (5)	8.6 (7)
Jiangxi	6.4 (24)	5.7 (26)	5.1 (26)	4.5 (27)	4.1 (26)
Shandong	8.5 (15)	7.7 (15)	6.8 (16)	6.2 (16)	5.4 (19)
Henan	5.6 (27)	4.7 (28)	4.1 (29)	3.5 (30)	3.0 (31)
Hubei	4.2 (31)	4.0 (31)	3.8 (30)	3.5 (29)	3.6 (29)
Hunan	5.7 (26)	5.7 (24)	5.3 (23)	4.5 (26)	3.7 (27)
Guangdong	12.8 (6)	12.0 (7)	9.6 (9)	8.6 (10)	7.6 (11)
Guangxi	7.5 (19)	7.1 (17)	6.1 (19)	5.9 (20)	5.6 (17)
Hainan	6.4 (25)	6.1 (22)	5.2 (24)	6.3 (15)	5.6 (18)
Chongqing	5.2 (29)	4.7 (29)	4.6 (28)	4.3 (28)	3.7 (28)
Sichuan	5.6 (28)	5.1 (27)	4.7 (27)	4.6 (25)	4.1 (25)
Guizhou	4.7 (30)	4.2 (30)	3.6 (31)	3.4 (31)	3.4 (30)
Yunnan	7.3 (21)	6.6 (21)	5.9 (21)	5.2 (22)	4.6 (21)
Xizang	21.7 (1)	19.7 (1)	19.4 (1)	15.6 (1)	13.5 (1)
Shaanxi	8.0 (16)	7.3 (16)	7.3 (15)	6.1 (17)	5.8 (16)
Gansu	7.6 (18)	6.9 (19)	6.6 (17)	5.9 (18)	6.0 (15)
Qinghai	13.8 (5)	13.7 (4)	12.2 (4)	11.6 (4)	11.0 (5)
Ningxia	14.7 (3)	13.5 (5)	11.2 (6)	9.5 (7)	8.6 (6)
Xinjiang	14.7 (4)	15.8 (2)	13.0 (3)	11.8 (3)	11.0 (4)
National	8.2	7.6	6.8	6.21	5.6

[a]Figures in brackets indicate ranking.

Table III Characteristics of nonfatal injuries and fatalities from road traffic crashes by gender and age in China, 2004–2008

	Nonfatal injuries		Fatalities	
	n	%	*n*	%
Gender				
Male	1,509,019	73.0	343,149	76.2
Female	558,256	27.0	107,254	23.8
Age (years)				
1–9	64,811	3.1	17,767	3.9
10–20	230,209	11.1	38,451	8.5
21–30	491,718	23.8	81,988	18.2
31–40	551,832	26.7	106,811	23.7
41–50	366,399	17.7	84,247	18.7
51–60	210,720	10.2	59,478	13.2
61–65	51,085	2.5	18,225	4.1
>65	100,455	4.9	43,434	9.6

lowest of 3.0 in Henan in 2008 to the highest of 21.7 in Xizang in 2004.

Table III presents the gender and age of individuals killed and injured in road traffic crashes. From 2004 to 2008, there were a total of 2,067,275 injuries and 450,403 deaths in road traffic crashes. Of these deaths, 76.2 percent were males and 23.8 percent were females (sex ratio of 3.2:1). Children aged 1 to 20 years accounted for more than 12 percent of total road traffic deaths. Adults aged 21 to 50 years accounted for more than 60 percent, and adults aged more than 65 years accounted for approximately 10 percent of total road traffic deaths.

Road traffic deaths by type of road user are presented in Figure 1. Of all road traffic deaths during the study period, automobile drivers accounted for 11.1 percent, passengers accounted for 24.3 percent, motorcyclists accounted for 20.9 percent, bicyclists accounted for 16.4 percent, and pedestrians accounted for 25.6 percent. During the 9-year period from 2000 to 2008, the proportion of motorcyclists killed in road traffic accidents had increased from 18.3 to 22.1 percent.

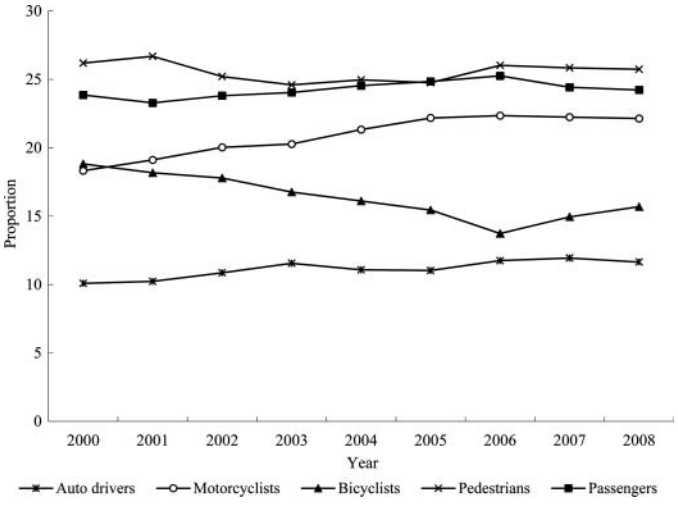

Figure 1 Trends for proportion of road traffic crashes fatalities by road user in China, 2000 to 2008.

Table IV Characteristics of crashes, nonfatal injuries, and fatalities due to road traffic crashes by road type in China, 2004–2008

		All crashes		Nonfatal injuries		Fatalities	
Type of road	Road mileage	*n*	Crashes/ 10,000 km	*n*	Injuries/ 10,000 km	*n*	Fatalities/ 10,000 km
Highways	234,847	80,278	3418.3	76,406	3253.4	31,361	1335.4
Main roads	3,296,864	919,747	2789.8	1,004,040	3045.4	265,686	805.9
Secondary main roads, city/branch roads	11,040,371	939,312	850.8	986,829	893.8	153,356	138.9
Total	14,572,082	1,939,337	1330.9	2,067,275	1418.7	450,403	309.1

Table IV presents the proportion of road kilometers covered by type of road and the proportion of all crashes, nonfatal injuries, and fatalities associated with each type of road. Although highways and main roads covered only 1.6 and 22.6 percent of the whole road surface, respectively, they were responsible for high proportions of crashes (3418.3 and 2789.8 crashes/10,000 km, respectively). Nonfatal injuries and fatalities were significantly overrepresented on both types of roads (3253.4 and 3045.4 injuries/10,000 km, respectively; 1335.4 and 805.9 fatalities/10,000 km, respectively). The crash fatality ratio (the average number of deaths per crash) is highest for highways (0.4), followed by main roads (0.3) and secondary main roads, city/branch roads (0.2).

DISCUSSION

Our study showed that RTIs still pose a major public health problem and cause thousands of deaths in China every year. Since 2000, more than 84,000 people in China have died from RTIs and more than 450,000 persons suffered nonfatal injuries. Our study also suggested that RTIs are significantly associated with factors such as age, gender, geographic area, road type, and number of motor vehicle. The patterns of road traffic and RTIs are very different in low- and middle-income countries than those in developed countries (Mohan 2002a; Odero et al. 2003).

The rates of nonfatal injuries and fatalities caused by road traffic crashes showed progressive declines for the period 2002 to 2008. One explanation for the declining trend is the improvement in road traffic control, engineering, other traffic safety measures implemented in China. In 2004, China implemented a new road traffic safety law (The Central People's Government of the People's Republic of China 2004). Since then, many safety interventions have been made to curb RTIs, including the enforcement of speed limits, speed radar systems, provision of median barriers, and traffic safety awareness campaigns. Previous studies have suggested that improvements in traffic safety control and road design are effective in reducing the rates of RTIs (Chawla et al. 2000; Elvik 1997; Rock 1995). A study suggests that between 1975 and 1994 the severity of RTIs increased in some countries, such as Holland and Denmark; fell in others, such as the U.K. and United States; and remained the same elsewhere, such as in Belgium and Italy, though they all had decreasing trends of road traffic fatalities (Beenstock and Gafni 1999). A second explanation for the declining rate of traffic crash deaths per 10,000 vehicles or per 100,000 people is possible slower travel speed caused by increases in traffic congestion and more experienced drivers. The third explanation for the declining trends is the underreporting of road traffic-related deaths in the police records. Hu et al. (2011) suggested that underreporting might be a major limitation in using police-reported traffic crash statistics. Police-reported RTIs and death registration data showed different trends in road traffic death rates. Though police-reported statistics suggested a significant decline of 27 percent of deaths caused by RTIs from 2002 to 2007, death registration data showed an increase of 8 percent during the same period. Many researchers believe that the declining trend of road traffic fatalities in the police-reported statistics needs to be examined more carefully using other multiple data sources, and China needs to improve the quality of the police-reported road traffic safety data (Hu et al. 2011; Zhang et al. 2010). There is room for improvement in road traffic safety in China. Many cars on the road, particularly used cars in poor rural areas, do not have good safety features. Many unsafe older cars that should be removed from the road end up in the hands of drivers who cannot afford 5 star–rated vehicles. Another important area for improvement is the low seat belt use by drivers and passengers in China. There is unequivocal evidence that seat belts can significantly reduce the risk of death in road traffic crashes. However, drivers' seat belt use rate in China is very low, from 47 percent in Beijing to 41 percent in Yantai and 23 percent in Tianjin and Pingyi (Huang et al. 2011). This is much lower than the seat belt use rate in developed countries (over 80%). An intervention study in Guangzhou by Stevenson et al. (2008) reported that it is possible to significantly increase the seat belt use rate using similar methods to those used in high-income countries. In our study, nonfatal injuries and fatalities due to road traffic crashes among males were greater than those for females from 2004 to 2008. The male : female ratio for road traffic crashes fatalities was 3.2:1 during that period. This is consistent with previous studies worldwide: 2.1:1 in Addis Ababa and Ethiopia (Dessie and Larson 1991), 9.6:1 in Thailand's rural areas (Swaddiwudhipong et al. 1994), 1.8:1 in Ghana (Mock et al. 1999), 1.3:1 in Wisconsin (Tavris et al. 2001), and 2.4:1 in the United States (National Highway Traffic Safety Administration 2007). The distribution of global road traffic fatalities by gender indicates that males account for more deaths than females (Peden 2005; Peden et al. 2004). This may reflect a higher exposure to risk

factors for RTIs in males, as well as more severe nonfatal injuries in males compared to females (Monarrez-Espino et al. 2006). The fact that drivers are significantly more likely to be males than females in China might explain why significantly more males than females die in road traffic crashes.

Low- and middle-income countries account for about 85 percent of deaths caused by road traffic crashes. About 50 percent of these deaths occur among young adults aged 15 to 44 years in low- and middle-income countries (Peden et al. 2002, 2004). In Mexico, the second most common cause of children being orphaned is traffic crashes (Hijar et al. 2003). China's road traffic deaths among young adults aged 16 to 45 years account for more than 60 percent of the total deaths. RTIs in China particularly affect the most productive age group. Those aged 16 to 45 are heavily represented in road traffic deaths. Therefore, the economic impacts of RTIs in this age group are the greatest (Hijar et al. 2003). According to the World Health Organization, RTIs in individuals in this age group "tend to affect productivity severely, particularly among the lowest-income groups whose exposure to risk is greatest and whose earning capacity is most likely to rely on physical activity" (Ad Hoc Committee on Health Research Relating to Future Intervention Options 1996, p. 68). Previous studies have suggested that more than 75 percent of road traffic casualties are among economically productive young adults (Odero et al. 1997). RTIs are not a major cause of death for the elderly. However, our study suggests that road traffic crash fatalities increased among those older than 65 years in recent years. Given the same chance of a crash, an older person is more likely to be killed or disabled than a younger one (Peden et al. 2004). Older pedestrians in particular are associated with a very high rate of road injury and death.

Pedestrians, bicyclists, and motorcyclists account for a large proportion of road traffic injuries in low- and middle-income countries (Peden et al. 2004). They are the most vulnerable road users (Mohan 2002b). Passengers on buses and other informal public transport systems also constitute a group at significant high risk of road traffic deaths (Odero et al. 1997). Results in our study suggest that 63 percent of road traffic crash deaths in China were accounted for by pedestrians, bicyclists, and motorcyclists, and 35 percent of deaths were accounted for by auto drivers/passengers. It has been shown that in developing countries, pedestrians, bicyclists, and motorcyclists account for most of the road traffic deaths (Nantulya and Reich 2003; Peden et al. 2004). In comparison, in high-income countries, car owners and drivers account for the majority of road users and, consequently, the majority of road traffic deaths (Peden 2005). This suggests that the characteristics of road traffic injuries are different in developing countries than in developed countries.

Main roads were overrepresented in road traffic crashes resulting in both nonfatal injuries and fatalities. Compared to secondary main roads and city/branch roads, a similar number of crashes occurred on main roads, but a greater proportion of nonfatal injuries and fatalities occurred on main roads than the proportion of road kilometers covered by main roads (48.6% and 59.0% compared to 22.6%, respectively). Highways were overrepresented in nonfatal crashes and had the lowest crash fatality ratio of 0.2 (Afukaar 2003; Qin et al. 2004). This may partially explain the geographic patterns of traffic crash deaths by province. In road traffic safety research it has been found that the road fatality rate per population has an inverted-U-shaped relationship (also called a *Kuznets curve*) with economic development level (gross domestic product [GDP] per capita; Zhang et al. 2010). Our results support this hypothesis. Though the mortality rate of road traffic crashes per 100,000 people was high in Xizang (13.5), Xinjiang (11.0), Qinghai (11.0), and Ningxia (8.6), which are underdeveloped provinces, the mortality rate in rich provinces or areas such as Tianjin (12.8), Zhejiang (11.6), Fujian (8.6), and Beijing (8.1) was also high. Low seat belt use rate might be another factor for the observed provincial difference. According to Liu et al. (2005), less than 5 percent of drivers in underdeveloped areas such as Xizang and Qinghai use seat belts, which is much lower than the seat belt use rate in richer provinces such as Guangdong, Tianjin, and Shanghai.

One of the main factors contributing to more road traffic crashes is the growing number of motor vehicles in China. Previous studies have shown a correlation between motor vehicle growth and the number of road traffic crashes and injuries (Suriyawongpaisal and Kanchanusut 2003; Winston et al. 1999). In China, whose economy is experiencing a rapid growth, the number of motor vehicles has increased more than 2744-fold to over 170 million since 1951. However, road mileage has only increased 32-fold (National Bureau of Statistics of China 2009). Therefore, traffic volume has increased along with the increased number of road traffic crash deaths. Furthermore, traffic volume is an important risk factor for RTIs among child pedestrians. Previous research has shown that when traffic volume falls there is a reduction in child pedestrian death rates (Roberts et al. 1992, 1995). Despite the rapid growth in motorized traffic, most of the increase in vehicles in China is accounted for by motorized 2-wheeled vehicles and 3-wheelers. Motorized 2-wheelers vehicles and 3-wheelers can also cause a significant number of RTIs to other road users (Chiu et al. 2000).

Several limitations of our study should be considered when interpreting our findings. First, the underreporting bias is well known from studies conducted using existing official statistics (Jacobs et al. 2000; Nakahara and Wakai 2001; Zheng et al. 2007). As reported by Hu et al. (2011), the police-reported traffic crash death rate is significantly lower than the traffic crash death rate extrapolated from the death registration data in China. According to Hu et al. (2011), for the period 2002 to 2007, police-reported deaths from traffic crashes were between 37 and 62 percent of the death registration data. More important, though police-reported data showed a significant decline in road traffic crash deaths in recent years, death registration data suggest no significant changes for the same period. It is also important to keep in mind that our study covered a long period from 1951 to 2008, during which significant socioeconomic changes occurred. It is unknown whether the reliability of police-reported traffic crash data has improved or not during the study period. Second, because data were collected in a

retrospective cross-sectional study, we could not calculate the incidence of RTIs. Third, detailed information about road traffic crashes was not available in the aggregated police-reported traffic crash statistics. For confidentiality reasons, the Chinese government does not make the traffic crash database available for research. A publicly available de-identified database will allow researchers to conduct in-depth research, which in turn will provide evidence for the design of road safety programs in China.

In China, economic growth and motorization are coupled with an increasing rate of road traffic crashes. The patterns of RTIs are very different in China compared to those in high-income countries. Our study suggests that geographic areas, type of road users, type of road, and traffic injury patterns are closely related in China. Some existing effective road traffic safety interventions developed in Western countries could be effective in reducing the risk of road traffic crashes in China. Future research and knowledge of important road safety interventions are essential to control RTIs and for safety promotion in China.

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REFERENCES

Ad hoc Committee on Health Research Relating to Future Intervention Options. *Investing in Health Research and Development*. Geneva, Switzerland: World Health Organization, 1996. Available at: http://apps.who.int/tdr/svc/publications/tdr-research-publications/investing-in-health. Accessed November 20, 2009.

Afukaar FK. Speed control in developing countries: issues, challenges and opportunities in reducing road traffic injuries. *Int J Inj Contr Saf Promot.* 2003;10:77–81.

Beenstock M, Gafni D. Globalisation in road safety: explaining the downward trend in road accident rates in a single country. *Accid Anal Prev.* 1999;32:71–84.

Bureau of Traffic Management of the Ministry of Public Security of PRC. *China road traffic accidents statistics*. Beijing; 2009.

The Central People's Government of the People's Republic of China. *Regulation on the Implementation of the Law of the People's Republic of China on Road Traffic Safety*. 2004. Available at: http://www.gov.cn/banshi/2005-08/23/content_25579.htm. Accessed November 20, 2009.

Chawla A, Mohan D, Sharma V, Kajzer J. Safe truck front design for pedestrian impacts. *J Crash Prev Inj Contr.* 2000;2:33–43.

Chi GB, Wang SY. Pattern of road traffic injuries in China. *Chin J Epidemiol.* 2004;25:598–601.

Chiu WT, Kuo CY, Hung CC, Chen M. The effect of the Taiwan motorcycle helmet use law on head injuries. *Am J Public Health.* 2000;90:793–796.

Dessie T, Larson CP. The occurrence and driver characteristics associated with motor vehicle injuries in Addis Ababa, Ethiopia. *J Trop Med Hyg.* 1991;94:395–400.

Elvik R. Evaluation of road accident blackspot treatment: a case of the iron law of evaluation studies? *Accid Anal Prev.* 1997;29:191–199.

Hijar M, Vazquez-Vela E, Arreola-Risa C. Pedestrian traffic injuries in Mexico: a country update. *Inj Contr Saf Promot.* 2003;10:37–43.

Hu GQ, Baker T, Baker SP. Comparing road traffic mortality rates from police-reported data and death registration data in China. *Bull World Health Organ.* 2011;89:41–45.

Huang YH, Zhang W, Murphy L, Shi G, Lin Y. Attitudes and behavior of Chinese drivers regarding seatbelt use. *Accid Anal Prev.* 2011;43:889–897.

Jacobs G, Aeron-Thomas A, Astrop A. *Estimating Global Road Fatalities*. Crowthorne: Transport Research Laboratory; 2000. TRL Report, No. 445. Available at: http://www.transport-links.org/transport_links/filearea/publications/1_329_TRL445.pdf. Accessed November 20 2009.

Kopits E, Cropper M. Traffic fatalities and economic growth. *Accid Anal Prev.* 2005;37:169–178.

Liu N, Yang GH, Ma JM, Chen AP. Injury associated health risk factors in Chinese people, in 2002. *Chin J Epidemiol.* 2005;26:746–750.

Mock CN, Forjuoh SN, Rivara FP. Epidemiology of transport-related injuries in Ghana. *Accid Anal Prev.* 1999;31:359–370.

Mohan D. Road safety in less-motorized environments: future concerns. *Int J Epidemiol.* 2002a;31:527–532.

Mohan D. Traffic safety and health in Indian cities. *J Transp Infrastructure.* 2002b;9:79–94.

Monarrez-Espino J, Hasselberg M, Laflamme L. First year as a licensed car driver: gender differences in crash experience. *Saf Sci.* 2006;44:75–85.

Murray CJ, Lopez AD. Alternative projections of mortality and disability by cause 1990–2020, Global Burden of Disease Study. *Lancet.* 1997;349:1498–1504.

Nakahara S, Wakai S. Underreporting of traffic injuries involving children in Japan. *Inj Prev.* 2001;7:242–244.

Nantulya VM, Reich MR. Equity dimensions of road traffic injuries in low- and middle-income countries. *Inj Contr Saf Promot.* 2003;10:13–20.

National Bureau of Statistics of China. *Annual Statistics Communique*. 2009. Available at: http://www.stats.gov.cn/tjgb/. Accessed November 20, 2009.

National Highway Traffic Safety Administration. Comparison of crash fatalities by gender and year from 1996 to 2005. NHTSA's national center for statistic and analysis. Traffic safety facts. 2007. Available at: http://www-nrd.nhtsa.dot.gov/Pubs/810780.PDF. Accessed November 20, 2009.

Odero W, Garner P, Zwi A. Road traffic injuries in developing countries: a comprehensive review of epidemiological studies. *Trop Med Int Health.* 1997;2:445–460.

Odero W, Khayesi M, Heda PM. Road traffic injuries in Kenya: magnitude, causes and status of intervention. *Inj Contr Saf Promot.* 2003;10:53–61.

Peden M. Global collaboration on road traffic injury prevention. *Int J Inj Contr Saf Promot.* 2005;12:85–91.

Peden M, McGee K, Sharma G. *The Injury Chart Book: A Graphical Overview of the Global Burden of Injuries*. Geneva, Switzerland: World Health Organization, 2002. Available at: http://whqlibdoc.who.int/publications/924156220X.pdf. Accessed November 20, 2009.

Peden M, Scurfield R, Sleet D, et al. *World Report on Road Traffic Injury Prevention*. Geneva, Switzerland: World Health Organization; 2004. Available at: http://www.who.int/violence_injury_prevention. Accessed November 20, 2009.

Qin HL, Zhao XC, Zhou JH, et al. Effect of environment on extremely severe road traffic crashes: retrospective epidemic analysis during 2000–2001. *Chin J Traumatol.* 2004;7:323–329.

Roberts I, Crombie I. Child pedestrian deaths: sensitivity to traffic volume—evidence from the USA. *J Epidemiol Community Health.* 1995;49:186–188.

Roberts I, Marshall R, Norton R. Child pedestrian mortality and traffic volume in New Zealand. *Br Med J.* 1992;305: 283.

Rock SM. Impact of the 65 mph speed limit on accidents, deaths and injuries in Illinois. *Accid Anal Prev.* 1995;27:207–214.

Soderlund N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. *Bull World Health Organ.* 1995;73:175–182.

Stevenson M, Yu J, Hendrie D, et al. Reducing the burden of road traffic injury: translating high-income country interventions to middle-income and low-income countries. *Inj Prev.* 2008;14:284–289.

Suriyawongpaisal P, Kanchanusut S. Road traffic injuries in Thailand: trends, selected underlying determinants and status of intervention. *Inj Contr Saf Promot.* 2003;10:95–104.

Swaddiwudhipong W, Nguntra P, Mahasakpan P, Koonchote S, Tantriratna G. Epidemiologic characteristics of drivers, vehicles, pedestrians and road environments involved in road traffic injuries in rural Thailand. *Southeast Asian J Trop Med Public Health.* 1994;25:37–44.

Tavris DR, Kuhn EM, Layde PM. Age and gender patterns in motor vehicle crash injuries: importance of type of crash and occupant role. *Accid Anal Prev.* 2001;33:167–172.

Wang SY, Li YH, Chi GB, Xiao SY, Ozanne-Smith J, Phillips MR. Injury-related fatalities in China: an under-recognised public-health problem. *Lancet.* 2008;372:1765–1773.

Winston FK, Rineer C, Menon R, Baker SP. The carnage wrought by major economic change: ecological study of traffic-related mortality and the re-unification of Germany. *Br Med J.* 1999;318:1647–1649.

Zhang W, Tsimhoni O, Sivak M, Flannagan MJ. Road safety in China: analysis of current challenges. *J Saf Res.* 2010;41:25–30.

Zheng YY, Cooper PJ, Dean CB. Modeling the contribution of speeding and impaired driving to insurance claim counts and costs when contributing factors are unknown. *J Saf Res.* 2007;38:25–33.