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Analysis of 121 fatal passenger car-adult pedestrian accidents in China

Hui Zhao [a,*], Zhiyong Yin [a], Guangyu Yang [a], Xingping Che [a], Jingru Xie [a], Wei Huang [b], Zhengguo Wang [a]

[a] Chongqing Key Laboratory of Vehicle Crash/Bio-impact and Traffic Safety, Department 4th, Institute of Surgery Research, Daping Hospital, Third Military Medical University, Chongqing 400042, China
[b] Chongqing Traffic Management Administration of Public Security Bureau, Chongqing 402260, China

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ABSTRACT

To study the characteristics of fatal vehicle-pedestrian accidents in China , a team was established and passenger car-pedestrian crash cases occurring between 2006 and 2011 in Beijing and Chongqing, China were collected. A total of 121 fatal passenger car-adult pedestrian collisions were sampled and analyzed. The pedestrian injuries were scored according to Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS). The demographical distributions of fatal pedestrian accidents differed from other pedestrian accidents. Among the victims, no significant discrepancy in the distribution of ISS and AIS in head, thorax, abdomen, and extremities by pedestrian age was found, while pedestrian behaviors prior to the crashes may affect the ISS. The distributions of AIS in head, thorax, and abdomen among the fatalities did not show any association with impact speeds or vehicle types, whereas there was a strong relationship between the ISS and impact speeds. Whether pedestrians died in the accident field or not was not associated with the ISS or AIS. The present results may be useful for not only forensic experts but also vehicle safety researchers. More investigations regarding fatal pedestrian accidents need be conducted in great detail.

1. Introduction

With the rise in global urbanization and motorization, road traffic accidents (RTAs) induced injuries have become major worldwide public health problems. According to a report by World Health Organization,[1] over 1.2 million people died from RTAs each year in the world and about 50 million were injured. It was predicated that the injuries related to RTAs will rise to become the fifth leading cause of death by 2030.[1] Pedestrians, as one of the most vulnerable road users, are accounted for a very high proportion of fatalities involved in RTAs around the world. For example, in the developed countries with high incomes, typically 10–30% of fatalities related to RTAs are pedestrians. Meanwhile, substantially higher pedestrian fatal proportions were reported in the other countries with middle or low-incomes, despite the figures are underestimated.[1]

For experts in forensic medicine, the analysis of causes of injuries or deaths from RTAs has become a very important part of their daily work.[2–4] Few studies have been performed to investigate the characters of fatal pedestrian accidents, especially for the middle and low income countries, e.g. China, although fatal pedestrian accidents occur very frequently in these countries.[1] It has been suggested that pedestrian injuries can provide evidential value for reconstruction of pedestrian-vehicle accidents at the moment of collision,[5] and that pedestrian injuries maybe a further evaluation index to reconstruct car-to-pedestrian collision.[6] In the authors' point of view, the injuries sustained by the pedestrians need to be studied in detail from fatal vehicle-pedestrian collisions to reconstruct the collisions.

To date, a large number of pedestrian accidents have been investigated worldwide, especially for some developed countries. It has been accepted that real-world vehicle-pedestrian collision data may provide first-hand information about patterns, causation, risk factors of accidents, and valuable background for decreasing pedestrian injuries and deaths.[7] The data are important not only to legal medical experts to validate the vehicle-pedestrian crash reconstruction, but also to researchers to develop the techniques to reduce or prevent such crashes.[8] However, limited research was focused on fatal vehicle-pedestrian accidents in the countries with middle or low incomes.

Nowadays, pedestrian accident databases with detailed information related to crashes and injuries are available for a small

* Corresponding author. Tel.: +86 23 68757446; fax: +86 23 68816153.
E-mail address: box.zhaohui@163.com (H. Zhao).

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number of developed countries. Such databases include the International Harmonization Research Activity (IHRA) dataset in Japan,[9] the German In-Depth Accident Study (GIDAS),[10] the United States Pedestrian Crash Data Study (PCDS),[11] and the Australian database.[12] There is still a great demand for accident data from developing countries because of their unique circumstances, e.g. lack of comprehensive, well-documented dataset, as well as difficulty accessing existing data,[13] although some investigations regarding pedestrian-accident crashes have been performed from the collected in-depth vehicle-pedestrian data at a regional level in China.[14,15] As an extension of these studies, this paper aims to address the characters of fatal pedestrian accidents by analyzing a large number of recent fatal vehicle-pedestrian crashes in multi areas.

2. Methods

A team, consisting of engineers and medical experts, has been found since 2006 in the Institute of Surgery, Third Military Medical University, Chongqing, China. The team, cooperating with police departments, collected onsite passenger car-pedestrian accident cases occurring between 2006 and 2011 in Beijing, Northern China, which are characterized by a flat area, and Chongqing, Southern China, which is characterized by mountainous regions. The accident-related information included the data of human, environmental, and vehicular factors.

Human information contained the pedestrian age, gender, injury outcome, injured body region, injury severity, person's action prior to the crash, with treatment or not, and surviving time. The age were classified as Group 1 (aged 16–25), Group 2 (aged 26–45), Group 3 (aged 46–60), and Group 4 (over 60 years). Pedestrian injuries within a specific body region or anatomical structure were scored according to 'The Abbreviated Injury Scale 2005 (AIS 2005) Revision' by the Association for the Advanced of Automotive Medicine,[16] from AIS 1 (minor), AIS 2 (moderate), AIS 3 (serious), AIS 4 (severe), AIS 5 (critical) to AIS 6 (currently untreatable). The Injury Severity Score (ISS) was calculated by summing the squares of the AIS codes of the three most severely injured body regions. Cases were grouped into three categories according to ISS values: 0-14, 16-66, and 75, representing minor, major, and incompatible-with-life injuries, respectively. Person's actions prior to the crashes were divided into standing still, crossing the road, and walking along the road.

Environmental factors included weather condition (Sunny, Others) and road types (Urban road, Highways, Others). The passenger cars enrolled in the study were classified as Sedan, sport utility vehicle (SUV), and 1-Box based on the front shape: (1) Bonnet Leading Edge (BLE) < 835 mm, Sedan; (2) BLE > 835 mm, SUV; (3) Bonnet angle $\geq 30^0$, 1-Box.[17,18]

The vehicle impact speed, v (unit: km/h), was derived from the braking distance[19] if the vehicle braking marks could be identified, where a is the deceleration (unit: m/s^2) and s is the braking skid distance (unit: m).

$$v = \sqrt{2as} \times 3.6 \quad (1)$$

or it was calculated from the pedestrian throwing distance,[1915]

$$v = \sqrt{2g} \times \varphi \times \left(\sqrt{h + \frac{x}{\varphi}} - \sqrt{h} \right) \times 3.6 \quad (2)$$

where φ is the friction coefficient between the pedestrian and road, x represents the pedestrian throwing distance (unit: m) and h means the height of the pedestrian's center of gravity (unit: m).

The accidents in which the pedestrians died within 7 days as a direct result of vehicle impact were sampled, and accidents in which the impact speed could not be estimated from either braking skid marks or pedestrian throwing distance were not considered in this study. The accidents enrolling pediatric pedestrians were excluded owing to the possible differences in the mechanism and/or injury patterns as compared with adults. Additionally, accidents in which a car collided with more than one pedestrian or one pedestrian sustained multi-vehicles collisions or run-over were not enrolled.

The associations between pedestrian injuries and personal, vehicular, and environmental factors were investigated via χ^2 test. The relative likelihood of pedestrians died in the field versus survived was analyzed from variables with environmental, human, and vehicle factors. Data were processed, by using software SPSS® 11.0 (SPSS Inc, Chicago, IL). The values, $p < 0.05$, were considered statistically significant.

3. Results

A total of 121 fatal passenger car-pedestrian crashes meeting the inclusion criteria were chosen. Among the sampled accidents, 26 (21%) cases occurred in Beijing, and 95 (79%) in Chongqing. For the accidents, 108 (89%) occurred under nice weather conditions, and 83 (69%) occurred in urban roads, while 34 (28%) in highway. It was shown that 29% of fatal pedestrian accidents occurred in highways in Chongqing, which have a higher probability than those in Beijing ($p = 0.021$), as exhibited in Fig. 1.

Of the vehicles involved in the crashes, there were 87 (72%) sedans, 20 (17%) 1-box vehicles, and 14 (12%) SUVs. For the vehicles involved in the crashes, the impact speeds varied from 23 km/h to 128 km/h, with an average speed of 64.1 ± 21.6 km/h Fig. 2 plots the distributions of impact speeds of accidents occurring in urban road and highways, in which the mean of impact speeds for the accidents in highway was 82.3 ± 23.8 km/h, higher than that in urban road, 56.7 ± 15.4 km/h ($p = 0.0001$). For the accidents sampled in urban road, 52 (63%) occurred at the impact speeds from 40 km/h to 69 km/h.

Of the killed pedestrians, males were 64 (53%), and females 57 (47%). Among the fatalities, the eldest was 87 years old, and the youngest was 23 years old, with an average age of 56.2 ± 15.0 years old. For the victims, 87 (82%) were crossing the roads prior to the crashes, 28 (23%) walking along the roads, and 6 (5%) standing still in the roads.

Among the killed pedestrians, head, neck, chest, abdomen, extremities, and spine were the common injury localizations. The victims with multiple injuries were up to 102, accounting for 84% of the fatalities. Among the deaths, 119 (98%) sustained head injuries, followed by 74 (61%) extremity injuries, 73 (60%) thorax injuries, and 32 (26%) abdomen injuries. Of the killed pedestrians, 99 (82%) died from head injuries, 36 (30%) from thorax injuries. A total of 32 (26%) pedestrians died in which both head injuries and thorax injuries were the fatal causes. The maximal ISS of the deaths was 75, and the minimal was 4, with an average ISS of 33.7 ± 18.0.

Of the victims, the common injury patterns included laceration, contusion, dislocation, fractures, etc., and the injury severities varied from AIS 1 to AIS 6. Table 1 summarizes the distributions of pedestrian ISS and AIS in head, thorax, abdomen, and extremity by age groups. No significant distribution discrepancy of AIS in pedestrian head, thorax, abdomen, as well as extremities was found by the age, and the ISS difference was not observed in the killed pedestrians by age groups, either, from the table. The data of pedestrian ISS and AIS distributions by pedestrian actions, as shown in Table 2, indicates that pedestrian head AIS distributions were associated significantly with their behaviors prior to the crash ($p < 0.05$). Meanwhile, ISS of pedestrians on crossing the road prior to the crashes was higher than that on standing still ($p < 0.05$).