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Logistic regression analysis of pedestrian casualty risk in passenger vehicle collisions in China

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ABSTRACT

A large number of pedestrian fatalities were reported in China since the 1990s, however the exposure of pedestrians in public traffic has never been measured quantitatively using in-depth accident data. This study aimed to investigate the association between the impact speed and risk of pedestrian casualties in passenger vehicle collisions based on real-world accident cases in China. The cases were selected from a database of in-depth investigation of vehicle accidents in Changsha-IVAC. The sampling criteria were defined as (1) the accident was a frontal impact that occurred between 2003 and 2009; (2) the pedestrian age was above 14; (3) the injury according to the Abbreviated Injury Scale (AIS) was 1+; (4) the accident involved passenger cars, SUVs, or MPVs; and (5) the vehicle impact speed can be determined. The selected IVAC data set, which included 104 pedestrian accident cases, was weighted based on the national traffic accident data. The logistical regression models of the risks for pedestrian fatalities and AIS 3+ injuries were developed in terms of vehicle impact speed using the unweighted and weighted data sets. A multiple logistic regression model on the risk of pedestrian AIS 3+ injury was developed considering the age and impact speed as two variables. It was found that the risk of pedestrian fatality is 26% at 50 km/h, 50% at 58 km/h, and 82% at 70 km/h. At an impact speed of 80 km/h, the pedestrian rarely survives. The weighted risk curves indicated that the risks of pedestrian fatality and injury in China were higher than that in other high-income countries, whereas the risks of pedestrian casualty was lower than in these countries 30 years ago. The findings could have a contribution to better understanding of the exposures of pedestrians in urban traffic in China, and provide background knowledge for the development of strategies for pedestrian protection.

1. Introduction

Road traffic injuries are growing, becoming a major public health issue throughout the world. According to the World Health Organization, 1.2 million people die every year in road accidents worldwide (Peden et al., 2004). An overwhelming majority of traffic deaths and injuries involve vulnerable road users such as pedestrians. In many European Union countries, about 10–16% of all road accident fatalities are pedestrians (Hoeglinger et al., 2007). In low-income countries, these proportions are substantially higher. For instance, pedestrian deaths accounted for more than 40% of all traffic fatalities in India (Peden et al., 2004), in China more than 23,000 pedestrians died in road traffic accidents in 2006 (TABC, 2007), accounting for approximately 26% of all traffic fatalities. Pedestrian casualties also represent a huge cost to society as traffic accidents result in extended medical treatment, the loss of the primary breadwinner, often pushing a family into poverty. Therefore, common efforts are necessary for the traffic safety community to reduce the incidence and injury severity of the accidents. For this purpose it is important to have a good understanding of real-world accidents for the development of countermeasures for pedestrian protection.

Studies of the risks of pedestrian injury and fatality were carried out in different countries since 1960s. The previous studies using real-world accident data (Table 1) determined that (1) injury severity among pedestrians strongly depended on the impact speed; (2) there was a positive relation between vehicle impact speed and the risks of pedestrian injury and fatality. Some regression models and risk curves were derived from these studies. It indicated that the fatality risks have been found in a range of 45–85% at an impact speed of 50 km/h from studies using accident data before 1980, and in a range of 8–70% at the same impact speed from studies using data after 1990 (Table 1). An analysis of the effects and the precision of the fatality risk curves from the previous study was presented by Rosén and Sander (2009). They pointed out that the bias of the curves in a few studies, such as Ashton et al. (1977) and Anderson et al. (1997), was due to the use of an outcome-based or retrospec-

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Table 1
Summary of previous study on the risk of pedestrian fatality in relation to impact speed.

	Year of data	Data source	30 km/h	50 km/h	70 km/h
Yaksich (1964)	1958–1963	US	22%	65%	100%
Ashton (1980)	1965–1979	UK	5%	45%	95%
Anderson et al. (1997)	1978	Australia	8%	85%	100%
Hannawald and Kauer (2004)	1991–2003	Germany	4%	14%	39%
Oh et al. (2008)	2003–2005	Korea	7%	34%	77%
Rosén and Sander (2009)	1999–2007	Germany	1.5%	8%	35%
Cuerden et al. (2007)	2000–2007	UK	2%	12%	33%

tive sampling plan (Davis, 2001). Furthermore, the bias was also attributed to the fact that the samples from the real-world were small, or that the data were more than 30–40 years old (Yaksich, 1964; Ashton, 1980).

In China the exposure of pedestrians in public transportation have never been measured quantitatively using real-world accident data. A study on this topic must be carried out based on the detailed data from in-depth accident investigation, but a nationwide database from in-depth accident investigation has not yet been established in China. Thus, currently national accident data could be collected only from the traffic management department. Due to the lack of some key data, such as impact speed, these national data are not suited for quantitative study on the association of impact speed and pedestrian injury risk. Although findings from high-income countries are valuable, they are not necessarily in full compliance with China's actual situation. Thus there is a need of quantitative study on the association of impact speed with risk of pedestrian casualties in China.

This study was to develop the knowledge of pedestrian casualty risks in passenger vehicle collisions. A selected data set for the study was based on in-depth investigations of real-world traffic accidents. The logistic regression analyses were conducted using the data set to find the risk function for pedestrian casualties in relation to the vehicle impact speed and pedestrian age. Furthermore, the pedestrian age, height, weight, and car registration year were descriptively investigated. The results will form the background knowledge for the development of strategies for pedestrian protection from vehicle collisions.

2. Methods and materials

2.1. Data set

In 2006, a special team from Hunan University carried out a vehicle traffic accident investigation in Changsha that is the capital city of the Hunan province located in middle of China, with a population 2,060,000 (6,133,000 including residents in suburb) and registered vehicles 452,809 in 2006. The team consisted of researchers from the university, medical, and traffic authority sectors. When an accident was reported, the researchers traveled to the spot to collect onsite accident data together with traffic policemen. The major methods of onsite investigation include measuring tracks, taking pictures, and interviewing the parties involved and witnesses. Detailed injury and diagnostic information about the victim(s) is collected from the emergency hospital. In addition, due to the limited time at the accident scene, a retrospective investigation is conducted to further collect and confirm the detailed information of the accident by visiting the victim(s) in hospital or conducting a phone interview with witnesses. A comprehensive analysis was carried out on a case-by-case basis for data collected onsite and the retrospective investigation. Once all of the in-depth investigation data are coordinated, they are stored in the database entitled "In-depth Investigation of Vehicle Accidents in Changsha (IVAC)".

The sampling criteria are defined as follows: (1) the accident was a frontal impact that occurred between 2003 and 2009 in an urban area; (2) the pedestrian age was above 14; (3) the injury according to Abbreviated Injury Scale (AIS) was 1+; (4) the accident vehicles included passenger cars, SUVs, and MPVs; and (5) the vehicle impact speed can be determined. Given the anatomical and biomechanical differences between children and adults (Tarriére, 1995), the current study will not address child pedestrian fatality risk. According to these criteria, a total of 107 cases were identified in IVAC. All of these cases were studied in detail to ensure data quality. Finally three more cases were excluded. One case involved a man being killed by a car while he was sitting on the road. The other two cases involved two pedestrians being sideswiped by cars; the main cause of injury was the ground. Hence, an IVAC data set was generated, which consisted of 104 cases, including 11 fatalities.

In order to have an expanded view of pedestrian exposure in public traffic in China, the weighting procedure was applied to the IVAC data set regarding the distribution of pedestrian injury severity in Changsha and national police data. The definitions of *severe* and *fatal* in the police data were equivalent to the IVAC definitions of AIS 3+. Using official statistics data, the two weighted data sets were derived as data set 1 and data set 2 (the IVAC data set is referred to as unweighted). Data set 1 was weighted based on pedestrian accident data in Changsha from 2003 to 2007. Data set 2 was weighted based on pedestrian accident data in China from 2003 to 2007. The weight factors were normalized so that the total size of the two weighted data sets also equaled to 104 cases. Table 2 presents the distributions of pedestrian injury severities for the national data set, the Changsha police data set, and the IVAC data set. These data sets were then used to derive the final, normalized weight factors for the weighted data set 1 ($W1_{slight} = 1.66$, $W1_{severe} = 0.26$, and $W1_{fatal} = 1.81$) and data set 2 ($W2_{injured} = 0.85$, $W2_{fatal} = 2.28$). Due to the fact that the pedestrian casualties in national data were coded as "injured" and "fatal," weighted data set 2 has only two weight factors.

2.2. Impact speed estimation

Vehicle travel speed refers to the vehicle speed without braking before the impact. *Vehicle impact speed* refers to the vehicle speed at the time of the car contacting with the pedestrian in an accident. The current study used four methods to estimate the vehicle impact speed.

The first method considered the skid mark available from accident investigations, in this case, the impact speed in km/h (v) can

Table 2
Distributions of pedestrian injury severities.

	Slight	Severe	Fatal
China (TABC, 2003–2007)	75.9%		24.1%
Changsha (2003–2007)	68.4%	12.4%	19.2%
IVAC data set (2003–2009)	41.3%	48.1%	10.6%