An In-Depth Study of Pedestrian Injuries in City Traffic Accidents

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Abstract：This study aimed at identifying the occurrence, type and mechanisms of the traumatic injuries of the pedestrians in the urban road vehicle collisions, and investigated the relation between human factor and engineering, environment factors, which formed a basis for improving pedestrian safety. The traffic accidents from 2000 to 2003 within urban area of Changsha, the capital of Hunan Province, were investigated in co-operation between Hunan University, Wujing Hospital in China and Chalmers University of Technology in Sweden. The 517 cases were collected from Wujing hospital of Changsha, of which 361 cases were vehicle-pedestrian crashes. Accident analysis was carried out on the original data of traffic accidents including the accident vehicle type, the pedestrian age group, gender, injuries location，treatment period, accident time distribution and injury severity and so on. Furthermore, the collected cases were analyzed with the information about the injury patterns, AIS, and the situation of heal based on hospital documentations. The results were discussed with regard to accident and injury characteristics of pedestrians. The factors influenced the injury outcomes were proposed and discussed in terms of vehicle transport environment and road users. The pedestrian accidents were identified as vital issue in urban traffic safety, and a high priority should be given to this issue to reduce the incidence and the severity of the accidents in an advanced urban transportation system.

keywords: Pedestrian，vulnerable road users, vehicle traffic accident，injury prevention

城区行人交通伤事故特点调查分析

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[摘要]：本文旨在研究长沙市城区行人车辆碰撞事故中行人损伤的发生特点、事故类型以及损伤机制，从而调查交通事故中行人、车辆以及环境三者之间的关系，提出改进行人交通安全的相应措施。事故数据来源于长沙市武警医院的原始医疗记录，事故调查在湖南大学、武警医院和瑞典查尔摩斯大学三方共同努力下合作完成。事故分析共收集 2000 年至 2003 年交通事故伤 517 例，其中 361 例为车辆行人碰撞。通过对行人的年龄分布、性别、损伤部位、治疗周期以及伤情严重程度、车辆类型、事故发生时间等进行统计分析，并对损伤严重程度按照国际标准进行 AIS 分级，确定了长沙市城区行人道路交通事故的发生特点以及规律。论文讨论了人、车、路、环境和管理等诸多影响行人安全的因素，由此可以看出，行人车辆碰撞事故已经是城区道路交通安全的一个首要问题，在建立完善的城区道路交通系统中应优先考虑控制和预防行人交通事故的发生，采取措施以减少行人损伤的严重程度。

[关键词]：行人，易受伤害道路使用者，车辆交通事故，损伤预防

1 Introduction

In China 106,367 road users are killed and 549,051 are injured in 2001, resulting in substantial economic losses due to fatalities and long-term consequences. The social cost was found as high as

湖南省自然科学基金资助项目-03JJY3009
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3090 millions RMB[1], which clearly demonstrates the urgent demand for preventive measures.

Pedestrians represent a high risk population since they are unprotected in vehicle impacts[2], they are one of the most vulnerable road users in city traffic. In the European Union (EU) more than 7,000 pedestrians are killed each year, about 3,000 in Japan, 5,000 in the USA, and about 25,000 pedestrians are killed in the traffic accidents each year recently in China[3]. Within the EU countries, the relative frequency of the pedestrian fatalities varies remarkably from 14% in Sweden to 32% in UK. Pedestrian protection is therefore a priority item in traffic safety strategies. For this reason the analysis of traffic accidents involving pedestrians and the measures for the reduction of accident consequences are of eminent importance.

Approaches to reducing pedestrian-motor vehicle collisions in urban areas have included engineering changes, driver and pedestrian education, and methods to alert drivers and pedestrians to one another's presence[4]. To assist countermeasure planning, it is useful to know the types of motor vehicle collisions that typically occur and the mechanisms resulting in the traumatic injuries of the pedestrians.

The first major study of pedestrian injury in the part of Changsha city began in 2001, the products of the original study was the primary analysis of the epidemiological characteristics of road traffic accidents in the city of Changsha, Hunan province, based on the 108 medical documents of traffic accidents collected from Wujing hospital in 2001. The weakness of that study was the data source utilized in the accident analysis was limited especially for pedestrian crash events, and the results partly reflects the real situations of pedestrian injury in the traffic accident. The objectives of this study today were to evaluate the crash patterns and occurrence rule more comprehensively based on the medical documents gathered from Wujing hospital from 2000 to 2003. The knowledge from the study will be a prerequisite for developing guidelines to improve pedestrian safety.

2 Method and Materials

Medical documents for fatal and non-fatal crashes involving a pedestrian from 2000 to 2003 were obtained from the Wujing hospital for the Changsha city. The Wujing hospital located in the central urban area of Changsha city and specialized in dealing with emergency cases of traffic accident in the urban area of Changsha city, which population is 6,133,000 and registered vehicle is 255,599 in 2000. Most crashes were non-fatal crashes, Only 0.9 % of the medical reports obtained were fatal crashes.

The relevant data was reviewed and analyzed through establishing database, which included the accident vehicle type, the pedestrian age group, gender, injuries location，treatment period, accident time distribution and injury severity and so on.

3 Results

3.1 Crash accident investigation

VULNERABLE ROAD USER — The Frequency distribution of injuries involved in the traffic accident of vulnerable road user was identified with collected samples. From the statistics analysis, pedestrian accidents formed a dominating part of all road traffic accidents. From 2000 to 2003, among 517 cases, 70 percent of pedestrians injuries having been involved in the road accident. Compared with the pedestrian injury, almost 19 percent of injuries were drivers, and 11 percent were occupants. Table 1 shows the trends by vulnerable road users for the data collected from 2000 to 2003. There were less pedestrian crashes, 54 % in 2003 and 69 % in 2000.

Table1: Distribution of vulnerable road users during 2000-2003

	2000		2001		2002		2003	
	number	%	number	%	number	%	number	%
Pedestrian	120	69 %	105	85 %	79	69 %	57	54 %
Driver	33	19 %	10	8 %	25	22 %	28	27 %
Occupant	21	12 %	8	7 %	11	9 %	20	19 %
Total	174	100 %	123	100 %	115	100 %	105	100 %

AGE DISTRIBUTION — Table 2 presents the results by pedestrian age involved in the traffic accident during 2000 to 2003. In the aggregate, pedestrian of the age group from 16 to 69 are the most frequently involved in traffic accidents. Of the 517 involved pedestrians, 88.4 percent of pedestrians are adults. For this age group, most of the pedestrians suffered moderate injury. For the age group from 0-15, the accidents are the first cause to induce their mortality and morbidity, and the following effects will disturb their whole life. With the involved children, the percentage is 7.8 %. For those older age group involved in the traffic accident, 3.8 percent are age 70 or older. We notice that for the older people, the probability of involving an accident is smaller than adults, but at the same time, their physical tolerance to the trauma is also lower than the adults, the risk of getting serious injury under the same crash accident situation will be higher than adults.

Table2: Distribution of pedestrian age involved in the traffic accident during 2000 to 2003

Age	Slight injury		Moderate injury		Serious injury	
	Number	%	Number	%	Number	%
0 ~ 15	6	7.2	19	7.7	3	9.7
16 ~ 69	73	88	219	88.7	27	87.1
70 ~	4	4.8	9	3.6	1	3.2
Total	83	100 %	247	100 %	31	100 %

GENDER — The analysis of gender reveals the always higher risks for the male pedestrians, which is true for the whole population as well as for the children. From the collected samples, we found that the wounded boy as pedestrian was 58 percent compared with the girls. For the adults, the male pedestrian are more likely than female pedestrians to be involved in, 72 % versus 28 %. The reason for the prevalence of the male pedestrians maybe is relevant to the higher frequency of their social and economic activities in daily life.

TIME DISTRIBUTION OF ACCIDENTS — They were a greater proportion of all crashes during winter months. From October to March, pedestrian vehicle crashes were 54 % of all crashes, compared with 46 % from April to September. The pedestrian crash accidents are most happened in March (11 %) and least took place in April and September. (7 % and 6.7 %). This feature of time distribution is not very clear by now and the influenced factors needed to be investigated in depth in later study.

VEHICLE TYPE — Of the 517 crashes studied, considering vehicle types involved in accidents, approximately 31 % of the accidents are pedestrian-car collisions and 59 % are motorcycle , then bicycle (7.7 %), lorry (1.5 %), tractor (0.9 %). (Fig.1.)

Considering the characteristics of the vehicle type distribution, we suppose there should attribute to the following reasons. According the statistical number in 2003, there are about 20,000,000 motorcycles running on the road in China. People have used it as a daily vehicle to engage various social and economic

activities, at the same time the traffic problems appeared, such as the speeding, driving outside the proper traffic lanes, failing to grant a pedestrian the right of way and so on.

At the same time, with the rapid economic and social development in China, more and more family can afford the private car. In 2003 in China, the private car has come to 4,890,000 and increased 1,460,000 than 2002. Compared ten years ago, today there are more car drivers, as opposed to pedestrians, and it is consistent with the vehicle type distribution in crash. Another reason is that the urban drivers may now be operating more aggressively, with less regard for traffic laws.

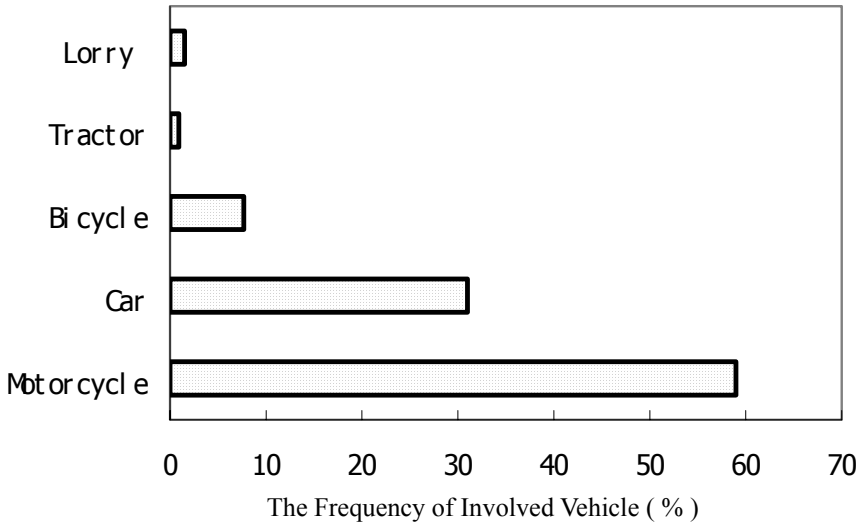

Fig.1 Frequency distribution of vehicle type in pedestrian accidents

ANALYSIS OF THE HOSPITAL STAY DURATION — For the different injury severity of pedestrian, the treatment period in the hospital is certainly various. As a rule, with the duration at the hospital longer, the treatment cost will be higher accordingly. Among the collected 361 injured pedestrians, the mean hospital stay is 19 days.

3.2 Injury situation

INJURY DISTRIBUTION ON THE BODY REGION — The analysis of the injury situation of pedestrian clearly shows that head and lower extremities injuries take priority, as far as frequency is concerned. This conclusion is not only suitable for the pedestrian children but also for the adults.

Among 28 pedestrian children, we note there are 18 head injuries and 10 lower extremities ones, upper extremities account for 7, chest and face injuries are 2 and 4, the least ones are neck and back injury, no one child was found being injured by this body region.

Of the 361 cases involved the pedestrian adults, 27.4 % sustained various degrees of head injuries. Lower extremities injuries accounted for 27.5 % of all reported injuries, and upper extremities 8.3 %. The upper extremities seems for children with 14 percent especially exposed to injury risk, when compared with a proportion of 8.3 percent for adults. In adult pedestrian accidents skin injuries also took a significant proportion of 9.2 % of all injuries. Chest injuries were found in 7.2 %, however the neck injuries were relatively rare, in 0.4 %.

The distribution of injury frequency by body regions shows the head and lower extremities were found to be the most frequently injured. All other body regions are much lower in injury frequency

and reveal nearly little difference between children and adults.

Table 3: Injury distribution on the body region

	Children (0-15)		Adult (>16)	
	Number	%	Number	%
Head	18	36 %	185	27.4 %
Lower Extremities	10	20 %	186	27.5 %
Upper Extremities	7	14 %	56	8.3 %
Face	4	8 %	24	3.6 %
Chest	2	4 %	49	7.2 %
Pelvis	2	4 %	37	5.5 %
Abdomen	1	2 %	13	1.9 %
Neck	0	0 %	3	0.4 %
Skin	3	6 %	62	9.2 %
Back	0	0 %	4	0.6 %
Others	3	6 %	57	8.4 %
Total	50	100 %	676	100 %

INJURY SEVERITY OF BODY REGIONS — The injury severity was evaluated in accordance with AIS[5]. The overall injury severity classified with AIS code is summarized in Table 5. Among 361 pedestrians, we notice that 25.9 % of the cases with AIS 1 injuries and 62.7 % with AIS 2 injuries are presented, the AIS 3-4 injured pedestrians are 9.6 %, the AIS 5-6 is 1.9 %. From the results, it was found that in road vehicle accidents the pedestrians encounter for always the slight injury, risks of involving in a fatal injury are lower. In 9 of the 517 cases, the fatal pedestrian crashes are determined. The injury severities analysis also reveals a higher incidence of lower extremities injuries and head injuries in non-fatal injury. Among 9 samples with AIS 5-6 injury, it was found that the head injury was most frequent (64.3 %).

Table 4: The valuation of the severity is defined by the AIS[6].

AIS	Severity code
0	No injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury (Virtually unsurvivable)
9	unknown

Table 5: Injury severity on the body region

Body regison	Injury severity							
	AIS 1		AIS 2		AIS 3-4		AIS 5-6	
	N	%	N	%	N	%	N	%
Head	54	28.6	118	25.8	23	32.9	9	64.3
Lower Extremities	34	18.0	143	31.2	19	27.1	0	0
Upper Extremities	21	11.1	35	7.6	6	8.6	1	7.1
Face	23	12.2	21	4.6	4	5.7	1	7.1
Chest	8	4.2	39	8.5	2	2.9	2	14.3
Pelvis	7	3.7	30	6.6	4	5.7	0	0
Abdomen	3	1.6	6	1.3	4	5.7	1	7.1
Neck	0	0	2	0.4	1	1.4	0	0
Skin	32	16.9	27	5.9	6	8.6	0	0
Back	2	1.0	4	0.8	0	0	0	0
Others	5	2.6	33	7.2	1	1.4	0	0
Total	189	100%	458	100%	70	100%	14	100%

（N is the summary number of injured body segment）

(% is the summary number of injured body segment / the collected total samples)

From the clinical documentation of the Wujng hospital we noted that the dominating head injury patterns are skull fractures and brain injuries, including cerebral concussion, lacerations, contusion, and intracranical hematoma. The common thorax injury patterns are rib fractures with hemoth and pneumoth. The leg injuries are more frequent than upper thigh fractures including the toe, tibia, fibula fracture. The pelvis injuries are parenchyma contusion.

4 Discussion

In 2003, the vehicle traffic accidents is 667,507 and an estimated 494,174 are injured on roads in China. Everyday there are 300 persons died from the traffic accidents. The annually fatalities increased from 50,000 in 1990 to 104,372 in 2003. The road traffic authority made large efforts to control incidence of the accidents, but the tendency of the accident growth is still a critical issue in China[7]. According to the statistical number, in the traffic accidents two thirds of drivers are to be judged culpable in the crash. Particularly the fatalities of vulnerable formed the main proportion of all reported fatalities, three fourths of fatalities are pedestrian、occupants and bicyclers.

The present study is based upon an analysis of 517 accidents from 2000 to 2003 in urban area of Changsha, the capital of Hunan province. The evaluation method was described and the available data were analyzed.

It was found that the present results are quite comparable with results from studies by other researchers. For instance, the pedestrian accident is a common problem in both motorized countries

and motorizing countries, which occur frequently in city build up area.

Pedestrian accident analyses have been conducted worldwide in the past four decades [8-13]. Pedestrian impact conditions and injury outcomes were identified from these studies. The findings of the distribution of pedestrian injuries to different body segments are compared between the results from this study and results from published studies by other researchers worldwide as presented in Table 6. It shows the distribution of injuries by body regions. As a common tendency, the head and the lower extremities have been found to be the most frequently injured body regions.

Table 6: Comparison of percentage distribution of pedestrian injuries by body region

Body region	China (Changsha)	Europe	Australia	Japan	USA
	(%)	(%)	(%)	(%)	(%)
Head	30.7	29.8	39.3	28.6	32.7
Face	4.2	5.3	3.7	2.4	3.7
Neck	0.5	1.8	3.1	4.5	0.0
Chest	7.7	11.6	10.4	8.5	9.5
Abdomen	2.5	3.8	4.9	4.8	7.7
Pelvis	5.9	7.9	4.9	4.5	5.3
Upper extremities	9.5	8.1	8.0	9.0	7.9
Lower extremities	30	31.3	25.8	37.2	33.3
Unkown	9.0	0.5	0.0	2.1	0.0
Total	100	100	100	100	100

Involvement of vehicles in pedestrian accidents in Changsha indicated that motorcycle are most frequently involved in vehicle pedestrian accident. 59 % of the pedestrian accidents are caused by motorcycle collisions (Fig.2), and 31 % passenger cars, 7.7 % bicycle, and 1.5 % lorry. In the EU countries, the number of pedestrian struck by passenger cars is around 60 % to 80 % of the reported vehicle pedestrian accidents[14], and 56% of the reported pedestrian accidents are caused by passenger cars in the USA. Due to the difference of involved vehicles from country to country, the priority of safety countermeasures should be given considering the frequency of involved vehicles[15-18].

The age distribution data (Table 2) indicated that adults (88 %) formed main part of injured pedestrians, elderly adults 4 %, and children 8 %. The finding of the frequency in age distribution is quite different from that in other motorized countries. Child pedestrian accidents accounted for 25.3% in the USA, 33.1% in Europe, and 34.2 in Japan. A further study is needed to identify the factors which affect the different results.

With the implement of the new road traffic safety rule on the May 1, 2004, the pedestrian traffic safety is given more guarantees than before. These countermeasures include that the motor vehicle should slow down when passing the crosswalk; the driver should stop and give the way to pedestrian when encountering the pedestrian crossing crosswalk; on encountering the pedestrian crossing the road without signalized light, the drivers should first grant the pedestrian's right of way. The prescript in the new rule is the important adjustment about the right of way in the traffic conflict between the motor vehicle and pedestrian, embody the respect for the life and health.

5 Conclusions

Pedestrian accidents represent a high risk to unprotected road users, and therefore a high priority should be given to this road user group in research of safe urban transportation.

The correlation of gender with accident risks is confirmed. About over two thirds of injured pedestrians are male pedestrians. The risk of injuries faced by males is much higher than females.

In urban area of Changsha, motorcycles are most frequently involved in vehicle pedestrian accidents in 59 % of the pedestrian accidents, 31 % passenger cars, 7.7 % bicycle, 1.5 % lorry and 0.9 % tractor.

Head and lower extremities injuries are the predominant types of pedestrian injuries. Chest and upper extremities were frequent injured, then followed by pelvis injuries, whereas injuries to abdomen and neck were relatively infrequent. It is necessary to give the priority of injury prevention to the head and lower extremities.

It is clear that head injury patterns are skull fractures and brain injuries, the thorax injury patterns are rib fractures with hemoth and pneumoth, the leg injury pattern are fracture of toe, tibia and fibula. The pelvis injuries are parenchyma contusion.

6 Acknowledgment

The author would like to thank WeiQiang Li and Zhi Zhao of the Wujing hospital for their contributions to this study. This work was supported by the project of Hunan province nature science fund.

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