Qiuju Chen, Qinghang Luo, Tao Xiong, Yong Zhang, Jia Yu, Jingyu Xv, Shengxiong Liu.
Pedestrian-vehicle collision posture analysis based on pedestrian lower limb injuries. Forensic Sci Sem, 2024, 14(1): 1-4.

Peer Reviewed
Received 11 October 2024
Received in revised form 16 November 2024
Accepted 20 November 2024
Available online 22 December 2024

Forensic Science Seminar
ISSN 2157-118X
Volume 14 Number 1
22 December 2024

Pedestrian-Vehicle Collision Posture Analysis Based on Pedestrian Lower Limb Injuries

Qiuju Chen [a, #], Qinghang Luo [a, #], Tao Xiong [a, #], Yong Zhang [b], Jia Yu [a], Jingyu Xv [a], *Assoc. Prof.*, Shengxiong Liu, *Ph.D.* [a, b, *]

[a] College of Pharmacy and Biological Engineering, Chongqing University of Technology, Chongqing 400054, China.
[b] Chongqing Anxin Institute Forensic Science, Chongqing 400054, China.

* CORRESPONDING AUTHOR. *Assoc. Prof.*, Shengxiong Liu, *Ph.D.* (E-mail: shengxiongliu@cqut.edu.cn).

# These authors contributed to the work equally and should be regarded as co-first authors.(Qiuju Chen, Qinghang Luo, Tao Xiong)

ABSTRACT This study examines the role of pedestrian lower limb injury characteristics in analyzing collision postures in traffic accidents. A real case of a pedestrian-vehicle collision involving typical pedestrian injuries is selected, and the pedestrian's posture at the moment of collision is comprehensively analyzed using lower limb injury characteristics, traffic accident traces, and findings from the autopsy report on brain injuries. The results indicate that relying solely on the surface characteristics of lower limb injuries to determine the collision direction may lead to erroneous conclusions. While the analysis of lower limb surface injuries is of significant practical value for reconstructing accident processes and determining responsibility in road traffic accidents, it also provides important reference value for improving pedestrian lower limb safety. However, analyzing pedestrian collision postures based on lower limb injuries is a complex and challenging task. It requires the integration of multiple factors and information for thorough analysis and research.

KEY WORDS Traffic Accident; Lower Limb Injury; Collision Posture; Traffic Safety

1. INTRODUCTION

With the rapid development of China's automobile and transportation industries, the total number of road traffic accidents and damage compensation cases has risen significantly. Among these, pedestrian-vehicle collisions occur more frequently than other types of accidents [1-2]. According to the World Health Organization (WHO) Global Road Traffic Safety Report 2023, global road traffic deaths in 2021 reached 1.19 million, with pedestrians accounting for 23% of fatalities. The global macroeconomic cost of road traffic injuries is estimated at $1.8 trillion, representing approximately 10-12% of global GDP [3]. Road traffic accidents not only endanger tens of millions of lives but also cause substantial public and private property losses, making them a critical safety issue.

Pedestrians are particularly vulnerable to severe injuries and fatalities in traffic accidents. Such incidents are often caused by driver error, vehicle performance issues, or unsafe pedestrian crossing behaviors [4-6]. Consequently, pedestrian-vehicle collisions have become a focal point in traffic safety discussions. Ann Mallory et al. [7] analyzed over 160,000 adult pedestrian injuries from the US National Trauma Database (2007–2016) and found that lower limb injuries accounted for 44% of cases, second only to head injuries (48.6%). Similarly, Duan Aowen et al. [8] investigated 2,131 traffic accidents in a region of China (2013–2018) and concluded that the head was the most frequently injured area in pedestrian-vehicle collisions, followed by the lower limbs, chest, and abdomen. These findings highlight the significant risk of lower limb injuries in pedestrian accidents.

Pedestrian lower limb injuries include femoral fractures, knee ligament tears, tibial fractures, ankle joint injuries, and soft tissue damage [9]. Although rarely fatal, such injuries can require extended recovery periods, lead to lifelong disabilities, and impose significant social and economic burdens. In legal assessments of road traffic accidents, pedestrian behavior at the time of the accident often serves as a critical factor in determining liability. Lower limb injuries are frequently analyzed to deduce pedestrian posture during a collision, as the lower limbs are typically the first point of contact with the vehicle's front bumper or hood. Higher vehicle speeds result in greater stress on the legs, leading to more severe injuries [10-11].

Currently, the judicial identification of pedestrian-vehicle collisions includes forensic assessments and comprehensive analyses of traffic accident trace evidence [12]. Pedestrian posture analysis is crucial in determining accident liability. For instance, if a pedestrian is suddenly struck from the right

Qiuju Chen, Qinghang Luo, Tao Xiong, Yong Zhang, Jia Yu, Jingyu Xv, Shengxiong Liu.
Pedestrian-vehicle collision posture analysis based on pedestrian lower limb injuries. Forensic Sci Sem, 2024, 14(1): 1-4.

side of a vehicle's path, delayed driver reaction typically results in a collision, with the driver bearing less responsibility than in other scenarios.

This paper examines pedestrian lower limb injuries from multiple perspectives to analyze collision postures. It explores the role of lower limb injury characteristics in traffic accident analysis, providing a reference for future investigations and liability assessments in pedestrian-vehicle collisions.

2. TRAFFIC ACCIDENT CASES

2.1 Traffic Accident

A car-pedestrian accident occurred in Chongqing, China, on a specific day. After the accident, the car came to a stop in the right lane of the road running from east to west, with its front facing east and rear facing west. The pedestrian was ultimately located in the left lane of the road running from west to east, with their head positioned near the central double yellow line and their feet oriented toward the edge of the road. The scene of the traffic accident is depicted in Figure 1.

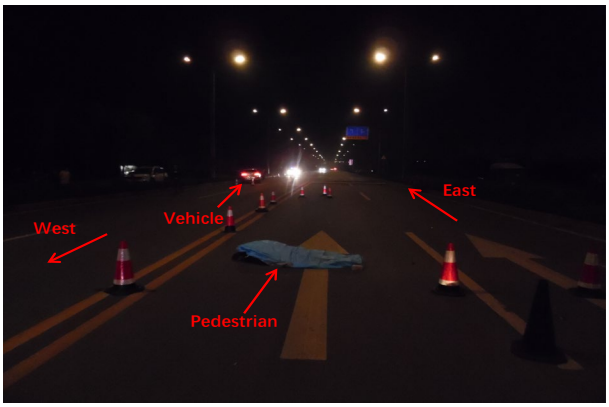

Fig.1 Traffic accident scene drawing

2.2 Trace Inspection

The collision between the vehicle and the pedestrian generated various traces, as illustrated in Figure 2. Multiple contact traces were observed on the vehicle body, primarily concentrated on the windshield, hood, and front bumper. A wide circular area of damage was present on the front windshield, accompanied by visible hair residues at the fractured region. Additionally, the hood displayed a large area of concave deformation.

2.3 Forensic Laboratory Examination

The autopsy revealed several injuries sustained by the pedestrian. A wound was observed below the left lateral malleolus, accompanied by subcutaneous hemorrhaging on the outer side of the right calf. There was also a wound on the inner side of the right knee. The injured person exhibited prominent wounds on the right side of the forehead, while the left side showed no significant injuries.

Specific injuries included a 5.2 cm × 1.6 cm irregular tear extending into the tendon below the left lateral malleolus, and a 3.9 cm × 1.5 cm irregular tear extending into the tibia below the right knee. The corresponding tibia and fibula exhibited comminuted fractures consistent with the site of the wounds, forming pseudoarthrosis.

The head injuries are shown in Figure 3, while the lower limb injuries are depicted in Figure 4.

(a) Car body marks

(b) The front of the vehicle

Fig.2 Traces of accident car body

(a) the injury of the right head of the injured

(b) the injury of the left head of the injured

Fig.3 Head injury of the injured

(a) Left lateral malleolus injury

(b) Right knee injury

(c) Lower limb injury

Fig.4 Lower limb injury of the injured

3. CASE STUDY OF TRAFFIC ACCIDENTS

The posture of a pedestrian in a traffic accident was analyzed based on the injuries to their lower limbs. Initial observations of wounds below the pedestrian's right knee and left lateral malleolus suggested that the pedestrian's left side was impacted, indicating they moved from the vehicle's right to its left during the collision.

However, further analysis of vehicle traces and head injuries revealed additional insights. The injury on the right side of the pedestrian's forehead was caused by contact with the front windshield. The irregular crack observed below the right knee, located in a concave area of the body surface, was unlikely to result from ground contact. According to the autopsy report, the fracture of the tibia and fibula at the injury site, coupled with the formation of pseudoarthrosis, indicated that the wound was caused by puncture from the fractured ends of these bones. The irregular fissure below the left lateral malleolus, a convex area of the body surface, was likely caused by contact with the ground after the pedestrian's right side was struck.

A comprehensive analysis of the site investigation, vehicle trace inspection, and autopsy findings concluded that the pedestrian was struck on the right side of their body, moving from the vehicle's left to its right. This conclusion aligns more closely with the evidence from the scene.

4. DISCUSSION

Traffic accidents are typically rapid and violent events. When the biomechanical response of the human body exceeds the tolerance limit of tissues due to mechanical external forces, injuries occur, leading to functional changes or damage. In cases involving diverse injuries and complex mechanisms, analyzing injury patterns becomes critical for understanding traffic behaviors, determining causes of death, and assigning liability.

While surface injuries to a pedestrian's lower limbs can provide clues to their posture at the time of collision, such evidence alone is often insufficient. Lower limb injuries are influenced by multiple factors, including vehicle speed, type, impact location, pedestrian posture, and direction of travel. During a collision, initial contact typically occurs between the vehicle bumper and the pedestrian's leg or knee joint, followed by contact between the thigh and the vehicle's hood edge [13]. Greater body weight increases inertia, resulting in prolonged contact time and higher impact forces on the lower limbs. Studies also show that higher impact speeds result in greater energy transfer and more severe lower limb injuries. Additionally, older and heavier pedestrians are more likely to sustain AIS2+ lower limb injuries [14-15].

A common characteristic of lower limb injuries in pedestrian-vehicle collisions is wedge fractures, caused by bending deformation of the bones due to compressive stress on the impact side and tensile stress on the opposite side. The apex of the wedge indicates the direction of the force and, consequently, the direction of the impact [16]. However,

wedge fractures are not always present, necessitating the use of additional evidence to comprehensively analyze pedestrian-vehicle contact postures.

In this case, the irregular crack observed from the right knee to the tibia, combined with autopsy findings, indicated that the injury was caused by puncture from the tibia and fibula fracture ends. A comprehensive analysis of vehicle traces and the pedestrian's head injury supported the conclusion that the pedestrian moved from the left side of the vehicle's driving direction to the right. Lower limb injuries vary based on the specifics of each collision, and surface injuries alone should not be used to determine collision posture. Instead, lower limb surface injuries should be analyzed alongside fracture patterns and injuries to other parts of the body for a more accurate assessment.

5. CONCLUSION

Practical cases demonstrate that analyzing pedestrian posture in pedestrian-vehicle collisions based solely on lower limb surface injuries is insufficient. A more thorough analysis requires integrating field investigation results, vehicle trace inspections, injury identification reports, and other relevant materials. A multi-angle, comprehensive approach allows for a more accurate and detailed understanding of pedestrian posture during the collision.

The analysis of pedestrian collision posture and movement in pedestrian-vehicle accidents is a complex and challenging task requiring consideration of multiple factors and information sources. This paper provides valuable practical references for the analysis of pedestrian posture and behavior in similar pedestrian-vehicle collision accidents.

ACKNOWLEDGMENTS

Supported by the National Key Research and Development Program of China (2016YFC0800702). The authors would like to acknowledge the constructive comments given by the anonymous reviewers.

REFERENCES

[1] ZHANG DW, LEI Y, REN Y, et al. Pedestrian lower limb dynamic response and injury biomechanical analysis based on pedestrian-vehicle collision accident reconstruction[J]. Journal of Automotive Safety and Energy, 2023, 14(06): 671-680.
[2] XIA B, YIN ZY, LIU SX, et al. Theoretical Analysis of Velocity Calculation Based on the Final Position of Human and Vehicle Collision[J]. journal of Chongqing University of Technology(Natural Science), 2018, 32(02): 38-45.
[3] World Health Organization. Global status report on road safety 2023. Geneva: World Health Organization, 2023.
[4] MAO YP, YU FQ, SUN YY, et al. Road Traffic Accident Data Mining and Application[J]. traffic & transportation, 2020, 33(S2): 106-111.
[5] ZHANG YL, JIANG C. Analysis of the causes and effective prevention of urban road traffic accidents[J]. People's Public Transportation, 2021, (06): 64-68.
[6] XIE JR, LIU SX, MING JX, et al. Design and construction of rotating crash experimental platform[J]. Chinese Journal of Medical Physics, 2018, 35(2): 201-204.
[7] Ann M, Rakshit R, Abby V, et al. Pedestrian injuries in the United States: Shifting injury patterns with the introduction of pedestrian protection into the passenger vehicle fleet[J]. Traffic injury prevention, 2024, 25(3): 1-9.
[8] Aowen D , Mingxia Z, Jinlong Q , et al. A 6-year survey of road traffic accidents in Southwest China: Emphasis on traumatic brain injury[J]. Journal of Safety Research, 2020, 73: 161-169.
[9] WANG MM. Study on the Vehicle-Pedestrian Collision Accident Reconstruction and Pedestrian Head Injury [D]. CHANG'an University, 2021.
[10] Yang J. Review of Injury Biomechanics in car-pedestrian collisions[J]. International Journal of Vehicle Safety, 2005, 1(1-3): 100-117.
[11] FAN XX, LI K, LIU SX, et al. Analysis of Lower Extremity Injuries Reconstruction in Car-Pedestrian Traffic Accident[J]. journal of Chongqing University of Technology(Natural Science), 2015, 29(02): 24-29.
[12] JIANG ZF, ZOU DH, ZHAO MH, et al. The Combined Application of Trace Science and Forensic Medicine in the Identification of Multi-vehicle Accidents[J]. Chinese Journal of Forensic Sciences, 2021, (06): 96-102.
[13] ZOU TF, LIU ZQ, WANG DQ. Research progress of pedestrian-ground contact injuries in pedestrian-vehicle collision accident[J]. Journal of Changsha University of Science & Technology (Natural Science), 2024, 21(3): 116-133.
[14] Wang B, Wang F, Otte D , et al. Effects of passenger car front profile and human factors on pedestrian lower extremity injury risk using German in-depth accident data[J].International Journal of Crashworthiness, 2019, 24(2): 163-170.
[15] LIU YT, ZHANG HC, YUAN SQ, et al. Research on traffic accident injury causation of elderly pedestrian based on FP-growth[J]. JOURNAL OF SAFETY SCIENCE AND TECHNOLOGY, 2024, 20(6): 176-182.
[16] Min Jianxiong. Forensic injury[M].People's Public Security University of China Press, 2010.

Conflicts of interests
None declared.