Rider Injuries in Sport Utility Vehicle to Powered Two-Wheeler Crashes in India

Aarti Ranmal, Nils Lubbe

Abstract Powered Two-Wheelers (PTWs) are a widely used mode of transport in India and are frequently involved in road traffic crashes. This study examines Sport Utility Vehicle (SUV)-to-PTW crashes using data from the latest Indian crash database, with the goal of assessing injuries sustained by PTW riders and the injury-causing contacts in SUV-to-PTW crashes. We analysed 87 SUV-to-PTW crashes, involving 131 PTW riders, from the Road Accident Sampling System India (RASSI) crash database. The head was identified as the most frequently and severely injured body region, primarily due to impacts with the windshield, A-pillar, and roof-rail of the SUV. These frequent and serious impacts should be prioritized in developing protection measures. The use of helmets and other protective gear by PTW riders, and pedestrian protection airbags installed in SUVs, might be viable countermeasures to substantially reduce injuries in SUV-to-PTW crashes in India.

Keywords Injury analysis, motorcycle, pedestrian protection airbag, sport utility vehicle, vulnerable road user.

I. INTRODUCTION

Globally, powered two- and three-wheeler (PTW/P3W) riders account for 30% of the 1.19 million road traffic deaths in 2021 [1]. In India alone, over 150,000 people lose their lives in road traffic crashes every year, with 45% of them being PTW/P3W users [2]. Powered two-wheeler (PTW) users comprised 40% of total crash fatalities in 2021 on National Highways in India [3]. Cars are the most frequent collision partners in PTW crashes, and head-on collisions are the most common crash scenario [3]. Impacts with Sport Utility Vehicle (SUV) often result in severe injuries due to the size and mass disparity between the vehicles. Studies from the US found higher injury risks for pedestrians and cyclists when crashing with SUVs compared to other passenger cars [4-6]. This is also true for PTW riders [7]. The large size, weight, and elevated design of SUVs pose a particular risk to PTW riders in collisions.

Six critical areas for improving road safety in India were identified in [8], with specific countermeasures proposed to enhance safety for vulnerable road users (VRUs). One recommendation involves improving vehicle front-end design to be more VRU-friendly. Tall and blunt, tall and sloped, medium-height and blunt vehicle front ends increase pedestrian fatality risks by 43.6%, 45.4%, and 25.6%, respectively, compared to low and sloped front ends [5]. A bicycle-to-car crash study identified that SUV crashes inflict more severe head injuries on bicyclists compared with small car crashes and that SUVs are disproportionately likely to throw bicyclists to the ground and run them over [4]. In contrast, a study analysing pedestrian injuries from cars and SUVs suggests that the elevated danger to pedestrians from SUVs is largely related to injuries caused by impacts with the vehicle's leading edge, i.e., the bumper, grille and headlights, and not from the ground [9]. Even after controlling pre-impact speed, pedestrian age, gender, and weight, SUVs cause significantly more severe pedestrian injuries than cars [9].

Currently, there is no regulation or rating in India to test the PTW-friendliness of SUVs in the case of a crash scenario. The absence of PTW-specific testing standards limits the promotion and adoption of countermeasures tailored to reduce injuries among PTW riders during such crashes. The first step in this direction is to design effective assessment methodologies and to define crash conditions for developing appropriate countermeasures. Hence, the objective of this study is to analyse the Indian crash database RASSI (Road Accident Sampling System India) to describe PTW rider injuries and injury-causing contacts in SUV-to-PTW crashes.

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II. METHODS

The RASSI database was initiated by JP Research India and is being developed by an international consortium of automobile manufacturers and suppliers. Trained crash investigators are sent to the crash scene if the crash involves at least one motorised vehicle and the accident scene is on a public road in one of the sample regions (Coimbatore, Pune, Ahmedabad, Kolkata, Jaipur, Nagpur, and Dehradun). The database includes information on the accident, vehicle, occupant, and injury factors associated with each crash and also reconstruction files wherever possible [10].

Field data

The RASSI database was queried for the period 2014–2023. The data sample includes SUV-to-PTW crashes where the model year of the SUV is 2010 and later. The most harmful collision for PTW was considered. The impact location was defined based on the general area of damage. Detailed inclusion criteria are shown in Fig. A1 in the Appendix. The Abbreviated Injury Scale (AIS), 2008 revision [11], was used to classify each injury by body region according to its related severity on a 6-point scale, where 1=minor and 6=maximal. Filtering RASSI for all types of SUV-to-PTW crashes returned 87 crashes, 131 PTW riders and pillion riders sustaining 707 injuries of all types and severity. Of these, 264 were AIS2+ injuries.

Data weighting

To make RASSI data representative of Indian national data, the weighting factors provided in the database (INDIAWEIGHT) [12] were used and capped at 5000. In the analysis, all percentage numbers are from weighted data. Sample size counts are provided for both unweighted and weighted (shown in parentheses) data.

Detailed injury analysis

The distribution of all injuries may be misleading since one body region can have multiple injuries of the same AIS severity. To avoid multiple counts, in the final sample, instead of injuries, we counted injured body regions for each AIS severity. For example, if the rider had sustained two head injuries with AIS severity 2, we considered only one AIS2 head injury. The detailed distribution of the most frequent injury-causing source is shown to determine the exact location of the rider impact on the SUV.

III. RESULTS

PTWs impacting the front of the SUV was the most frequent (76%). As shown in Fig. 1, in 40% of cases the SUV front impacted the side of the PTW, and in 28% of cases the SUV front impacted the front of the PTW. The delta-V of the PTW was less than 50 km/h in 77% of the crashes (Fig. A2, Appendix). PTW with engine size less than 125 cc were common (59%). Of all the PTW riders, 59% were riders operating the controls and 40% were pillion riders. The majority of riders were male (95%) and did not use a helmet (85%). Of the riders, 67% were seriously and fatally injured.

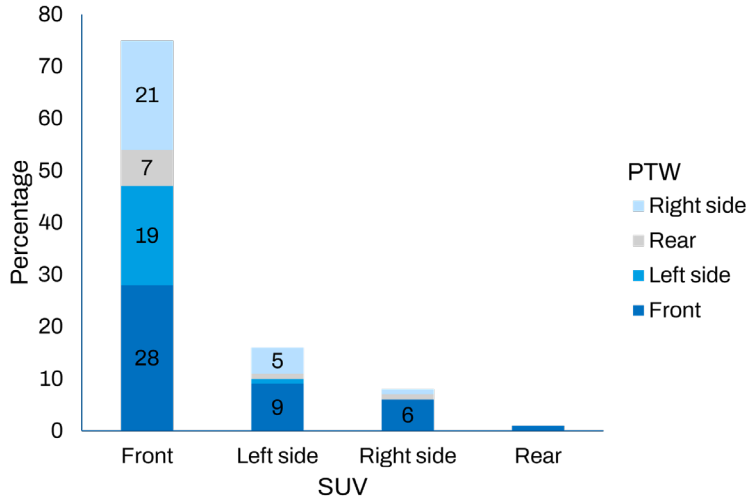

Fig. 1. Distribution of general area of damage, n=87 (10,932).

Counting one injury for each body region led to 391 (41,970) total injured body regions and 178 (16,086) AIS2+ injured body regions. As depicted in Fig. 2, lower extremities, head, and upper extremities were the most frequently AIS2+ injured body regions. Figure 3 shows that the SUV front is the most frequent injury source for AIS2+ injuries among PTW riders. As shown in Table I, the most frequent lower extremity and head injuries are caused by contact with the front of the SUV.

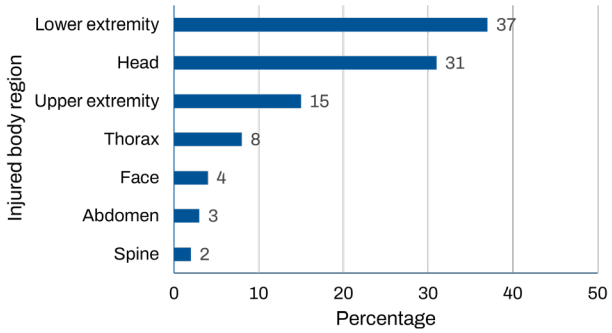

Fig. 2. AIS2+ injured body region distribution of PTW riders, n=178 (16,086).

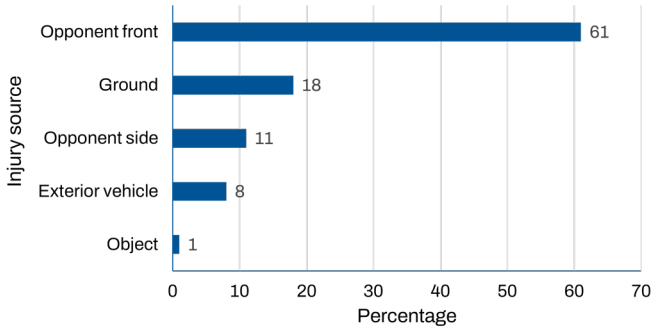

Fig. 3. Injury source distribution of AIS2+ injuries sustained by PTW riders, n=178 (16,086).

TABLE I
DISTRIBUTION OF INJURY SOURCE AND INJURED BODY REGION (AIS2+ INJURIES)

Injury region	Ground	Exterior of PTW	Object	Opponent front	Opponent side	Total
Lower extremity	4%	7%	-	21%	6%	**38%**
Head	6%	-	2%	21%	1%	**30%**
Upper extremity	4%	-	-	8%	3%	**15%**
Thorax	2%	2%	-	4%	-	**8%**
Face	-	-	-	3%	-	**4%**
Abdomen	1%	-	-	2%	-	**3%**
Spine	-	-	-	1%	-	**2%**
Total	**18%**	**9%**	**2%**	**60%**	**11%**	**100%**

Focusing solely on the SUV front as a source of injury, the windshield and bumper are the primary causes of AIS2+ injuries for PTW riders. The front bumper and hood are responsible for most lower extremity injuries. Head and face injuries are caused by contacting the windshield and hood, as shown in Fig. 4.

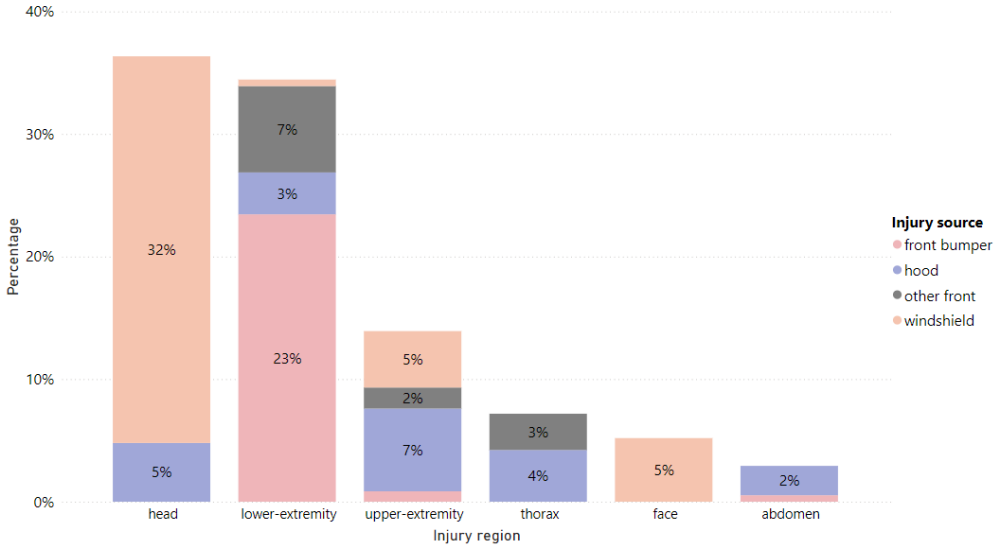

Fig. 4. Most frequent AIS2+ injured body regions when injury source is SUV front, n=103 (9,813).

The sources of the most severe and critical AIS5 and AIS6 head injuries are coded in the database as windshield, roof-rail, and A-pillar under a single classification (code 506). As a result, it was initially unclear which specific contact point contributed to these injuries. A detailed review of case photographs revealed that the primary head contact areas associated with these severe and critical injuries were predominantly the roof-rail and the A-pillar frame surrounding the windshield. The contact area is depicted in Fig. A3 in the Appendix.

IV. DISCUSSION

The objective of this study was to analyse the Indian crash database to describe PTW rider injuries and injury-causing contacts in PTW-to-SUV crashes. The results from the analysis show that PTW impact with the SUV front is the most frequent contact. The majority of the riders are not helmeted and this finding is in line with [3], where low helmet usage is a significant cause of sustaining head injuries in PTW riders. Fatally and seriously injured riders account for 67% of all riders. The most frequently injured body regions with AIS2+ severity are the lower extremity, head, and the upper extremity. The main injury source for these injuries is SUV front, including windshield, roof-rail, A-pillar, hood, and ground contact. Similar results were observed in [13], but in that study SUVs were excluded from the analysis and cars were included without SUVs.

India currently lacks regulations or assessment programs to evaluate the crash compatibility of SUVs with PTW. The absence of PTW-specific testing standards hinders the development and implementation of countermeasures aimed at mitigating injuries to PTW riders in such crashes. The first step in this direction is to design assessments effectively. This analysis suggests that PTW side impact followed by head-on impact with the SUV should be assessed. In addition, mitigating lower extremities and head injuries should be prioritised while developing the SUV-to-PTW crash test scenario. Further research is needed to make SUV front-end design PTW-friendly.

The opponent front was the source of the most AIS2+ injuries to the PTW riders, followed by ground contact. Since 85% of the riders were unhelmeted, helmet usage can be a solution to mitigate head injuries. As shown in [3], serious injuries still occur even when the rider is helmeted, which indicates that riders must be educated and encouraged to use the good quality and certified helmets and instructed how to use them properly. The most frequently occurring lower extremity injuries caused by contact with the SUV hood can be mitigated by using protective gear. In addition, pedestrian protection airbags, originally designed to protect pedestrians during collisions with the front of car, might have the potential to be adapted as a safety feature for PTW riders. These airbags deploy externally from the car, often from the hood or windshield area, creating a cushioning barrier between the PTW rider and the SUV. In the context of SUV-to-PTW crashes, this airbag system could mitigate the severity of injuries by reducing the direct impact forces on the PTW rider.

This study focused on analysing crash configurations, injury patterns, and injury sources for PTWs involved in collisions with SUVs. Future research should examine the effects of factors such as rider age, sex, impact speed, collision dynamics, and PTW body type. These insights would support the development of a comprehensive crash test methodology to enhance the safety of PTW riders.

V. CONCLUSION

The study identified that AIS2+ head and lower extremity injuries sustained by PTW riders were the most frequent injuries in SUV-to-PTW crashes. The most severe head injuries were caused by the rider's head impacting the A-pillar on the front of the SUV's windshield. Helmet use, protective gear for PTW riders, and pedestrian protection airbags in SUVs could be viable countermeasures to mitigate these injuries.

VI. REFERENCES

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VII. APPENDIX

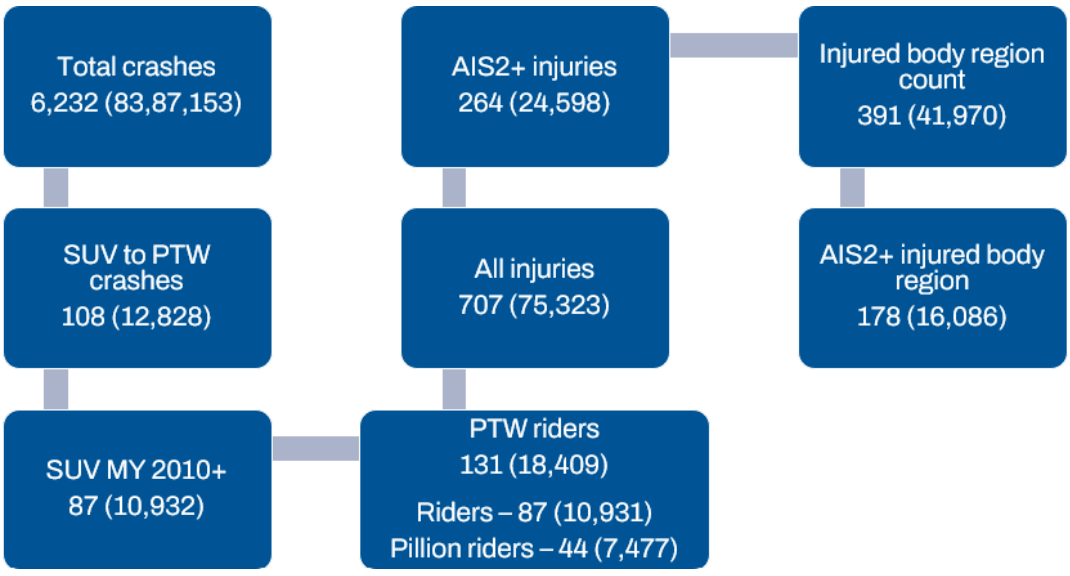

Fig. A1. Detailed inclusion criteria for field data analysis.

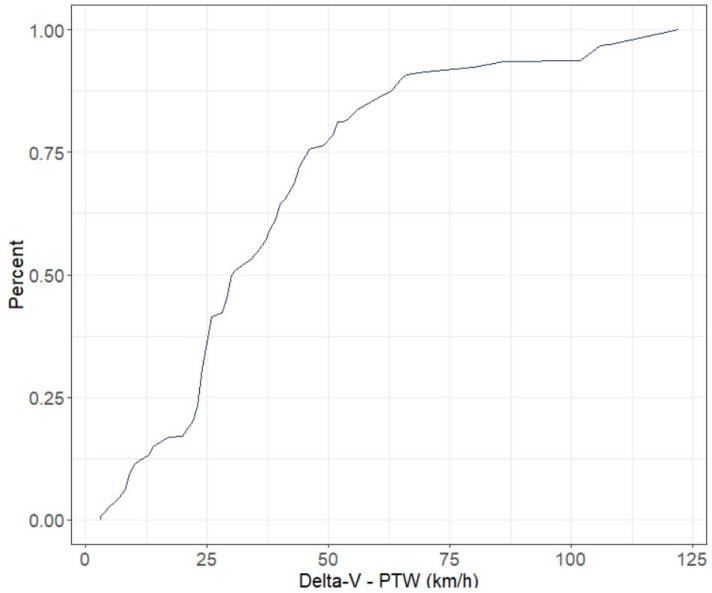

Fig. A2. Delta-V distribution for PTW, n=80 (10,654).

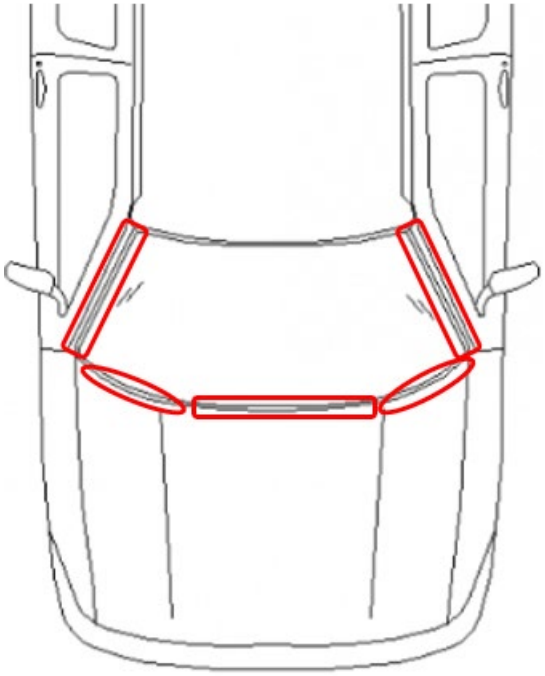

Fig. A3. Head contact area for the severe and critical head injuries.