Rider Injuries in Frequent Crash Scenarios of Powered Two-Wheeler to Heavy Vehicle in India

Aarti Ranmal, Pradeep Puthan

I. INTRODUCTION

The global share of fatalities among powered-two and three-wheeled (PTW and P3W) users increased by 30% since 2010 [1]. In India, the most common collision partners in crashes where the riders were fatally and seriously injured, were trucks. Among all the crash scenarios, PTW head-on collision with the truck was the most frequent [2]. Previous investigations of PTW rider crash kinematics have often use multi-body simulations or Anthropometric Test Devices (ATDs), commonly referred to as crash test dummies [3]. Despite their use in crash testing, ATDs like MATDs (The Motorcyclist ATD) have limitations affecting their biofidelity as models for PTW riders [4][5]. Incorporating softer front ends and underride protection in trucks and buses will help reduce fatalities among vulnerable road users [6]. Hence, understanding the injury pattern in different collision scenarios is crucial for studying effective safety measures. Therefore, the current study focuses on injuries sustained in the three most common PTW to heavy vehicle (HV which includes heavy goods vehicles and buses) crash scenarios.

II. METHODS

The RASSI (Road Accident Sampling System in India) data was analysed in this study. To qualify as a case in RASSI, the crash must involve at least one motorised vehicle and occur on a public road within one of the sample regions. The queried data from 2014–2024 includes a total of 7,118 crashes, involving 20,299 people with 3,579 fatalities, 4,337 serious injuries, 4,709 minor injuries, and 7,674 no injuries.

Crash scenario

The data sample includes PTW-to-HV crashes, where the model year of the HV is 2009 and later. For this study, the most harmful collision for the PTW was considered, and only cases where the PTWs impact the front of the HV are included. Three crash scenarios are analysed: head-on (front-to-front collision of PTW and HV), side-front (side of PTW impacting the front of HV), and back-front (rear of PTW impacting the front of HV). The data is weighted with the weight factors provided in the database to make it representative of Indian national data. The missing weights were imputed based on known case weights and the high weights were capped to 30,000. Further, injuries sustained in these three crash scenarios are studied. The Abbreviated Injury Scale (AIS), 2008 revision [7] was used to classify each injury by body region according to its related severity on a six-point scale, where one is minor and six is maximal.

III. INITIAL FINDINGS

The filtering resulted in 388,547 (404 unweighted) PTWs, 513,418 (580 unweighted) PTW riders and pillion riders sustaining 1,723,353 (4,255 unweighted) injuries of all types and severity. Of these, 767,908 (1,976 unweighted) were AIS2+ injuries. The percentages are calculated for the weighted data. Side-front was the most frequent scenario (47%) followed by head-on (35%) and back-front (19%). Of all the powered two-wheeler (PTW) riders, 72% were riders (operating the controls) and 28% were pillion riders. The majority of riders were male (89%) and did not use a helmet (85%). Of all riders, 14% were runover and 49% were seriously or fatally injured. Head (32%), lower extremity (21%), and abdomen (17%) were the most frequently injured body regions for AIS2+ severity levels. But for non-runover cases (Fig. 1), head (41%), lower extremity (25%), and thorax (12%) were the most frequent AIS2+ severity injured body regions. Heavy vehicle (HV) front (40%), wheel (35%) and ground (13%) were the most frequent injury sources for all AIS2+ injuries. For non-runover cases, HV front (62%), ground (15%), and HV wheel (6%) were the most common injury sources.

A. Ranmal (email: aarti.dattatray@autoliv.com; tel: +918605739449) is an Associate Lead Engineer at Autoliv India. P. Puthan is Senior Project Tech Lead II at Autoliv India

Considering the top three most common injury sources (Fig. 2), it was shown that in head-on and side-front impact, the opponent front was the major injury-causing component. The most common injury types were subarachnoid hemorrhage and skull fracture for the head; fibula, femur, and tibia fractures for lower extremities; injuries to the internal organs such as liver, kidney for abdomen, and rib fractures and lung contusion for the thorax region.

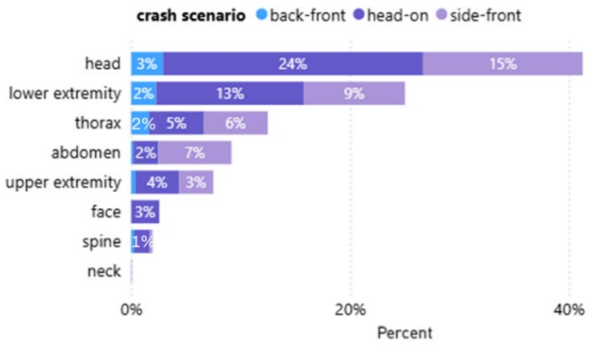

Fig. 1. Distribution of AIS2+ injured body regions for PTW riders in non-runover cases, n=481,713 (1,059 unweighted).

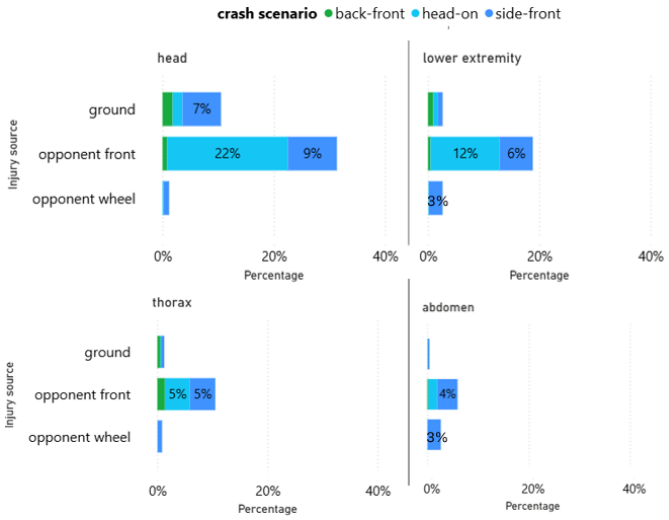

Fig. 2. Distribution of AIS2+ injured body regions and top three most common injury sources in different crash scenarios, n=397,024 (859 unweighted)

IV. DISCUSSION

This study demonstrates that the riders sustained most injuries in head-on collisions, followed by side-front and back-front crash scenarios. In head-on collisions, the impact with the front-end structure of the HV often results in the separation of the rider and a subsequent secondary impact with the ground. In side-front collisions, the front structure of the HV crushes the rider's lower extremities, often followed by secondary head impacts with either the vehicle or the road surface. In back-front impact, the rider is thrown forward from the motorcycle, leading to head and spinal injuries. Making softer front-end designs and installing UPD can help reduce injuries of the PTW riders.

The head is the most frequently injured body region in all crash scenarios. Since 85% of the riders were not wearing a helmet, increased helmet usage can be an initial step to reduce head injuries. In addition to head injuries, lower extremity and abdominal injuries are common in side-front impacts, which can be reduced by wearing protective gears.

Current crash test dummies, such as the PTW dummy, have not been validated for PTW-HV crashes. Hence, a deeper understanding of crash dynamics, PTW rider interaction with HV components, and further development of specialised PTW dummies are essential for accurate injury assessment. This study identifies HV front-to-PTW side and HV front-to-PTW front collisions as the most frequent, with HV front impacts being the primary cause of rider injuries. Therefore, crash tests and ATDs should be designed to replicate these scenarios effectively.

Future research should focus on several key areas: rider behavior, detailed analyses of injury types, and the effects of factors such as rider age, sex, impact speed, collision dynamics, and the type of PTW involved. Gaining insights into these aspects will support the development of comprehensive crash test methodologies, ultimately enhancing the safety of PTW riders.

V. REFERENCES

[1] WHO Global status report on road safety, 2023.
[2] Puthan P *et al.*, AAP, 2021.
[3] Carroll J *et al.*, ESV, 2023.
[4] Carroll J *et al.*, IRCOBI conference, 2024.
[5] Yoganandan *et al.*, Accidental injury: biomechanics and prevention, 2015.
[6] Puthan P *et al.*, IRCOBI conference, 2021.
[7] Association for the Advancement of Automotive Medicine, 2008.