Crash and Injury Characteristics of Powered Three-Wheelers in India: Implications for Occupant Protection and Safety Regulation

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I. INTRODUCTION

In 2023, India reported 172,890 road traffic fatalities and 462,825 injured persons [1]. These fatalities and injuries are among pedestrians, motorcyclists, car and truck occupants, autorickshaw (also known as powered three-wheelers) occupants, bicyclists, and others. While some studies have used hospital or camera data [2–3] to assess the safety of autorickshaws in India, research in this area is still remarkably limited. Further, these studies have limitations on data availability – speed-related information, missing a clear linkage between injury outcomes and the injury-causing sources, etc. Many of these data limitations can be addressed through in-depth crash investigation databases, which provide detailed information on crash circumstances, vehicle deformation, occupant kinematics, and injury mechanisms. The objective of this investigation is to use an in-depth crash database to identify the crash characteristics and injury patterns of occupants in autorickshaws, thereby helping to understand the requirements for safety regulations and safety interventions.

II. METHODS

The Road Accident Sampling System India (RASSI) [4], an in-depth crash database, was queried from April 2014 to March 2025. There was a total of 7,972 crashes, of which autorickshaw-involved (including electric-powered) crashes were selected. Crashes where an autorickshaw was parked were excluded, resulting in 482 crashes involving 493 autorickshaws (the dataset with 493 autorickshaws was labelled as “All”). Further, autorickshaws where the occupant was either killed or seriously injured were labelled as “KSI” (killed or seriously injured; n=222; 45%). Similarly, on the person level, there were two groups: the All – containing all occupants in an autorickshaw, and the KSI – killed or seriously injured occupants in an autorickshaw. Descriptive statistics were performed on the following categorical parameters: vehicle class, collision partner, relative speed, crash direction (based on direction of force and area of damage), occupant role, sex, and age group. Along with descriptive statistics, the KSI rate was calculated as the proportion of KSI within the All group. A Chi-square test (for contingency tables) assessed the association between selected categorical parameters (excluding “other” or “unknown") and the KSI rate. Finally, to guide future safety interventions based on occupants’ roles, an overview of the injured body regions and their injury sources for KSI occupants with serious or higher injury severity injuries (AIS3+) is provided. The analysis used the Abbreviated Injury Scale 2005 version with the 2008 update [5] and was performed in R [6].

III. INITIAL FINDINGS

Out of the 493 autorickshaws, there were 1,268 occupants (killed–136, seriously injured–155, minorly injured–441, and uninjured–536), of which 291 were KSI occupants. On average, three people were sitting in the passenger area with a standard deviation of 2. The descriptive statistics at the vehicle and person level, along with the KSI rate, are shown in Table I. The parameters later found to be statistically significant are marked with a star (*) in the table.

Nearly 33% of the injury records for the KSI occupants (n=95) were unavailable. However, among the remaining 196 KSI occupants, the drivers (n=67) had 189 serious or higher-severity injuries, while the passengers (n=60) had 149. The most frequently injured body region for drivers was thorax (47%), followed by head (32%), while for passengers, it was head (39%), followed by thorax (32%) and lower extremities (13%). The most common sources of these injuries were: opponent exterior, own vehicle exterior, front windshield, instrument panel (only for drivers), and ground.

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TABLE I: DESCRIPTIVE STATISTICS

Level	Parameter	Values	All	KSI (KSI rate)
Vehicle	Class	Passenger carrier	394	176 (45%)
		Goods carrier	97	44 (45%)
		Other	2	2
Vehicle	Collision partner*	Rollover	110	76 (69%)
		Car	92	50 (54%)
		Motorcycle	79	14 (18%)
		Pedestrian	73	0 (0%)
		Heavy vehicle	68	49 (72%)
		Object	43	23 (36%)
		Autorickshaw	17	6 (35%)
		Other	11	4
Vehicle	Relative speed (km/h)	Less than 30	179	79 (44%)
		30-60	214	99 (46%)
		Greater than 60	38	23 (61%)
		Unknown	62	21
Vehicle	Crash direction*	Front	185	53 (29%)
		Side	65	33 (51%)
		Rear	46	24 (52%)
		Rollover	110	76 (69%)
		Other	87	36
Person	Occupant role*	Driver	490	134 (27%)
		Passenger	778	157 (20%)
Person	Sex	Male	919	221 (24%)
		Female	283	65 (23%)
		Other or Unknown	66	5
Person	Age (years)*	Less than 16	54	16 (30%)
		16-30	243	66 (27%)
		31-45	251	86 (34%)
		46-60	121	62 (51%)
		Greater than 60	43	21 (49%)
		Unknown	556	40

* *statistically significant ($p<0.05$)*

IV. DISCUSSION

The study shows autorickshaw occupants in collisions with heavy vehicles or rollover have higher KSI rates than those involved in collisions with any other vehicle or object. Rear and side impacts result in higher KSI rates than frontal impacts. Drivers and seniors have higher rates than passengers and younger occupants. By trend, the KSI rate increases with relative speed. Autorickshaw classes and occupant sex did not significantly affect the KSI rate.

The thorax and head sustained most injuries, especially among drivers, often from impacts with the exterior of opponents' and own vehicles. During a rollover, occupants are partially or fully ejected, often hitting their own vehicle, and causing thorax injuries. Autorickshaws experienced rollovers not only during the initial event (n=110, Table 1) but also in subsequent events (n=150). Further research is needed to understand the loading on these body regions during the rollover phase and to evaluate the feasibility and effectiveness of safety interventions, such as seat belts and curtain airbags, for preventing occupant ejections. To implement such safety interventions, ejection mitigation should be integrated into the regulatory framework for autorickshaws in India.

V. REFERENCES

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