A Comparative Crash Database Study of Upper Extremity Injury Patterns among Car Occupants in the USA and Germany

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I. INTRODUCTION

Upper extremity injuries are common in motor vehicle collisions [1–3]. Although rarely fatal, they are associated with a high risk of permanent medical impairment (PMI) [4] and therefore impose a substantial societal burden. Effective mitigation strategies could significantly reduce this burden. To maximize the societal benefit of upper extremity injury prevention, it is essential to identify which injuries are most prevalent and the crash scenarios in which they occur. Despite their frequency and high risk of PMI, few studies have systematically examined the most common upper extremity injuries or compared patterns across different geographical locations. Therefore, the aim of this study was to identify the most frequently injured upper extremity regions in the United States and Germany and to investigate in which crash directions these injuries occur, thereby providing a foundation for future determination of injury mechanisms and subsequent injury prediction and prevention efforts.

II. METHODS

This study used data from the German In-Depth Accident Study (GIDAS) and the National Highway Traffic Safety Administration's (NHTSA's) Crash Investigation Sampling System (CISS) to compare the prevalence of upper extremity injuries in Europe and the United States. Three datasets were created: GIDAS drivers, CISS drivers, and CISS front seat passengers. To ensure comparability, similar filtering procedures were applied across datasets. Included were passenger cars involved in single-event crashes of all directions between 2017 and 2022; crashes involving rollovers or fires were excluded. Occupants younger than 13 years, as well as those who were unbelted or ejected, were excluded. For GIDAS, only drivers were included, resulting in 7,016 exposed drivers, of whom 58 sustained a total of 77 AIS2+ upper extremity injuries. For CISS, separate datasets were created for drivers and front seat passengers. The CISS driver dataset comprised 7,563 exposed drivers, with 218 occupants sustaining 263 AIS2+ upper extremity injuries. Among 1,760 exposed front seat passengers, 41 occupants sustained 51 AIS2+ upper extremity injuries. Upper extremity injuries in each dataset were grouped by injured anatomical region and categorized into one of seven groups: shoulder, upper arm, elbow, forearm, wrist, hand and fingers, or other. The shoulder category included injuries to the scapula, clavicle, proximal humerus, associated joints, and surrounding tissues. The upper arm included injuries to the humeral shaft and surrounding tissues. The elbow category comprised injuries to the distal humerus, proximal radius and ulna, the elbow joint, and surrounding tissue. The forearm included injuries to the radial and ulnar shafts and surrounding tissues. The wrist included injuries to the distal radius and ulna, carpal bones, associated joints, and surrounding tissues, while the hand and fingers category included injuries to the metacarpals, phalanges, associated joints, and surrounding tissues. Injuries involving the entire arm or with unspecified location were categorized as other upper extremity injuries.

III. INITIAL FINDINGS

The wrist, shoulder, and forearm were the most commonly injured upper extremity regions (Figure 1). In the GIDAS dataset, hand and finger injuries also represented a notable share (21%). Among CISS drivers with AIS2+ upper extremity injuries, wrist, shoulder, and forearm injuries accounted for 38.5%, 27.1%, and 22.5%, respectively. Corresponding proportions were 39.0%, 24.4%, and 19.5% among CISS front seat passengers, and 37.9%, 34.4%, and 19.0% among GIDAS drivers. Across all datasets, distal radius fractures were the most common wrist injury, clavicle fractures accounted for more than half of shoulder injuries, and forearm injuries

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predominantly involved radial and ulnar shaft fractures. Wrist and forearm injuries occurred most frequently in frontal crashes (principal direction of force [PDOF] 12), while shoulder injuries—though also most common in frontal crashes—also were seen in side crashes (PDOF 3 or 9), particularly near-side driver crashes (PDOF 9) (Figure 2).

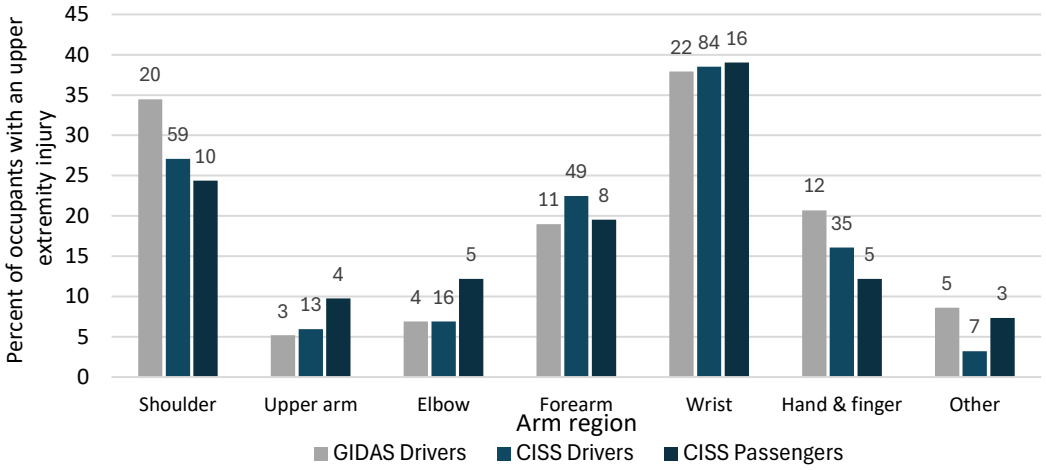

Fig. 1. Injury distribution of all upper extremity injuries sustained in the three datasets showed as percentage of occupants sustaining any upper extremity injury. Actual number of injuries are shown over each bar.

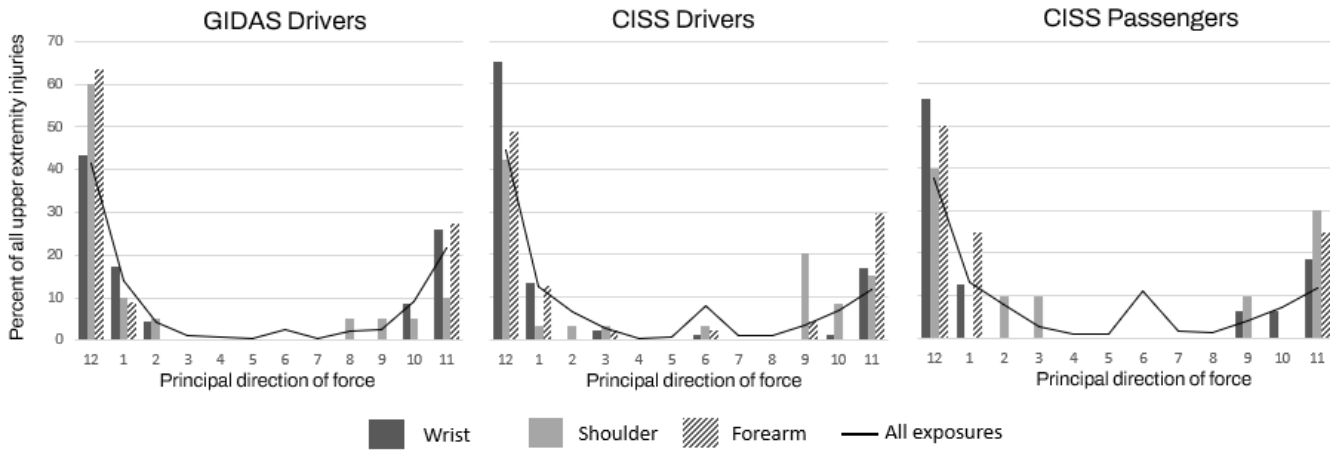

Fig. 2. Principal direction of force shown for the three most commonly injured areas of the upper extremity, together with the distribution of all exposed occupants, for each of the three datasets.

IV. DISCUSSION

Overall, injury distributions were similar across databases and between drivers and passengers, supporting the robustness of these findings, however the sample sizes for GIDAS drivers and CISS passengers were relatively small, affecting the reliability. Differences in the proportion of occupants sustaining upper extremity injuries likely reflect differences in database sampling criteria, as CISS intentionally oversamples severe accidents where more injuries are expected [5]. Wrist injuries were the most prevalent across all datasets, and given the high mean PMI reported for fractures in the wrist area [6], future research on determining injury mechanisms, should prioritize wrist injuries—particularly distal radius fractures—in frontal impacts to achieve beneficial reduction in upper extremity related PMI. Shoulder injuries, especially clavicle fractures, also warrant attention in both frontal and side impacts, as they occur primarily in frontal crashes but appear to be overrepresented in side impacts.

V. REFERENCES

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