Relative Risk in Heavy Goods Vehicle Rollover Crashes Using Crash Databases from the USA, Germany and India

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I. INTRODUCTION

Heavy goods vehicle (HGV) crashes remain a significant public health concern worldwide. In 2023, 5,472 people were killed in traffic crashes involving HGVs in the United States alone. While representing an absolute decrease from previous years, rates of injurious and fatal HGV crashes per vehicle miles travelled remain high [1]. Rollover events are disproportionately associated with serious or fatal injuries to HGV drivers [2]. Despite these risks, and a reported need for additional HGV crashworthiness standards [3], occupants of HGVs constitute a crash-involved population that remains under-studied and under-reported relative to light passenger vehicle occupants, likely reflecting their lower overall crash involvement. Cross-jurisdictional comparisons of HGV crashes, such as those between the United States, Germany and India, have largely been anecdotal, underscoring the need for systematic statistical analyses to inform prevention strategies and policy. To address these gaps, the aim of the current research is to investigate how rollovers and (for comparison) non-rollovers correlate with various crash-, vehicle- and occupant-related factors in these three jurisdictions. This initial sub-analysis focuses on relative risks between rollovers and non-rollovers for key occupant-related factors.

II. METHODS

We extracted data from three multi-site crash databases: the Crash Report Sampling System (CRSS, USA, 2016–2023), the German In-Depth Accident Study (GIDAS, 1999–2024), and the Road Accident Sampling System-India (RASSI, 2014–2025) to examine and compare HGV crash trends across regions. HGVs were identified using each database's body type and vehicle classifications, and were restricted to truck-type vehicles with a gross vehicle weight exceeding 3,500 kg (7,700 lbs). This approach ensured consistency in vehicle category definitions across datasets. Rollover crashes were defined as any vehicle rotation of ≥ 90° about a true longitudinal or lateral axis. As only CRSS provides probability-based national sampling weights, all analyses were performed using unweighted case counts to maintain comparability across datasets.

Occupant-level variables of interest included sex, seat-belt use, ejection status, and injury severity. To accommodate differences in variable structures between databases, each categorical variable contained a "Rest" subgroup representing cases coded as unknown, not reported, or not classifiable into the other defined subcategories. Relative risks were calculated using 2 × 2 frequency tables (Eq. 1) to compare the likelihood of each occupant outcome between rollover-involved and non-rollover-involved occupants. The 95% confidence intervals for the relative risks were computed using the Wald method [4], the default approach implemented in the *relrisk* option of PROC FREQ in SAS (SAS Institute, Cary, NC). Relative risks were considered statistically significant when the 95% confidence interval excluded 1.0. In rare situations, where a contingency table cell contained a zero (observed only in RASSI for the "Rest" category), a continuity correction of 0.5 was applied to all four cells of the table to enable risk estimation [5].

$$Relative\ Risk\ (RR) = \frac{\frac{a}{(a+b)}}{\frac{c}{(c+d)}} \quad \text{(Eq. 1)}$$

| a: Exposed (rollover) with condition; b: Exposed without condition;
| c: Unexposed with condition; d: Unexposed without condition.

III. INITIAL FINDINGS

Across the three databases, the average number of HGV occupants analysed per year differed substantially (GIDAS: 104 cases/year; RASSI: 195 cases/year; CRSS: 4,312 cases/year). Despite these region-specific differences in sample size, data collection and data structure, a consistent pattern emerged across most occupant-related

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categories. Rollover crashes represented 4–11% (Fig. 1A) of the analysed HGV crashes across the three datasets. Occupants involved in rollovers were substantially more likely to experience ejection, with relative risks of RR ≥ 4.32 (95% CI: 3.26–5.72). Similarly, rollovers were associated with significantly increased risks of injury of any severity level, with RR ≥ 4.51 (95% CI: 3.74–5.44) (Fig. 1B). While male occupants were more prevalent overall, sex-specific relative risks did not indicate systematic differences between rollover and non-rollover crashes. Belt use was more nuanced: in CRSS and RASSI only, rollover-involved occupants were more likely to be unbelted than belted, with relative risks of RR ≥ 3.09 (95% CI: 2.61–3.66).

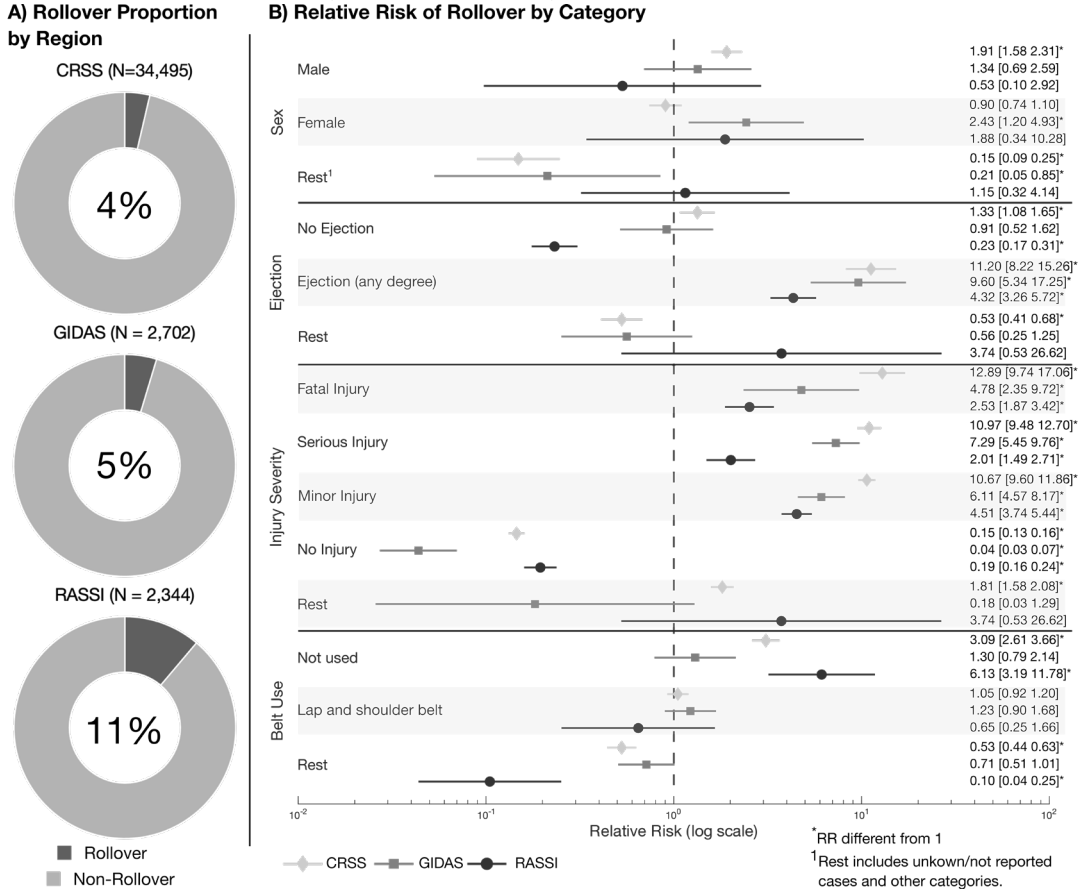

Fig. 1. A) Total number of cases and proportion of rollover cases by region (CRSS=USA, GIDAS=Germany, RASSI=India). B) Occupant-level relative risk for occupant-related factors (sex, ejection, injury severity and belt use). Relative risks are given as the mean [95th percentile confidence interval] and are shown on a logarithmic scale.

IV. DISCUSSION

Our initial results already show a clear pattern: rollover occupants remain at a greater risk of being ejected and sustaining injuries at any severity level. These increased ejections may be attributable to lower seat-belt use among rollover occupants compared to non-rollover occupants. To ensure that our findings were not biased by relying on unweighted data, we repeated the analysis with weighted data in CRSS, which has an established weighting methodology, and found comparable results. Our results align with analyses from other jurisdictions, such as Sweden [6], where unbelted occupants were found to contribute to fatality numbers in HGV rollovers. The ongoing study of crash- and vehicle-related variables, as well as in-depth case-by-case analyses, may reveal injury patterns unique to rollovers, consistent with a prior rollover analysis performed for smaller motor vehicles [7]. Moving forward, these results will help inform future safety priorities for rollover occupants in HGVs.

V. REFERENCES

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