69th Annual
Scientific Conference
Indianapolis
Indiana, USA

AAAM 69th Annual Conference Late Breaking Oral-Only Abstracts

October 7-10, 2025
Indianapolis, Indiana, USA

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TITLE: Differences in thoracic injuries by body mass index in motor vehicle collisions using KIDAS database

OBJECTIVES

The thorax is a common injury region in motor vehicle collisions, with studies indicating that a higher body mass index (BMI) increases the risk of injury (Choi et al. 2024). This study topic has been studied and validated the United States using their database. However, the proportion of obese Asian is not large in the database. This study aims to analyze the characteristics of thoracic injuries among vehicle occupants concerning BMI, using accident data from South Korea.

METHODS

This study utilized the Korean In-Depth Accident Study (KIDAS) Database as the data source. A total of 3,335 vehicle occupants admitted to South Korean trauma centers due to motor vehicle collisions between 2011 and 2024 were included. Occupants were categorized into four BMI groups: underweight, normal, overweight, and obesity (World Health Organization 2005). The study examined the distribution of collision-related variables and compared the occurrence of moderate or serious injuries (AIS2+ and AIS3+) in the thoracic region. The thoracic injury was analyzed for differences in specific types, including rib fractures, sternum injury, hemothorax, pneumothorax, lung injury, and heart injury.

RESULTS

Among the study targets, 99.6% were Korean. Variables that sex, age, seating position, vehicle type, seatbelt use, and MAIS2+ differed significantly across BMI groups ($P<0.05$). BMI did not significantly differ between AIS2+ and AIS3+ thoracic injury risk. Specific thoracic injuries that showed significant differences in rates by BMI were rib fracture and heart injury ($P<0.05$). Compared to normal BMI, overweight showed an increased risk of ≥1 and ≥2 rib fractures (AOR: 1.31 and 1.38, respectively). Obesity also showed an increased risk of ≥1 and ≥3 rib fractures (AOR: 1.52 and 1.67, respectively).

CONCLUSIONS

In collisions that occurred in Korea, the proportion of overweight and obese people was lower than in the United States data, but the risk of thoracic injuries according to BMI was similar. These findings provide valuable insights into the relationship between BMI and thoracic injuries in vehicle occupants and serve as a resource for future research on occupant safety and injury prevention.

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TABLES AND FIGURES:

Table 1. Risk factors for thoracic injury severity of occupants

Variable		Thorax AIS2+		Thorax AIS3+	
		AOR[a]	95% CI[b]	AOR	95% CI
Sex, male (ref)	Female	0.78	0.64-0.96	0.76	0.60-0.96
Age (years)		1.03	1.02-1.03	1.03	1.02-1.04
BMI, normal (ref)	Underweight	1.07	0.70-1.64	1.08	0.64-1.80
	Overweight	1.06	0.67-1.29	1.18	0.94-1.47
	Obesity	1.07	0.74-1.56	1.48	0.99-2.22
SP[c], driver (ref)	Frontal Passenger	1.02	0.80-1.30	0.98	0.73-1.30
	2nd-row Passenger	1.04	0.76-1.42	0.97	0.67-1.40
VT[d], Sedan (ref)	SUV[f]	0.80	0.63-1.01	0.93	0.71-1.22
	Light truck	0.85	0.65-1.11	0.95	0.70-1.29
	Van	0.87	0.63-1.22	0.90	0.61-1.32
	Heavy duties	0.86	0.54-1.36	0.98	0.58-1.66
CT[e], Frontal (ref)	Rear-end	0.24	0.16-0.35	0.29	0.18-0.46
	Near-side	1.01	0.75-1.37	1.36	0.98-1.88
	Far-side	0.50	0.34-0.75	0.61	0.39-0.96
	Rollover	0.91	0.72-1.16	0.84	0.63-1.12
Seatbelt use (ref)	Not use	1.51	1.25-1.82	1.70	1.37-2.11

[a] Adjusted odds ratio
[b] Confidence interval
[c] Seating position
[d] Vehicle type
[e] Crash type
[f] Sport utility vehicle

Table 2. Risk factors for rib fracture of occupants

Variable		≥1 Rib fracture		≥2 Rib fracture		≥3 Rib fracture	
		AOR[a]	95% CI[b]	AOR	95% CI	AOR	95% CI
Sex, male (ref)	Female	0.73	0.58-0.92	0.71	0.55-0.92	0.77	0.59-1.02
Age (years)		1.03	1.03-1.04	1.04	1.03-1.05	1.04	1.03-1.05
BMI, normal (ref)	Underweight	0.95	0.56-1.61	1.07	0.60-1.91	0.94	0.50-1.79
	Overweight	1.31	1.05-1.63	1.38	1.09-1.74	1.25	0.97-1.62
	Obesity	1.52	1.02-2.26	1.51	0.97-2.33	1.66	1.05-2.63
SP[c], driver (ref)	Frontal Passenger	1.05	0.79-1.38	1.08	0.80-1.46	1.12	0.81-1.55
	2nd-row Passenger	0.97	0.67-1.40	0.77	0.51-1.18	0.75	0.47-1.20
VT[d], Sedan (ref)	SUV[f]	0.87	0.66-1.13	0.88	0.66-1.17	1.06	0.78-1.43
	Light truck	1.28	0.97-1.70	1.10	0.81-1.49	1.12	0.80-1.57
	Van	0.89	0.61-1.30	0.92	0.61-1.39	0.86	0.54-1.37
	Heavy duties	1.10	0.66-1.82	1.05	0.61-1.83	0.99	0.53-1.85
CT[e], Frontal (ref)	Rear-end	0.23	0.14-0.37	0.24	0.14-0.40	0.32	0.19-0.55
	Near-side	1.45	1.06-1.99	1.50	1.08-2.10	1.54	1.08-2.21
	Far-side	0.68	0.45-1.03	0.63	0.39-1.00	0.63	0.38-1.06
	Rollover	0.69	0.52-0.92	0.57	0.41-0.79	0.60	0.42-0.86
Seatbelt use (ref)	Not use	1.51	1.22-1.86	1.61	1.28-2.02	1.63	1.28-2.09

[a] Adjusted odds ratio
[b] Confidence interval
[c] Seating position
[d] Vehicle type
[e] Crash type
[f] Sport utility vehicle

Amy Courtney

TITLE: SUV and second-row pediatric occupant response to high-speed rear impacts from a tractor-trailer.

OBJECTIVES

While rare, severe rear impact collisions present a high risk of serious or greater (AIS3+) injury to second-row occupants when substantial intrusion is present (Stephens 2020, Parenteau 2023). Published data from high-speed, vehicle-to-vehicle rear impact crash testing is sparse, especially data from SUVs. Potential injury mechanisms include but are not limited to acceleration due to crash forces, occupant-to-occupant contact, and interaction with intruding structures. Second-row occupants in SUVs are often children. Parenteau et al. (2020) reported that half of AIS3+ injuries in children in the second row in rear impacts were due to intrusion into the seating area (30+ cm) pushing the child forward. Since the full implementation of FMVSS 301R in 2009, vehicles better preserve rear occupant space and reduce injuries (Kahane 2015, Viano 2016).

This study evaluated the response of an SUV to a severe, offset rear impact and the kinematics and biomechanical mechanisms of head and neck injury for a second-row pediatric occupant.

METHODS

In two crash tests, the same model of full size, three-row 2011 MY SUVs sustained a severe, offset rear impact from a 357.6 kN (80,400 lb) tractor-trailer traveling at 58.6 kph (36.4 mph). An HIII 6-year-old ATD was restrained with a lap belt in the second row, driver side seat; the shoulder belt was routed behind the torso. With a weight of about 28 kg (62 lb), the 6 y/o HIII anthropometry also represents the lower quartile of 8- and 9-year-old children (Fryar 2021), who are not required to use booster seats in most U.S. states. Tests were documented with on-board accelerometers, the struck vehicle's airbag control module, and high-speed cameras. The ATD was instrumented with a tri-axial head accelerometer and triaxial load sensors in the upper cervical spine.

RESULTS

The rear impacts involved much higher kinetic energy than the FMVSS 301R protocol (Kahane 2015). Each test resulted in a maximum change in velocity of 60 kph (40 mph) of the struck SUVs over 130 ms. The side curtain airbag deployed. Rear vehicle structures were crushed forward, stiffening and pushing forward the second-row seat and seatback. Each HIC15 was greater than 2500, corresponding to a 98% or greater risk of skull fracture and of severe (ASI4+) brain injury. Each peak head acceleration occurred approximately 70 ms into the crash pulse. Cervical spine loads were above IARVs and less than 50% likely to result in AIS3+ injury.

CONCLUSIONS

This SUV was highly rated for crashworthiness and compliant with FMVSS 301R and 201U. Each test vehicle sustained a large amount of intrusion due to the offset, severe rear impact. Intrusion involved third-row and driver side vehicle structures and pushed them into the second row seat area (Figure 1). Both tests resulted in similar head injury metrics indicating high likelihood of skull fracture and severe (AIS4+) brain injury (Figure 2) due to direct impact and inertial brain acceleration (Leestma 2006). Peak biomechanical loading occurred early in the crash pulse, coincident with intrusion. Proper routing of the shoulder belt would not likely have affected these measurements.

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TABLES AND FIGURES:

Figure 1. Still frame from high-speed video recording of full-scale crash test around the time of peak head and neck loading to second-row pediatric occupant.

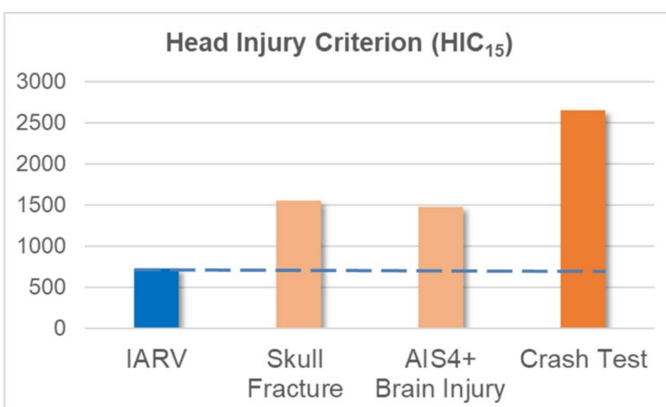

Figure 2. IARV for HIC15, 50% risk values for skull fracture and AIS4+ brain injury in 6-10 year-old children, along with HIC15 computed from head acceleration data in the subject tests.

Quantification of Buttocks and Thigh Deformation in Seating: A Multi-Modality Approach

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Objective: To quantify human to seat interactions via analysis of deformation characteristics of the buttocks and thighs in both supported and loaded seated configurations.

Methods: We present a multi-modality approach involving anthropometric measurements, 3D surface scan data, pressure mat data collection, and MRI imaging to quantify how the human body deforms under load in the buttocks and hamstrings. Eight males and nine females were employed in this study (IRB IRB00109011, age range 24 to 44 years, BMI range 20.1 to 29.9). We used an upper body harness to position participants without external load on the buttocks and thigh and compared that to a loaded seating configuration. A 2.5 cm translucent acrylic sheet was used as the seated surface, and a scissor jack was used to achieve the desired lower extremity posture. Participants were positioned with the hip, knee, and ankle at 90 degrees. Post-collection analysis was done for comparison of the two configurations, and to investigate how age, BMI, sex, anthropometric measures, and cross-sectional adipose ratio (via MRI) influenced the body's displacement under load.

Results: Significant differences ($p < 0.05$) in surface deformation, hip breadth, and leg morphology were observed between the two seating configurations due to displacement of soft tissue under load. Leg cross-sectional analysis of 3D scans revealed statistically significant increased leg breadth under load, with notable sex-based differences in surface deformation and pressure distribution patterns. Males exhibited higher peak normalized pressure at the contact interface (0.79 vs. 0.58), as well as higher average pressure, 9.72 kPa (male) vs. 7.65 kPa PSI (female), while females showed greater adipose tissue displacement and a stronger correlation between BMI and contact area, ($R^2 = 0.1489$ for males, 0.9157 for females).

Conclusions: This study integrated multiple modalities to elucidate body-to-seat interactions and changes in surface geometry. The interdisciplinary use of biomechanical and ergonomic assessment techniques offers valuable data for groups focused on human-to-seat interaction in automotive applications. This data is intended for use in validating how human body finite element models conform to seats for subsequent safety or comfort studies.

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Priority research questions in post-crash care

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Objective: Effective post-crash care is vital to reducing the road traffic crash burden and achieving vision zero. It is highlighted as a key element of the Safe Systems Approach, one of the five pillars of the UN Decade of Action for Road Safety, and an important phase for intervention in the Haddon Matrix. Renewed focus on the role of the post-crash period in crash outcomes combined with advancements in areas such as medical interventions and vehicle technology, suggest the need to reflect on research needs that will maximize impact. This late breaking oral-only presentation will report on the results of a recently published study aimed at setting a national agenda for postcrash care (Goolsby 2025) in the context of AAAM's aim to facilitate interdisciplinary and impactful research that reduces lives lost in road traffic crashes.

Methods: Researchers used a modified Delphi method with 27 subject matter experts (SME) to reach consensus on high priority research questions related to improving post-crash care. The process involved four rounds: prioritization of 10 themes from an original list of 21, individual SME generation of research questions within the themes, question prioritization in small groups, and finalization of high-priority questions in a large group.

Results: Participants prioritized 10 important themes in post-crash care, individually generated research questions then collectively identified the highest priority research questions within the following 10 themes: safety; workforce issues; system issues; novel equipment, treatment or medications; resuscitation; health care disparities; vehicle technology; policy; research infrastructure; and prehospital medical technology. The 74 priority research questions identified span topics of particular interest to AAAM such as improved triage, electric vehicles, and advanced automatic crash notification.

Conclusions: This study developed high-priority research questions to optimize post-crash care and can serve as a reference for AAAM membership. AAAM represents a critical junction of skilled researchers and potential funders with multidisciplinary expertise in trauma care, emergency medical services, epidemiology and automotive safety. AAAM researchers may be uniquely poised to form collaborations that help answer some of the critical remaining research questions in post-crash care.

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Kathryn Loftis

TITLE: Applying Veterinary Abbreviated Injury Scale to Dogs Injured in Vehicle Crashes

OBJECTIVES: The Veterinary Abbreviated Injury Scale (V-AIS) [1] was created to mirror the human AIS [2] and fill a critical gap in retrospective veterinary trauma analysis. Dogs struck by a vehicle or injured inside a vehicle have the highest mortality rates among cases presenting to Veterinary Trauma Centers (VTC) across North America [3, 4]. Better understanding of injury mechanisms and patterns will facilitate development of scientifically validated vehicle restraints for canines and support the safer transport of four-legged family members and operational working dogs [5, 6].

METHODS: The Veterinary Committee on Trauma (VetCOT) Registry was queried with the inclusion criteria "canine," and "injured while inside vehicle." A total of 269 reports from 2013-2024 were returned. Descriptive statistics were performed on all reports using this VetCOT registry data (JMP, SAS, Cary, NC).

RESULTS: There were 269 canines injured while inside vehicles and treated within the VetCOT network between 2013-2024. There were 88 spayed females (32%), 28 intact females (10%), 94 neutered males (35%), and 59 intact males (22%). Just over 30% of the dogs were mixed breed (81), with the three most frequent breeds being Labrador Retrievers (19, 7.1%), German Shepherds (15, 5.6%), and Chihuahuas (13, 4.9%). Overall weight ranges for patients included 1.7 kg – 51.4 kg, with a mean of 17.7 kg. The average age of the canine patients was 5.75 years (4.4 st dev). Over 90% of these canines survived to discharge (245/269), with 4 dying and 20 euthanized due to extent of injuries/cost of treatment. Based on specific fields within the VetCOT registry data, there were 29 patients with evidence of spinal trauma, 38 patients with evidence of head trauma, and 9 patients with evidence of head and spinal trauma. These database results show that there is a need to record and analyze canine injury data in a systematic way to better understand intravehicular canine trauma and improve protection and treatment. These results will provide a basis for further analysis of the remaining VetCOT registry records, ultimately improving the understanding of severity, mechanisms, and patterns of canine vehicular injury.

CONCLUSIONS: Future work will focus on selecting and applying V-AIS codes to canine representative cases to demonstrate the depth and breadth of information that may be gleaned from analyzing medical records of dogs injured in vehicle crashes. Trained V-AIS coders with access to veterinary trauma records will provide automotive manufacturers with valuable data necessary to implement safety measures for four-legged family members. Incorporation of the V-AIS coding system into the VetCOT registry and subsequent record abstraction by trained V-AIS coders will exponentially increase the amount of actionable information gleaned from veterinary medical records. These efforts will improve outcomes and protect the health and safety of beloved pets.

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Francisco Lopez Valdes

TITLE: The kinematics of six Post Mortem Human Subjects under seatbelt and airbag loading in frontal impacts

OBJECTIVE

The objective of this study is to discuss the kinematics and injuries of six Post Mortem Human Subjects (PMHS) restrained by a force-limited seatbelt and a generic airbag in a 35 km/h frontal impact.

METHODS

Six male PMHS aged 63 to 94 years were included in the study. Except for PMHS 3, who was notably smaller (34 kg, 156 cm), the subjects were within average size for their age group (mean: 172.5 cm, 69 kg, BMI 22.9 kg/m²). The test fixture simulated a front-seat passenger using simplified geometry: a rigid, inclined seat along the sled's axis, a footrest, and an adjustable metal-wire backrest (Pipkorn et al. 2019). Restraints included a force-limited, non-retractor three-point seatbelt and a pre-inflated airbag (vented at t = 0 ms). Belt force was controlled via plastic deformation of calibrated metal strips pulled through rollers, with adjustability based on strip thickness, count, rollers engaged, and deformation level. Two restraint conditions were tested. RC A featured a 2.5 kN belt, 12 kPa airbag, forward D-ring, and low-friction seat. RC B used a 2 kN belt, 10 kPa airbag, rearward D-ring, and high-friction seat. In addition, in RC A the relative position of the restraint systems was kept approximately constant with respect to the subjects, while in RC B, the location of the seat belt anchorages and airbag were adapted to the particular anthropometry of the PMHS. Three subjects were tested per condition. Kinematics of key anatomical landmarks were captured in the 3D space using a 1,000 Hz VICON motion tracking system. The study was approved by the relevant Ethics Board.

RESULTS

The results include the sagittal trajectories of the above mentioned anatomical locations. The changes between RC A and RC B resulted in distinct kinematics of the six PMHS, that were associated with substantial differences in the injury patterns observed in the autopsies. In RC A, the head of the PMHS interacted earlier with the airbag, while in RC B, the torso was allowed to pitch forward farther, resulting in a later interaction with the airbag and different pelvic trajectories as illustrated in Figure 1. The lack of pre-tensioned lap belt favored a relatively large forward excursion of the pelvis in both conditions.

As for the injuries, RC A injury pattern was more severe than RC B, resulting in more than 10 rib fractures per PMHS compared to the 2 rib fractures found in the autopsies of the PMHS exposed to RC B (Lopez-Valdes et al, 2018).

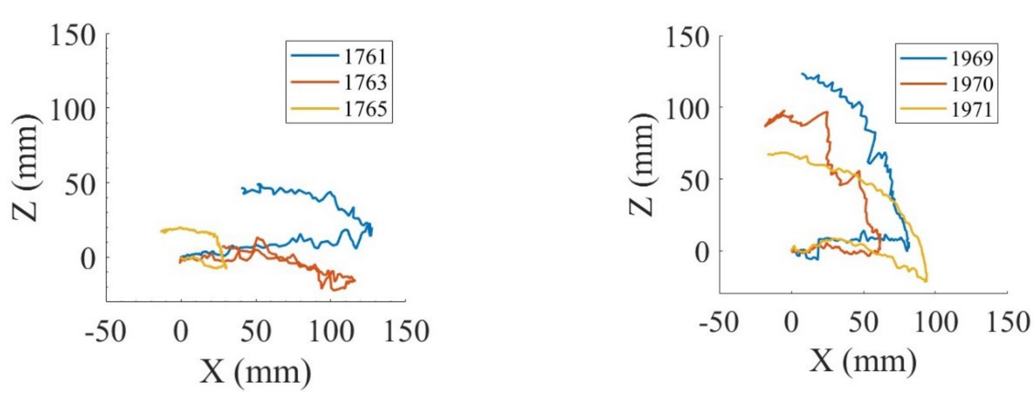

Figure 1. Comparison of the sagittal trajectory of the pelvis between RC A (left) and RC B (right).

CONCLUSIONS

This paper includes unpublished results corresponding to the kinematics of six PMHS restrained with a generic seatbelt and a pre-inflated generic airbag. The experimental data will be made available to the public through the THUMS Users Community (TUC) repository.

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TITLE: Small Size Female Injury Risk Curves for Automotive Applications

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OBJECTIVES: Injury risk curves for small size female dummies are needed to advance safety. NHTSA database has information on recent sled tests conducted using whole-body small female post-mortem human surrogates (PMHS) from which injury risk curves for this group of the population can be developed. The objective of the analysis-based study was to develop human injury risk curves in frontal impacts with a focus on injuries to the iliac wing bone.
METHODS: Test data from PMHS (termed as specimens) were obtained from the NHTSA database. Briefly, the specimens were positioned on a custom seat attached to a horizontal deceleration sled and restrained with a three-point belt. They were accelerated to a peak change in velocity of 14 m/s. The duration of the pulse was approximately 100 ms. One impact test was conducted on each specimen. Fractures were scored using autopsy and the 2015 version of the Abbreviated Injury Scale. Peak outboard and inboard forces sustained by the specimen during the loading scenario were normalized using the equal stress equal velocity method to the standardized automotive small female total body mass of 50 kg to develop human injury probability curves for fractures to the iliac wing. Survival analysis techniques were used. Lognormal, loglogistic and Weibull distributions were considered as potential risk functions. The optimum distribution for each metric for the risk curves was selected based on the corrected Akaike Information Criterion. Plus-minus 95% confidence intervals for the estimated (mean) risk curve were calculated using the delta method. Statistical analysis was performed using the R-software, version, 4.4.3 (PBC, Boston, MA, USA).
RESULTS: The mean age, stature, weight of the twelve specimens were 72±16 years, 160±7.1 cm, and 44.6±6.9 kg, respectively. Iliac wing fractures were identified in seven specimens, while the remaining specimens did not have these injuries. The Weibull and lognormal distributions were determined to be the optimal injury risk functions for the outboard and inboard forces, respectively. At 10%, 25% and 50% injury probability levels, the peak forces and 95% confidence intervals for the outboard and inboard belt forces were 4.7 (3.9-5.8) kN, 5.5 (4.8-6.4) kN and 6.3 (5.6-7.0) kN, and 5.8 (5.2-6.4) kN, 6.2 (5.7-6.8) kN and 6.8 (6.2-7.4) kN, respectively. Individual risk curves are shown
CONCLUSIONS: The present analysis provides small female human injury probability curves for advancing crashworthiness of vehicles and occupant safety.

Keya Zambare

TITLE: The Characterization of Lumbar Acceleration in Rear-End Impacts Across Different Surrogate Occupant Types

OBJECTIVES

Despite the low incidence of serious lumbar injuries following low-speed motor vehicle rear-end impacts, occupants frequently report low back pain. Longitudinal lumbar acceleration is often overlooked as a key variable when biomechanically assessing lumbar response in rear-end collisions. Our objective is twofold: (1) to conduct a comprehensive literature review of peak longitudinal occupant lumbar acceleration data to statistically evaluate the differences between human volunteers, post-mortem human subjects (PMHS), and anthropomorphic test devices (ATDs) and (2) to construct a mathematical predictive model of lumbar acceleration using peak longitudinal vehicle or sled change in velocity (delta-V) and peak longitudinal vehicle or sled acceleration (vehicle acceleration) in rear-end impacts.

METHODS

Peak longitudinal lumbar acceleration was obtained from peer-reviewed literature (n=90) and the Insurance Institute for Highway Safety (IIHS) database (n=709). Rear-end impact tests included belted human volunteers (n=64), PMHS (n=1), and BioRID ATD (n=734). Occupants were seated upright in unmodified, conventional driver seats and categorized as sled (n=716) or vehicle-to-vehicle (n=83) collisions. Lumbar acceleration was normalized by vehicle acceleration and delta-V to account for variations in impact severity. Differences between accelerometer location (L1 vs. L5) and crash test configuration (sled vs. vehicle-to-vehicle collision) across occupant types (human volunteers and ATDs) were assessed with t-tests. Linear regressions were used to characterize lumbar acceleration across all occupant types as functions of vehicle acceleration and delta-V.

RESULTS

Lumbar acceleration ranged from 0.70-10.28 g for human volunteers, 4.20 g for PMHS, and 1.90-14.91 g for ATDs. Human volunteer tests were generally conducted at lower vehicle accelerations and delta-Vs compared to ATD and PMHS occupant crash tests. Statistically significant differences ($p < 0.001$) in lumbar acceleration were found between human volunteers and ATDs when normalized by vehicle acceleration and delta-V. Human volunteers had higher mean acceleration ratios (1.01 ± 0.04) but lower mean delta-V ratios (0.45 ± 0.03), whereas ATDs showed lower mean acceleration ratios (0.84 ± 0.03) and higher mean delta-V ratios (0.54 ± 0.001). Accelerometer placement and crash test configuration significantly influenced lumbar acceleration relative to both vehicle acceleration and delta-V ($p < 0.001$). Regressions for all occupant types indicated a positive relationship for lumbar acceleration with respect to vehicle acceleration ($R^2=0.96$, $p < 0.001$) and delta-V ($R^2=0.96$, $p < 0.001$).

CONCLUSIONS

Normalized lumbar accelerations suggested that ATDs may underpredict lumbar response compared to human volunteers, particularly when normalized by vehicle acceleration, although differences in accelerometer placement and crash test configuration may have confounded comparisons. Statistically significant differences between ATD and volunteer lumbar acceleration may suggest a need to improve ATD lumbar biofidelity in low-speed rear impact testing. This study quantified differences in lumbar acceleration across occupant types in rear-end collisions and developed two models to predict lumbar acceleration from delta-V ($y = 0.54x$, $R^2=0.96$) and vehicle acceleration ($y = 0.84x$, $R^2=0.96$). Biomechanical experts can use these models to estimate occupant lumbar acceleration from crash parameters and predict lumbar loads for injury analysis. Future work should include additional PMHS crash testing and standardize accelerometer placement for improved comparisons and model accuracy.

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TABLES AND FIGURES:

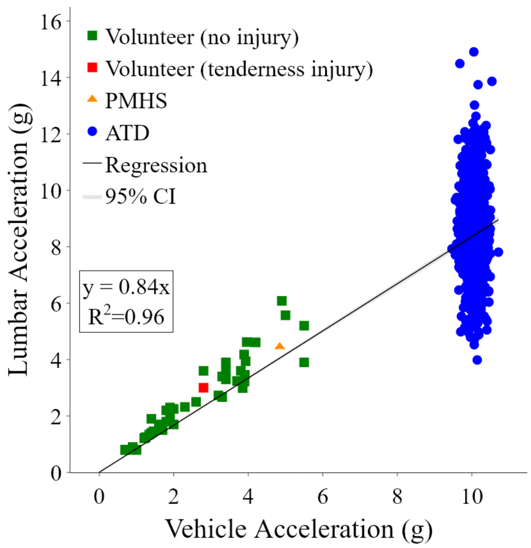

Figure 1. Relationship between peak longitudinal lumbar acceleration and vehicle acceleration for human volunteers, PMHS, and ATDs in rear-end impacts.

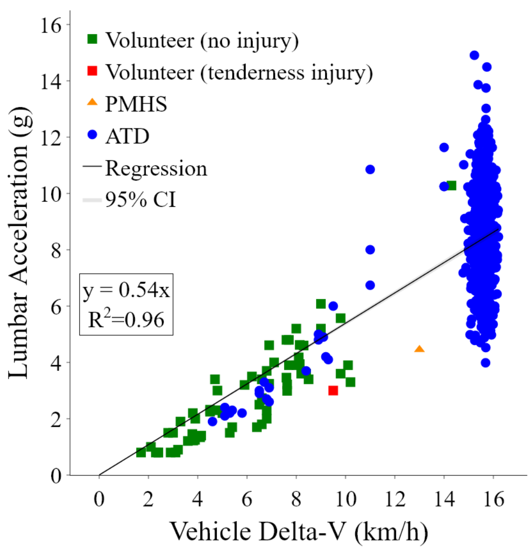

Figure 2. Relationship between peak longitudinal lumbar acceleration and vehicle delta-V for human volunteers, PMHS, and ATDs in rear-end impacts.