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Sex-Based Differences in Odds of Motor Vehicle Crash Injury Outcomes

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16. Abstract Several studies have documented the relative risk or odds of injury and fatality for females versus males in motor vehicle crashes, but none have combined the National Automotive Sampling System–Crashworthiness Data System (NASS-CDS) and the Crash Investigation Sampling System (CISS). The study aimed to document the odds of various injury outcomes for females versus males while considering a range of crash types, pre-crash and crash variables, and occupant demographics. Multivariable logistic regression was used for this purpose. The Approximate Bayesian Bootstrap hot-deck imputation method was applied as part of efforts to create multivariable logistic regression models for 25 different injury outcomes associated with occupants 13 years and older. These models were applied to passenger vehicle crashes published in NASS-CDS (2000 to 2015) and CISS (2017 to 2022). Twenty-four predictor variables (including sex and 23 other occupant, crash, and vehicle covariates) were used across the models. Six crash-type models were produced for each injury outcome; one for each of four different planar crashes (frontal, near-side, far-side, rear), one that included the planar crashes combined, and one for primary rollover crashes. Different than other recent studies, a broader range of crash types, occupant restraint conditions, and seating positions were considered. The results suggest that females tended to have higher injury odds than males, but this varies by injury outcome and the associated crash type.			
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Acronyms and abbreviations

AAAM	Association for the Advancement of Automotive Medicine
ABB	Approximate Bayesian Bootstrap
AIS	Abbreviated Injury Scale
BMI	body mass index
CDC	Collision Deformation Classification
CI	confidence interval
CISS	Crash Investigation Sampling System
DF	degrees of freedom
FARS	Fatality Analysis Reporting System
FEFI	fully efficient fractional imputation
GAD	general area of damage
HD	hot-deck
MAIS	Maximum Abbreviated Injury Scale
NASS-CDS	National Automotive Sampling System – Crashworthiness Data System
OR	odds ratio
SE	standard error
VIF	variance inflation factors

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Executive Summary

Objective

Several studies have documented the relative risk or odds of injury and fatality for females versus males in motor vehicle crashes (Parenteau et al., 2013; Forman et al., 2019; Brumbelow and Jermakian, 2021; Noh et al., 2022), but none have combined 22 years of data from the National Automotive Sampling System–Crashworthiness Data System (NASS-CDS) and the Crash Investigation Sampling System (CISS). The aim of this study was to document the odds of various injury outcomes for females versus males while considering a range of crash types, pre-crash and crash variables, and occupant characteristics.

Methods

We estimated odds ratios (ORs) of injuries for females versus males 13 years or older using multivariable logistic regression models, accounting for 23 occupant, crash, and vehicle covariates in addition to sex (the specific covariates included in each model depend on the crash type but not the injury outcomes). OR findings were considered statistically significant for p-values ≤ .05. Due to high missing data rates (~68% of occupants were missing at least one relevant variable), we used the Approximate Bayesian Bootstrap (ABB) hot-deck imputation method to impute both covariates and injury outcomes (10 total imputations). Each model corresponds with a combination of injury outcome and crash type. We applied the models to passenger vehicle crashes published in NASS-CDS (2000 to 2015) and CISS (2017 to 2022). Different than other recent studies, this study did not remove occupants based on seating position or restraint condition.

This study included 25 injury outcomes corresponding to body regions and injury severity levels. Four injury outcomes included overall Maximum Abbreviated Injury Scale regardless of body region injured (MAIS 2+, MAIS 3+, MAIS 4+, & fatal injuries).[1] Twenty-one additional injury outcomes specified different body regions, 11 Abbreviated Injury Scale (AIS) 2+ and 10 AIS 3+ injuries. Note that we only included body regions in the analysis of a given severity level if we could estimate injury ORs in all six crash types.

We modeled each of the 25 injury outcomes within six crash types; one crash type for each of four different planar crashes (*Frontal*, *Near-Side, Far-Side, and Rear*), one that included all planar crashes combined (*Combined Planar*), and one for *Primary Rollovers* (highest severity event was a rollover). Table 1 shows total weighted injury counts (average of the 10 imputations) for each injury outcome/crash type combination. Overall, we built 150 models covering each injury outcome and crash type pairing. Although the models are consistent across injury outcomes, they differ in some cases between crash types. The biggest difference occurs between *Primary Rollovers* and the other crash types. We determined that the variables delta V, vehicle

[1] The Abbreviated Injury Scale (AIS) is defined by the Association for the Advancement of Automotive Medicine (AAAM) and incorporates standardized current medical terminology to provide an internationally accepted tool for rating injury severity (AAAM, 2025). Each injury sustained by a crash victim receives a code, which defines the nature of the injury and its severity. Severity levels range from 1 to 6 (1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, 6 = maximal). The maximum severity level for an individual, the MAIS, is a globally accepted and widely used indicator of overall trauma severity.

weight ratio, and crash compatibility, included in planar crash models, do not have sensible definitions for *Primary Rollovers.* Therefore, these variables are excluded from the *Primary Rollover* models. The Methods section of this report gives further details on differences between crash type models.

Table 1. Weighted totals of injuries (average per imputation) for each crash type/injury outcome combination

		All	Frontal	Near	Far	Rear	Roll
Overall Severity	**MAIS 2+**	5,320,914	3,520,380	882,041	638,531	277,794	437,795
	MAIS 3+	1,953,559	1,254,948	384,480	234,972	77,343	196,347
	MAIS 4+	719,543	404,155	175,948	107,238	30,758	100,486
	Fatal	324,630	182,989	85,864	44,382	10,802	59,914
Body Region AIS 2+	**Head**	1,812,137	1,094,277	354,129	239,991	122,165	196,966
	Neck & C-spine	313,729	188,800	69,522	41,542	13,654	46,468
	Thorax	1,285,886	809,157	269,730	156,435	49,464	130,154
	Abdomen	438,714	269,065	97,850	53,765	17,457	36,952
	Thoracolumbar	412,613	252,886	73,333	59,157	26,628	60,804
	Torso	1,905,117	1,191,634	407,237	223,995	80,929	203,550
	Knee-Thigh-Hip	969,083	640,878	177,231	123,046	27,036	48,350
	Leg	306,617	231,204	47,902	16,630	10,738	19,332
	Foot & Ankle	546,403	472,648	39,283	22,798	11,660	12,993
	Upper Extremity	870,500	684,584	84,434	82,463	18,768	67,061
	Lower Extremity	1,558,498	1,130,970	230,236	152,810	43,550	70,998
Body Region AIS 3+	**Head**	477,178	273,393	105,531	75,690	21,295	57,985
	Neck & C-spine	131,268	77,945	29,670	17,207	6,409	21,297
	Thorax	793,555	472,621	195,966	96,783	27,119	88,670
	Abdomen	191,585	116,231	41,561	24,259	9,160	16,929
	Thoracolumbar	98,446	61,388	10,345	19,807	6,879	17,484
	Torso	921,448	566,690	208,804	112,861	32,027	101,959
	Knee-Thigh-Hip	407,413	281,016	91,731	25,961	8,002	25,412
	Leg	131,159	104,721	17,994	5,801	2,549	4,248
	Upper Extremity	215,856	158,620	30,586	21,666	4,930	21,248
	Lower Extremity	507,540	360,970	105,195	30,633	10,033	28,911

Results

Females had significantly higher odds of injury than males in 39 (OR > 1.0, *p*-value ≤ .05) out of 150 models. For the remaining 111 models, females had non-significantly (*p* > .05) higher injury odds in 81, compared to 30 for males. Males did not have significantly higher injury odds in any models. See below for results related specifically to *Overall Severity* and *Body Region* injury outcomes.

Overall Severity

Generally, females had higher injury odds than males when the injury outcome includes MAIS 2+ or MAIS 3+. For all six crash types, females had higher injury odds than males for these two injury outcomes except for MAIS 3+ injuries in rear crashes. However, the findings were only statistically significant in 4 out of 12 MAIS 2+ and 3+ models. These included MAIS 2+ injuries for *Combined Planar Crashes* (OR = 1.39, 95% confidence interval 1.18 to 1.63, *p*-value = .0004), *Frontal* Crashes (OR = 1.46, 95% CI 1.18 to 1.81, *p*-value = .0015) and Primary Rollovers (OR = 1.55, 95% CI 1.06 to 2.27, *p*-value = .0275), as well as MAIS 3+ injuries for *Primary Rollovers* (OR = 1.61, 95% CI 1.14 to 2.27, *p*-value = .0091).

The injury odds shifted toward males being higher for MAIS 4+ and *Fatal* injury models, although none of the results were statistically significant. Males had higher injury odds of MAIS 4+ injuries in three out of six crash models (*Combined Planar, Near-Side,* and *Far-Side Crashes*) and fatal injuries in four out of six crash models (*Combined Planar, Frontal, Far-Side,* and *Rear Crashes*).

Only *Primary Rollovers* had results where females had higher injury odds in all four *Overall Severity* injury outcomes. Table 2 shows ORs for *Overall Severity* injury outcomes by crash type.

Table 2. Female versus male Overall Severity injury outcome ORs by crash type

	Combined Planar	Frontal	Near-Side	Far-Side	Rear	Primary Rollovers
MAIS 2+	**1.3881**	**1.4608**	1.0489	1.5380	1.2600	**1.5467**
MAIS 3+	1.1456	1.1636	1.1266	1.1345	0.9116	**1.6096**
MAIS 4+	0.9796	1.0335	0.9203	0.7799	1.0678	1.2499
Fatal	0.8868	0.8208	1.1208	0.8045	0.7807	1.0464

Note: Primary rollovers have substantially different models than the other crash types and therefore the results should not be compared.
Bolded results are significant at *p* ≤ .05.

Body Regions

Females had higher injury odds than males in 56 out of 66 *Body Region* AIS 2+ injury outcomes (21 significantly higher) and 48 out of 60 *Body Region* AIS 3+ injury outcomes (14 significantly higher). Males had no significantly higher odds in any body region injury outcome.

Frontal Crashes had the most AIS 2+ body regions with higher injury odds for females (all 11), while *Combined Planar and Frontal Crashes* each had the highest number of body regions where females had significantly higher injury odds (7 out of 11). *Primary Rollover Crashes* had

the highest number of AIS 3+ body regions where females had higher (10 out of 10) and significantly higher (7 out of 10) injury odds than males. Table 3 shows counts of higher and significantly higher injury odds by injury severity, sex, and crash type.

Table 3. Counts of direction and significance of ORs by sex, body region injury severity, and crash type

		Combined Planar	Frontal	Near-Side	Far-Side	Rear	Primary Rollovers
Body Region AIS 2+	**Females Higher**	10	11	7	10	8	10
	Females Significantly Higher	7	7	0	2	0	5
	Males Higher	1	0	4	1	3	1
	Males Significantly Higher	0	0	0	0	0	0
Body Region AIS 3+	**Females Higher**	9	9	6	8	6	10
	Females Significantly Higher	4	0	1	2	0	7
	Males Higher	1	1	4	2	4	0
	Males Significantly Higher	0	0	0	0	0	0

In both AIS 2+ and AIS 3+ body region injury outcomes, females most consistently had higher (and significantly higher) injury odds for extremities (upper and lower). In all crash models for upper and lower extremity injuries AIS 2+ and AIS 3+, females had higher injury odds than males. For AIS 2+, females had significantly higher upper-extremity injury odds in *Combined Planar Crashes* (OR = 1.62, 95% CI 1.14 to 2.30, *p*-value = .0097) and *Frontal Crashes* (OR = 1.67, 95% CI 1.10 to 2.53, *p*-value = .0178), while having significantly higher lower-extremity injury odds in *Combined Planar Crashes* (OR = 1.67, 95% CI 1.26 to 2.20, *p*-value = .0008), *Frontal Crashes* (OR = 1.62, 95% CI 1.17 to 2.24, *p*-value = .0054), and *Far-Side Crashes* (OR = 2.73, 95% CI 1.46 to 5.09, *p*-value = .0047). For AIS 3+, females had significantly higher upper-extremity injury odds in *Combined Planar Crashes* (OR = 1.52, 95% CI 1.07 to 2.16, *p*-value = .0204), *Far-Side Crashes* (OR = 2.71, 95% CI 1.27 to 5.77, *p*-value = .0134), and *Primary Rollover Crashes* (OR = 2.87, 95% CI 1.26 to 6.53, *p*-value = .0138), while having significantly higher lower-extremity injury odds in *Combined Planar Crashes* (OR = 1.30, 95% CI 1.06 to 1.59, *p*-value = .0143), *Near-Side Crashes* (OR = 1.44, 95% CI 1.04 to 2.01, *p*-value = .0306), and *Primary Rollover Crashes* (OR = 2.08, 95% CI 1.17 to 3.68, *p*-value = .0147).

Males had higher injury odds than females most often for head injuries, although none of these findings were statistically significant (*p*-value > .05). Males had higher head injury odds for AIS

2+ injuries in two out of six crash types (*Near-Side* and *Far-Side Crashes*) and four out of six crash types for AIS 3+ injuries (*Combined Planar, Frontal, Far-Side,* and *Rear Crashes*). However, females did have significantly higher AIS 2+ head injury odds than males for *Combined Planar Crashes* (OR = 1.21, 95% CI 1.03 to 1.42, *p*-value = .0252), *Frontal Crashes* (OR = 1.33, 95% CI 1.09 to 1.62, *p*-value = .0068), and *Primary Rollover Crashes* (OR = 1.77, 95% CI 1.12 to 2.80, *p*-value = .0170). Females also had significantly higher AIS 3+ head injury odds than males for *Primary Rollover Crashes* (OR = 1.43, 95% CI 1.02 to 2.00, *p*-value = .0403).

Conclusions

This study assessed injury odds in females versus males in a variety of injury outcomes within six crash types while accounting for a variety of relevant covariates in a nationally representative set of data over 22 years. The results show that females more often have higher injury odds than males (120 out of 150 models; 39 with statistical significance or *p*-value ≤ .05). This result varies both within severity levels and body regions. Females were more likely to show higher and significantly higher odds in *Overall Severity* injury outcomes where lower-severity injuries (levels 2 and 3) are included. Additionally, females showed higher injury odds most often for extremity (upper and lower) injuries and least often for head injuries.

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Introduction

Prior studies have documented the relative risk or odds of injury and fatality for females versus males in motor vehicle crashes (Bose et al., 2011; Parenteau et al., 2013; Forman et al., 2019; Brumbelow & Jermakian, 2021; Noh et al. 2022). Largely, these studies have found that females are more often at higher relative risk or odds of injury than males. In using data from the Fatality Analysis Reporting System (FARS), Noh et al. (2022) found that newer model year vehicles, generally those with the newest vehicle occupant protection systems, had significantly reduced and, in some cases, non-significant relative fatality risk or odds differences between females and males. This contrasts with earlier reporting by Kahane (2013) where the main finding was that females were at significantly higher odds of fatality (17%), but the finding was associated with a wide range of vehicle model years where most of the case vehicles were not equipped with air bags. Brumbelow (2023) concluded that different vehicle and crash types must be controlled for as they can affect male and female relative odds analyses.

Prior studies have documented significantly higher odds of injury for females versus males. Notably, Forman et al. (2019) found that females had 2.4 times higher odds of sustaining an AIS 2+ injury, 1.7 times higher odds of sustaining an AIS 3+ injury, and 3.8 times higher odds of sustaining an ankle injury. Forman's study was limited to data from the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS), included only belted front-row occupants in frontal crashes, and considered a limited set of covariates. While Parenteau et al. (2013) did not produce female versus male injury ORs, they did report a higher relative risk of injury among female occupants than among male occupants. They defined relative risk as the ratio of the percentage of occupant cases with injury for females over the same percentage for males without accounting for differences in vehicle and crash types between female and male occupants. However, like Forman et al., the Parenteau et al. study was limited to belted occupants in frontal crashes found in NASS-CDS. Brumbelow and Jermakian (2021) also used NASS-CDS data but went further by including struck- or near-side drivers and right-front passengers involved in side-impact crashes in addition to frontal crashes. They also found females to be at higher odds of MAIS 2+ injury (OR of 2.2) in frontal crashes even after controlling for vehicle and crash differences but found a non-significant difference for MAIS 3+ (OR of 0.98). However, for side impacts, they found no significant difference in odds of injury between females and males. Brumbelow and Jermakian showed that females experienced similar or greater improvements (i.e., reductions in injury risk) with improved vehicle crashworthiness performance (compatible crashes with airbag deployment). Finally, Brumbelow (2023) observed that females are more often driving the struck vehicle in front-to-rear and front-to-side crashes and that females were more commonly in the lighter vehicle of the two crash partners in two-vehicle crashes overall.

The prior studies, while exploring similar aims to our study, did not combine data for various crash types and seating positions from NASS-CDS and the newer Crash Investigation Sampling System (CISS). Additionally, they applied a more restricted set of covariates. The aim of this study was to document the odds of various injury outcomes for females versus males while considering a broad range of passenger vehicle crash scenarios, pre-crash and crash covariates, and occupants.

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Methods

Data

This study used NASS-CDS and CISS data to produce multivariable logistic regression models relating relevant pre-crash and crash covariates to dependent injury outcomes for occupants 13 and older of passenger cars, light trucks, or vans. The estimation of these models took the survey design of NASS-CDS and CISS into account.

NASS-CDS and CISS are nationally representative surveys of police-reported passenger vehicle crashes. Both NASS-CDS and CISS focus on crashes involving passenger cars, light trucks, vans, and automobile derivatives (e.g., truck- and van-based vehicles) with a gross vehicle weight less than 10,000 lb (4,536 kg). The NASS-CDS and CISS three-stage sample design and weighting process are described by Zhang and Chen (2013) and Zhang et al. (2019a). NASS-CDS and CISS target populations differ slightly. The target population for the CISS is all police-reported motor vehicle crashes on a public trafficway, each involving at least one passenger vehicle towed from the scene for any reason (Zhang et al., 2019a). NASS-CDS requires that at least one passenger vehicle involved in the crash be towed due to damage. This effectively puts NASS-CDS cases within the domain of cases collected by CISS. Procedures described by Zhang et al. (2019b) were used in combining NASS-CDS and CISS for the current study. Crash technicians investigate an annual sample of about 4,000 crashes and collect detailed information about the crash, vehicles, and occupants. The data for this study is at the occupant level and was compiled from NASS-CDS years 2000 to 2015 and CISS years 2017 to 2022. There was no usable sample available in either NASS-CDS or CISS in 2016.

Crash Types

This study examines how injury odds differ between males and females at least 13 years old, in two general types of crashes: planar crashes and primary rollovers. This approach defines planar crashes as those where the highest change in velocity or delta V (where available) was determined to be associated with damage to the vehicle's front, side, or rear plane. The general area of damage for the most severe crash event, or GAD1, was the variable that defined this area of damage in NASS-CDS. In CISS, the defining variable was CDCPLANE when the DVRANK (ranking the Collision Deformation Classification or CDC, event in terms of total delta V) = 1, the highest severity ranking, producing the equivalent of GAD1 from NASS-CDS. Side impact cases were further broken down into cases where the case occupant was seated in an outboard position on the struck side of the vehicle (near-side) or middle seat or non-struck side of the vehicle (far-side). This results in four planar crash types that are considered in this study: frontal, near-side, far-side, and rear. An additional crash grouping was defined as the combination of these four crash types, totaling five crash types involving planar crashes.

Primary rollovers represent the sixth crash type used in this study. Only crashes where the GAD1 was the top of the vehicle and the ROLLOVER (ROLLTURN in CISS) variable was not zero were included in this crash type. Any primary planar case, based on GAD1, that also experienced a rollover event was assigned to the appropriate planar crash type. For example, if a vehicle was involved in a frontal crash (GAD1 = the front of the vehicle), and there was a subsequent rollover, occupants from that vehicle were included in the frontal crash type and not the rollover crash type. If a vehicle was involved in more than one event where the rollover event was determined the most severe (in terms of GAD1) and the other events were planar in nature, then

occupants of that vehicle were included in the primary rollover crash type. Occupants of vehicles that were not involved in either a planar crash or a primary rollover were not included in this study.

The following summarizes the inclusion criteria for each of the six crash types:

- **Frontal**: Occupants where the area of damage for the most severe event (GAD1) = F.
- **Side:** Occupants where GAD1 = (L, R). Around 99.9 percent of occupants fit into either near-side or far-side crashes, defined below. The remaining 0.1 percent of occupants were seated either in the cargo area or an unenclosed area. These occupants were not included in near-side or far-side crashes (defined by where the occupants sat relative to the side of the impact) but were included in the side impact crashes (defined only in terms of whether the impact occurred on the left or right side of the vehicle).
    - **Near-Side**: Outboard occupants in a GAD1 = L or R where they are seated on the struck- or near-side position (same side as crash).
    - **Far-Side**: Same as near-side but targeting center-seated occupants or outboard-seated occupants located opposite the struck side of the vehicle.
- **Rear**: Occupants involved in GAD1 = (B, C, D) crashes.
- **Combined Planar Crashes**: Includes all planar crash types (frontal, side, and rear) as defined above. All occupants 13 and older involved in these crashes were included in this type regardless of whether that crash had a subsequent rollover and regardless of seating position.
- **Primary Rollover**: All occupants in a vehicle where a rollover (vehicle turned onto side or roof) was the highest severity event. Here, GAD1 was restricted to the top of the vehicle (T).

GAD1 was missing in ~20 percent of cases initially. However, other variables accurately predicted the highest level of damage in over 99 percent of cases. In NASS-CDS, this was general area of damage for each vehicle (regardless of severity), represented by GADEV1 (first vehicle) or GADEV2 (other vehicle). In CISS, this was most-severely damaged plane without regard to delta V, represented by DAMPLANE. These variables filled in when GAD1 was missing and reduced the missing GAD1 to ~4.5 percent of cases. These remaining missing cases were imputed along with injury levels and model covariates. The imputation is discussed further in the *Missing Data and Imputation* section. Further details on crash type assessment are in Appendix B.

Variables

This study included 24 covariates for modeling (the specific covariates used depend upon the crash type, as described in Table 4), one of which is female/male, the primary covariate of interest (Table 4). Because the effect of female/male on injury odds may be explained by other factors involved in the crash (occupant, vehicle, or crash factors), 23 other covariates within NASS-CDS and CISS were selected to produce a more unbiased estimate of female/male injury OR. These covariates were either “crashworthiness” covariates (relevant given the type and severity, as well as vehicle and occupant covariates associated with a crash case), or non-crash

covariates (pre-crash). The crashworthiness covariates included occupant covariates (seat belt use, ejection, entrapment, age, body mass index, height, and seating position), crash type/severity covariates (crash type, manner of collision, delta V, air bag deployment, intrusion, and multi-impact), and vehicle covariates (body type, age, vintage, weight ratio, and compatibility). A break point of model year 2009 was chosen for the vehicle vintage covariate because it represents a reasonable balance between the date before and after which many occupant protection focused Federal Motor Vehicle Safety Standards (e.g., FMVSS Nos. 208 and 214) and consumer metric changes (U.S. New Car Assessment Program and Insurance Institute for Highway Safety) were taking effect.

For some covariates the specific crash type dictated whether these variables were used or not. Delta V, weight ratio, and crash compatibility were considered undefined for the primary rollover crash type designation where the highest severity event was not to the front, side, or rear of the vehicle, and therefore not included for *Primary Rollover* models. Additionally, the covariate crash type applies only to the *Combined Planar* models, as this is the only set of models with more than one crash type.

Two additional variables involved the presence and severity of rollovers and were applied differently for planar crashes versus primary rollovers. For planar crashes, an indicator covariate for the presence or absence of a rollover event in the vehicle's crash sequence was included. For *Primary Rollovers*, a covariate counting the number of roof inversions (times when the vehicle rolls over the top) was used instead of delta V as a measure of crash severity. Thus, the use of delta V and roof inversions are mutually exclusive. More details on the roof inversion classification are in Appendix B. Overall, the models for *Combined Planar Crashes* include 23 covariates, the individual planar crash models (*Frontal, Near-Side, Far-Side,* and *Rear)* include 22 covariates, and *Primary Rollovers* models include 19 covariates. Table 4 shows which crash types include each covariate.

The compatibility and weight ratio covariates call for an overview given their limited applicability and method of determination. Most importantly, both compatibility and weight ratio were only applicable for planar vehicle-to-vehicle crashes. Both covariates were set to *Not Applicable* for single vehicle or rollover crashes. The compatibility assessment considered the subject and partner vehicles' body types as well as the subject vehicle's override or underride coding (FOVERIDE and ROVERIDE in NASS-CDS, OVERUNDER in CISS). For front and rear crash types, presence of override or underride at the damage plane leads to a Not Compatible classification. Additional details on the compatibility definition and weight ratio calculation are in Appendix B.

The non-crashworthiness covariates included pre-crash occupant, event, and environment variables that were judged to be relevant to the resulting crash or that were found to be distributed with a bias towards one sex or the other. These covariates included avoidance maneuver, critical event, and pre-impact movement. As these pre-crash elements may be significantly associated with the likelihood of sustaining serious injury outcomes and possibly have some bias toward one sex versus the other (e.g., males more often experience control loss and make an avoidance maneuver), they were retained for use in this study.

Table 4 shows detailed information on these covariates, including definitions, categories (including reference levels) for categorical covariates, total counts (weighted imputed and unweighted unimputed) of the categories for males and females, and the percentage of occupants with missing values.

*Table 4. Predictor variable counts, weighted imputed and unweighted unimputed, by sex. Missing percentage for each predictor also included. Categories marked with * indicate reference categories for modeling.*

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	Female	Male	Female	
Sex	Case occupant's documented sex	All	*Male	52,408,334	-	96,080	-	1.43
			Female	-	46,022,335	-	81,412	
Avoidance Maneuver	Pre-impact crash avoidance maneuver documented for case vehicle	All	*None	15,885,121	16,573,313	30,569	29,987	0.00
			Any avoidance maneuver	18,558,232	14,935,215	28,739	24,815	
			Other/unknown	17,964,981	14,513,807	36,772	26,610	
Critical Event	Recorded pre-crash event associated with the crash of the case vehicle; many variables categorized into more limited groups for model development purposes (limit variance)	All	Control loss	5,746,601	3,621,664	10,875	6,988	0.06
			Run off road/turn into path	19,003,773	16,619,957	39,802	31,659	
			*Other vehicle in lane	25,812,180	24,171,735	42,956	40,755	
			Ped/animal/other object	1,845,780	1,608,980	2,384	1,979	
Pre-Impact Movement	Description of case vehicle's pre-impact movement	All	*Going straight	28,555,815	24,475,626	53,678	45,143	0.00
			Negotiating curve	10,221,641	7,378,603	18,874	12,734	
			Decelerating	1,281,738	1,193,642	1,831	1,956	
			Turning	6,905,970	7,765,138	12,363	12,990	
			Lane change/merge	1,271,347	1,127,967	1,986	1,572	

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	**Female**	**Male**	**Female**	
			Avoidance maneuver	423,781	235,661	620	444	
			Stopped	2,632,802	3,032,102	4,506	5,010	
			Other/unknown	1,115,241	813,596	2,222	1,563	
Seat Belt Use	Case occupant documented seat belt use	All	*Belted	43,347,502	39,689,853	51,230	51,000	25.54
			Unbelted	9,060,832	6,332,482	18,936	11,970	
Ejection	Case occupant ejection where any ejection (partial or full) is grouped as "yes" versus no ejection	All	Yes	460,074	226,196	3,236	1,691	13.46
			*No	51,948,259	45,796,140	79,108	70,054	
Entrapment	Case occupant entrapment is grouped as "yes" versus cases designated as no entrapment	All	*No	51,676,230	45,336,419	72,350	64,558	19.28
			Yes	732,103	685,916	4,070	2,849	
Seating Position	Designated Seating Position	All	*Driver	38,694,663	31,232,697	63,117	47,636	7.23
			Right-front passenger	7,691,451	8,836,590	14,131	17,100	
			Rear passenger	6,022,219	5,953,048	11,779	11,578	
BMI Group	Case occupant's calculated body mass index (BMI); calculated with recorded or	All	*18.5-25	20,386,381	20,305,506	22,556	24,089	35.15
			<18.5	2,563,330	3,567,470	2,562	4,371	
			25-30	18,192,970	12,450,686	22,400	13,694	

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	Female	Male	Female	
	imputed height and weight		30+	11,265,653	9,698,674	14,650	12,416	
Crash Type	Designated crash type by general area of damage for most severe crash event; rollover crash type required non-zero quarter turns and top plane damage coding	Combined Planar Crash	Rollover	2,265,774	1,435,528	5,462	3,581	4.51
			*Frontal	31,768,264	26,916,125	54,281	44,766	
			Side	13,833,859	13,223,138	24,188	22,760	
			Rear	4,012,019	4,051,502	6,211	6,577	
			**Other	528,418	396,042	1,004	698	
Manner of Collision	Generic description of crash scenario	All	*Not collision	16,081,657	10,670,604	29,764	18,667	1.91
			Rear-end	12,135,199	11,080,803	15,807	14,418	
			Head-on	1,276,476	1,229,722	5,178	3,838	
			Angle	19,596,567	20,053,507	37,250	37,839	
			Sideswipe	3,318,435	2,987,699	6,261	5,097	
Air bag Deployment	Air bag deployment status at case occupant seating location	All	*None	39,470,864	34,125,248	61,762	52,027	6.37
			Deployed at occ seat	12,937,470	11,897,088	27,815	24,606	
Intrusion	Any intrusion at occupant seating location versus no intrusion at seating location	All	*None	48,162,818	42,616,828	80,130	70,355	0.00
			At occ seat	4,245,516	3,405,507	15,950	11,057	

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	Female	Male	Female	
Multi-Impact	Case vehicles experiencing more than one documented crash event; no minimum threshold for second event	All	Yes	14,574,123	11,926,271	33,460	26,100	0.00
			*No	37,834,211	34,096,064	62,620	55,312	
Vehicle Body Type	Case vehicle body type	All	*Passenger cars	31,202,150	30,961,987	56,277	53,329	0.00
			Utility	9,018,359	9,521,244	17,199	17,432	
			Vans	3,575,201	3,151,683	7,203	6,193	
			Pickups	8,533,479	2,382,319	15,176	4,431	
			Other/unknown	79,145	5,102	225	27	
Vehicle Vintage	Binary measure of vehicle model year with 2009 and newer versus 2008 and older	All	*<2009	42,091,300	34,981,425	79,393	63,967	0.00
			2009+	10,317,033	11,040,910	16,685	17,445	
Weight Ratio	Case vehicle weight divided by other vehicle weight when known for vehicle-to-vehicle crashes. For impacts to objects and non-collisions, ratio was not applicable.	Combined, Frontal, Side, Rear	*< 1.0	16,994,479	18,039,462	24,369	27,123	9.64
			1.0-2.0	13,123,225	11,544,420	22,154	19,707	
			> 2.0	310,836	151,534	834	429	
			Not Applicable	21,979,795	16,286,919	38,727	27,023	
			*Yes	15,534,309	15,453,647	25,439	26,425	6.05

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	Female	Male	Female	
Compatible Crash	Compatibility based on classes and weights of subject and partner vehicle in planar vehicle-to-vehicle crashes. For impacts to objects and non-collisions, compatibility was not applicable.	Combined, Frontal, Side, Rear	No	15,153,124	14,533,477	25,523	23,657	
			Not Applicable	21,720,901	16,035,211	38,727	27,023	
Occupant Age Group	Occupant age grouped into categories	All	<13	3,773,402	3,782,976	6,915	6,812	2.39
			*13-24	17,312,107	14,314,192	29,925	24,105	
			25-34	10,739,890	8,800,697	19,676	15,118	
			35-44	7,656,757	6,636,559	13,479	11,286	
			45-54	5,605,316	5,055,122	10,536	9,270	
			55-64	3,721,418	3,587,914	6,931	6,678	
			65+	3,599,443	3,844,876	7,376	7,462	
Occupant Height Group	Occupant height grouped into categories	All	1-100 cm	1,432,806	1,312,503	1,553	1,530	35.15
			*100-163 cm	8,406,204	19,844,422	5,316	27,631	
			163-170 cm	10,223,761	14,297,925	10,746	18,445	
			170-180 cm	18,998,316	7,863,215	26,395	6,490	
			180-220 cm	13,347,247	2,704,271	18,158	474	

Variable	Description	Models	Units/Levels	Weighted (Imputed)		Unweighted (Unimputed)		Missing %
				Male	**Female**	**Male**	**Female**	
Planar Rollover	Binary measure of whether the vehicle experienced a rollover during a planar crash	Combined, Frontal, Side, Rear	*No	50,610,806	44,697,181	90,572	77,784	0.00
			Yes	1,797,528	1,325,155	5,508	3,628	
Inversions	Number of times the vehicle roof faces the ground in a rollover	Rollovers	*No Inversions	59,260	22,928	198	105	0.00
			One Inversion	1,733,136	1,159,936	3,467	2,347	
			Two or More Inversions	448,280	246,889	1,692	1,087	
			End over End or Unknown	25,098	5,774	105	42	
			Not Primary Rollover	50,142,559	44,586,807	90,618	77,831	
Delta V	Case vehicle change in velocity associated with most significant crash event	Combined, Frontal, Side, Rear	Km/h – Average per Imputation	19.66	19.47	25.49	23.63	47.17
Vehicle Age	Case vehicle age at time of crash	All	Years – Average per Imputation	8.96	7.86	8.25	7.14	0.02

** “Other” crash type included for information only. It is not included as category for *Crash Type* for statistical modeling purposes.

Missing Data and Imputation

As with many other surveys, the sampled crashes in the NASS-CDS and CISS suffered from non-response. There were two types of non-response in the sampled crashes: unit non-response and item non-response. Unit non-response refers to a crash that was not available for investigation (NASS-CDS definition) or the key vehicle of the crash was not available for investigation (CISS definition). Unit non-responses in NASS-CDS and CISS are handled by weighting adjustment as described in Zhang et al. (2019a). On the other hand, item non-response refers to missing or unknown values of the study covariates such as a vehicle's change in velocity (delta V) measurement or an occupant's height, etc.

Covariates that had the highest missing rates included delta V (47.2% of cases) and both body mass index (BMI) and height (35.2%), while some covariates do not have missing values (e.g., pre-impact movement, vehicle body type, and vehicle age). In addition to covariates, 21.1 percent of injury outcome data was missing. This is largely due to NASS-CDS 2009 to 2015 case collection limitations where injury data was not collected for occupants in passenger vehicles older than 10 years old. Given high missing data rates, we did not opt for the complete-case approach, which would have resulted in the deletion of approximately 68 percent of occupants.

Without treatment, both unit non-response and item non-response may bias the estimates. Generally, unit non-response is handled by weighting adjustments. Proper weighting adjustment takes the non-response mechanism into account and hence reduces the non-response bias. Item non-response is often handled by imputation. Imputation assigns plausible values to the missing items of a case so that its non-missing items can be used for analysis. Proper imputation not only prevents further non-response bias caused by missing items but also increases the effective sample size used for the analysis. For a review of various unit non-response adjustments and missing value imputation methods, see Brick and Kalton (1996).

Part of the NASS-CDS and CISS annual weighting procedures includes adjusting the analysis weights to compensate for the excluded unit non-response crashes. Details about the NASS-CDS and CISS sample designs and weighting processes, and the CISS weighting process are in Zhang and Chen (2013) and Zhang et al. (2019a). On the other hand, item non-response or missing values were left for the data users to make their own customized imputation or adjustments.

Various imputation methods and software have been developed to handle missing values. The PROC SURVEYIMPUTE procedure, first available with SAS/STAT 14.1 software,[2] provides several imputation methods, including the fully efficient fractional imputation and one of the hot-deck (HD) imputation methods - the Approximate Bayesian Bootstrap.

FEFI was first considered for this study. For any occupant with any missing values (recipients), FEFI uses all complete case occupants with identical values of non-missing recipient variables as donors. For each donor, a fractional weight is computed using the expectation maximization algorithm such that the fractional weights sum up to the recipient's original weight.

Fuller and Kim (2005) mathematically proved that FEFI is equivalent to a weighting adjustment, hence it does not incur imputation variance. However, FEFI is computationally intensive because the process results in datasets several times larger than the original, especially with high missing rates. As a result, FEFI did not run to completion. We used ABB instead. ABB is a donor

[2] SAS Institute Inc., Arlington, VA. www.sas.com/en_us/software/stat.html

selection method for HD imputation that is recommended for use with multiple imputation (Rubin, 1987). According to the *SAS/STAT 15.1 User's Guide* (SAS Institute, 2019), assuming the non-response mechanism becomes ignorable (or the non-response mechanism does not need to be modeled) in an imputation cell, ABB uses the following two steps for donor selection if there are *m* recipient units and *r* donor units.

1. Select a sample of size *r* from the *r* donor units using a simple random sampling with replacement method. Because the selection is with replacement, some donors may be selected several times, and some may not be selected at all.
2. Select *m* donor units from the *r* donor units selected in Step 1 using a simple random sampling with replacement method. Then the *m* donor units are randomly matched to the *m* recipient units. The missing values of each recipient unit are then imputed by the corresponding non-missing values of the matched donor unit.

First, variables correlated with the data missingness mechanism are used to form the imputation cells. Second, one set of donors is selected from each imputation cell to impute the missing values of the recipient units in the same imputation cell. The imputed data set is then used to make point estimates and variance estimates. To capture the imputation variance, ABB is combined with the multiple imputation method by repeating the above two-step process several times (10 times for this study). The final point estimates and the associated variance estimates are then made from the individual point estimates (10 estimates in this case) and individual variance estimates. For detailed information about ABB and multiple imputation, see Rubin (1987). Several studies have shown the advantages of the multiple HD imputation with ABB sample selection scheme (Vinod & Punithavalli, 2011; Soley-Bori, 2013; Durrant, 2005).

Due to the complex nature of the NASS-CDS/CISS sample survey design, we used SURVEYLOGISTIC procedure of SAS Version 9.4 within each of the 10 imputed datasets. We then combined the 10 imputation estimates using SAS PROC MIANALYZE procedure to output the final point and variance (including the *p*-value) estimates of the OR (Rubin, 1987; Mukhopadhyay, 2016).

Statistical Modeling

A logistic regression model allows for the prediction of a dichotomous outcome, defined by the dependent variable, from a set of independent variables that may be continuous or dichotomous or both. For this study's purposes, logistic regression can estimate how injury odds differ between females and males after accounting for many occupant, crash, and vehicle factors.

The logistic regression model, as expressed below, assumes a specific structure between a set of independent variables and the probability (p_i) of a certain class of the dependent variable for the *ith* subject

$$Logit(p_i) = \log\left(\frac{p_i}{1 - p_i}\right) = \log(odds_i)$$

$$= \beta_0 + \beta_1 X_{1\mathrm{i}} + \cdots + \beta_k X_{ki}$$

where k is the number of independent variables, $X_{1\mathrm{i}}, \ldots, X_{ki}$ are independent variable values for the *ith* subject, and $\beta_0, \ldots, \beta_k$ are coefficient estimates.

This study uses 24 independent variables: female/male, and 23 other variables chosen as possible explainers of injury odds. As noted earlier the most any single model has is 23 variables (*Combined Planar Crashes* models). Female/male is defined as a categorical variable with "male" as the reference level. This is equivalent to setting the *ith* subject as "0" if male and "1" if female such that

$$FM_i = \begin{cases} 1 & if\ Female \\ 0 & if\ Male. \end{cases}$$

Other categorical variables are defined similarly, where if there are *C* categories of that variable, then one category is chosen as the reference level, and the remaining *C – 1* categories are assigned dichotomous variables as with FM_i above. Additionally, there were two continuous variables (delta V and vehicle age), whose values were assigned as is.

Inference was done primarily on the sex coefficient, expressed as β_{FM}. The interpretation of β_{FM} is as follows: the log odds of injury for a female is β_{FM} higher/lower than males while holding the other factors fixed. Once an estimate for β_{FM}, $\widehat{\beta_{FM}}$, is computed, the interpretation is as follows: If $\widehat{\beta_{FM}} > 0$, females are estimated to have higher injury log odds. If $\widehat{\beta_{FM}} < 0$, males are estimated to have higher injury log odds.

The reported values are the estimated ORs of female to male injury, which are expressed as

$$\widehat{OR_{FM}} = e^{\widehat{\beta_{FM}}}.$$

As noted in the *Missing Data and Imputation* section, the final OR estimates make use of the 10 estimates from the individual imputations. Standard errors for the final coefficient estimates are also calculated using the standard errors of the model coefficients in the individual imputations.

To construct s (CI) for the ORs, we first need CIs for the model coefficients. We constructed the CIs using the t-distribution, where degrees of freedom are model specific after accounting for the imputation, which means that the 0.05 critical value is also model specific. See the MIANALYZE procedure manual of SAS Version 9.4 for details. Let C_j be the imputation-adjusted critical value for the jth model. Then the coefficient CI is

$$LCL_{\widehat{\beta_{FM\,J}}} = \widehat{\beta_{FM\,J}} - C_j * \widehat{SE}_{\widehat{\beta_{FM\,J}}},\ UCL_{\widehat{\beta_{FM\,J}}} = \widehat{\beta_{FM\,J}} + C_j * \widehat{SE}_{\widehat{\beta_{FM\,J}}}.$$

Then, the OR CI is

$$LCL_{\widehat{OR_{FM\,J}}} = e^{LCL_{\widehat{\beta_{FM\,J}}}},\ UCL_{\widehat{OR_{FM\,J}}} = e^{UCL_{\widehat{\beta_{FM\,J}}}}.$$

A separate logistic regression model was developed for each combination of 25 injury types and six crash types, totaling 150 models. For example, consider MAIS 2+ overall injury severity for frontal crashes (vehicles where the plane of impact for the highest-ranked event was determined to be the vehicle's front). The model had a dichotomous dependent variable showing whether an occupant sustained moderate injuries as defined by having a MAIS severity score of 2 or higher.

$$MAIS2_i = \begin{cases} 1 & if\ MAIS\ 2+ \\ 0 & otherwise \end{cases}$$

The injury levels considered included severity levels (MAIS 2+, 3+, 4+ and fatal injury) regardless of body region. Additionally, we studied body-region-specific injuries at AIS 2+ or AIS 3+ levels.

The occurrence of body region injuries was determined from data collected and recorded in NASS-CDS and CISS via AIS codes, which are seven-digit codes that have information about the injury's body region, organ, type of injury, and severity. The NASS-CDS injuries were classified per AIS 1990 (1998 update) (Association for the Advancement of Automotive Medicine, 1998) and CISS cases were coded using AIS 2015 (AAAM, 2015). Table 2 lists the AIS-related body region codes as documented in NASS-CDS and CISS and how they were mapped to represent the respective injury outcome groupings used in this study.

Table 5. Body region injury codes for NASS-CDS and CISS

Body Region	**Codes**	
	NASS-CDS: *Bodyreg* (AIS 1990/1998 update)	**CISS: *Bri* (AIS 2015)**
Head	F, H	1
Neck/Cervical Spine	N	2, 3
Thorax	C	12
Abdomen	M	13
Thoracolumbar Spine	B	4, 5
Knee-Thigh-Hip	K, T, P	14, 15, 16, 17
Leg	L	18
Foot/Ankle	Q	19, 20
Upper Extremities	A, E, R, W, X	7, 8, 9, 10, 11
Lower Extremities	K, L, P, Q, T, Y	14, 15, 16, 17, 18, 19, 20
Torso	M, C, B, S	4, 5, 6, 12, 13

All 11 body regions in Table 2 were used for AIS 2+ injuries. Foot/ankle AIS 3+ injuries were dropped due to low numbers of such injuries.

Multicollinearity (correlation between covariates) can adversely impact model coefficients (including the sex coefficient) by inflating their variances, and this impact can be measured using variance inflation factors. Typically, VIFs greater than 5 or 10 are concerning. A multicollinearity analysis was performed separately with *Combined Planar* and *Primary Rollover* covariates (since *Planar* models have five covariates not contained in *Primary Rollover* models) to check the VIF for sex. The VIF was found to be 1.30 for *Planar* models and 1.44 for *Primary Rollover* models indicating no evidence of excessive variance of the sex coefficient. The coefficients for age group, height group, and BMI group, all which are discussed in Appendix A, also do not have any VIFs greater than 2.

We present female/male injury ORs and 95 percent CIs among occupants at least 13 years old for planar crashes (*Combined Planar, Frontal, Near-Side, Far-Side, and Rear*) and separately for *Primary Rollover* crashes. Injury ORs were considered statistically significant for p-values $\leq .05$. The occupant injury mechanisms, distribution of injured body regions, and the injury contact sources in frontal impact, near-side impact, far-side impact, rear impact, and rollover crashes have been shown to be different from each other (Liu et al., 2007).

Results

The final imputed sample of weighted cases from NASS-CDS 2000 to 2015 and CISS 2017 to 2022 included a total of 98,430,669 (average of female = 46,022,335; male = 52,408,334 per imputation) occupants of passenger vehicles in police-reported crashes. Of these occupants, 90,874,291 (female = 42,239,359; male = 48,634,932) were at least 13 years old. The corresponding injury data is summarized in Table 6, which also includes unweighted totals (both imputed and unimputed). Note that odds ratios are computed using uninjured occupants, logistic regression models, and potential confounding factors, so they should not be inferred from numbers in Table 6 (which do not make use of any of these factors). Predictor variable data is summarized in Table 4, where both weighted case counts of the imputed sample and unweighted counts of the unimputed sample are shown (as well as the unweighted missing percentage). See Appendix C for specific DF and *p*-values for each of the 150 models.

Table 7 shows female to male ORs with 95 percent CIs for planar crashes. Figure 1 shows significant results for *Combined Planar Crashes* and *Frontal Crashes.* For *Overall Severity* injury outcomes, females show significantly higher odds (OR > 1.0; *p*-value ≤ .05) of MAIS 2+ injuries for *Combined Planar Crashes* (OR = 1.39, 95% CI 1.18-1.63, *p*-value = .0004). Females also had significantly higher MAIS 2+ injury odds for *Frontal Crashes* (OR = 1.46, 95% CI 1.18-1.81, *p*-value = .0015). The remaining OR estimates for overall injury severity among planar crashes were not statistically significant. Overall, females had higher odds in 12 out of 20 *Overall Severity* planar crash models, but only 2 results were statistically significant. Generally, female/male OR estimates decreased as the injury severity level increased. Females had higher overall MAIS 2+ injury odds for all five planar crash models (two models statistically significant), while males had higher fatal injury odds in four out of five models (excluding near-side crashes; results in all models were not statistically significant).

For specific body regions, females had significantly higher odds of AIS 2+ injuries than males in 16 out of 55 planar crash body region models, while males had none that were significantly higher. *Combined Planar Crashes* (head, thoracolumbar, knee-thigh-hip, leg, foot/ankle, and upper/lower extremities) and *Frontal Crashes* (head, thoracolumbar, torso, leg, foot/ankle, and upper/lower extremities) both had seven body regions with significantly higher injury odds for females, while *Far-Side Crashes* had two (knee-thigh-hip and lower extremities). Only lower extremities had significantly higher AIS 2+ injury odds for females in all three of these crash types (*Combined Planar, Frontal, and Far-Side*). For AIS 3+ injuries, females had seven significantly higher injury odds out of 50 body regions, while males had none. Four of those significant results were in *Combined Planar Crashes* (knee-thigh-hip, leg, and upper/lower extremities), two in *Far-Side Crashes* (thoracolumbar and upper extremities), and one in *Near-Side Crashes* (lower extremities).

Table 6. MAIS and body region injury counts (weighted imputed, unweighted imputed, and unweighted unimputed) for age ≥ 13 occupants by sex for each crash model type. Imputed totals are the averages per imputation.

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Overall Severity	MAIS 2+	Weighted Imputed	2,615,986	2,704,929	1,756,185	1,764,195	450,008	432,033	282,698	355,833	125,534	152,260	267,634	170,161
		Unweighted Imputed	18,356	14,153	11,741	8,812	3,479	2,814	2,320	1,850	794	661	1,949	1,161
		Unweighted Unimputed	14,073	11,278	8,950	7,040	2,851	2,363	1,716	1,412	530	443	1,718	1,036
	MAIS 3+	Weighted Imputed	1,075,498	878,060	715,249	539,698	195,882	188,598	123,678	111,294	39,404	37,939	115,730	80,617
		Unweighted Imputed	10,981	7,465	6,759	4,417	2,384	1,764	1,417	971	404	300	1,280	740
		Unweighted Unimputed	8,590	6,007	5,199	3,518	2,026	1,532	1,073	745	270	195	1,149	671
	MAIS 4+	Weighted Imputed	432,400	287,143	251,922	152,233	98,660	77,288	65,931	41,308	14,955	15,803	63,267	37,219
		Unweighted Imputed	5,819	3,308	3,205	1,666	1,480	977	880	499	241	153	824	436
		Unweighted Unimputed	4,682	2,665	2,471	1,272	1,308	873	704	396	180	108	763	407
	Fatal	Weighted Imputed	210,279	114,351	125,394	57,595	49,609	36,255	29,049	15,333	5,959	4,843	41,191	18,723
		Unweighted Imputed	3,320	1,745	1,801	864	886	550	485	238	141	83	552	261
		Unweighted Unimputed	2,857	1,496	1,506	709	812	509	409	198	118	68	525	252

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Body Region AIS 2+	Head	Weighted Imputed	989,884	822,253	602,053	492,223	187,352	166,776	139,847	100,144	59,570	62,594	112,379	84,587
		Unweighted Imputed	7,938	5,060	4,646	2,766	1,681	1,237	1,199	779	398	265	942	549
		Unweighted Unimputed	6,721	4,364	3,866	2,331	1,489	1,118	1,019	678	329	222	873	520
	Neck and C Spine	Weighted Imputed	175,877	137,851	110,109	78,691	34,517	35,005	23,264	18,278	7,844	5,810	28,755	17,714
		Unweighted Imputed	1,882	1,276	1,032	678	426	325	324	210	96	60	321	210
		Unweighted Unimputed	1,594	1,116	843	578	382	299	285	188	80	49	306	204
	Thorax	Weighted Imputed	711,569	574,317	462,134	347,023	150,532	119,198	77,594	78,841	20,543	28,921	78,689	51,465
		Unweighted Imputed	6,203	4,240	3,608	2,365	1,541	1,124	835	571	207	169	711	393
		Unweighted Unimputed	5,332	3,734	3,049	2,044	1,405	1,040	703	499	159	138	663	370
	Abdomen	Weighted Imputed	240,370	198,344	149,208	119,857	52,964	44,886	25,930	27,835	11,938	5,520	16,551	20,401
		Unweighted Imputed	2,875	2,056	1,648	1,092	769	593	359	303	92	60	238	164
		Unweighted Unimputed	2,473	1,824	1,387	947	707	554	296	267	71	48	213	153
	Thoracolumbar	Weighted Imputed	193,875	218,739	122,042	130,844	35,673	37,660	23,055	36,103	12,534	14,094	38,793	22,011
		Unweighted Imputed	1,803	1,363	1,022	775	401	282	266	219	109	85	304	213

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
		Unweighted Unimputed	1,579	1,209	878	676	369	255	233	199	94	75	293	208
	Torso	Weighted Imputed	1,018,088	887,030	640,149	551,485	231,103	176,134	109,311	114,684	36,652	44,276	128,427	75,123
		Unweighted Imputed	8,203	5,936	4,796	3,380	1,987	1,483	1,102	828	303	234	993	574
		Unweighted Unimputed	7,021	5,240	4,038	2,943	1,803	1,366	925	725	236	191	927	543
	Knee-Thigh-Hip	Weighted Imputed	485,310	483,773	365,992	274,885	79,251	97,981	29,088	93,959	10,235	16,801	25,134	23,215
		Unweighted Imputed	4,642	3,537	3,143	2,097	1,007	948	377	375	109	109	259	209
		Unweighted Unimputed	3,996	3,122	2,725	1,836	904	876	288	313	72	87	222	189
	Leg	Weighted Imputed	152,353	154,265	114,409	116,795	24,515	23,386	8,289	8,341	5,016	5,722	14,058	5,274
		Unweighted Imputed	1,572	1,373	1,177	1,065	266	186	97	88	30	32	81	61
		Unweighted Unimputed	1,324	1,218	1,013	969	230	158	63	69	15	21	67	54
	Foot & Ankle	Weighted Imputed	199,303	347,100	172,593	300,054	14,686	24,597	6,356	16,442	5,668	5,992	5,488	7,505
		Unweighted Imputed	1,660	1,921	1,393	1,639	157	142	79	109	30	30	72	58
		Unweighted Unimputed	1,395	1,735	1,216	1,517	118	113	47	84	14	19	55	50
	Upper Extremity	Weighted Imputed	390,590	479,910	309,223	375,361	40,398	44,036	33,110	49,353	7,723	11,044	42,518	24,543

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
		Unweighted Imputed	2,958	2,842	2,127	2,063	458	402	281	293	88	78	327	228
		Unweighted Unimputed	2,508	2,528	1,831	1,861	390	353	217	248	65	58	301	214
	Lower Extremity	Weighted Imputed	701,557	856,941	542,029	588,941	101,228	129,008	39,503	113,308	18,018	25,532	39,367	31,631
		Unweighted Imputed	6,379	5,538	4,509	3,733	1,217	1,133	493	510	152	155	363	284
		Unweighted Unimputed	5,405	4,902	3,871	3,330	1,067	1,025	360	419	97	118	307	256
Body Region AIS 3+	Head	Weighted Imputed	302,889	174,289	182,261	91,132	59,347	46,184	47,648	28,043	12,691	8,604	33,273	24,712
		Unweighted Imputed	3,579	2,017	1,893	955	914	612	602	343	160	97	468	274
		Unweighted Unimputed	3,011	1,729	1,528	773	823	564	515	302	131	80	437	262
	Neck and C Spine	Weighted Imputed	76,758	54,510	47,681	30,264	14,501	15,170	10,688	6,519	3,888	2,520	13,940	7,357
		Unweighted Imputed	875	573	496	294	182	152	155	96	42	31	157	91
		Unweighted Unimputed	728	500	399	248	158	139	136	86	35	27	150	88
	Thorax	Weighted Imputed	439,999	353,556	266,979	205,642	109,974	85,992	46,245	50,538	16,068	11,051	50,991	37,679
		Unweighted Imputed	4,924	3,189	2,741	1,685	1,322	926	674	437	176	132	589	319
		Unweighted Unimputed	4,227	2,789	2,294	1,432	1,213	859	568	380	137	106	552	301

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	Abdomen	Weighted Imputed	104,571	87,014	63,173	53,058	22,882	18,679	12,309	11,950	6,032	3,129	7,001	9,928
		Unweighted Imputed	1,297	921	711	504	378	263	171	122	33	26	104	68
		Unweighted Unimputed	1,124	816	600	440	350	245	145	107	24	19	93	64
	Thoracolumbar	Weighted Imputed	42,316	56,130	28,919	32,469	6,236	4,108	3,953	15,854	3,202	3,677	10,321	7,164
		Unweighted Imputed	429	294	261	175	76	45	60	44	31	28	83	58
		Unweighted Unimputed	375	260	224	153	70	39	53	41	28	26	80	56
	Torso	Weighted Imputed	497,112	424,336	308,271	258,420	116,953	91,850	53,497	59,364	17,657	14,370	58,222	43,737
		Unweighted Imputed	5,400	3,626	3,077	1,979	1,400	996	723	496	189	143	644	365
		Unweighted Unimputed	4,628	3,178	2,579	1,698	1,280	920	607	433	147	115	603	345
	Knee-Thigh-Hip	Weighted Imputed	230,130	177,283	173,703	107,313	40,265	51,466	12,736	13,225	2,834	5,167	12,662	12,750
		Unweighted Imputed	2,905	1,909	1,990	1,191	639	515	221	158	51	40	160	124
		Unweighted Unimputed	2,519	1,681	1,739	1,046	575	475	169	124	30	29	138	112
	Leg	Weighted Imputed	65,810	65,349	54,970	49,752	6,963	11,031	2,766	3,036	1,018	1,531	2,228	2,020
		Unweighted Imputed	821	694	640	558	126	84	42	38	13	14	37	24

			Combined Planar		Frontal		Near-Side		Far-Side		Rear		Roll	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
		Unweighted Unimputed	690	606	551	504	107	68	26	27	5	7	29	21
	Upper Extremity	Weighted Imputed	108,285	107,571	81,857	76,763	15,129	15,457	9,537	12,129	1,763	3,168	9,001	12,247
		Unweighted Imputed	1,059	1,016	754	718	176	149	98	121	31	26	120	100
		Unweighted Unimputed	879	900	635	644	149	129	73	105	22	19	108	94
	Lower Extremity	Weighted Imputed	275,669	231,871	211,863	149,106	44,632	60,562	15,018	15,614	3,558	6,476	14,355	14,556
		Unweighted Imputed	3,442	2,458	2,413	1,641	714	577	249	184	60	50	192	142
		Unweighted Unimputed	2,955	2,164	2,093	1,456	636	525	185	142	34	34	164	128

Table 7. Female versus male injury ORs for planar crashes with 95% CIs

		Combined Planar	Frontal	Near-Side	Far-Side	Rear
Overall Severity	**MAIS 2+**	**1.39 (1.18, 1.63)**	**1.46 (1.18, 1.81)**	1.05 (0.75, 1.46)	1.54 (0.94, 2.52)	1.26 (0.68, 2.34)
	MAIS 3+	1.15 (0.97, 1.35)	1.16 (0.94, 1.45)	1.13 (0.76, 1.67)	1.13 (0.64, 2.01)	0.91 (0.41, 2.03)
	MAIS 4+	0.98 (0.69, 1.38)	1.03 (0.68, 1.56)	0.92 (0.54, 1.58)	0.78 (0.45, 1.36)	1.07 (0.40, 2.88)
	Fatal	0.89 (0.74, 1.06)	0.82 (0.64, 1.05)	1.12 (0.79, 1.60)	0.80 (0.51, 1.26)	0.78 (0.45, 1.37)
Body Region AIS 2+	**Head**	**1.21 (1.03, 1.42)**	**1.33 (1.09, 1.62)**	0.97 (0.68, 1.37)	0.93 (0.64, 1.34)	1.25 (0.54, 2.90)
	Neck & C-spine	1.18 (0.76, 1.85)	1.16 (0.70, 1.93)	1.19 (0.74, 1.90)	1.22 (0.53, 2.80)	1.28 (0.32, 5.13)
	Thorax	0.98 (0.79, 1.22)	1.01 (0.77, 1.32)	0.79 (0.55, 1.12)	1.22 (0.52, 2.84)	1.02 (0.39, 2.65)
	Abdomen	1.11 (0.82, 1.50)	1.18 (0.84, 1.66)	0.94 (0.72, 1.22)	1.19 (0.67, 2.11)	0.44 (0.14, 1.38)
	Thoracolumbar	**1.69 (1.26, 2.28)**	**1.61 (1.01, 2.59)**	1.46 (0.90, 2.36)	2.46 (0.90, 6.71)	1.33 (0.53, 3.36)
	Torso	1.15 (0.98, 1.35)	**1.24 (1.01, 1.52)**	0.83 (0.61, 1.12)	1.34 (0.63, 2.84)	1.10 (0.51, 2.37)
	Knee-Thigh-Hip	**1.37 (1.14, 1.65)**	1.13 (0.90, 1.42)	1.28 (0.84, 1.96)	**2.82 (1.60, 4.96)**	2.12 (0.93, 4.85)
	Leg	**1.34 (1.02, 1.76)**	**1.44 (1.00, 2.08)**	1.12 (0.58, 2.14)	1.37 (0.45, 4.23)	0.84 (0.20, 3.41)
	Foot & Ankle	**2.17 (1.25, 3.75)**	**2.28 (1.23, 4.21)**	1.44 (0.56, 3.74)	2.56 (0.90, 7.27)	0.90 (0.14, 5.62)
	Upper Extremity	**1.62 (1.14, 2.30)**	**1.67 (1.10, 2.53)**	1.38 (0.89, 2.12)	1.64 (1.00, 2.71)	1.51 (0.31, 7.34)
	Lower Extremity	**1.67 (1.26, 2.20)**	**1.62 (1.17, 2.24)**	1.30 (0.81, 2.10)	**2.73 (1.46, 5.09)**	1.53 (0.67, 3.52)

		Combined Planar	Frontal	Near-Side	Far-Side	Rear
Body Region AIS 3+	**Head**	0.85 (0.63, 1.14)	0.81 (0.53, 1.25)	1.07 (0.70, 1.63)	0.78 (0.38, 1.56)	0.63 (0.24, 1.65)
	Neck & C-spine	1.07 (0.59, 1.95)	1.09 (0.47, 2.55)	1.16 (0.72, 1.85)	0.81 (0.37, 1.79)	1.08 (0.30, 3.93)
	Thorax	1.09 (0.83, 1.43)	1.19 (0.85, 1.66)	0.82 (0.59, 1.12)	1.38 (0.65, 2.89)	0.53 (0.19, 1.48)
	Abdomen	1.03 (0.68, 1.55)	1.11 (0.66, 1.88)	0.90 (0.60, 1.36)	1.08 (0.60, 1.95)	0.47 (0.10, 2.30)
	Thoracolumbar	1.85 (0.91, 3.76)	1.48 (0.86, 2.53)	0.95 (0.38, 2.34)	**4.86 (1.02, 23.04)**	1.39 (0.71, 2.74)
	Torso	1.14 (0.90, 1.45)	1.25 (0.93, 1.66)	0.83 (0.61, 1.13)	1.36 (0.69, 2.69)	0.66 (0.23, 1.89)
	Knee-Thigh-Hip	**1.22 (1.00, 1.49)**	1.10 (0.85, 1.43)	1.37 (0.95, 1.98)	1.54 (0.81, 2.94)	1.90 (0.39, 9.28)
	Leg	**1.45 (1.01, 2.08)**	1.42 (0.95, 2.13)	1.78 (0.80, 3.97)	1.37 (0.24, 7.92)	1.41 (0.07, 30.32)
	Upper Extremity	**1.52 (1.07, 2.16)**	1.43 (0.93, 2.21)	1.43 (0.64, 3.18)	**2.71 (1.27, 5.76)**	1.46 (0.13, 16.25)
	Lower Extremity	**1.30 (1.06, 1.59)**	1.21 (0.93, 1.57)	**1.44 (1.04, 2.01)**	1.55 (0.69, 3.50)	1.79 (0.29, 11.01)

Bolded results are significant at $p \leq .05$.

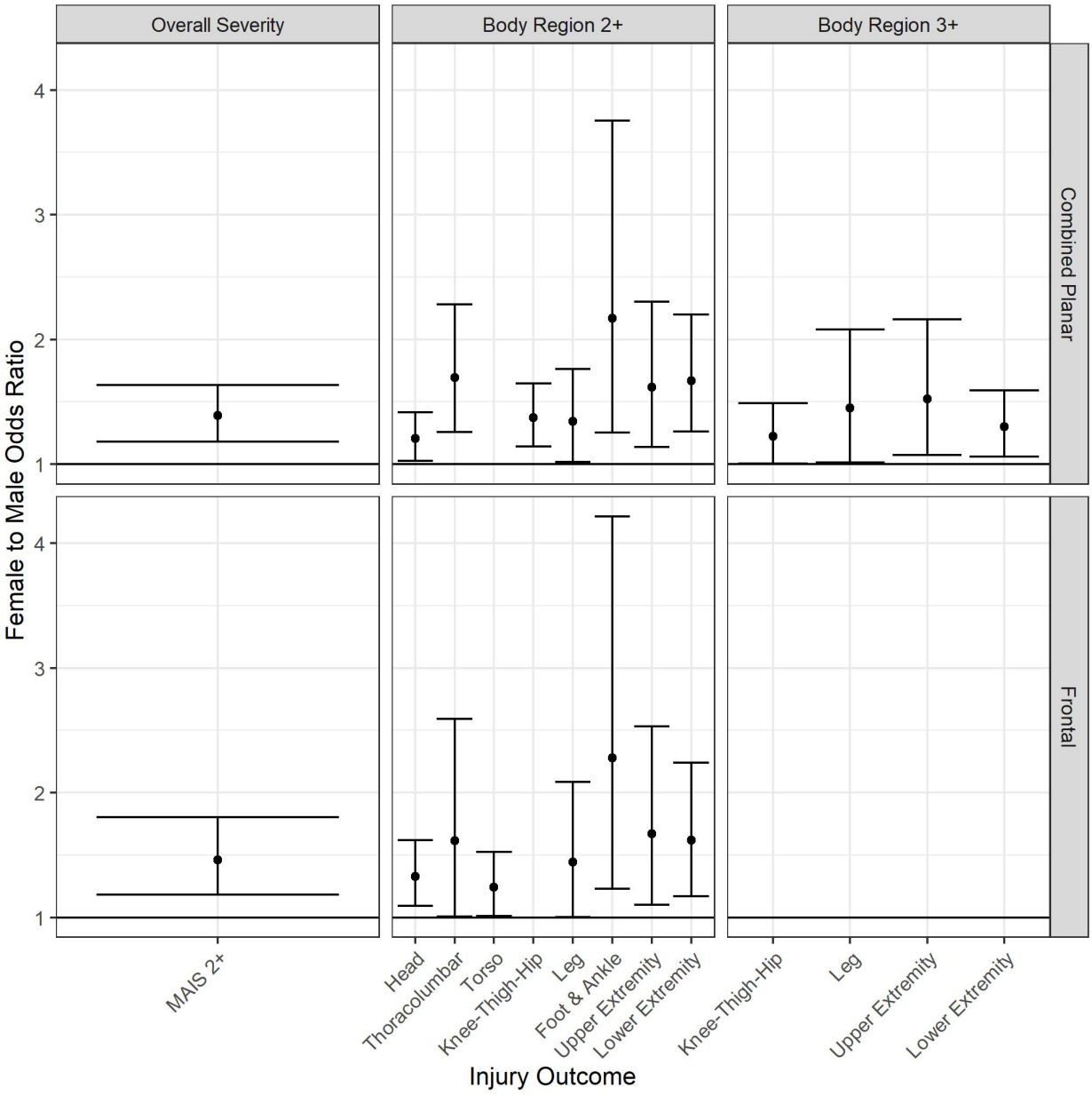

Figure 1. Significant results for Combined Planar Crashes and Frontal Crashes. Note: No significant results were found for body region AIS 3+ Frontal Crash models.

Table 8 shows full ORs and 95 percent CIs for female versus male occupants in *Primary Rollover Crashes*. Figure 2 shows significant results for *Primary Rollover Crashes*. Females had significantly higher odds of overall injury severity than males in *Primary Rollover Crashes* for both MAIS 2+ injuries (OR = 1.55, 95% CI 1.06-2.27, *p*-value = .0275) and MAIS 3+ injuries (OR = 1.61, 95% CI 1.14-2.27, *p*-value = .0091). OR estimates were also higher for females for MAIS 4+ and fatal injury models but these results were not statistically significant.

Females had significantly higher odds of AIS 2+ injuries in 5 out of 11 body regions in *Primary Rollover Crashes* (head, thorax, abdomen, torso, and foot/ankle), while males had none. In 5 body regions, females had non-significantly higher odds of AIS 2+ injuries (neck/c-spine,

thoracolumbar, knee-thigh-hip, and upper/lower extremities). Males had higher odds of AIS 2+ leg injuries, but this result was not statistically significant. Meanwhile for AIS 3+ injuries, females had significantly higher injury odds in 7 out of 10 studied body regions (head, thorax, abdomen, torso, knee-thigh-hip, and upper/lower extremities). The remaining three AIS 3+ body regions OR estimates were higher for females, but the findings were not statistically significant.

Table 8. Female versus male injury ORs for Primary Rollover Crashes with 95% CIs

		Primary Rollovers
Overall Severity	**MAIS 2+**	**1.55 (1.06, 2.27)**
	MAIS 3+	**1.61 (1.14, 2.27)**
	MAIS 4+	1.25 (0.91, 1.71)
	Fatal	1.05 (0.72, 1.53)
Body Region AIS 2+	**Head**	**1.77 (1.12, 2.80)**
	Neck & C-spine	1.29 (0.78, 2.12)
	Thorax	**1.81 (1.22, 2.71)**
	Abdomen	**2.53 (1.43, 4.47)**
	Thoracolumbar	1.32 (0.79, 2.21)
	Torso	**1.48 (1.01, 2.18)**
	Knee-Thigh-Hip	2.01 (0.97, 4.17)
	Leg	0.94 (0.42, 2.11)
	Foot & Ankle	**2.84 (1.26, 6.42)**
	Upper Extremity	1.35 (0.85, 2.14)
	Lower Extremity	1.90 (0.98, 3.68)
Body Region AIS 3+	**Head**	**1.43 (1.02, 2.00)**
	Neck & C-spine	1.23 (0.66, 2.27)
	Thorax	**1.92 (1.23, 3.01)**
	Abdomen	**3.07 (1.42, 6.63)**
	Thoracolumbar	1.21 (0.67, 2.16)
	Torso	**1.90 (1.27, 2.84)**
	Knee-Thigh-Hip	**2.08 (1.13, 3.82)**
	Leg	1.50 (0.41, 5.50)
	Upper Extremity	**2.87 (1.26, 6.53)**
	Lower Extremity	**2.08 (1.17, 3.68)**

Bolded results are significant at $p \leq .05$.

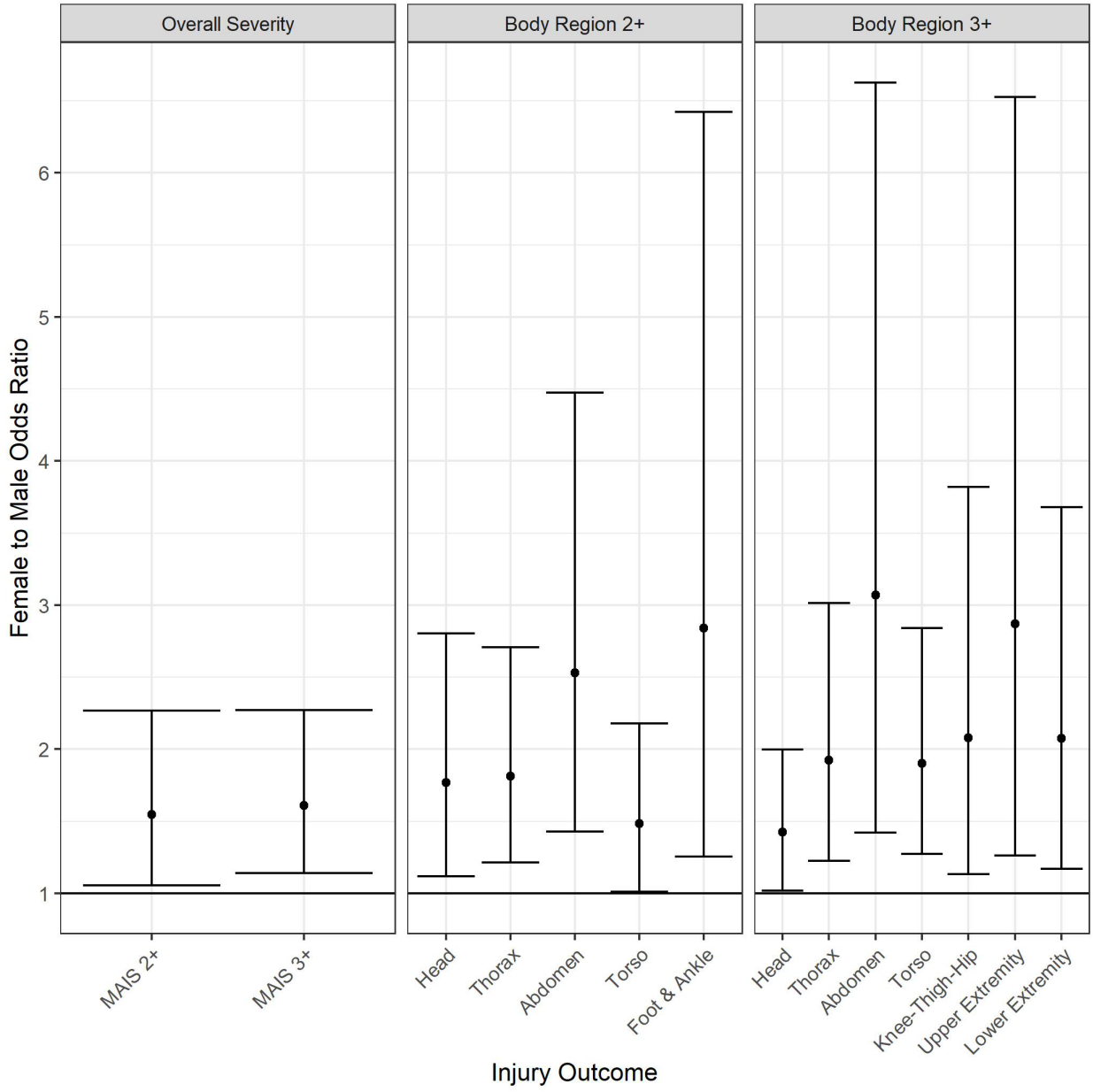

Figure 2. Significant results for Primary Rollover Crashes

Table 9 shows results from a small sample of models that were run with the *Combined Planar Crashes* sample of crash types for both imputed and unimputed (published sample data with missing values for study variables) versions of the sample. In both the imputed and unimputed cases, females had significantly higher odds of MAIS 2+, head AIS 2+, foot/ankle AIS 2+, and upper extremity AIS 2+ injuries than males. Females had higher odds of MAIS 3+ injuries in both the imputed and unimputed samples, but these results were not statistically significant. Thorax AIS 3+ injury odds were higher for females in the imputed sample but higher for males in the unimputed sample, though neither result was statistically significant. In all ORs except for

thorax AIS 3+ injuries, the ORs decreased after applying the imputation, and in all ORs imputation narrowed the CIs.

Table 9. Female versus male ORs with 95% CIs for select injury levels, imputed versus unimputed

Injury Description	Combined Planar Crashes	
	Imputed	Unimputed
MAIS 2+	**1.39 (1.18, 1.63)**	**1.85 (1.51, 2.26)**
MAIS 3+	1.15 (0.97, 1.35)	1.22 (0.95, 1.57)
Head - AIS 2+	**1.21 (1.03, 1.42)**	**1.48 (1.07, 2.06)**
Foot & Ankle - AIS 2+	**2.17 (1.25, 3.75)**	**4.22 (2.54, 6.99)**
Upper Extremity - AIS 2+	**1.62 (1.14, 2.30)**	**2.51 (1.9, 3.31)**
Thorax - AIS 3+	1.09 (0.83, 1.43)	0.93 (0.61, 1.41)

Bolded results are significant at $p \leq .05$

Table 10 shows a frequency summary of significant and non-significant OR findings, including how often a female was at significantly higher or lower ($p \leq .05$) odds of injury as compared to males, as well as how often females and males had higher odds that were not statistically significant ($p > .05$). Out of the 150 unique models, females had significantly higher injury odds than males 39 times, while there were no findings where females had significantly lower injury odds. The remaining 111 estimates for ORs comparing female versus male injury odds were not statistically significant. Of these, there were 81 with higher injury odds for females and 30 with lower injury odds for females. The sets of models that more frequently had significantly higher ORs for females versus males was seven AIS 3+ injuries in *Primary Rollover Crashes*, and AIS 2+ injuries for *Combined Planar Crashes* and *Frontal Crashes.* The two crash types with the highest number of injuries where males had higher injury odds were *Near-Side Crashes* and *Rear Crashes* (each with 9 out of 25 injury outcomes having higher injury odds for males), although none of these results were statistically significant.

Table 10. Significance counts of ORs for various crash types

Crash Type	Injury Models	No. of Models	Female Odds Significantly Higher $p \leq .05$	Female Odds Higher, but Not Significantly, $p > .05$	Male Odds Higher, but Not Significantly, $p > .05$
All Crash Types	**All**	150	39	81	30
Combined Planar	**Body Region AIS 2+**	11	7	3	1
Combined Planar	**Body Region AIS 3+**	10	4	5	1
Frontal	**Body Region AIS 2+**	11	7	4	0
Frontal	**Body Region AIS 3+**	10	0	9	1
Near-Side	**Body Region AIS 2+**	11	0	7	4
Near-Side	**Body Region AIS 3+**	10	1	5	4
Far-Side	**Body Region AIS 2+**	11	2	8	1
Far-Side	**Body Region AIS 3+**	10	2	6	2
Rear	**Body Region AIS 2+**	11	0	8	3
Rear	**Body Region AIS 3+**	10	0	6	4
Primary Rollover	**Body Region AIS 2+**	11	5	5	1
Primary Rollover	**Body Region AIS 3+**	10	7	3	0

The aim of this report was to present female versus male injury outcome ORs. However, other occupant predictor variables can be seen to have significant positive and negative influence on injury outcomes. Appendix A has tables of OR for age group, height group, and BMI groups. These are model ORs in which a reference level is chosen for age group (13-24 years), height group (100-163 cm) and BMI group (18.5-25), and every other group is compared to the reference group. Tables A-1 to A-6 show age group results, A-7 to A-12 height group results, and A-13 to A-18 BMI group results.

Table 11 summarizes the frequency of overall male and female occupant counts that correspond with each of the unique planar and rollover crash type models that were produced (the crash type "Other" is not included in any crash type model and therefore not included in Table 11 counts). More than 60 percent of these cases are *Frontal Crashes,* where MAIS 2+ and body region AIS

2+ models trend towards having higher injury ORs for females (Table 7). While *Frontal Crashes* had 8 significant results for females, none of the remaining planar crash types (*Near-Side, Far-Side, or Rear*) had more than 4. However, all planar crash type models had at least 16 out of 25 injury outcomes where females had the higher estimated injury odds regardless of significance. These may all contribute to the finding of 12 out of 25 significant results for females in the *Combined Planar Crashes* model (Table 4), which combines all the planar crashes. Still, *Near-Side, Far-Side,* and *Rear Crashes* only contribute around 36 percent of population cases (compared to ~60% for *Frontal Crashes,*), and so *Frontal Crashes* provide the primary contribution to the *Combined Planar* results. Although *Primary Rollover Crashes* had the highest number of significant results for females (14 out of 25), *Primary Rollover Crashes* represent the smallest amount of population cases (~4%). Additionally, *Primary Rollover Crashes* were not included in the *Combined Planar Crashes* count, and so did not contribute to significant results in that category.

Table 11. Total and percentages of weighted case counts for crash types

	Male	**Female**	**Combined**		**Male**	**Female**	**Combined**
	Total Occupant Cases				**% of Totals**		
Frontal	28,417,998	23,834,776	52,252,774		61.3	58.8	60.1
Near-Side	6,414,246	5,848,742	12,262,988		13.8	14.4	14.1
Far-Side	5,926,480	5,921,367	11,847,847		12.8	14.6	13.6
Rear	3,583,488	3,645,149	7,228,637		7.7	9.0	8.3
Primary Rollover	2,024,867	1,272,898	3,297,765		4.4	3.1	3.8
Total	46,367,079	40,522,932	86,890,011				

Table 12 shows weighted injury counts for the respective models by the respective significant and nonsignificant OR model results. For the *Combined Planar Crashes* models we estimate that there were ~6.5M AIS 2+ body region injuries in the general population across this study associated with models where females were at significantly higher odds of injury ($p \leq .05$). The estimate was only ~1.3M injuries in the general population for AIS 3+ injuries in the *Combined Planar Crashes* models. The estimated total AIS 2+ injuries for planar plus rollover models associated with significantly increased odds for females was ~5.9M. There were 488K AIS 3+ injuries associated with significantly increased odds of injury for females for planar plus rollover models, while zero cases were associated with decreased odds. As seen in the model results and given the relative frequency of body region AIS 2+ and 3+ injuries seen between males and females in the full sample of crashes (Table 6), females were most likely to show overall higher odds for upper and lower extremity injuries.

Table 12. Total weighted, imputed injury counts for injury outcomes from Combined Planar Crashes, Planar, and Rollover Crashes models. The counts of total injuries by injury type are mapped to the respective significant and non-significant OR results.

		Combined Planar Crashes Models				**Planar Models (n = 4) + Rollover Models**			
		OR Higher	**OR Lower**	**OR Higher**	**OR Lower**	**OR Higher**	**OR Lower**	**OR Higher**	**OR Lower**
		$p \leq .05$		**$p > .05$**		**$p \leq .05$**		**$p > .05$**	
Body Region 2+	**Head**	1,812,137	-	-	-	1,291,243	-	122,165	594,120
	Neck & C Spine	-	-	313,729	-	-	-	359,987	-
	Thorax	-	-	-	1,285,886	130,154	-	1,015,057	269,730
	Abdomen	-	-	438,714	-	36,952	-	322,830	115,308
	Thoracolumbar	412,613	-	-	-	252,886	-	219,922	-
	Torso	-	-	1,905,117	-	1,395,183	-	304,924	407,237
	Knee-Thigh-Hip	969,083	-	-	-	123,046	-	893,495	-
	Leg	306,617	-	-	-	231,204	-	64,532	30,070
	Foot & Ankle	546,403	-	-	-	485,640	-	62,082	11,660
	Upper Extremity	870,500	-	-	-	684,584	-	252,726	-
	Lower Extremity	1,558,498	-	-	-	1,283,780	-	344,784	-
Body Region 3+	**Head**	-	-	-	477,178	57,985	-	105,531	370,378
	Neck & C Spine	-	-	131,268	-	-	-	135,321	17,207
	Thorax	-	-	793,555	-	88,670	-	569,404	223,085
	Abdomen	-	-	191,585	-	16,929	-	140,490	50,721
	Thoracolumbar	-	-	98,446	-	19,807	-	85,752	10,345
	Torso	-	-	921,448	-	101,959	-	679,551	240,831
	Knee-Thigh-Hip	407,413	-	-	-	25,412	-	406,709	-
	Leg	131,159	-	-	-	-	-	135,314	-
	Upper Extremity	215,856	-	-	-	42,914	-	194,136	-
	Lower Extremity	507,540	-	-	-	134,106	-	401,636	-

Discussion

This study broadly looked across *all* age 13+ occupants, seating positions, crash types, and occupant restraint system statuses, among other independent predictor variables, to produce a set of comprehensive multivariable logistic regression models for 25 different injury outcomes across six crash types. These models were produced using both a sample that included all planar crash types and samples representing four focused subsets of planar crash types. Separate models were created for primary rollover crash types. The models considered 21 crashworthiness and 3 non-crashworthiness or pre-crash predictor variables, although their use depended on the crash type. The principal aim was to estimate the odds of the various injury outcomes for females as compared to males given the same crash, vehicle, restraint status, and occupant conditions.

A prior version of this study was published in 2023 (Craig et al. 2023). The current version of the study corrected an error that affected how uninjured body region injury cases were handled in developing injury OR estimates. Specifically, occupants who did not suffer any injury to a body region were not included in the analysis of that body region. For example, for head AIS 2+, any occupant who did not suffer a head injury should have been included in the category as head AIS 2+ = 0. However, only occupants for whom head AIS = 1 were included in this category. This means that the ORs computed for body regions did not have all the necessary occupant information and were therefore inaccurate. After addressing the error, the injury OR estimates for females versus males, which were relatively evenly split between higher and lower for females in the 2023 version of the study, uniformly shifted towards females on average having higher injury odds than males. Additionally, while correcting the error, we made other changes to improve upon the prior version of the study (e.g., refined the predictor variable list and definitions, separated planar crash types from crashes where rollover was the principal cause of damage, added CISS 2022).

The current results in some cases compare well to prior studies that considered only belted, front-row occupants. For the *Frontal* model results the current study found females to be at roughly 1.46-times higher odds of MAIS 2+ than males, a statistically significant difference. The odds of MAIS 3+ was 1.16 times higher for females, but not statistically significant in this study. These findings are lower than the 2.4- and 1.7-times higher odds of AIS 2+ and 3+ injuries, documented by Forman et al. (2019). It is important to consider that this study did not restrict by occupant location or seat belt status like prior studies. Like Forman et al., the current study found significantly increased odds of AIS 2+ foot and ankle injuries for females with ORs of 2.17 and 2.28 in *Combined Planar Crashes* and *Frontal Crashes* models. This compares to the 3.8 times higher odds of ankle injuries for females in frontal crashes found by Forman et al. The similarities with Forman et al. end there, however. Whereas Forman et al. found significantly higher odds of cervical spine, abdomen, knee-thigh-hip, sternum, and rib fractures, we did not find significantly increased odds for comparable body region injuries in the *Frontal Crashes* models. This study did find a significantly higher knee-thigh-hip AIS 2+ (OR = 1.37) and AIS 3+ (OR = 1.22) odds for females in the *Combined Planar Crashes* model, but the Forman et al. study reported an OR of 1.89 for AIS 2+ injuries in this region in frontal crashes. Separately, we observed significantly higher odds of thoracolumbar spine injuries for females (OR = 1.69 and 1.61 for *Combined Planar Crashes* and *Frontal Crashes* models), which was not a body region included in the Forman et al. study.

Brumbelow and Jermakian (2021) also studied NASS-CDS data in producing logistic regression models for both frontal and side crashes. For frontal crashes they found significantly higher odds

of MAIS 2+ and 3+ injury for females with ORs of 3.1 and 1.9 ($p \leq .05$). They found females to have 4.4 times higher odds of lower extremity injuries. This is substantially higher than similar estimates made in the current study (ORs of 1.67 and 1.62 for *Combined Planar Crashes* and *Frontal Crashes* models for AIS 2+). Again, it is important to consider that the current study did not restrict by occupant location or seat belt status. When including only compatible crashes with air bag deployments, Brumbelow and Jermakian saw decreases for all female injury ORs with only MAIS 2+ and upper and lower extremity AIS 2+ ORs remaining significantly higher for females. None of their side impact models produced any significant findings ($p > .05$), and none of their front or side models showed significantly lower odds of injury for females. The *Near-Side Crashes* models in this study showed no significant differences in odds in any of the injury categories except AIS 3+ lower extremity with an OR of 1.44. *Far-Side Crashes* models produced significantly higher ORs for AIS 2+ knee-thigh-hip and lower extremity injuries, and AIS 3+ thoracolumbar and upper extremity injuries.

The differences in the estimated ORs in the current study as compared to Forman et al. (2019) and Brumbelow and Jermakian (2021) exist for a variety of reasons. First, the current study used a larger sample of data that included both NASS-CDS and CISS. By including 2017 to 2022 CISS, the current study is employing a sample of crashes that has a greater number of newer model year vehicles, which is shown in Noh et al. (2022), may result in reduced relative risk (or odds, as is the case in the current study) for females versus males. Second, the current study accounted for a wider range of confounding factors (i.e., predictor variables), included amongst them were considerations for different restraint system statuses, crash types, and seating positions, and other vehicle/occupant factors. The *Combined Planar Crashes* MAIS 2+ model found females to be at higher odds of injury with an OR of 1.39. Running the same model restricted to belted occupants produced an OR of 1.47 and was statistically significant. This compares to an OR of 1.21 for unbelted, which was not statistically significant. Finally, the current study also applied a different imputation method, ABB, to use the partial data in the sample. The result is a set of more robust or true estimates of the odds of injury for female motor vehicle crash occupants as compared to males.

The results for the *Primary Rollover Crashes* models showed many models with significantly higher injury odds for females. Of all the crash types included in the modeling, *Primary Rollovers* made up the smallest group. Females are exposed to primary rollover crashes less often than males, yet the results show significantly higher odds for females for head, thorax, abdomen, and torso injuries at both the AIS 2+ and 3+ levels. Overall, females had ORs of 1.55 and 1.61 for MAIS 2+ and 3+, for *Primary Rollover Crashes*. Unlike prior studies that focused on frontal and side crashes, we do not have prior study comparison results for rollover crashes. Particularly notable is the 1.43 OR for AIS 3+ head injuries in *Primary Rollover Crashes*, yet females had a non-significantly lower odds than males in the *Combined Planar Crashes* model and three planar crash models (excluding *Near-Side Crashes*). Note that the *Primary Rollover Crashes* models differed substantially from the other models, in that delta V, weight ratio, and crash compatibility, present in planar models, were not defined for *Primary Rollovers* and were therefore excluded. Hence, some of the differences in results between *Primary Rollover Crashes* models and other models may be due to the differences in model variables.

Regarding fatal injury cases, Noh et al. (2022) reported on the relative odds of fatalities using logistic regression models and paired male/female driver and right-front passenger data from FARS. Noh et al. found that as vehicles became newer (either in model year or occupant

protection technologies), the relative increase in risk for fatality of females versus males decreased. For the newest model year range that was compared (2015 to 2020), the difference was estimated to be 2.9 percent but was not statistically significant ($p > .05$). A larger range of model year comparisons that included more older vehicles (model years 2010 to 2020) had higher relative fatality odds for females versus males with statistical significance (6.3 ± 5.4%). The current study found the odds of fatal injury to trend toward being lower for females with an OR of 0.89 (95% CI – 0.75, 1.05) for the *Combined Planar Crashes* model, but the findings were not significant ($p > .05$). Given the case years included in the current study (2000 to 2022), the closest equivalent result in Noh et al. was a 13.5±1.4 percent relative fatality odds increase for females compared to males for case years 2000-2019 (see Table 8 in Noh et al.).

There were several differences between the current study and Noh et al. (2022), which may explain their different results for fatal crashes. First, Noh et al. used FARS and included only vehicles where either the driver or the right-front passenger died, whereas the current study is based on Combined Planar Crashes (fatal and non-fatal) from NASS-CDS/CISS. Second, they looked at different risk metrics (relative risk versus OR in current study) and used different methods in estimating them. Noh et al. used a paired comparison method where crash conditions are effectively equalized because female drivers and right-front passengers are paired with male right-front passengers and drivers, from the same vehicle. Two sets of average risk ratios are computed with this method: one representing driver versus right-front passenger fatality probability when the driver is assumed to be a female and one where the same ratio is calculated when the driver is assumed to be a male. In this example the ratio of the two ratios produces the relative fatality risk of female versus male drivers. By contrast, the current study fits a multivariable statistical model to relate sex to the probability of fatality while controlling for variables listed in Table 4 such as delta V and BMI. In other words, the Noh et al. study establishes the causal effect of sex in a fatal crash (i.e., the likelihood of a female dying in a crash compared to a male in the same crash), whereas the current study is based on a model that controls for crash severity. Although the FARS-based study of Noh et al. was able to account for crashes being comparable using driver and right-front passenger occupant pairs, it was not able to adjust estimates based on other confounding factors (e.g., occupant size – BMI, vehicle body type, seat position), as was possible in the current study.

To further compare the current and Noh et al. (2022) FARS study results, two multivariable regression models were created to estimate *Sex* ORs using only the fatal crash involved vehicle domain in NASS-CDS and CISS to better match the sample constraints of Noh et al. These two models differed in how closely the sample restrictions mirrored the Noh et al. study. The restrictions are as follows:

1. Only occupants in vehicles where there was at least one fatality; and
2. Only occupants in vehicles where there was a driver and right-front passenger present, each with age ≥ 13, and at least one of them died. This restriction is closer to Noh et al. than just restriction 1.

Although the second restriction makes the sample from the current study more closely mirror the Noh et al. study, some differences remained. First, the current study did not include primary rollovers (without a planar event), while the Noh et al. study included such crashes. Second, the current study included pairs of occupants regardless of whether they shared the same belt status (belted or unbelted) or not, while in Noh et al. the paired occupants all shared the same seat belt

status. Finally, the Noh et al. study was restricted to occupants at least 16 years old, while the current study included occupants at least 13 years old.

Restricting the occupant sample more towards the Noh et al. study made the odds estimate closer to the estimate from that study. When only restricting to vehicles with a fatality somewhere, the OR increased from 0.87 to 0.9853 (equivalent to 1.47% lower odds for females). When further restricting the sample to vehicles with a driver and right-front passenger, where at least one of them died, the OR increased to 1.1202 (12.02% higher odds for females). None of the ORs were statistically significant ($p > .05$). This compares with the 13.5±1.4 percent increase in relative fatality odds for females for case years 2000 to 2019 from Noh et al. We also attempted to replicate the trend found in Noh et al. where the difference in relative fatality risk for females compared to males decreased for newer model year vehicles; however, we faced sample sizes that were too small when isolating specific model year ranges. The resulting model year range-based fatality ORs (e.g., 2009 and newer versus 2008 and older) had wide CIs and the differences between the OR estimates for newer versus older model year ranges were not statistically significant ($p > .05$).

Separate from the analysis that compared our fatal injury findings to Noh et al. (2022), we applied the core analytic approach employed for the principal female versus male injury odds comparisons to examine how sex differences vary by vehicle vintage. To assess the effect of vehicle vintage, we modified the multivariable injury outcome models to estimate female versus male injury odds independently for older and newer vehicles. Vehicle vintage was coded as a binary variable (model year 2009 and newer being versus 2008 and older; see Table 4), and that classification was retained for the vintage stratified analysis. Twelve selected injury outcome models were adapted for *Combined Planar*, *Frontal*, and *Primary Rollover* crash types to support the comparison. Results showed generally small, non-significant reductions in female versus male injury odds in newer compared with older ones ($p > .05$). Reductions were observed in 21 of 36 injury outcome models, but only one reached statistical significance ($p \leq .05$). Across the unmodified multivariable injury models, newer vintage vehicles were associated with lower injury odds than older vehicles in 124 of 150 models, with 45 results statistically significant ($p \leq .05$; Table A-19). Although injury odds were higher for newer vehicles in 26 models, only one result (AIS 3+ thoracolumbar spine injuries in *Frontal* crashes) was statistically significant ($p \leq .05$).

Overall, the current study shows a diverse set of results in comparing female injury odds as compared to males. Table 10 summarized counts of the respective OR results, which shows no models where female odds were significantly lower than those for males. Female odds were significantly higher in 39 of the 150 models. The remaining ORs shown in Tables 4 and 5 were not statistically significant ($p > .05$), but females had higher injury odds in a majority (81) compared to males (30).

Limitations

The current study has several limitations. First, NASS-CDS and CISS have high missing rates for certain important variables that can be used to predict injuries. The most prominent is delta V (missing in 47.2% of cases). Similarly, missing injury data in 2009 to 2015 NASS-CDS cases is not desirable. While the preference would be to have complete case data as collected, imputation allows for the retention of cases with missing data. The underlying condition for the imputation method (ABB) to give unbiased point estimates is that the missing mechanism can be modeled by a discrete distribution. This, however, cannot be tested. In this study, vehicle age is used to model the missing mechanism because in NASS-CDS some of the older vehicles' data were not collected. A more in-depth non-response study may result in better missing mechanism models.

The alternative is to drop such incomplete cases. In this case, this would have equated to us using only 32 percent of NASS-CDS and CISS cases given the distribution of missing predictor variables over the full data sample, thus excluding a significant amount of usable data.

Another limitation is the sample size for some crash and injury types. Smaller samples for crashes, particularly *Rear Crashes*, and associated injury counts, coupled with a large selection of predictor variables, results in a greater percentage of non-significant findings. For example, the *Combined Planar Crashes* models, which includes all the planar crash types in this study, produced 12 significant ($p \leq .05$) OR estimates out of 25 total models. *Rear Crashes,* which typically had less than one-twentieth the injury counts of *Combined Planar Crashes*, did not produce any significant results. Although *Rear Crashes* may in general have a smaller difference in injury odds between males and females, small sample sizes do make detecting significant results more difficult.

There are also limitations related to injury coding. First, the AIS 1990/1998 version was used for NASS-CDS, while CISS used AIS 2015. Coding definitions for some body regions and injury types differ between the two versions, and there are minor differences in attribution of some injuries among the two body region coding schemes for NASS-CDS versus CISS. In some studies that shift between AIS versions could result in overestimated injury improvements. However, this issue would most likely affect males and females equally in the current study. Second, there is a tendency for females to have higher odds for lower severity (AIS 2) injuries to extremity body regions where there are few corresponding AIS 3+ codes.

The results of this study highlight possible areas for improvement or needs for the safety or protection of both female and male motor vehicle occupants, since the aim is not to eliminate the injury risk differences between females and males, but to improve safety for both. This study did not attempt to identify causes regarding differences in injury odds, nor does it attempt to suggest what solutions or countermeasures may entail. Other factors such as age, BMI, vehicle selection, and relevant comorbidities (e.g., osteoporosis) likely require a deeper case study-style approach to better understand how those factors may contribute to differences in injury odds or risks. The National Highway Traffic Safety Administration is pursuing other research in the form of field data analysis, experimental biomechanics/crash test dummy development, human body modeling-based studies, as well as production vehicle fleet testing and countermeasure studies to address issues related to female crash safety (NHTSA, 2022). This study is just one part of the larger effort to identify and then direct further studies towards addressing sex-based differences in crash injury risk.

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Conclusions

The results of this study suggest that females may have elevated injury odds in motor vehicle crashes compared to males in a variety of body regions and crash types after controlling for potentially confounding factors. The extent of this depends on the injury outcome (type and severity) and the associated crash type.

Females had higher injury odds with statistical significance (p-value $\leq .05$) in 39 out of 150 models, whereas males had zero. In 111 models without a statistically significant difference (p-value $> .05$), females had higher injury odds in 81, while males had higher injury odds in 30.

This study presents the most comprehensive view to date of the differential odds of various injury outcomes for females versus males when considering all crash data in NASS-CDS and CISS from case years 2000 to 2022. The findings can be used, in part, to focus future research and associated physical and virtual testing efforts towards addressing possible injury scenarios and crash types where discrepancies in injury odds exist for both sexes.

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Appendix A. Injury Odds Ratios for Select Variables

Age Group

Generally, the results show that injury odds increase with age. When compared to the youngest age group (13 to 24-year-olds), each subsequent age group (25-34, 35-44, 45-54, 55-64, and 65+) has higher MAIS 2+, MAIS 3+, MAIS 4+, and fatal injury odds than the previous age group in the *Combined Planar Crash* models. The number of significant results increases as the age group increases. For age 65+, all 25 MAIS and body region injury models show significantly higher injury odds than the 13 to 24 group for *Combined Planar Crashes*. For age 55 to 64, some 23 of 25 models found significantly higher injury odds, while for ages 45 to 54, 35 to 44, and 25 to 34, there were 18, 14, and 11 models each, out of 25 that found significantly higher injury odds as compared to the youngest age group. Tables A-1 to A-6 show all ORs for age group categories 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 65+ compared to 13 to 24 for *Combined Planar, Frontal, Near-Side, Far-Side, Rear,* and *Primary Rollover Crashes*. For all tables, bolded ORs indicate statistical significance ($p \leq .05$). Note that some ORs in smaller-sample crash types or injury outcomes have very wide CIs, which may indicate quasi-separation issues within statistical models, and therefore those ORs should be interpreted with caution.

Table A-1. Age group ORs for Combined Planar Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	**1.41 (1.19, 1.68)**	**1.44 (1.17, 1.77)**	**1.69 (1.41, 2.02)**	**2.13 (1.74, 2.61)**	**2.95 (2.48, 3.50)**
	MAIS 3+	**1.31 (1.04, 1.64)**	**1.52 (1.12, 2.06)**	**1.97 (1.39, 2.79)**	**2.80 (2.20, 3.57)**	**5.11 (3.76, 6.94)**
	MAIS 4+	1.23 (0.98, 1.55)	**1.50 (1.10, 2.07)**	**2.02 (1.21, 3.37)**	**2.63 (1.68, 4.12)**	**5.41 (3.63, 8.07)**
	Fatal	**1.37 (1.11, 1.70)**	**1.79 (1.43, 2.25)**	**2.07 (1.54, 2.79)**	**3.31 (2.49, 4.41)**	**7.72 (5.90, 10.09)**
Body Region AIS 2+	**Head**	1.16 (0.98, 1.37)	1.23 (0.94, 1.60)	1.18 (0.94, 1.49)	1.17 (0.89, 1.54)	**1.56 (1.29, 1.88)**
	Neck & C-spine	**1.56 (1.19, 2.06)**	**2.18 (1.19, 4.01)**	**2.95 (1.91, 4.55)**	**3.61 (2.35, 5.54)**	**7.57 (5.64, 10.17)**
	Thorax	**1.54 (1.19, 2.01)**	**2.37 (1.83, 3.08)**	**3.02 (2.24, 4.06)**	**4.78 (3.75, 6.09)**	**10.12 (7.47, 13.71)**
	Abdomen	1.19 (0.86, 1.64)	1.19 (0.79, 1.81)	1.25 (0.72, 2.17)	**1.69 (1.11, 2.55)**	**2.33 (1.43, 3.81)**
	Thoracolumbar	1.19 (0.84, 1.68)	**1.65 (1.11, 2.43)**	**2.28 (1.39, 3.74)**	**2.97 (1.86, 4.74)**	**6.36 (3.95, 10.23)**
	Torso	**1.32 (1.03, 1.70)**	**1.83 (1.44, 2.31)**	**2.44 (1.82, 3.26)**	**3.51 (2.72, 4.52)**	**6.43 (4.67, 8.86)**
	Knee-Thigh-Hip	1.48 (0.97, 2.26)	1.15 (0.89, 1.49)	**1.46 (1.11, 1.93)**	**1.60 (1.16, 2.21)**	**2.44 (1.91, 3.10)**
	Leg	1.30 (0.90, 1.90)	**1.56 (1.04, 2.34)**	**1.64 (1.07, 2.52)**	**3.32 (1.96, 5.64)**	**3.46 (2.19, 5.47)**
	Foot & Ankle	1.46 (0.81, 2.64)	1.35 (0.91, 2.02)	**1.86 (1.34, 2.59)**	**3.05 (1.10, 8.48)**	**2.80 (1.78, 4.42)**
	Upper Extremity	**2.03 (1.44, 2.88)**	**1.92 (1.36, 2.72)**	**2.07 (1.52, 2.81)**	**2.52 (1.65, 3.86)**	**2.76 (2.10, 3.62)**
	Lower Extremity	1.50 (0.99, 2.29)	**1.27 (1.02, 1.56)**	**1.67 (1.37, 2.04)**	**2.28 (1.47, 3.54)**	**2.72 (2.14, 3.46)**
Body Region AIS 3+	**Head**	1.14 (0.73, 1.79)	1.14 (0.76, 1.72)	1.42 (0.89, 2.27)	**1.76 (1.19, 2.60)**	**3.77 (2.35, 6.04)**
	Neck & C-spine	**1.78 (1.08, 2.93)**	2.06 (0.98, 4.35)	**2.19 (1.13, 4.24)**	**3.56 (2.05, 6.18)**	**6.74 (4.45, 10.20)**
	Thorax	**1.39 (1.09, 1.77)**	**1.90 (1.46, 2.48)**	**2.80 (1.97, 3.99)**	**4.60 (3.63, 5.82)**	**8.03 (5.82, 11.08)**
	Abdomen	1.12 (0.78, 1.62)	1.67 (0.91, 3.06)	1.37 (0.63, 2.96)	1.62 (0.89, 2.95)	**2.27 (1.28, 4.02)**
	Thoracolumbar	0.96 (0.43, 2.14)	1.59 (0.79, 3.23)	2.33 (0.79, 6.90)	**3.68 (1.55, 8.72)**	**8.61 (4.12, 18.00)**
	Torso	**1.27 (1.00, 1.61)**	**1.86 (1.43, 2.42)**	**2.53 (1.69, 3.79)**	**4.08 (3.23, 5.17)**	**7.03 (4.96, 9.96)**
	Knee-Thigh-Hip	1.22 (1.00, 1.48)	1.02 (0.77, 1.33)	1.29 (0.96, 1.73)	**1.64 (1.16, 2.30)**	**2.60 (1.94, 3.50)**
	Leg	1.41 (0.86, 2.32)	**1.76 (1.08, 2.89)**	1.65 (0.91, 2.98)	**2.31 (1.26, 4.22)**	**2.54 (1.30, 4.96)**
	Upper Extremity	1.31 (0.76, 2.23)	1.55 (0.88, 2.73)	**1.67 (1.01, 2.77)**	**2.27 (1.17, 4.42)**	**2.63 (1.60, 4.33)**
	Lower Extremity	**1.21 (1.03, 1.42)**	1.20 (0.92, 1.55)	**1.35 (1.03, 1.77)**	**1.75 (1.28, 2.40)**	**2.72 (2.03, 3.63)**

Bolded results are significant at $p \leq .05$.

Table A-2. Age group ORs for Frontal Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	**1.47 (1.14, 1.88)**	**1.54 (1.16, 2.06)**	**1.74 (1.43, 2.11)**	**2.37 (1.85, 3.04)**	**3.07 (2.40, 3.93)**
	MAIS 3+	1.34 (0.95, 1.88)	1.37 (0.95, 1.99)	**1.70 (1.13, 2.54)**	**3.04 (2.36, 3.92)**	**4.56 (3.29, 6.32)**
	MAIS 4+	1.27 (0.87, 1.84)	1.51 (0.93, 2.47)	**1.83 (1.08, 3.10)**	**2.73 (1.74, 4.26)**	**4.82 (3.42, 6.81)**
	Fatal	**1.59 (1.14, 2.22)**	**2.10 (1.55, 2.85)**	**2.21 (1.50, 3.25)**	**4.23 (2.85, 6.29)**	**8.58 (6.14, 11.99)**
Body Region AIS 2+	**Head**	1.09 (0.86, 1.37)	1.41 (0.96, 2.09)	1.22 (0.92, 1.61)	1.18 (0.86, 1.61)	1.32 (0.92, 1.89)
	Neck & C-spine	**1.68 (1.14, 2.48)**	**2.03 (1.08, 3.82)**	**2.83 (1.48, 5.40)**	**4.37 (2.37, 8.05)**	**8.12 (5.58, 11.81)**
	Thorax	**1.78 (1.28, 2.46)**	**2.58 (1.80, 3.70)**	**3.06 (1.98, 4.72)**	**5.74 (4.07, 8.10)**	**11.02 (6.92, 17.55)**
	Abdomen	1.24 (0.79, 1.95)	1.08 (0.75, 1.54)	0.92 (0.43, 1.97)	**1.77 (1.11, 2.81)**	**2.28 (1.30, 3.98)**
	Thoracolumbar	1.31 (0.80, 2.14)	1.41 (0.82, 2.45)	**2.19 (1.24, 3.89)**	**3.43 (1.89, 6.23)**	**6.83 (3.59, 12.99)**
	Torso	**1.49 (1.11, 2.00)**	**1.86 (1.42, 2.45)**	**2.34 (1.55, 3.53)**	**4.09 (2.98, 5.60)**	**6.84 (4.73, 9.91)**
	Knee-Thigh-Hip	1.32 (0.91, 1.91)	1.21 (0.89, 1.64)	**1.52 (1.14, 2.02)**	**1.85 (1.22, 2.80)**	**2.69 (1.90, 3.79)**
	Leg	**1.38 (0.91, 2.10)**	**1.60 (1.01, 2.52)**	**1.55 (1.03, 2.34)**	**3.65 (2.07, 6.44)**	**3.46 (1.98, 6.07)**
	Foot & Ankle	1.52 (0.77, 3.00)	1.39 (0.92, 2.11)	**1.89 (1.37, 2.62)**	**3.54 (1.14, 10.96)**	**2.40 (1.41, 4.09)**
	Upper Extremity	**2.29 (1.52, 3.47)**	**2.05 (1.38, 3.04)**	**2.10 (1.46, 3.02)**	**2.11 (1.28, 3.46)**	**2.60 (1.89, 3.57)**
	Lower Extremity	1.44 (0.98, 2.12)	**1.35 (1.08, 1.68)**	**1.72 (1.43, 2.08)**	**2.76 (1.43, 5.32)**	**2.84 (2.04, 3.94)**
Body Region AIS 3+	**Head**	1.20 (0.63, 2.26)	1.07 (0.59, 1.94)	1.31 (0.75, 2.29)	1.45 (0.79, 2.67)	**2.30 (1.26, 4.19)**
	Neck & C-spine	1.66 (0.79, 3.49)	2.04 (0.80, 5.24)	1.97 (0.83, 4.68)	**4.04 (1.88, 8.70)**	**7.19 (4.65, 11.10)**
	Thorax	**1.57 (1.14, 2.15)**	**1.74 (1.21, 2.49)**	**2.51 (1.49, 4.25)**	**6.08 (4.53, 8.16)**	**7.54 (5.09, 11.15)**
	Abdomen	1.05 (0.62, 1.75)	1.13 (0.67, 1.90)	0.82 (0.28, 2.41)	1.48 (0.67, 3.27)	1.99 (1.00, 3.97)
	Thoracolumbar	0.77 (0.30, 1.98)	1.08 (0.55, 2.13)	1.89 (0.88, 4.04)	**4.06 (1.70, 9.66)**	**4.85 (2.12, 11.10)**
	Torso	1.32 (0.92, 1.91)	**1.61 (1.17, 2.22)**	**2.11 (1.28, 3.47)**	**4.93 (3.57, 6.80)**	**6.34 (4.15, 9.69)**
	Knee-Thigh-Hip	1.28 (0.97, 1.68)	1.06 (0.76, 1.50)	1.15 (0.81, 1.65)	**1.74 (1.11, 2.74)**	**2.41 (1.64, 3.52)**
	Leg	1.50 (0.87, 2.59)	1.63 (0.99, 2.69)	1.57 (0.90, 2.76)	**2.70 (1.40, 5.18)**	**2.82 (1.38, 5.78)**
	Upper Extremity	1.15 (0.61, 2.20)	1.41 (0.72, 2.76)	1.35 (0.72, 2.54)	2.04 (0.89, 4.68)	**2.73 (1.51, 4.94)**
	Lower Extremity	**1.27 (1.03, 1.58)**	1.23 (0.89, 1.69)	1.21 (0.89, 1.66)	**1.92 (1.28, 2.88)**	**2.70 (1.90, 3.82)**

Bolded results are significant at $p \leq .05$.

Table A-3. Age group ORs for Near-Side Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	1.14 (0.66, 1.97)	1.26 (0.85, 1.88)	**1.63 (1.03, 2.57)**	1.29 (0.63, 2.64)	**3.15 (2.18, 4.53)**
	MAIS 3+	1.28 (0.82, 2.00)	**1.78 (1.01, 3.13)**	**2.72 (1.46, 5.05)**	**2.16 (1.01, 4.64)**	**6.55 (3.88, 11.05)**
	MAIS 4+	1.18 (0.73, 1.90)	1.18 (0.55, 2.52)	**2.24 (1.12, 4.48)**	2.29 (0.86, 6.07)	**6.62 (4.07, 10.78)**
	Fatal	1.14 (0.84, 1.56)	1.58 (0.98, 2.56)	**1.75 (1.06, 2.87)**	**2.67 (1.59, 4.49)**	**8.33 (5.27, 13.16)**
Body Region AIS 2+	**Head**	1.25 (0.64, 2.42)	0.77 (0.44, 1.34)	0.99 (0.49, 2.00)	0.74 (0.40, 1.37)	**2.07 (1.46, 2.95)**
	Neck & C-spine	1.35 (0.81, 2.25)	**2.55 (1.21, 5.34)**	**3.23 (1.42, 7.38)**	2.20 (0.95, 5.12)	**8.31 (4.14, 16.68)**
	Thorax	1.59 (0.95, 2.67)	**2.53 (1.69, 3.78)**	**3.67 (2.07, 6.49)**	**2.98 (2.01, 4.42)**	**9.55 (6.37, 14.31)**
	Abdomen	0.93 (0.69, 1.27)	0.95 (0.55, 1.63)	1.66 (0.96, 2.84)	1.54 (0.89, 2.67)	1.85 (0.77, 4.43)
	Thoracolumbar	0.88 (0.56, 1.38)	1.82 (0.78, 4.23)	2.23 (0.86, 5.79)	2.84 (0.96, 8.39)	**3.33 (1.18, 9.40)**
	Torso	1.06 (0.55, 2.04)	1.76 (0.92, 3.36)	**2.68 (1.28, 5.64)**	**2.22 (1.15, 4.28)**	**4.82 (2.58, 8.99)**
	Knee-Thigh-Hip	0.99 (0.59, 1.65)	1.18 (0.76, 1.84)	1.49 (0.68, 3.27)	1.17 (0.73, 1.86)	**3.40 (1.97, 5.89)**
	Leg	1.22 (0.61, 2.46)	1.54 (0.66, 3.60)	1.84 (0.68, 5.02)	1.54 (0.51, 4.62)	**3.32 (1.43, 7.73)**
	Foot & Ankle	0.81 (0.29, 2.29)	0.75 (0.23, 2.48)	0.79 (0.13, 4.98)	0.82 (0.10, 6.76)	**6.28 (1.80, 21.88)**
	Upper Extremity	1.31 (0.71, 2.43)	**1.94 (1.04, 3.62)**	2.09 (0.87, 5.04)	**2.87 (1.24, 6.64)**	**2.81 (1.47, 5.35)**
	Lower Extremity	0.98 (0.62, 1.53)	1.23 (0.75, 2.04)	1.57 (0.74, 3.34)	1.21 (0.63, 2.34)	**4.01 (2.08, 7.72)**
Body Region AIS 3+	**Head**	1.07 (0.68, 1.69)	0.74 (0.35, 1.55)	1.60 (0.96, 2.67)	1.59 (0.82, 3.08)	**6.95 (4.02, 12.02)**
	Neck & C-spine	1.98 (1.00, 3.92)	1.43 (0.62, 3.30)	1.45 (0.63, 3.31)	**3.12 (1.23, 7.90)**	**9.08 (3.75, 22.02)**
	Thorax	1.33 (0.84, 2.11)	**2.45 (1.51, 3.98)**	**3.95 (2.18, 7.16)**	**3.14 (1.84, 5.36)**	**9.25 (6.09, 14.04)**
	Abdomen	1.29 (0.83, 2.00)	1.44 (0.74, 2.82)	**2.39 (1.28, 4.47)**	1.83 (0.79, 4.23)	**2.43 (1.12, 5.27)**
	Thoracolumbar	1.58 (0.45, 5.58)	2.50 (0.61, 10.27)	3.51 (0.36, 34.55)	2.43 (0.86, 6.88)	**6.45 (1.82, 22.95)**
	Torso	1.34 (0.88, 2.05)	**2.32 (1.46, 3.69)**	**3.82 (1.84, 7.93)**	**2.91 (1.73, 4.89)**	**8.34 (5.46, 12.73)**
	Knee-Thigh-Hip	1.08 (0.56, 2.10)	1.04 (0.60, 1.79)	1.35 (0.71, 2.55)	1.06 (0.67, 1.66)	**3.27 (1.99, 5.38)**
	Leg	1.22 (0.41, 3.64)	**2.91 (1.21, 6.99)**	2.78 (0.89, 8.69)	1.02 (0.27, 3.78)	1.27 (0.55, 2.94)
	Upper Extremity	1.38 (0.44, 4.26)	**2.58 (1.31, 5.08)**	**3.89 (1.82, 8.30)**	**4.24 (1.30, 13.77)**	**2.48 (1.01, 6.11)**
	Lower Extremity	1.16 (0.67, 1.99)	1.36 (0.74, 2.51)	1.69 (0.83, 3.45)	1.09 (0.68, 1.75)	**3.14 (1.96, 5.03)**

Bolded results are significant at $p \leq .05$.

Table A-4. Age group ORs for Far-Side Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	1.42 (0.81, 2.49)	1.28 (0.73, 2.24)	1.50 (0.96, 2.34)	**2.04 (1.05, 3.95)**	**3.22 (2.09, 4.94)**
	MAIS 3+	1.30 (0.79, 2.16)	**1.91 (1.05, 3.47)**	**2.72 (1.39, 5.33)**	**3.56 (1.66, 7.66)**	**8.50 (3.83, 18.87)**
	MAIS 4+	1.38 (0.82, 2.30)	**1.99 (1.19, 3.33)**	**2.91 (1.36, 6.21)**	**4.31 (2.14, 8.68)**	**9.25 (4.29, 19.95)**
	Fatal	1.50 (0.95, 2.37)	1.56 (0.90, 2.70)	**2.69 (1.34, 5.39)**	**2.92 (1.52, 5.62)**	**7.48 (4.27, 13.10)**
Body Region AIS 2+	**Head**	1.00 (0.53, 1.90)	1.34 (0.84, 2.13)	1.14 (0.55, 2.36)	1.24 (0.64, 2.37)	1.74 (0.98, 3.09)
	Neck & C-spine	1.55 (0.88, 2.72)	**3.12 (1.20, 8.15)**	**3.47 (1.32, 9.13)**	**4.67 (2.49, 8.75)**	**7.39 (4.02, 13.57)**
	Thorax	1.03 (0.51, 2.05)	1.57 (0.74, 3.34)	**3.26 (1.34, 7.92)**	**2.64 (1.32, 5.29)**	**12.57 (6.16, 25.66)**
	Abdomen	1.14 (0.71, 1.81)	1.22 (0.41, 3.65)	**2.83 (1.28, 6.29)**	2.08 (0.93, 4.65)	**4.04 (1.92, 8.51)**
	Thoracolumbar	1.48 (0.57, 3.87)	2.32 (0.86, 6.29)	2.89 (0.99, 8.44)	**3.01 (1.22, 7.39)**	**13.11 (4.44, 38.67)**
	Torso	1.25 (0.70, 2.24)	**1.77 (1.00, 3.13)**	**3.50 (1.79, 6.85)**	**2.39 (1.34, 4.24)**	**10.88 (6.07, 19.49)**
	Knee-Thigh-Hip	1.91 (0.71, 5.16)	0.74 (0.27, 2.09)	1.52 (0.63, 3.68)	1.50 (0.57, 3.99)	2.12 (0.83, 5.41)
	Leg	1.22 (0.18, 8.45)	0.95 (0.13, 7.02)	1.45 (0.21, 10.13)	5.38 (0.94, 30.88)	**7.15 (1.13, 45.06)**
	Foot & Ankle	1.85 (0.58, 5.92)	1.39 (0.29, 6.59)	1.00 (0.23, 4.25)	1.57 (0.19, 12.84)	2.93 (0.81, 10.63)
	Upper Extremity	1.12 (0.57, 2.17)	1.24 (0.52, 2.94)	2.03 (0.86, 4.79)	**7.36 (4.20, 12.88)**	**5.31 (2.43, 11.59)**
	Lower Extremity	2.03 (0.90, 4.57)	0.82 (0.35, 1.90)	1.33 (0.61, 2.89)	1.73 (0.52, 5.76)	**2.44 (1.01, 5.90)**
Body Region AIS 3+	**Head**	0.84 (0.46, 1.53)	**2.07 (1.15, 3.73)**	1.82 (0.96, 3.47)	**3.34 (1.23, 9.05)**	**6.93 (3.21, 14.94)**
	Neck & C-spine	2.46 (0.95, 6.36)	**4.02 (1.34, 12.08)**	3.45 (0.83, 14.37)	**3.09 (1.04, 9.20)**	**5.16 (1.54, 17.31)**
	Thorax	0.95 (0.44, 2.04)	1.36 (0.59, 3.18)	2.58 (0.94, 7.06)	**2.53 (1.14, 5.62)**	**10.28 (4.62, 22.88)**
	Abdomen	1.36 (0.74, 2.47)	**3.27 (1.16, 9.24)**	**4.79 (1.93, 11.88)**	3.10 (0.90, 10.62)	**4.87 (2.12, 11.17)**
	Thoracolumbar	3.12 (0.86, 11.35)	4.54 (0.81, 25.62)	3.13 (0.44, 22.35)	**6.98 (1.28, 38.15)**	**70.16 (17.67, 278.57)**
	Torso	1.04 (0.51, 2.11)	1.89 (0.94, 3.80)	**3.12 (1.24, 7.87)**	**3.06 (1.49, 6.30)**	**10.13 (4.66, 22.02)**
	Knee-Thigh-Hip	1.34 (0.55, 3.29)	0.48 (0.11, 2.07)	**3.06 (1.15, 8.13)**	**3.87 (1.22, 12.26)**	**4.94 (1.98, 12.31)**
	Leg	1.07 (0.03, 33.14)	1.60 (0.09, 29.42)	0.97 (0.06, 16.69)	2.06 (0.18, 24.11)	8.12 (0.61, 108.03)
	Upper Extremity	1.39 (0.56, 3.45)	1.60 (0.37, 6.99)	2.31 (0.76, 6.96)	**3.36 (1.19, 9.47)**	3.17 (0.95, 10.62)
	Lower Extremity	1.25 (0.43, 3.58)	0.63 (0.14, 2.81)	2.63 (0.83, 8.36)	3.38 (0.91, 12.60)	**5.05 (1.48, 17.31)**

Bolded results are significant at $p \leq .05$.

Table A-5. Age group ORs for Rear Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	1.69 (0.91, 3.14)	1.55 (0.84, 2.86)	2.06 (0.98, 4.33)	**2.80 (1.43, 5.47)**	1.79 (0.90, 3.54)
	MAIS 3+	1.09 (0.32, 3.71)	2.63 (0.88, 7.88)	**2.70 (1.03, 7.06)**	2.19 (0.70, 6.85)	**4.54 (1.40, 14.66)**
	MAIS 4+	0.74 (0.16, 3.47)	1.68 (0.43, 6.63)	1.38 (0.25, 7.71)	1.26 (0.27, 5.91)	**3.93 (1.18, 13.09)**
	Fatal	0.96 (0.39, 2.34)	0.69 (0.26, 1.83)	1.15 (0.34, 3.93)	1.26 (0.38, 4.15)	**9.20 (2.86, 29.56)**
Body Region AIS 2+	**Head**	2.14 (0.80, 5.68)	0.81 (0.36, 1.83)	1.66 (0.65, 4.22)	2.70 (0.99, 7.35)	1.68 (0.77, 3.65)
	Neck & C-spine	2.47 (0.28, 21.54)	1.67 (0.18, 15.90)	4.92 (0.78, 31.15)	3.04 (0.53, 17.43)	7.31 (0.91, 58.46)
	Thorax	0.92 (0.30, 2.80)	3.24 (0.55, 19.14)	2.46 (0.64, 9.46)	**9.08 (2.40, 34.30)**	4.78 (1.00, 22.83)
	Abdomen	2.05 (0.44, 9.66)	4.98 (0.95, 26.17)	1.49 (0.28, 7.87)	1.22 (0.13, 11.32)	0.75 (0.08, 7.07)
	Thoracolumbar	0.90 (0.30, 2.71)	2.73 (0.59, 12.59)	3.43 (0.85, 13.77)	1.57 (0.32, 7.70)	3.33 (0.79, 14.03)
	Torso	1.23 (0.45, 3.33)	2.83 (0.74, 10.79)	2.42 (0.87, 6.73)	**6.73 (2.20, 20.62)**	3.33 (0.88, 12.67)
	Knee-Thigh-Hip	1.20 (0.43, 3.38)	1.79 (0.56, 5.73)	1.34 (0.32, 5.53)	0.72 (0.13, 4.10)	1.55 (0.40, 6.05)
	Leg	2.44 (0.21, 28.64)	4.53 (0.42, 48.55)	**11.20 (1.33, 94.01)**	**14.97 (1.59, 141.05)**	4.04 (0.39, 42.20)
	Foot & Ankle	1.95 (0.18, 21.20)	3.52 (0.53, 23.33)	8.12 (0.80, 82.25)	0.42 (0.01, 12.76)	1.02 (0.06, 18.62)
	Upper Extremity	1.76 (0.20, 15.27)	1.38 (0.08, 23.87)	4.17 (0.47, 36.97)	4.23 (0.59, 30.59)	2.63 (0.41, 16.96)
	Lower Extremity	1.35 (0.45, 3.99)	1.88 (0.71, 4.97)	2.74 (0.70, 10.63)	1.84 (0.52, 6.56)	1.56 (0.47, 5.21)
Body Region AIS 3+	**Head**	1.02 (0.25, 4.20)	1.90 (0.56, 6.40)	2.28 (0.77, 6.76)	**5.52 (1.32, 23.18)**	**8.85 (1.96, 39.90)**
	Neck & C-spine	1.45 (0.07, 31.63)	1.46 (0.11, 19.93)	**8.11 (2.08, 31.72)**	4.69 (0.89, 24.65)	3.47 (0.66, 18.19)
	Thorax	1.12 (0.32, 3.91)	**6.52 (1.27, 33.59)**	**4.28 (1.21, 15.10)**	3.32 (0.71, 15.45)	**11.18 (2.43, 51.51)**
	Abdomen	1.77 (0.04, 75.28)	**22.46 (1.20, 419.38)**	2.04 (0.05, 77.60)	2.63 (0.04, 171.74)	1.51 (0.04, 57.41)
	Thoracolumbar	0.52 (0.04, 7.43)	6.20 (0.82, 46.98)	**6.03 (1.15, 31.59)**	3.30 (0.41, 26.52)	**9.60 (1.28, 71.98)**
	Torso	0.97 (0.28, 3.40)	**5.94 (1.28, 27.58)**	**3.54 (1.21, 10.36)**	2.99 (0.61, 14.62)	**8.61 (2.00, 37.05)**
	Knee-Thigh-Hip	0.45 (0.13, 1.56)	0.32 (0.03, 3.58)	0.83 (0.11, 6.51)	0.37 (0.06, 2.25)	1.33 (0.18, 9.99)
	Leg	6.17 (0.04, 927.59)	3.96 (0.03, 553.27)	2.84 (0.03, 243.64)	16.00 (0.15, 1712.81)	13.73 (0.07, 2734.40)
	Upper Extremity	3.28 (0.16, 65.91)	2.94 (0.21, 41.35)	5.33 (0.49, 58.45)	1.78 (0.04, 73.80)	1.60 (0.07, 37.85)
	Lower Extremity	0.56 (0.10, 3.31)	0.60 (0.06, 6.19)	0.97 (0.13, 7.58)	0.66 (0.11, 4.03)	1.59 (0.28, 9.06)

Bolded results are significant at $p \leq .05$.

Table A-6. Age group ORs for Primary Rollover Crashes. Reference is "13-24 years" with 95% CIs.

		25-34	35-44	45-54	55-64	65+
Overall Severity	**MAIS 2+**	1.22 (0.77, 1.94)	1.37 (0.74, 2.53)	1.43 (0.88, 2.32)	**2.51 (1.21, 5.21)**	**5.37 (2.94, 9.79)**
	MAIS 3+	1.61 (0.98, 2.66)	1.57 (0.95, 2.61)	**3.09 (1.86, 5.13)**	**3.47 (1.82, 6.64)**	**4.35 (1.44, 13.12)**
	MAIS 4+	**1.68 (1.09, 2.59)**	1.53 (0.66, 3.58)	**3.64 (2.39, 5.55)**	**4.34 (2.35, 8.03)**	**3.03 (1.16, 7.86)**
	Fatal	1.35 (0.77, 2.37)	1.41 (0.92, 2.17)	**4.70 (2.83, 7.82)**	**6.45 (2.90, 14.36)**	1.96 (0.56, 6.84)
Body Region AIS 2+	**Head**	0.71 (0.43, 1.20)	0.84 (0.44, 1.63)	0.87 (0.56, 1.36)	1.63 (0.81, 3.25)	1.73 (0.61, 4.94)
	Neck & C-spine	1.54 (0.95, 2.47)	**2.43 (1.45, 4.08)**	**3.27 (1.65, 6.48)**	**4.33 (2.01, 9.34)**	**4.98 (2.34, 10.59)**
	Thorax	1.81 (0.89, 3.70)	1.18 (0.67, 2.08)	1.66 (0.87, 3.16)	**3.50 (1.83, 6.70)**	**12.22 (6.34, 23.55)**
	Abdomen	1.51 (0.59, 3.85)	1.10 (0.58, 2.10)	0.63 (0.26, 1.50)	1.87 (0.77, 4.52)	**4.44 (1.12, 17.55)**
	Thoracolumbar	1.57 (0.85, 2.91)	1.92 (0.84, 4.40)	1.16 (0.32, 4.15)	1.81 (0.84, 3.90)	**4.06 (1.29, 12.73)**
	Torso	1.60 (0.89, 2.90)	1.24 (0.61, 2.49)	1.46 (0.71, 3.01)	**2.50 (1.36, 4.61)**	**7.08 (4.13, 12.13)**
	Knee-Thigh-Hip	0.77 (0.37, 1.60)	0.69 (0.30, 1.61)	0.58 (0.27, 1.25)	0.66 (0.26, 1.66)	2.74 (0.69, 10.85)
	Leg	1.04 (0.46, 2.38)	**2.84 (1.08, 7.51)**	1.27 (0.39, 4.14)	0.92 (0.18, 4.69)	2.68 (0.78, 9.22)
	Foot & Ankle	2.06 (0.71, 5.96)	1.16 (0.35, 3.86)	2.25 (0.71, 7.15)	1.94 (0.28, 13.40)	1.91 (0.31, 11.77)
	Upper Extremity	0.82 (0.52, 1.31)	0.95 (0.50, 1.81)	1.45 (0.86, 2.44)	**2.23 (1.12, 4.41)**	**4.20 (1.88, 9.35)**
	Lower Extremity	1.01 (0.55, 1.87)	1.16 (0.57, 2.35)	0.95 (0.52, 1.75)	0.91 (0.35, 2.36)	2.94 (0.85, 10.16)
Body Region AIS 3+	**Head**	1.36 (0.95, 1.96)	0.93 (0.28, 3.05)	1.55 (0.83, 2.88)	**2.00 (1.21, 3.33)**	1.63 (0.59, 4.48)
	Neck & C-spine	0.94 (0.46, 1.91)	**2.54 (1.19, 5.41)**	**3.15 (1.65, 5.98)**	**4.38 (1.32, 14.56)**	**3.47 (1.04, 11.54)**
	Thorax	1.65 (0.87, 3.12)	1.10 (0.65, 1.87)	1.70 (0.92, 3.15)	**2.57 (1.47, 4.50)**	**6.31 (2.56, 15.53)**
	Abdomen	2.44 (0.58, 10.28)	1.08 (0.51, 2.27)	0.66 (0.21, 2.05)	0.43 (0.09, 2.19)	0.87 (0.23, 3.23)
	Thoracolumbar	1.18 (0.60, 2.33)	**2.41 (1.14, 5.09)**	3.51 (0.46, 26.65)	**3.23 (1.06, 9.83)**	**11.28 (2.46, 51.68)**
	Torso	1.79 (0.91, 3.53)	1.16 (0.75, 1.80)	2.13 (0.92, 4.91)	**2.60 (1.53, 4.44)**	**5.64 (2.25, 14.15)**
	Knee-Thigh-Hip	0.53 (0.22, 1.30)	0.43 (0.18, 1.05)	0.61 (0.26, 1.39)	0.62 (0.24, 1.59)	**5.57 (1.45, 21.35)**
	Leg	1.35 (0.45, 4.07)	1.10 (0.22, 5.59)	1.79 (0.37, 8.70)	2.39 (0.46, 12.49)	4.22 (0.85, 20.86)
	Upper Extremity	0.98 (0.49, 1.96)	1.54 (0.70, 3.38)	**2.87 (1.81, 4.56)**	3.02 (0.99, 9.28)	2.84 (0.67, 12.02)
	Lower Extremity	0.57 (0.28, 1.18)	**0.47 (0.22, 1.00)**	0.78 (0.38, 1.61)	0.80 (0.34, 1.87)	**4.68 (1.16, 18.89)**

Bolded results are significant at $p \leq .05$.

Height

The results suggest that height does not have a persistently significant association with injury odds. Out of 150 injury severity/crash type combinations, none of the height groups had any more than 10 significant results (170-180 cm) when compared to height 100 to 163 cm. Further, these significant results did not follow any consistent pattern across or within crash types. Tables A-7 to A-12 show all ORs for height categories 163 to 170 cm, 170 to 180 cm, and 180 to 220 cm compared to 100 to 163 cm for *Combined Planar, Frontal, Near-Side, Far-Side, Rear, and Primary Rollover Crashes*. For all tables, bolded ORs indicate statistical significance ($p \leq .05$). Note that some ORs in smaller-sample crash types or injury outcomes have very wide CIs, which may indicate quasi-separation issues within statistical models, and therefore those ORs should be interpreted with caution.

Table A-7. Height group ORs for Combined Planar Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	1.17 (0.88, 1.56)	1.13 (0.93, 1.37)	1.11 (0.90, 1.39)
	MAIS 3+	1.02 (0.78, 1.34)	1.19 (0.92, 1.53)	1.05 (0.82, 1.35)
	MAIS 4+	1.11 (0.80, 1.55)	**1.40 (1.03, 1.91)**	1.19 (0.72, 1.96)
	Fatal	0.96 (0.70, 1.32)	**1.51 (1.23, 1.84)**	**1.38 (1.10, 1.74)**
Body Region AIS 2+	**Head**	**1.37 (1.07, 1.77)**	**1.39 (1.10, 1.74)**	**1.35 (1.03, 1.77)**
	Neck & C-spine	0.86 (0.57, 1.29)	1.33 (0.71, 2.49)	1.16 (0.70, 1.94)
	Thorax	0.94 (0.70, 1.25)	1.10 (0.82, 1.46)	1.02 (0.75, 1.39)
	Abdomen	1.02 (0.72, 1.45)	0.97 (0.74, 1.28)	0.99 (0.74, 1.32)
	Thoracolumbar	1.16 (0.73, 1.86)	**1.48 (1.03, 2.13)**	1.35 (0.83, 2.20)
	Torso	1.06 (0.82, 1.36)	1.20 (0.96, 1.49)	1.20 (0.92, 1.57)
	Knee-Thigh-Hip	1.27 (0.88, 1.83)	1.22 (0.94, 1.58)	1.25 (0.98, 1.60)
	Leg	0.85 (0.59, 1.23)	1.00 (0.69, 1.46)	0.90 (0.58, 1.39)
	Foot & Ankle	1.11 (0.57, 2.17)	0.72 (0.49, 1.08)	0.62 (0.37, 1.06)
	Upper Extremity	0.96 (0.63, 1.47)	1.01 (0.74, 1.36)	0.98 (0.52, 1.83)
	Lower Extremity	1.21 (0.75, 1.95)	1.03 (0.84, 1.27)	0.98 (0.75, 1.27)
Body Region AIS 3+	**Head**	1.37 (0.84, 2.22)	1.47 (0.81, 2.69)	1.10 (0.58, 2.07)
	Neck & C-spine	0.89 (0.51, 1.54)	1.40 (0.60, 3.30)	1.10 (0.57, 2.12)
	Thorax	1.03 (0.67, 1.58)	1.27 (0.89, 1.81)	1.07 (0.76, 1.50)
	Abdomen	0.96 (0.60, 1.52)	0.80 (0.52, 1.21)	0.79 (0.51, 1.22)
	Thoracolumbar	0.83 (0.27, 2.54)	1.18 (0.43, 3.21)	1.38 (0.47, 4.09)
	Torso	0.93 (0.62, 1.39)	1.13 (0.82, 1.55)	1.01 (0.74, 1.37)
	Knee-Thigh-Hip	1.09 (0.86, 1.39)	1.23 (0.91, 1.65)	**1.33 (1.02, 1.73)**
	Leg	0.86 (0.59, 1.25)	0.95 (0.59, 1.52)	0.93 (0.56, 1.55)
	Upper Extremity	0.83 (0.53, 1.30)	1.05 (0.71, 1.55)	1.05 (0.59, 1.86)
	Lower Extremity	1.03 (0.84, 1.25)	1.12 (0.85, 1.49)	1.20 (0.96, 1.49)

Bolded results are significant at $p \leq .05$.

Table A-8. Height group ORs for Frontal Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	1.10 (0.80, 1.51)	1.07 (0.86, 1.32)	1.01 (0.80, 1.28)
	MAIS 3+	0.89 (0.58, 1.36)	1.08 (0.78, 1.50)	0.93 (0.66, 1.31)
	MAIS 4+	0.89 (0.56, 1.42)	1.34 (0.93, 1.93)	1.11 (0.65, 1.91)
	Fatal	0.81 (0.55, 1.19)	**1.34 (1.04, 1.73)**	**1.41 (1.04, 1.91)**
Body Region AIS 2+	**Head**	1.37 (0.99, 1.90)	**1.43 (1.01, 2.04)**	1.27 (0.88, 1.85)
	Neck & C-spine	0.73 (0.42, 1.27)	1.36 (0.72, 2.56)	1.11 (0.62, 1.96)
	Thorax	0.80 (0.53, 1.20)	1.05 (0.74, 1.47)	0.86 (0.59, 1.25)
	Abdomen	0.75 (0.48, 1.18)	0.83 (0.59, 1.17)	0.79 (0.55, 1.12)
	Thoracolumbar	0.99 (0.59, 1.69)	1.27 (0.85, 1.92)	1.10 (0.65, 1.88)
	Torso	0.92 (0.66, 1.29)	1.10 (0.85, 1.41)	1.03 (0.73, 1.45)
	Knee-Thigh-Hip	0.93 (0.69, 1.25)	1.13 (0.73, 1.75)	1.19 (0.81, 1.77)
	Leg	0.80 (0.50, 1.27)	0.93 (0.60, 1.44)	0.89 (0.53, 1.48)
	Foot & Ankle	1.14 (0.53, 2.47)	0.71 (0.46, 1.11)	0.62 (0.36, 1.08)
	Upper Extremity	0.97 (0.59, 1.57)	1.02 (0.72, 1.44)	1.02 (0.49, 2.10)
	Lower Extremity	1.06 (0.69, 1.64)	0.96 (0.74, 1.24)	0.95 (0.69, 1.31)
Body Region AIS 3+	**Head**	1.17 (0.50, 2.74)	1.40 (0.57, 3.46)	0.83 (0.29, 2.33)
	Neck & C-spine	0.66 (0.32, 1.37)	1.53 (0.56, 4.14)	1.24 (0.51, 3.01)
	Thorax	0.88 (0.51, 1.51)	1.15 (0.78, 1.71)	0.91 (0.62, 1.33)
	Abdomen	0.64 (0.35, 1.19)	0.66 (0.39, 1.14)	**0.57 (0.36, 0.91)**
	Thoracolumbar	0.49 (0.23, 1.04)	0.79 (0.33, 1.87)	0.99 (0.41, 2.42)
	Torso	0.76 (0.47, 1.23)	0.98 (0.69, 1.38)	0.83 (0.59, 1.16)
	Knee-Thigh-Hip	1.02 (0.75, 1.40)	1.25 (0.88, 1.80)	1.32 (0.92, 1.90)
	Leg	0.94 (0.61, 1.46)	0.99 (0.66, 1.49)	1.09 (0.61, 1.92)
	Upper Extremity	0.85 (0.49, 1.48)	1.05 (0.67, 1.64)	0.99 (0.51, 1.91)
	Lower Extremity	1.01 (0.77, 1.33)	1.16 (0.83, 1.60)	1.23 (0.92, 1.63)

Bolded results are significant at $p \leq .05$.

Table A-9. Height group ORs for Near-Side Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	1.23 (0.79, 1.93)	1.09 (0.67, 1.75)	1.33 (0.72, 2.44)
	MAIS 3+	1.35 (0.83, 2.19)	1.27 (0.72, 2.23)	1.46 (0.80, 2.68)
	MAIS 4+	1.60 (0.88, 2.90)	1.44 (0.71, 2.92)	1.45 (0.62, 3.43)
	Fatal	1.08 (0.62, 1.88)	1.52 (0.94, 2.47)	1.46 (0.80, 2.67)
Body Region AIS 2+	**Head**	1.46 (0.89, 2.39)	1.08 (0.58, 2.01)	1.19 (0.61, 2.29)
	Neck & C-spine	0.96 (0.44, 2.07)	0.82 (0.39, 1.70)	1.01 (0.46, 2.21)
	Thorax	1.56 (0.88, 2.76)	1.23 (0.81, 1.87)	1.63 (0.84, 3.14)
	Abdomen	**1.68 (1.11, 2.54)**	1.35 (0.90, 2.04)	**1.74 (1.02, 2.96)**
	Thoracolumbar	1.00 (0.39, 2.60)	1.43 (0.68, 2.98)	1.28 (0.62, 2.63)
	Torso	**1.63 (1.03, 2.59)**	**1.44 (1.02, 2.03)**	**1.82 (1.06, 3.12)**
	Knee-Thigh-Hip	0.98 (0.63, 1.54)	0.99 (0.54, 1.80)	1.01 (0.65, 1.58)
	Leg	1.06 (0.49, 2.34)	1.15 (0.45, 2.93)	1.11 (0.41, 3.01)
	Foot & Ankle	0.65 (0.17, 2.45)	0.46 (0.14, 1.49)	0.57 (0.12, 2.70)
	Upper Extremity	0.64 (0.36, 1.11)	0.80 (0.52, 1.22)	0.68 (0.41, 1.12)
	Lower Extremity	0.85 (0.49, 1.48)	0.90 (0.49, 1.65)	0.86 (0.46, 1.59)
Body Region AIS 3+	**Head**	**1.82 (1.01, 3.30)**	1.53 (0.79, 2.97)	1.61 (0.95, 2.73)
	Neck & C-spine	0.99 (0.42, 2.29)	0.77 (0.34, 1.77)	0.68 (0.22, 2.11)
	Thorax	1.18 (0.68, 2.03)	1.27 (0.79, 2.06)	1.39 (0.78, 2.48)
	Abdomen	1.48 (0.81, 2.71)	1.19 (0.60, 2.34)	1.55 (0.85, 2.84)
	Thoracolumbar	0.97 (0.15, 6.45)	1.16 (0.34, 3.97)	1.75 (0.38, 8.03)
	Torso	1.18 (0.65, 2.14)	1.28 (0.78, 2.09)	1.45 (0.82, 2.57)
	Knee-Thigh-Hip	1.06 (0.62, 1.82)	0.92 (0.54, 1.59)	1.26 (0.73, 2.19)
	Leg	0.80 (0.42, 1.53)	0.91 (0.35, 2.39)	0.58 (0.21, 1.66)
	Upper Extremity	0.59 (0.24, 1.46)	0.81 (0.48, 1.38)	0.61 (0.24, 1.59)
	Lower Extremity	0.98 (0.61, 1.58)	0.85 (0.50, 1.45)	1.12 (0.66, 1.90)

Bolded results are significant at $p \leq .05$.

Table A-10. Height group ORs for Far-Side Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	1.49 (0.78, 2.83)	1.46 (0.88, 2.44)	1.43 (0.67, 3.04)
	MAIS 3+	1.18 (0.60, 2.30)	1.45 (0.77, 2.72)	1.33 (0.53, 3.35)
	MAIS 4+	1.01 (0.51, 1.99)	1.25 (0.65, 2.41)	1.11 (0.45, 2.75)
	Fatal	1.25 (0.68, 2.30)	**1.83 (1.15, 2.93)**	1.14 (0.61, 2.10)
Body Region AIS 2+	**Head**	1.40 (0.76, 2.58)	1.56 (0.95, 2.57)	1.76 (0.97, 3.19)
	Neck & C-spine	1.62 (0.83, 3.13)	1.86 (0.72, 4.78)	2.16 (0.91, 5.15)
	Thorax	1.01 (0.49, 2.10)	1.18 (0.50, 2.77)	1.44 (0.50, 4.13)
	Abdomen	1.17 (0.66, 2.08)	0.95 (0.50, 1.79)	0.97 (0.40, 2.33)
	Thoracolumbar	1.95 (0.48, 7.91)	2.13 (0.48, 9.45)	3.11 (0.67, 14.42)
	Torso	1.05 (0.59, 1.87)	1.29 (0.64, 2.63)	1.60 (0.63, 4.08)
	Knee-Thigh-Hip	2.17 (0.89, 5.31)	1.46 (0.59, 3.59)	1.14 (0.48, 2.74)
	Leg	1.00 (0.35, 2.80)	1.84 (0.42, 8.04)	1.07 (0.36, 3.13)
	Foot & Ankle	1.39 (0.40, 4.87)	0.98 (0.37, 2.64)	0.64 (0.17, 2.36)
	Upper Extremity	1.41 (0.60, 3.29)	1.07 (0.51, 2.22)	1.09 (0.51, 2.33)
	Lower Extremity	2.13 (0.85, 5.38)	1.45 (0.62, 3.38)	1.04 (0.48, 2.26)
Body Region AIS 3+	**Head**	1.55 (0.70, 3.45)	1.38 (0.59, 3.20)	1.55 (0.58, 4.13)
	Neck & C-spine	2.07 (0.82, 5.22)	1.44 (0.56, 3.71)	1.20 (0.50, 2.86)
	Thorax	1.39 (0.56, 3.45)	1.58 (0.57, 4.38)	1.49 (0.52, 4.27)
	Abdomen	1.26 (0.52, 3.04)	0.91 (0.36, 2.27)	1.22 (0.30, 4.92)
	Thoracolumbar	1.82 (0.09, 34.98)	2.11 (0.12, 38.19)	4.22 (0.29, 61.13)
	Torso	1.22 (0.55, 2.73)	1.34 (0.53, 3.39)	1.43 (0.54, 3.78)
	Knee-Thigh-Hip	1.66 (0.99, 2.77)	2.00 (0.96, 4.14)	1.63 (0.91, 2.91)
	Leg	0.86 (0.21, 3.46)	1.26 (0.13, 12.47)	0.27 (0.03, 2.69)
	Upper Extremity	0.80 (0.23, 2.84)	1.34 (0.36, 4.92)	2.44 (0.63, 9.49)
	Lower Extremity	1.49 (0.82, 2.72)	1.97 (0.72, 5.40)	1.28 (0.65, 2.54)

Bolded results are significant at $p \leq .05$.

Table A-11. Height group ORs for Rear Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	0.87 (0.44, 1.74)	0.96 (0.49, 1.90)	1.03 (0.52, 2.03)
	MAIS 3+	1.30 (0.48, 3.52)	1.37 (0.60, 3.16)	0.82 (0.27, 2.52)
	MAIS 4+	1.77 (0.54, 5.81)	1.96 (0.74, 5.20)	0.76 (0.17, 3.29)
	Fatal	1.05 (0.39, 2.82)	1.60 (0.72, 3.57)	0.57 (0.19, 1.75)
Body Region AIS 2+	**Head**	0.81 (0.34, 1.96)	0.99 (0.45, 2.19)	1.54 (0.73, 3.26)
	Neck & C-spine	0.69 (0.15, 3.20)	2.07 (0.46, 9.40)	0.90 (0.09, 9.26)
	Thorax	0.56 (0.15, 2.05)	0.61 (0.17, 2.20)	0.31 (0.06, 1.59)
	Abdomen	**5.31 (1.20, 23.38)**	1.99 (0.42, 9.41)	1.72 (0.30, 9.84)
	Thoracolumbar	2.31 (0.73, 7.29)	2.85 (0.74, 11.05)	1.41 (0.23, 8.54)
	Torso	0.86 (0.31, 2.42)	0.94 (0.29, 3.00)	0.63 (0.19, 2.07)
	Knee-Thigh-Hip	2.01 (0.70, 5.80)	1.83 (0.57, 5.79)	1.37 (0.32, 5.85)
	Leg	1.20 (0.25, 5.68)	1.32 (0.24, 7.39)	0.22 (0.01, 3.96)
	Foot & Ankle	1.16 (0.17, 7.73)	1.38 (0.20, 9.57)	0.32 (0.01, 9.89)
	Upper Extremity	0.58 (0.06, 5.62)	0.59 (0.09, 3.68)	0.77 (0.12, 4.81)
	Lower Extremity	1.39 (0.57, 3.38)	1.50 (0.54, 4.17)	0.74 (0.22, 2.44)
Body Region AIS 3+	**Head**	0.87 (0.17, 4.47)	1.15 (0.28, 4.78)	1.12 (0.18, 6.80)
	Neck & C-spine	1.16 (0.09, 14.33)	5.78 (0.45, 73.41)	1.28 (0.05, 33.22)
	Thorax	1.19 (0.40, 3.57)	1.07 (0.39, 2.95)	0.51 (0.14, 1.90)
	Abdomen	**11.34 (1.13, 113.54)**	1.04 (0.04, 28.06)	0.57 (0.01, 21.92)
	Thoracolumbar	4.89 (0.75, 32.03)	6.43 (0.94, 43.82)	0.94 (0.04, 21.50)
	Torso	1.57 (0.53, 4.64)	1.21 (0.42, 3.46)	0.58 (0.13, 2.49)
	Knee-Thigh-Hip	1.40 (0.24, 8.06)	1.08 (0.16, 7.17)	0.86 (0.07, 11.11)
	Leg	0.84 (0.05, 13.10)	0.11 (0.00, 5.21)	0.34 (0.00, 76.65)
	Upper Extremity	0.81 (0.07, 9.79)	0.66 (0.05, 9.29)	0.35 (0.01, 21.56)
	Lower Extremity	1.06 (0.18, 6.20)	0.73 (0.18, 2.96)	0.66 (0.05, 9.07)

Bolded results are significant at $p \leq .05$.

Table A-12. Height group ORs for Primary Rollover Crashes. Reference is "100-163 cm" with 95% CIs.

		163-170 cm	170-180 cm	180-220 cm
Overall Severity	**MAIS 2+**	1.46 (0.92, 2.31)	1.54 (0.91, 2.59)	**1.75 (1.01, 3.02)**
	MAIS 3+	1.17 (0.72, 1.90)	1.01 (0.58, 1.74)	1.10 (0.66, 1.85)
	MAIS 4+	**1.74 (1.02, 2.99)**	1.22 (0.70, 2.13)	1.19 (0.65, 2.18)
	Fatal	1.46 (0.84, 2.52)	1.32 (0.72, 2.43)	1.48 (0.73, 3.00)
Body Region AIS 2+	**Head**	**1.55 (1.03, 2.34)**	1.69 (0.93, 3.07)	1.68 (0.91, 3.09)
	Neck & C-spine	1.64 (0.92, 2.94)	**1.77 (1.02, 3.09)**	**1.98 (1.10, 3.56)**
	Thorax	1.42 (0.76, 2.65)	1.21 (0.69, 2.10)	1.49 (0.84, 2.62)
	Abdomen	0.90 (0.47, 1.74)	0.61 (0.23, 1.58)	0.76 (0.28, 2.08)
	Thoracolumbar	1.05 (0.56, 1.96)	1.07 (0.56, 2.06)	1.83 (0.71, 4.74)
	Torso	1.31 (0.79, 2.17)	1.24 (0.75, 2.06)	**1.93 (1.10, 3.38)**
	Knee-Thigh-Hip	1.31 (0.54, 3.17)	1.08 (0.39, 2.98)	0.93 (0.25, 3.44)
	Leg	1.21 (0.48, 3.06)	1.00 (0.36, 2.76)	1.38 (0.51, 3.74)
	Foot & Ankle	0.58 (0.17, 1.96)	0.57 (0.15, 2.21)	0.83 (0.20, 3.48)
	Upper Extremity	1.15 (0.59, 2.23)	1.27 (0.66, 2.42)	1.19 (0.53, 2.69)
	Lower Extremity	1.11 (0.50, 2.48)	0.89 (0.36, 2.19)	1.19 (0.41, 3.48)
Body Region AIS 3+	**Head**	**1.71 (1.06, 2.75)**	1.12 (0.66, 1.89)	1.31 (0.74, 2.31)
	Neck & C-spine	1.16 (0.53, 2.54)	**2.33 (1.09, 4.96)**	2.02 (0.82, 4.94)
	Thorax	1.21 (0.65, 2.26)	1.09 (0.55, 2.19)	1.32 (0.73, 2.39)
	Abdomen	0.82 (0.19, 3.48)	0.65 (0.12, 3.51)	0.65 (0.12, 3.52)
	Thoracolumbar	0.59 (0.21, 1.64)	0.79 (0.27, 2.28)	1.57 (0.52, 4.79)
	Torso	1.08 (0.63, 1.86)	0.99 (0.52, 1.88)	1.40 (0.82, 2.40)
	Knee-Thigh-Hip	0.78 (0.35, 1.76)	0.80 (0.36, 1.78)	0.80 (0.33, 1.91)
	Leg	1.37 (0.31, 6.18)	0.57 (0.12, 2.71)	1.12 (0.17, 7.36)
	Upper Extremity	1.16 (0.50, 2.70)	0.84 (0.27, 2.63)	1.04 (0.34, 3.13)
	Lower Extremity	0.91 (0.44, 1.89)	0.80 (0.37, 1.72)	0.85 (0.37, 1.96)

Bolded results are significant at $p \leq .05$.

BMI

Having a BMI of 30 or higher was associated with having significantly higher injury odds in *Frontal Crashes*. Occupants with a BMI of 30+ had significantly higher injury odds in 16 out of 25 body region/injury severity models in *Frontal Crashes* than occupants with a normal BMI (18.5-25). For example, occupants with BMI of 30+ had significantly higher MAIS 2+ (OR = 1.30, 95% CI 1.01-1.69), MAIS 3+ (OR = 1.51, 95% CI 1.09-2.09), MAIS 4+ (OR = 1.42, 95% CI 1.07-1.88), and fatal injuries (OR = 1.86, 95% CI 1.43-2.42) than occupants with a normal BMI. Frontal crash results largely contributed to BMI of 30+ occupants having significantly higher injury odds in 16 out of 25 body region/injury severity levels than occupants with a normal BMI in the *Combined Planar Crashes* models. By contrast, occupants with a BMI of 25 to 30 had only four significant differences in injury odds from occupants with a normal BMI across all 150 injury severity/crash type combinations, and occupants with a BMI less than 18.5 only had one. Tables A-13 to A-18 show all ORs for BMI categories <18.5, 25 to 30, and 30+ compared to normal BMI for *Combined Planar, Frontal, Near-ide, Far-Side, Rear, and Primary Rollover Crashes*. For all tables, bolded ORs indicate statistical significance ($p \leq .05$). Note that some ORs in smaller-sample crash types or injury outcomes have very wide CIs, which may indicate quasi-separation issues within statistical models, and therefore those ORs should be interpreted with caution.

Table A-13. BMI group ORs for Combined Planar Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	0.87 (0.65, 1.16)	1.00 (0.85, 1.19)	**1.37 (1.17, 1.61)**
	MAIS 3+	0.91 (0.59, 1.41)	1.05 (0.83, 1.33)	**1.43 (1.13, 1.80)**
	MAIS 4+	1.12 (0.53, 2.38)	0.99 (0.72, 1.36)	**1.38 (1.03, 1.86)**
	Fatal	1.18 (0.62, 2.24)	1.23 (0.98, 1.54)	**1.74 (1.41, 2.15)**
Body Region AIS 2+	**Head**	0.87 (0.52, 1.46)	0.94 (0.69, 1.27)	1.10 (0.82, 1.47)
	Neck & C-spine	1.29 (0.56, 2.95)	1.05 (0.76, 1.44)	1.37 (0.90, 2.09)
	Thorax	1.10 (0.58, 2.09)	1.07 (0.86, 1.33)	**1.28 (1.05, 1.56)**
	Abdomen	1.16 (0.67, 2.01)	0.90 (0.67, 1.21)	1.38 (0.94, 2.02)
	Thoracolumbar	1.34 (0.55, 3.29)	0.97 (0.68, 1.38)	1.32 (0.98, 1.78)
	Torso	1.06 (0.66, 1.70)	1.02 (0.85, 1.21)	**1.21 (1.04, 1.42)**
	Knee-Thigh-Hip	0.85 (0.57, 1.28)	0.92 (0.71, 1.20)	**1.55 (1.19, 2.03)**
	Leg	0.77 (0.47, 1.24)	1.20 (0.89, 1.64)	**1.48 (1.09, 2.02)**
	Foot & Ankle	1.17 (0.62, 2.21)	1.27 (0.90, 1.80)	**2.00 (1.54, 2.59)**
	Upper Extremity	0.63 (0.38, 1.04)	1.04 (0.64, 1.67)	**1.51 (1.02, 2.23)**
	Lower Extremity	0.96 (0.63, 1.48)	1.07 (0.92, 1.25)	**1.72 (1.45, 2.04)**
Body Region AIS 3+	**Head**	0.92 (0.65, 1.29)	1.14 (0.73, 1.76)	1.42 (0.89, 2.25)
	Neck & C-spine	0.90 (0.33, 2.43)	1.03 (0.74, 1.45)	1.45 (0.90, 2.33)
	Thorax	1.39 (0.69, 2.79)	1.01 (0.80, 1.28)	**1.41 (1.12, 1.79)**
	Abdomen	1.07 (0.44, 2.63)	0.82 (0.55, 1.23)	1.11 (0.66, 1.87)
	Thoracolumbar	1.07 (0.15, 7.80)	0.79 (0.31, 1.99)	1.21 (0.53, 2.77)
	Torso	1.24 (0.67, 2.31)	0.95 (0.76, 1.19)	**1.32 (1.06, 1.63)**
	Knee-Thigh-Hip	0.92 (0.60, 1.40)	0.99 (0.76, 1.29)	**1.41 (1.15, 1.72)**
	Leg	0.75 (0.41, 1.36)	1.12 (0.68, 1.84)	1.27 (0.84, 1.92)
	Upper Extremity	0.69 (0.33, 1.45)	1.25 (0.81, 1.93)	**1.60 (1.05, 2.44)**
	Lower Extremity	0.87 (0.57, 1.32)	1.05 (0.79, 1.41)	**1.41 (1.13, 1.76)**

Bolded results are significant at $p \leq .05$.

Table A-14. BMI group ORs for Frontal Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	0.81 (0.61, 1.08)	1.01 (0.81, 1.27)	**1.30 (1.01, 1.69)**
	MAIS 3+	0.81 (0.54, 1.21)	1.11 (0.82, 1.50)	**1.51 (1.09, 2.09)**
	MAIS 4+	0.90 (0.46, 1.77)	0.98 (0.69, 1.40)	**1.42 (1.07, 1.88)**
	Fatal	1.13 (0.56, 2.28)	1.28 (0.98, 1.67)	**1.86 (1.43, 2.42)**
Body Region AIS 2+	**Head**	0.81 (0.51, 1.31)	0.96 (0.69, 1.33)	1.14 (0.84, 1.55)
	Neck & C-spine	0.87 (0.32, 2.40)	1.11 (0.72, 1.72)	1.54 (0.91, 2.60)
	Thorax	1.07 (0.53, 2.13)	1.15 (0.88, 1.52)	1.25 (0.95, 1.63)
	Abdomen	1.11 (0.58, 2.13)	0.94 (0.61, 1.44)	1.38 (0.79, 2.40)
	Thoracolumbar	1.14 (0.58, 2.24)	1.09 (0.73, 1.63)	**1.59 (1.10, 2.30)**
	Torso	0.99 (0.58, 1.70)	1.08 (0.87, 1.35)	1.22 (0.98, 1.50)
	Knee-Thigh-Hip	0.69 (0.39, 1.20)	0.89 (0.61, 1.29)	1.25 (0.93, 1.70)
	Leg	0.72 (0.39, 1.34)	1.17 (0.83, 1.65)	**1.51 (1.04, 2.19)**
	Foot & Ankle	1.23 (0.59, 2.57)	1.25 (0.89, 1.74)	**1.88 (1.36, 2.59)**
	Upper Extremity	**0.54 (0.29, 0.98)**	1.00 (0.58, 1.73)	1.34 (0.85, 2.11)
	Lower Extremity	0.90 (0.48, 1.70)	1.05 (0.86, 1.28)	**1.53 (1.18, 1.98)**
Body Region AIS 3+	**Head**	0.73 (0.43, 1.25)	1.27 (0.64, 2.53)	1.62 (0.86, 3.06)
	Neck & C-spine	0.64 (0.22, 1.91)	1.06 (0.72, 1.55)	1.68 (0.81, 3.51)
	Thorax	1.29 (0.74, 2.24)	1.12 (0.84, 1.50)	**1.54 (1.07, 2.21)**
	Abdomen	0.85 (0.40, 1.77)	0.81 (0.50, 1.29)	1.03 (0.52, 2.07)
	Thoracolumbar	1.13 (0.22, 5.74)	1.02 (0.55, 1.86)	1.54 (0.71, 3.33)
	Torso	1.13 (0.70, 1.81)	1.04 (0.80, 1.34)	**1.39 (1.01, 1.93)**
	Knee-Thigh-Hip	0.75 (0.41, 1.37)	1.09 (0.78, 1.54)	**1.56 (1.23, 1.98)**
	Leg	0.85 (0.44, 1.67)	1.09 (0.64, 1.86)	1.32 (0.81, 2.14)
	Upper Extremity	0.55 (0.22, 1.36)	1.26 (0.77, 2.07)	1.50 (0.92, 2.45)
	Lower Extremity	0.75 (0.44, 1.27)	1.12 (0.80, 1.59)	**1.55 (1.23, 1.95)**

Bolded results are significant at $p \leq .05$.

Table A-15. BMI group ORs for Near-Side Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	0.82 (0.40, 1.64)	0.91 (0.65, 1.28)	1.16 (0.80, 1.67)
	MAIS 3+	0.96 (0.33, 2.82)	0.87 (0.55, 1.37)	1.20 (0.79, 1.83)
	MAIS 4+	1.68 (0.44, 6.47)	0.80 (0.52, 1.24)	1.16 (0.68, 2.00)
	Fatal	1.44 (0.40, 5.11)	1.08 (0.77, 1.52)	**1.45 (1.02, 2.07)**
Body Region AIS 2+	**Head**	0.68 (0.23, 2.01)	0.88 (0.51, 1.53)	0.94 (0.54, 1.66)
	Neck & C-spine	2.45 (0.74, 8.07)	0.88 (0.52, 1.47)	1.05 (0.53, 2.06)
	Thorax	0.98 (0.32, 3.03)	0.78 (0.51, 1.20)	1.19 (0.88, 1.62)
	Abdomen	1.08 (0.28, 4.12)	0.81 (0.49, 1.34)	1.38 (0.95, 2.01)
	Thoracolumbar	1.55 (0.38, 6.35)	0.64 (0.31, 1.29)	0.75 (0.38, 1.48)
	Torso	1.09 (0.44, 2.70)	0.81 (0.58, 1.15)	0.99 (0.76, 1.31)
	Knee-Thigh-Hip	0.89 (0.39, 2.00)	0.74 (0.48, 1.15)	1.33 (0.90, 1.96)
	Leg	0.84 (0.24, 2.93)	1.17 (0.50, 2.73)	1.22 (0.58, 2.56)
	Foot & Ankle	0.73 (0.17, 3.17)	1.24 (0.38, 4.04)	3.30 (0.94, 11.57)
	Upper Extremity	1.01 (0.48, 2.13)	1.08 (0.56, 2.07)	1.65 (0.92, 2.95)
	Lower Extremity	0.85 (0.40, 1.85)	0.91 (0.59, 1.39)	1.49 (0.82, 2.69)
Body Region AIS 3+	**Head**	0.81 (0.37, 1.76)	0.75 (0.54, 1.04)	0.98 (0.64, 1.50)
	Neck & C-spine	1.69 (0.30, 9.54)	0.93 (0.47, 1.84)	1.05 (0.47, 2.36)
	Thorax	1.43 (0.41, 4.96)	0.83 (0.53, 1.31)	1.31 (0.86, 1.99)
	Abdomen	1.33 (0.19, 9.23)	0.89 (0.52, 1.53)	1.16 (0.69, 1.95)
	Thoracolumbar	0.07 (0.00, 2.31)	0.36 (0.07, 1.91)	0.89 (0.24, 3.21)
	Torso	1.32 (0.38, 4.64)	0.75 (0.48, 1.18)	1.22 (0.80, 1.87)
	Knee-Thigh-Hip	1.00 (0.36, 2.79)	0.70 (0.44, 1.11)	1.08 (0.66, 1.77)
	Leg	0.31 (0.05, 2.06)	0.93 (0.35, 2.44)	0.82 (0.31, 2.22)
	Upper Extremity	0.81 (0.24, 2.73)	1.10 (0.41, 2.96)	1.20 (0.51, 2.82)
	Lower Extremity	0.92 (0.32, 2.67)	0.76 (0.48, 1.21)	1.03 (0.61, 1.75)

Bolded results are significant at $p \leq .05$.

Table A-16. BMI group ORs for Far-Side Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	1.46 (0.67, 3.18)	1.12 (0.81, 1.53)	**2.12 (1.24, 3.62)**
	MAIS 3+	1.20 (0.35, 4.12)	1.03 (0.64, 1.67)	1.43 (0.86, 2.37)
	MAIS 4+	1.09 (0.40, 2.95)	1.09 (0.53, 2.23)	1.35 (0.73, 2.52)
	Fatal	0.61 (0.17, 2.17)	1.24 (0.81, 1.92)	**1.70 (1.10, 2.64)**
Body Region AIS 2+	**Head**	1.71 (0.58, 5.01)	0.90 (0.53, 1.53)	1.25 (0.66, 2.34)
	Neck & C-spine	0.82 (0.19, 3.60)	0.86 (0.51, 1.46)	0.98 (0.47, 2.07)
	Thorax	1.41 (0.32, 6.27)	1.28 (0.70, 2.34)	1.32 (0.69, 2.50)
	Abdomen	1.45 (0.62, 3.39)	0.98 (0.47, 2.02)	**1.83 (1.05, 3.21)**
	Thoracolumbar	1.51 (0.20, 11.17)	0.78 (0.25, 2.43)	1.07 (0.38, 3.05)
	Torso	1.21 (0.42, 3.47)	1.09 (0.67, 1.76)	1.48 (0.87, 2.52)
	Knee-Thigh-Hip	2.29 (0.79, 6.67)	1.37 (0.60, 3.13)	**2.77 (1.11, 6.92)**
	Leg	0.77 (0.15, 3.94)	0.92 (0.20, 4.26)	1.09 (0.35, 3.38)
	Foot & Ankle	1.08 (0.20, 5.74)	1.20 (0.23, 6.28)	2.59 (0.95, 7.10)
	Upper Extremity	1.19 (0.40, 3.60)	1.22 (0.64, 2.30)	**3.08 (1.53, 6.18)**
	Lower Extremity	2.02 (0.75, 5.47)	1.36 (0.65, 2.86)	**2.77 (1.29, 5.92)**
Body Region AIS 3+	**Head**	1.57 (0.74, 3.34)	1.10 (0.45, 2.67)	1.25 (0.63, 2.49)
	Neck & C-spine	0.41 (0.02, 7.76)	0.92 (0.41, 2.09)	0.95 (0.35, 2.54)
	Thorax	1.57 (0.31, 7.88)	1.02 (0.51, 2.04)	1.12 (0.51, 2.50)
	Abdomen	2.37 (0.65, 8.58)	1.26 (0.42, 3.84)	**2.08 (1.08, 4.01)**
	Thoracolumbar	1.73 (0.06, 49.48)	0.53 (0.04, 6.75)	0.57 (0.03, 9.35)
	Torso	1.52 (0.37, 6.26)	1.06 (0.57, 1.97)	1.19 (0.59, 2.43)
	Knee-Thigh-Hip	1.85 (0.46, 7.34)	0.81 (0.44, 1.49)	1.37 (0.67, 2.82)
	Leg	0.74 (0.04, 13.83)	1.01 (0.08, 12.09)	2.07 (0.35, 12.24)
	Upper Extremity	1.10 (0.13, 9.69)	0.91 (0.26, 3.16)	2.13 (0.80, 5.65)
	Lower Extremity	1.76 (0.49, 6.37)	0.93 (0.35, 2.49)	1.50 (0.69, 3.24)

Bolded results are significant at $p \leq .05$.

Table A-17. BMI group ORs for Rear Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	0.58 (0.15, 2.17)	0.97 (0.60, 1.57)	1.19 (0.68, 2.10)
	MAIS 3+	0.45 (0.06, 3.16)	1.03 (0.50, 2.13)	1.22 (0.58, 2.58)
	MAIS 4+	0.50 (0.05, 5.14)	1.56 (0.59, 4.15)	1.90 (0.85, 4.25)
	Fatal	0.60 (0.02, 14.53)	1.44 (0.60, 3.47)	2.16 (0.99, 4.74)
Body Region AIS 2+	**Head**	0.34 (0.06, 1.86)	0.92 (0.47, 1.80)	0.80 (0.33, 1.97)
	Neck & C-spine	0.98 (0.19, 5.16)	1.49 (0.45, 4.97)	2.07 (0.50, 8.54)
	Thorax	0.20 (0.03, 1.56)	0.91 (0.30, 2.72)	1.96 (0.77, 4.98)
	Abdomen	0.90 (0.07, 11.31)	0.37 (0.10, 1.34)	0.56 (0.14, 2.15)
	Thoracolumbar	0.45 (0.04, 5.09)	1.02 (0.33, 3.15)	1.24 (0.47, 3.30)
	Torso	0.36 (0.06, 2.02)	0.94 (0.42, 2.13)	1.45 (0.70, 3.03)
	Knee-Thigh-Hip	0.27 (0.03, 2.16)	1.40 (0.68, 2.87)	1.13 (0.46, 2.78)
	Leg	1.47 (0.09, 24.06)	3.14 (0.50, 19.90)	4.05 (0.59, 27.71)
	Foot & Ankle	0.02 (0.00, 1.09e+23)	2.39 (0.44, 13.14)	1.35 (0.19, 9.70)
	Upper Extremity	0.60 (0.04, 10.11)	2.20 (0.41, 11.70)	1.73 (0.33, 9.04)
	Lower Extremity	0.48 (0.10, 2.19)	1.77 (0.90, 3.48)	1.35 (0.57, 3.16)
Body Region AIS 3+	**Head**	0.42 (0.02, 7.39)	1.35 (0.64, 2.87)	1.19 (0.50, 2.82)
	Neck & C-spine	0.46 (0.01, 15.00)	1.79 (0.27, 11.90)	1.60 (0.34, 7.56)
	Thorax	0.19 (0.02, 1.47)	0.67 (0.22, 2.02)	1.39 (0.46, 4.17)
	Abdomen	Non-estimable	**0.11 (0.02, 0.84)**	0.44 (0.05, 3.64)
	Thoracolumbar	0.00 (0.00, 7.16e+11)	0.37 (0.08, 1.85)	1.97 (0.63, 6.09)
	Torso	0.17 (0.01, 3.14)	0.61 (0.21, 1.79)	1.28 (0.47, 3.46)
	Knee-Thigh-Hip	0.12 (0.00, 8.37)	1.64 (0.36, 7.38)	0.86 (0.17, 4.29)
	Leg	0.01 (0.00, 6.06e+23)	1.75 (0.03, 97.81)	0.83 (0.02, 45.51)
	Upper Extremity	Non-estimable	2.23 (0.44, 11.27)	1.80 (0.19, 16.75)
	Lower Extremity	0.13 (0.00, 28.71)	1.58 (0.38, 6.57)	0.79 (0.18, 3.46)

Bolded results are significant at $p \leq .05$.

Note: Where imputation-adjusted DF were less than 1, CIs could not be calculated. The estimates and CIs therefore are listed as "Non-estimable."

Table A-18. BMI group ORs for Primary Rollover Crashes. Reference is "18.5-25" with 95% CIs.

		< 18.5	25-30	30+
Overall Severity	**MAIS 2+**	0.73 (0.35, 1.53)	0.95 (0.64, 1.39)	1.24 (0.80, 1.93)
	MAIS 3+	1.40 (0.79, 2.49)	1.31 (0.88, 1.97)	**1.65 (1.07, 2.54)**
	MAIS 4+	1.19 (0.60, 2.38)	1.26 (0.83, 1.90)	**1.73 (1.05, 2.86)**
	Fatal	1.48 (0.61, 3.58)	1.38 (0.86, 2.22)	**2.33 (1.45, 3.76)**
Body Region AIS 2+	**Head**	0.54 (0.22, 1.34)	0.91 (0.56, 1.49)	1.30 (0.85, 1.98)
	Neck & C-spine	2.17 (0.89, 5.29)	1.14 (0.74, 1.76)	1.63 (0.93, 2.87)
	Thorax	0.82 (0.43, 1.57)	1.05 (0.57, 1.90)	0.97 (0.59, 1.58)
	Abdomen	1.15 (0.60, 2.18)	1.49 (0.64, 3.46)	1.17 (0.64, 2.14)
	Thoracolumbar	0.68 (0.26, 1.77)	1.44 (0.97, 2.14)	0.93 (0.53, 1.64)
	Torso	0.67 (0.39, 1.14)	1.05 (0.78, 1.40)	0.83 (0.56, 1.22)
	Knee-Thigh-Hip	0.99 (0.38, 2.59)	1.56 (0.72, 3.38)	1.69 (0.76, 3.76)
	Leg	0.26 (0.01, 5.90)	1.10 (0.41, 2.91)	0.96 (0.38, 2.45)
	Foot & Ankle	1.56 (0.26, 9.32)	**2.16 (1.11, 4.22)**	1.77 (0.56, 5.59)
	Upper Extremity	0.70 (0.30, 1.59)	0.83 (0.50, 1.38)	1.35 (0.66, 2.77)
	Lower Extremity	1.06 (0.42, 2.67)	1.44 (0.75, 2.75)	1.42 (0.67, 3.02)
Body Region AIS 3+	**Head**	0.76 (0.31, 1.85)	0.89 (0.63, 1.27)	0.97 (0.57, 1.65)
	Neck & C-spine	2.53 (0.60, 10.62)	1.41 (0.93, 2.15)	**2.34 (1.12, 4.88)**
	Thorax	1.01 (0.47, 2.14)	1.40 (0.77, 2.54)	1.42 (0.81, 2.48)
	Abdomen	1.03 (0.44, 2.40)	0.95 (0.34, 2.63)	1.02 (0.40, 2.56)
	Thoracolumbar	0.64 (0.13, 3.11)	**2.15 (1.03, 4.50)**	0.89 (0.38, 2.06)
	Torso	1.09 (0.60, 1.96)	1.36 (0.76, 2.43)	1.27 (0.72, 2.26)
	Knee-Thigh-Hip	1.40 (0.48, 4.09)	**2.42 (1.01, 5.81)**	1.98 (0.84, 4.68)
	Leg	0.32 (0.00, 22.35)	1.14 (0.43, 3.05)	1.58 (0.45, 5.56)
	Upper Extremity	0.65 (0.25, 1.73)	1.34 (0.70, 2.57)	1.86 (0.87, 3.96)
	Lower Extremity	1.25 (0.53, 2.92)	2.19 (0.96, 4.98)	2.07 (0.97, 4.43)

Bolded results are significant at $p \leq .05$.

Vehicle Vintage

Newer vehicles (model year 2009 and greater) showed lower injury odds in 124 of 150 models (Table A-19). Of these results, 45 were statistically significant ($p \leq .05$). Notably, injury odds ratios for leg, foot and ankle, and lower extremities for AIS 2+ and leg and lower extremities for AIS 3+ were significantly lower in *Combined Planar* and *Frontal* crash models ($p \leq .05$). Of the crash type models, *Far-Side* showed the most significant reductions in injury odds for newer vintage vehicles with 15 results having statistical significance ($p \leq .05$). Bolded ORs in Table A-19 indicate statistical significance ($p \leq .05$). Note that some ORs in smaller-sample crash types or injury outcomes have very wide CIs, which may indicate quasi-separation issues within statistical models, and therefore those ORs should be interpreted with caution.

Table A-19. Vehicle vintage ORs for newer versus older vehicles. Reference is "older" with 95% CIs.

		Combined Planar	Frontal	Near-Side	Far-Side	Rear	Primary Rollover
Overall Severity	**MAIS 2+**	0.89 (0.78, 1.01)	**0.82 (0.68, 0.99)**	0.84 (0.52, 1.35)	1.03 (0.6, 1.78)	1.22 (0.75, 1.99)	0.69 (0.34, 1.39)
	MAIS 3+	**0.78 (0.63, 0.97)**	0.86 (0.65, 1.14)	0.72 (0.5, 1.05)	0.49 (0.24, 1.01)	1.12 (0.5, 2.51)	0.55 (0.27, 1.12)
	MAIS 4+	0.77 (0.6, 1)	1.04 (0.72, 1.5)	**0.57 (0.36, 0.89)**	**0.36 (0.21, 0.6)**	0.73 (0.23, 2.38)	**0.39 (0.2, 0.75)**
	Fatal	0.87 (0.68, 1.12)	1.12 (0.86, 1.46)	**0.57 (0.35, 0.92)**	0.74 (0.48, 1.13)	0.4 (0.1, 1.71)	0.42 (0.17, 1.07)
Body Region AIS 2+	**Head**	**0.76 (0.6, 0.97)**	0.79 (0.6, 1.05)	0.75 (0.43, 1.32)	0.65 (0.38, 1.09)	0.8 (0.43, 1.51)	**0.55 (0.31, 0.95)**
	Neck & C-spine	0.77 (0.56, 1.04)	**0.68 (0.47, 0.96)**	1.33 (0.71, 2.5)	**0.51 (0.3, 0.88)**	**0.31 (0.11, 0.89)**	0.83 (0.46, 1.51)
	Thorax	0.93 (0.74, 1.17)	1.02 (0.73, 1.41)	0.77 (0.5, 1.2)	**0.51 (0.33, 0.8)**	2.06 (0.91, 4.66)	0.68 (0.35, 1.32)
	Abdomen	0.88 (0.64, 1.2)	1.22 (0.87, 1.7)	**0.58 (0.35, 0.97)**	**0.36 (0.18, 0.72)**	0.96 (0.28, 3.29)	0.57 (0.22, 1.5)
	Thoracolumbar	1.06 (0.78, 1.44)	1.28 (0.97, 1.68)	1.01 (0.47, 2.14)	0.44 (0.19, 1.01)	0.96 (0.4, 2.34)	0.64 (0.23, 1.74)
	Torso	0.9 (0.72, 1.11)	1 (0.78, 1.29)	0.78 (0.55, 1.1)	**0.52 (0.38, 0.72)**	1.69 (0.79, 3.6)	0.76 (0.41, 1.43)
	Knee-Thigh-Hip	0.98 (0.56, 1.72)	0.79 (0.57, 1.1)	0.85 (0.58, 1.25)	1.05 (0.33, 3.39)	0.52 (0.19, 1.42)	1.33 (0.45, 3.9)
	Leg	**0.59 (0.44, 0.79)**	**0.59 (0.4, 0.87)**	0.75 (0.3, 1.91)	**0.23 (0.09, 0.61)**	0.59 (0.12, 2.85)	0.6 (0.09, 4.08)
	Foot & Ankle	**0.58 (0.37, 0.91)**	**0.58 (0.34, 0.98)**	0.78 (0.2, 3.07)	**0.39 (0.17, 0.9)**	0.77 (0.26, 2.29)	0.53 (0.12, 2.29)
	Upper Extremity	**0.78 (0.63, 0.96)**	0.83 (0.63, 1.08)	**0.43 (0.27, 0.69)**	0.75 (0.41, 1.37)	1.15 (0.48, 2.76)	0.69 (0.29, 1.63)
	Lower Extremity	**0.71 (0.51, 0.97)**	**0.57 (0.42, 0.78)**	0.72 (0.43, 1.2)	0.93 (0.3, 2.87)	**0.45 (0.23, 0.89)**	1.23 (0.42, 3.58)
Body Region AIS 3+	**Head**	**0.56 (0.43, 0.73)**	0.62 (0.37, 1.04)	**0.55 (0.3, 1)**	**0.31 (0.16, 0.61)**	1.12 (0.59, 2.12)	0.57 (0.31, 1.06)
	Neck & C-spine	0.8 (0.54, 1.18)	0.81 (0.5, 1.31)	0.97 (0.42, 2.25)	0.53 (0.27, 1.05)	0.68 (0.19, 2.47)	0.56 (0.29, 1.09)
	Thorax	**0.74 (0.6, 0.91)**	0.81 (0.62, 1.06)	0.73 (0.48, 1.11)	**0.5 (0.3, 0.81)**	0.95 (0.36, 2.55)	0.69 (0.38, 1.25)
	Abdomen	0.89 (0.59, 1.35)	1.15 (0.66, 1.98)	0.82 (0.49, 1.39)	**0.31 (0.12, 0.84)**	0.52 (0.11, 2.44)	0.71 (0.22, 2.25)
	Thoracolumbar	1.55 (0.77, 3.13)	**2.38 (1.1, 5.14)**	1.29 (0.52, 3.18)	0.58 (0.19, 1.83)	0.58 (0.12, 2.84)	1.7 (0.66, 4.38)
	Torso	0.86 (0.66, 1.12)	1 (0.73, 1.37)	0.75 (0.5, 1.14)	**0.51 (0.34, 0.76)**	1.03 (0.39, 2.75)	0.7 (0.38, 1.29)
	Knee-Thigh-Hip	0.8 (0.61, 1.04)	0.94 (0.76, 1.16)	0.67 (0.28, 1.59)	**0.21 (0.11, 0.4)**	0.81 (0.2, 3.29)	0.85 (0.28, 2.56)
	Leg	**0.2 (0.12, 0.33)**	**0.18 (0.1, 0.3)**	0.43 (0.09, 1.93)	**0.13 (0.02, 0.78)**	**0 (0, 0.43)**	0.66 (0.11, 3.86)
	Upper Extremity	**0.27 (0.18, 0.4)**	**0.33 (0.2, 0.56)**	**0.14 (0.06, 0.32)**	**0.09 (0.03, 0.32)**	0.3 (0.06, 1.49)	0.31 (0.1, 1.02)
	Lower Extremity	**0.62 (0.49, 0.77)**	**0.67 (0.54, 0.82)**	0.62 (0.3, 1.28)	**0.21 (0.11, 0.39)**	0.58 (0.17, 1.96)	0.78 (0.28, 2.21)

Bolded results are significant at $p \leq .05$.

Appendix B. Crash Type

Assessment of a vehicle's crash type was based on the vehicle's most severe crash event regardless of the number or sequence of events documented. For inspected vehicles, the damaged plane (GAD) identified in the highest severity event's CDC coding determined the crash type, called GAD1 in NASS-CDS and CDCPLANE in CISS (the CDCPLANE must be selected where DVRANK = 1 to select the GAD1). Planar crash types included frontal, side, and rear planes (F, L, R, B, C, D), and the rollover crash type required a top plane (T) with non-zero or unknown rollover turns. While rare, a top plane impact without rollover may occur from an object contacting the roof while all four tires remained in contact with the ground – such an event was not included in this study. Table B-1 shows crash type coding using GAD1 and CDCPLANE.

Table B-1. GAD1 (NASS-CDS) and CDCPLANE (CISS) crash type coding

	Variable Coding	
Crash Type	**GAD1 (NASS-CDS)**	**CDCPLANE (CISS)**
Frontal	F	F
Side	L, R	L, R
Rear	B, C, D	B
Top	T	T
Other	N, U, V	U

Non-inspected vehicles are not assigned CDC codes in NASS-CDS and CISS, and this condition affected about 20 percent of the vehicles in this study. The non-inspected vehicles still normally include an indication of the damaged plane in the most severe event. Identification of the most severe event's damage plane required a unique process, which differed slightly for NASS-CDS and CISS cases.

Establishing a surrogate GAD1 (damage plane for highest severity impact) for uninspected NASS-CDS vehicles relied on analysis of the events table in conjunction with the general vehicle table. For each event in a crash, the event record documents the involved vehicle's damage plane as either GADEV1 or GADEV2. The possible attributes for GADEV1 or GADEV2 include the front, left, right, rear, and top planes similar to what is defined for the CDC GAD. The event record also shows the event sequence number ACCSEQ. For the non-inspected vehicles, the first step was to identify the damage plane from GADEV1 or GADEV2 for the crash event identified by the ACCSEQDV variable that shows the most significant event for the vehicle. If ACCSEQDV was unknown, and the vehicle was involved in only one event, the damage plane was determined from GADEV1 or GADEV2 for the vehicle's sole event. If ACCSEQDV was unknown and a vehicle experienced more than one event, no surrogate for GAD1 was assigned.

Changes in CISS allowed a simpler approach for identifying a surrogate GAD1 for uninspected vehicles. The vehicle table has a variable DAMPLANE that shows the most severe damage plane, which eliminates the need for the routine described for NASS-CDS using event table records. The possible attributes for DAMPLANE include the front, left, right, rear, and top planes similar to what is defined for the CDC GAD.

If the surrogate GAD1 was not unknown or indicative of a non-collision event, it was then subjected to the same filter as a CDC-derived GAD1 to identify the crash type used for the study. This approach allowed for determination of a crash type for most of the non-inspected vehicles. This approach was tested by identifying the surrogate GAD1 and comparing to the coded GAD1

for inspected vehicles. Among the inspected vehicles, the alternate method matched the investigator-assigned CDC plane nearly 100 percent of the time.

Compatibility

We developed a revised approach to assess crash compatibility, which is intended to distinguish impacts that engage typical crash structures (e.g., front-end longitudinal structures or side sill structures) from those that likely do not. Prior studies have presented criteria for compatibility that consider the subject vehicle, crash type, and collision partner (Brumbelow & Jermakian, 2021). Our revised approach limits the assessment of compatibility to planar vehicle-to-vehicle crashes based on a vehicle's highest severity event. The concept of compatibility encompasses the relative mass, stiffness, and vertical alignment of energy absorbing structures of two crash partners. Therefore, we opted to segregate vehicle-to-object and rollover crashes such that the compatibility assessment was not applicable.

For the vehicle-to-vehicle planar crashes, the first step was to identify the presence of front or rear override or underride. A front or rear crash type was considered not compatible if a case vehicle experienced override or underride at its highest severity damage plane. The next step for front and rear crash types assessed the body types of the subject vehicle and partner vehicle. If the body types were similar, the crash was considered compatible if the mass difference was less than 454 kg (1,000 lb). If the body types were different, but the striking vehicle was a light duty vehicle, the crash was considered compatible if the mass difference was less than 454 kg (1,000 lb). A crash where the subject vehicle was struck by a heavy vehicle was considered not compatible.

For side crash types where the subject vehicle was struck by a vehicle of the same body type, the crash was considered compatible if the mass difference was less than 454 kg (1,000 lb). If a utility vehicle, light truck, or van was struck by another light vehicle and the mass difference was less than 454 kg (1,000 lb), the crash was considered compatible. If a passenger car was struck by a utility vehicle, light truck, or van, the crash was considered not compatible. A heavy vehicle striking the side of a light vehicle resulted in an incompatible crash.

For assessments dependent on the mass difference between the two vehicles, unknown mass for either vehicle resulted in an unknown compatibility assessment. If either body type was unknown, the compatibility was unknown.

Mass Ratio

The mass ratio was calculated for planar vehicle-to-vehicle crashes when the mass of both vehicles was known. When the weight of either vehicle was unknown or for vehicle-to-object or rollover crashes, the weight ratio was unknown. Known weight ratios were calculated by dividing the subject vehicle's mass by the partner vehicle's mass.

Roof Inversions

Delta V was used to control for crash severity for planar crashes. For primary (highest severity event) rollover crashes, delta V is not a suitable indicator of crash severity. Prior studies have found that the number of roof inversions occurring during a rollover event give a good indication of occupant outcome for both restrained and unrestrained occupants (Strashny, 2007; Digges & Eigen, 2006; Eigen, 2005). The count of roof inversions aggregates cases as either 0, 1, or 2 or

more based on the number of quarter-turns. End-over-end and unknown responses for the quarter-turn variable were treated as a fourth (unknown) category for the roof inversion variable.

Appendix C. Specific DF and *p*-Values for Each of the 150 Models

DF and *p*-values are displayed in Table C-1 for each of the 150 sex ORs.

Table C-1. DF and p-values for sex ORs

		Combined Planar		Frontal		Near-Side		Far-Side		Rear		Primary Rollovers	
		DF	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**
Overall Severity	**MAIS 2+**	**19.9693**	**0.0004**	**17.3821**	**0.0015**	17.5954	0.7642	10.0824	0.0817	17.0838	0.4408	**19.9587**	**0.0275**
	MAIS 3+	14.4579	0.1042	16.9481	0.1602	11.8750	0.5195	22.9667	0.6527	14.8248	0.8082	**20.8271**	**0.0091**
	MAIS 4+	14.3348	0.8998	10.4336	0.8625	7.5084	0.7288	23.2077	0.3657	7.5659	0.8815	22.6975	0.1558
	Fatal	19.0093	0.1712	19.1935	0.1097	26.5001	0.5141	26.1873	0.3282	20.1722	0.3690	20.2514	0.8056
Body Region AIS 2+	**Head**	**20.8327**	**0.0252**	**22.0164**	**0.0068**	22.5178	0.8402	21.9296	0.6848	19.1190	0.5862	**26.8240**	**0.0170**
	Neck & C-spine	7.0049	0.4008	10.6826	0.5282	17.0092	0.4488	7.7081	0.5963	8.6982	0.6987	23.8849	0.3106
	Thorax	15.0732	0.8637	24.4865	0.9483	14.4801	0.1708	23.5834	0.6366	27.5172	0.9667	**24.6902**	**0.0052**
	Abdomen	21.7164	0.4767	15.8722	0.3248	26.5171	0.6165	26.1542	0.5394	21.4307	0.1513	**16.5860**	**0.0032**
	Thoracolumbar	**21.8529**	**0.0013**	**24.0289**	**0.0474**	14.9685	0.1173	19.0289	0.0755	18.1379	0.5203	26.5032	0.2731
	Torso	20.3254	0.0819	**23.7875**	**0.0398**	15.7158	0.1981	23.4250	0.4286	27.6827	0.7957	**21.6354**	**0.0452**
	Knee-Thigh-Hip	**20.1820**	**0.0018**	15.2626	0.2558	15.3871	0.2285	**13.0714**	**0.0016**	13.3849	0.0717	15.3091	0.0599
	Leg	**23.8412**	**0.0370**	**18.2102**	**0.0493**	16.6865	0.7229	9.1737	0.5401	24.9439	0.7945	25.1598	0.8824
	Foot & Ankle	**27.1985**	**0.0075**	**27.2951**	**0.0106**	13.6988	0.4214	14.5099	0.0741	16.6535	0.9033	**16.7509**	**0.0152**
	Upper Extremity	**24.0401**	**0.0097**	**23.7708**	**0.0178**	16.4912	0.1357	16.7651	0.0512	6.0742	0.5493	18.6701	0.1961
	Lower Extremity	**27.2548**	**0.0008**	**24.2185**	**0.0054**	13.1151	0.2513	**11.0123**	**0.0047**	23.7929	0.2991	12.8721	0.0561
Body Region AIS 3+	**Head**	19.5468	0.2574	18.6597	0.3318	24.0195	0.7608	18.6472	0.4561	13.7397	0.3181	**24.0486**	**0.0403**
	Neck & C-spine	8.4334	0.7912	8.7858	0.8216	19.5363	0.5207	16.0110	0.5817	19.8759	0.8977	19.4618	0.4916
	Thorax	12.4387	0.5122	17.2329	0.2835	14.2253	0.1925	20.6390	0.3825	19.1628	0.2113	**17.6488**	**0.0068**
	Abdomen	15.6292	0.8884	8.5148	0.6555	23.7899	0.6035	21.4245	0.7921	13.0653	0.3225	**19.0663**	**0.0066**
	Thoracolumbar	15.0639	0.0837	13.3282	0.1418	9.6225	0.8963	**15.2780**	**0.0471**	18.0248	0.3208	29.2022	0.5168
	Torso	15.5847	0.2591	18.2594	0.1278	15.4019	0.2149	20.6792	0.3521	18.2908	0.4140	**18.1784**	**0.0035**
	Knee-Thigh-Hip	**23.7274**	**0.0461**	20.7857	0.4309	21.7563	0.0851	22.0512	0.1772	6.5116	0.3670	**25.0464**	**0.0202**

		Combined Planar		Frontal		Near-Side		Far-Side		Rear			Primary Rollovers	
		DF	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**	**DF**	***P*-Value**		**DF**	***P*-Value**
	Leg	**22.1391**	**0.0431**	24.2748	0.0881	16.4776	0.1477	7.2027	0.6871	5.9676	0.7931		8.3105	0.4949
	Upper Extremity	**24.3879**	**0.0204**	26.7147	0.1028	7.9239	0.3304	**14.6340**	**0.0134**	7.6045	0.7236		**26.9563**	**0.0138**
	Lower Extremity	**24.8279**	**0.0143**	23.4890	0.1457	**18.9716**	**0.0306**	12.3888	0.2652	5.5019	0.4560		**22.1475**	**0.0147**

Bolded results are significant at $p \leq .05$.

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**National Highway
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