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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 aim of this study was to document the relative odds of various injury outcomes for females versus males while considering a broad range of crash types, pre-crash and crash variables, and occupant demographics. Multivariable logistic regression was carried out to study the odds of injury for females versus males. 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 age 13 years and older involved in passenger vehicle crashes published in NASS-CDS (2000 to 2015) and CISS (2017-2021). Seven pre-crash predictor variables and 22 crashworthiness predictor variables were considered, but only significant variables at $p \leq 0.10$ level were retained in final models. Six crash-type models were produced for each injury outcome; one that included all crashes, one for each of four different planar crashes (frontal, near-side, far-side, rear), and one for crashes involving rollover. These six sets of models were expanded further to include a model version that included both pre-crash/environment and crashworthiness predictors, and one that was limited to crashworthiness predictors only. Different than other recent studies, all crash types, occupant restraint conditions, and seating positions were considered. Occupant sex was retained in all models to facilitate female versus male injury outcome odds ratio (OR) assessments. The results of this study suggest that increased or decreased odds of injury for females versus males is dependent on the type of injury outcome and the associated crash type.

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Acronyms

ABB	Approximate Bayesian Bootstrap
AIS	Abbreviated Injury Scale
BMI	Body Mass Index
CISS	Crash Investigation Sampling System
CW	Crashworthiness
FARS	Fatality Analysis Reporting System
FEFI	Fully Efficient Fractional Imputation
GAD	General Area of Damage
HD	Hot-Deck
MAIS	Maximum Abbreviated Injury Scale
NHTSA	National Highway Traffic Safety Administration
NASS-CDS	National Automotive Sampling System–Crashworthiness Data System
OR	Odds Ratio

Executive Summary

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, 2022; Noh et al. 2022), but none have combined 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 relative odds of various injury outcomes for females versus males while considering a broad range of crash types, pre-crash and crash variables, and occupant characteristics.

Multivariable logistic regression was carried out to study the odds of injury for females versus males. 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 age 13 years and older involved in passenger vehicle crashes published in NASS-CDS (2000 to 2015) and CISS (2017-2021). Seven pre-crash predictor variables and 22 crashworthiness predictor variables were considered, but only significant variables at $p \leq 0.10$ level were retained in final models. Six crash-type models were produced for each injury outcome; one that included all crashes, one for each of four different planar crashes (frontal, near-side, far-side, rear), and one for crashes involving rollover. These six sets of models were expanded further to include a model version that included both pre-crash/environment and crashworthiness predictors and one that was limited to crashworthiness predictors only. Different than other recent studies, all crash types, occupant restraint conditions, and seating positions were considered. Occupant sex was retained in all models to facilitate female versus male injury outcome odds ratio (OR) assessments.

Female versus male injury OR estimates for 300 unique models are presented. Females had significantly higher odds of injury than males in 36 models ($OR > 1.0$, p-value ≤ 0.05). This contrasts with 43 models where females had significantly lower odds ($OR < 1.0$, $p \leq 0.05$). For the remaining 221 models, there was a near even split in how often the odds of injury were non-significantly higher (n=103) and non-significantly lower (n=114) for females as compared to males ($p>0.05$). In four cases, the OR estimate was 1.00. Amongst the results, there was a trend for females to have higher odds of AIS 2+ injuries (MAIS 2+ OR=1.75 and 1.69 for *Full* and *Crashworthiness* models for the *All Crashes* dataset). These increases included higher estimates for lower extremity injuries in frontal crashes, consistent with earlier studies (e.g., Forman et al. 2019). However, for certain AIS 2+ injuries (neck, thorax) and many AIS 3+ injuries (head, neck, thorax), females had significantly lower odds of injury ($p \leq 0.05$). The trends for reduced odds of injury for females were most prevalent in non-frontal crash models.

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 and Jermakian, 2022; 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 differences between females and males. This contrasts with earlier reporting (Kahane 2013) where the main finding was that females were at significantly higher risk of fatality (17%), but this was associated with a wide range of vehicle model years where most of the case vehicles were not equipped with airbags.

Prior studies have documented injury ORs presenting 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 Abbreviated Injury Scale (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 predictor variables. While Parenteau et al. (2013) did not produce female versus male injury ORs, they did find overall higher relative injury risks for females versus males, but like Forman et al., their study was limited to belted occupants in frontal crashes found in NASS-CDS. Brumbelow and Jermakian (2022) 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 similarly found females to be at higher odds of Maximum AIS (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. Finally, Brumbelow and Jermakian demonstrated that females experienced similar or greater improvements (i.e., reductions in injury risk) with improved vehicle crashworthiness performance (compatible crashes with airbag deployment).

The prior studies, while exploring similar aims to our study, did not combine data from NASS-CDS and the newer Crash Investigation Sampling System (CISS). Additionally, they focused on a more limited sample of crash types and seating positions, among other restrictions. 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 variables, and occupants.

Methods

Data

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

NASS-CDS and CISS are national 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 gross vehicle weight less than 10,000 pounds (4,536 kilograms). 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 traffic way, each involving at least one passenger vehicle towed from the scene for any reason (Zhang et al., 2019a). NASS-CDS requires that a 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 2021. There was no usable sample available in either NASS-CDS or CISS in 2016.

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-response 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 variables such as a vehicle's change in velocity (delta V) measurement, driver's alcohol use information, etc.

Tables 1 and 2 summarize the predictor variables that were included in this study and show how often the predictor variables had a missing value in the sampled cases. Predictor variables that had the highest missing rates included delta V (43.4% of cases), body mass index or BMI (32.3%), and seat track position (20.8%), while some variables don't have item missing values (e.g., pre-impact movement, vehicle body type, crash type, vehicle age). In addition to predictor variables, 16.5% 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 72% of cases.

Table 1. Pre-crash/environment predictor variable descriptions, imputed counts, and percent missing from base sample. Weighted (imputed) and unweighted (unimputed) counts shown.

	Variable	Description	Units / Levels	Weighted (Imputed)		Missing %	Unweighted (Unimputed)	
				Male	*Female*		*Male*	*Female*
Pre-/Post-crash Predictor Variables	**Alcohol / Drug Use**	Documented presences of alcohol/drugs in system of case occupant	Yes	5,347,663	3,246,912	16.3%	17,711	9,654
			*No	36,130,185	34,484,689		42,747	43,041
	Avoidance Maneuver	Pre-impact crash avoidance maneuver documented for case vehicle	*None	13,579,512	14,395,432	0.0%	26,020	26,034
			Any avoidance maneuver	15,753,270	13,108,476		24,717	21,732
			Other/unknown	12,145,066	10,227,693		26,526	19,379
	Critical Event	Recorded pre-crash event associated with the crash of the case vehicle; numerous variables categorized into more limited groups for model development purposes (limit variance)	Control loss	4,652,492	3,027,605	0.0%	8,939	5,908
			Run off road/turn into path	14,749,947	13,538,504		31,816	25,781
			Other vehicle in lane	20,658,400	19,890,921		34,590	33,853
			*Ped/animal/other object	1,417,009	1,274,572		1,881	1,584
	Pre-impact Movement	Description of case vehicle's pre-impact movement	Going straight	22,421,836	19,928,753	0.0%	42,898	37,151
			Negotiating curve	8,080,655	5,953,167		15,634	10,713
			Decelerating	985,229	1,004,857		1,473	1,637
			Turning	5,446,892	6,508,824		9,794	10,598
			Lange change/merge	1,022,736	909,330		1,531	1,212
			Avoidance maneuver	385,350	207,815		511	381
			Stopped	2,204,733	2,514,520		3,589	4,150
			*Other/unknown	930,417	704,335		1,833	1,303
	Weather	Documented weather conditions at time of crash: normal vs. any adverse condition	*Normal	31,792,501	29,018,756	0.6%	60,615	52,597
			Adverse	9,685,347	8,712,845		16,171	14,173
	Lighting	Documented lighting conditions at time of crash: daylight vs. dawn/dusk/dark	*Daylight	25,760,773	26,140,115	0.1%	44,281	45,026
			Dark	15,717,074	11,591,486		32,822	21,999
	Rural/Urban	Crash location	*Urban	26,006,673	23,687,091	0.0%	27,846	25,367
			Rural	15,471,175	14,044,510		49,417	41,778

*Reference variable in logistic regression modeling

Table 2. Crash (or crashworthiness) predictor variable descriptions, imputed counts, and percent missing from base sample. Weighted (imputed) and unweighted (unimputed) counts shown.

	Variable	Description	Units / Levels	Weighted (Imputed)		Missing %	Unweighted (Unimputed)	
				Male	*Female*		*Male*	*Female*
Crash Predictor Variables	**Sex**	Case occupant's documented sex	Female	-	37,731,601	0.0%	-	67,145
			*Male	41,477,848	-		77,263	-
	Seat Belt Use	Case occupant documented seat belt use	*Belted	34,054,068	32,453,557	17.3%	45,329	45,544
			Unbelted	7,423,780	5,278,044		17,504	11,036
	Ejection	Case occupant ejection where any ejection (partial or full) is grouped as "yes" vs. no ejection	Yes	402,508	195,802	9.4%	2,870	1,526
			*No	41,075,340	37,535,799		64,873	58,684
	Entrapment	Case occupant entrapment where any level of entrapment is grouped as "yes" vs. cases designated as no entrapment	Yes	624,888	584,378	11.7%	62,069	56,270
			*No	40,852,959	37,147,223		3,723	2,587
	Seating Position	Designated seating position for case occupant	*Driver	30,406,043	25,602,991	4.5%	50,587	39,453
			Right front passenger	6,213,986	7,270,068		11,487	14,158
			Rear passenger	4,857,819	4,858,542		9,744	9,498
	BMI	Case occupant's calculated body mass index (BMI); calculated with recorded occupant height and weight	* <18.5	1,949,963	2,932,687	32.2%	2,251	3,860
			18.5 - 25.0	15,966,691	16,705,923		19,319	21,019
			25.0 - 30.0	14,536,851	10,101,660		19,139	12,004
			30+	9,024,343	7,991,331		12,747	10,958
	Belt Anchor	Documented shoulder belt adjustment position	No shoulder belt	2,586,351	2,488,398	19.2%	4,606	3,972
			Upr anchor - not adjustable	15,116,322	11,566,137		23,734	17,244
			Full up	11,855,312	10,139,013		15,965	13,994
			Middle position	3,684,553	3,748,498		5,043	5,152
			*Full down	8,235,310	9,789,555		11,453	14,331

	Variable	Description	Units / Levels	Weighted (Imputed)		Missing %	Unweighted (Unimputed)	
				Male	*Female*		*Male*	*Female*
Crash Predictor Variables	**Seat Track Position**	Case occupant seat's seat track position	*Not adjustable	5,019,323	4,805,758	20.8%	8,487	8,051
			Forward most position	1,188,993	1,696,355		1,576	2,832
			Between forward and middle	3,608,359	5,350,208		4,905	8,113
			Middle position	9,544,317	9,822,850		13,168	14,166
			Between middle and rear	10,597,814	8,227,552		14,535	10,492
			Rear most position	11,519,043	7,828,878		15,938	9,709
	Crash Type	Designated crash type by general area of damage and principal direction of force for most severe crash event; if case includes any amount of rolls, case is designated a rollover;	Rollover	3,874,637	2,650,322	0.0%	10,645	6,959
			Frontal	22,268,406	19,780,450		40,771	34,676
			Side	9,153,231	9,335,533		16,971	16,709
			*Rear	2,908,907	3,102,198		4,677	5,148
			Other	3,272,666	2,863,097		4,199	3,653
	Manner of Collision	Generic description of crash scenario	*Not collision	12,752,358	8,845,646	2.3%	24,357	15,565
			Rear-end	9,388,613	8,787,963		12,182	11,566
			Head-on	1,029,127	1,031,087		4,351	3,286
			Angle	15,764,405	16,663,725		30,000	31,341
			Sideswipe	2,543,344	2,403,181		5,011	4,165
	Object Contacted	Partner vehicle/object that case vehicle interacted with as part of most severe event. Non-contact (rollover) is included in third category.	Vehicle	29,352,379	28,977,541	4.4%	51,019	49,798
			Fixed object	8,339,462	5,918,220		16,361	10,404
			*Non-fixed/other/unknown	3,786,007	2,835,839		7,751	5,349
	Airbag Deployment	Airbag deployment status at case occupant seating location	Yes	30,928,654	27,810,189	1.2%	51,330	44,266
			*No	10,549,194	9,921,412		24,876	22,084

	Variable	Description	Units / Levels	Weighted (Imputed)		Missing %	Unweighted (Unimputed)	
				Male	*Female*		*Male*	*Female*
Crash Predictor Variables	**Intrusion**	Any intrusion at occupant seating location vs. no intrusion at seating location	Yes	4,067,628	3,270,808	0.0%	61,719	56,375
			*No	37,410,220	34,460,793		15,544	10,770
	Multi-impact	Case vehicles experiencing more than one documented crash event; no minimum threshold for 2nd event	Yes	12,826,688	10,559,137	0.0%	29,851	23,296
			*No	28,651,160	27,172,464		47,412	43,849
	Vehicle Body Type	Case vehicle body type	*Passenger cars	24,612,766	25,223,375	0.0%	45,064	43,807
			Utility	7,198,157	7,914,956		14,043	14,537
			Vans	2,822,953	2,582,641		5,656	5,076
			Pickups	6,773,821	2,006,244		12,307	3,702
			Other/unknown	70,151	4,384		193	23
	Vehicle Vintage	Binary measure of vehicle MY with 2009 and newer vs. 2008 and older.	*<2009	33,214,985	28,669,622	0.0%	63,674	52,766
			2009+	8,262,863	9,061,979		13,587	14,374
	Weight Ratio	Case vehicle weight divided by other vehicle weight. For non-fixed objects ratio was set to third level. For fixed objects, ratio was set to first level.	*<= 1.0	25,304,968	23,770,956	10.6%	40,937	37,208
			1.0 - 2.0	12,411,276	11,152,132		21,539	19,118
			> 2.0	3,761,604	2,808,513		7,726	5,230
	Compatible Crash	Compatible: case and other vehicle weight within 1000 lbs; All other - not compatible	*Yes	22,227,955	18,627,877	10.6%	39,235	30,652
			No	19,249,893	19,103,724		30,967	30,904
	Occupant Age	Case occupant's age in years; 13 to 96, 97+ designated as 97	Years - average	33	34	2.8%	34	35
	Delta V	Case vehicle change in velocity associated with most significant crash event	kph - average	19.8	19.6	43.4%	25.7	23.8
	Vehicle Age	Case vehicle age at time of crash	Years - average	8.8	7.7	0.0%	8.1	7
	Curb Weight	Case vehicle curb weight in kilograms	kg - average	1,615	1,537	40.0%	1628	1562

*Reference variable in logistic regression modeling

Without treatment, both unit non-response and item non-response may bias the estimates and/or distort the distribution. 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, refer to 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 can be found in Zhang and Chen (2013) and Zhang et al. (2019a), respectively. 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, provides several imputation methods, including the fully efficient fractional imputation (FEFI) and one of the hot-deck (HD) imputation methods - the Approximate Bayesian Bootstrap (ABB).

Fuller and Kim (2005) mathematically proved that FEFI is equivalent to a weighting adjustment, hence it does not incur imputation variance. FEFI is fully efficient but computationally intensive. In this study, we first considered using FEFI to impute the item missing. However, because of the large number of covariates under consideration, the size of the data sets, and the high item missing rates, the FEFI procedure did not run to completion.

The imputation method used in this study is ABB. ABB is a donor 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, assuming the non-response mechanism becomes ignorable in an imputation cell, if there are m recipient units (these are observation units with item missing values that need to be imputed) and r donor units (these are observation units that have no item missing values and provide imputed values for the recipient units), the ABB uses the following two steps for donor selection:

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 multiple 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 multiple

times (10 times). 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 MI, see Rubin et al. (1986) and Rubin (1987). Several studies have shown the advantages of the multiple HD imputation with ABB sample selection scheme (Vinod and Punithavalli, 2011; Soley-Bori, 2013; Durrant, 2005).

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 and/or dichotomous. The logistic regression model, as expressed below, assumes a specific structure between a set of independent variables and the probability (p) of a certain class of the dependent variable

$$Logit(p) = \log\left(\frac{p}{1-p}\right) = \log(odds)$$

$$= \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k$$

where k is the number of independent variables, $X_1, \ldots, X_k$ are independent variables, and $\beta_0, \ldots, \beta_k$ are coefficient estimates. Numerous logistic regression models were developed in the current study. For example, a MAIS 2+ model had a dichotomous dependent variable indicating whether an occupant sustained moderate injuries as defined by having a MAIS severity score of 2 or higher.

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

Multivariable logistic regression models were used to estimate the effect of occupant sex on the risks of overall (MAIS 2+, 3+, 4+ and fatal injury) and body-region-specific injury at AIS ≥ 2 or AIS ≥ 3 levels after controlling for other confounding factors.

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 contain information about the injury's body region, organ, type of injury, and severity. The NASS-CDS injuries were classified per AIS 1990 (1998 update) (AAAM, 1998) and CISS cases were coded using AIS 2015 (AAAM, 2015). Table 3 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 3. 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

Body Region	Codes	
	NASS-CDS: *Bodyreg* (AIS 1990/1998 update)	**CISS: *Bri* (AIS 2015)**
Knee-Thigh-Hip	K, T, P	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

Several pre-crash and crashworthiness predictor variables were selected for inclusion in the development of the logistic regression models. Tables 1 and 2 provide lists of pre-crash and crashworthiness predictor variables that were included, as well as a description, and the units (continuous variables) or levels (dichotomous or categorical variables) for the respective predictor variables. In total, there were 29 variables used. Twenty-two (22) were those considered to be "crashworthiness" variables that are relevant given the type and severity, as well as vehicle and occupant variables associated with a crash case. Seven variables were considered non-crash variables (pre-crash or environment). The crashworthiness variables included occupant variables (sex, seatbelt use, ejection, entrapment, age, body mass index, seating position, seat track position, seat belt anchor/shoulder belt adjuster location), crash type/severity variables (crash type, manner of collision, object contacted, delta V, airbag deployment, intrusion, multiple impacts), and vehicle variables (body type, age, vintage, curb weight, weight ratio, compatibility). A break point of model year 2009 was chosen for the vehicle vintage predictor variable given that 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.

The non-crashworthiness variables 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 (Figure 1). 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 drive during dark lighting conditions, experience control loss, make an avoidance maneuver), they were retained for use in this study. To present multivariable model results that considered both traditional crashworthiness predictor variables and variables that would be considered pre-crash or environment variables, two sets of multi-variable models were developed, one that considered only the crashworthiness variables and one that considered both crashworthiness and pre-crash/environment variables.

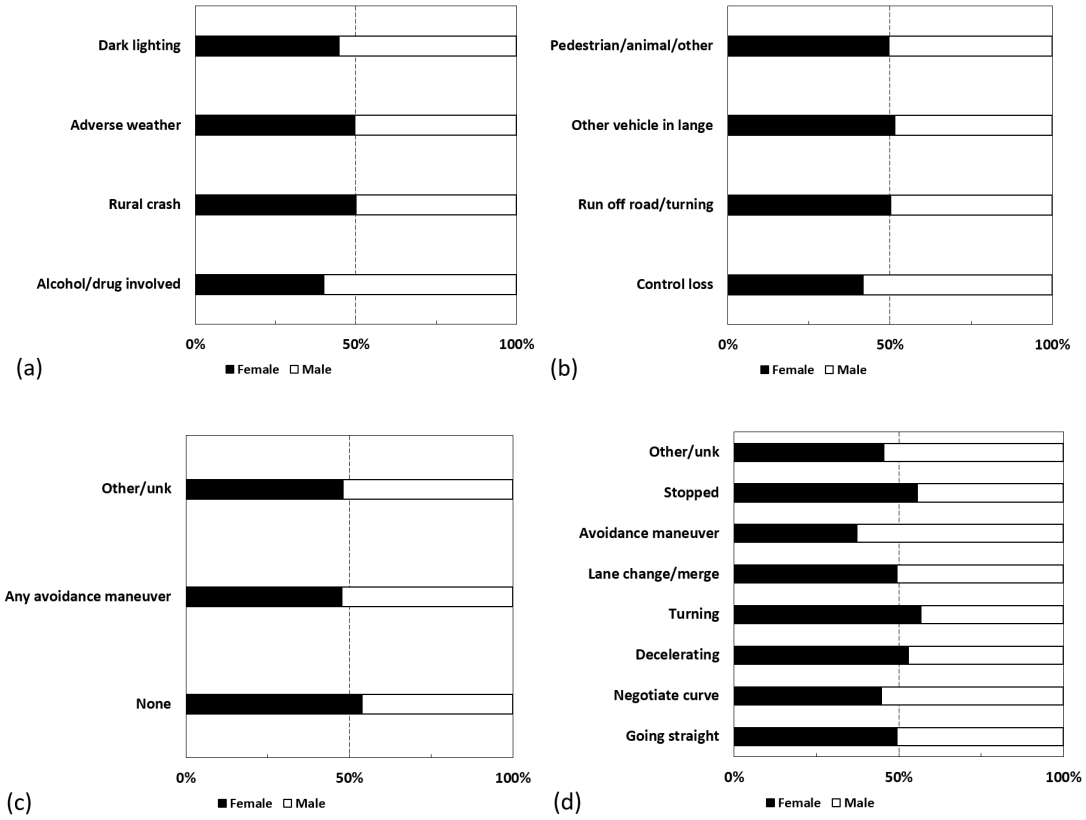

Figure 1. Relative distributions of pre-crash variables – male vs. female: (a) driver alcohol/drug use; weather and lighting conditions; (b) pre-crash critical event; (c) pre-crash avoidance maneuver; (d) pre-impact movement

We performed the following four logistic regression model calculations for each injury outcome and crash type grouping (i.e., for each of the 150 injury outcome/crash type pairings).

- Model 1: using all 29 predictors (Table 1 and 2)
- Model 2 (*Full* models): using only predictors found to be significant at $p \leq 0.1$ after running Model 1
- Model 3: using only the 22 crashworthiness predictor variables (Table 2)
- Model 4 (*Crashworthiness* or *CW* models): using only predictors found to be significant at $p \leq 0.1$ after running Model 3

Note that the 300 resulting models (150 *Full* and 150 *CW*) could contain a different set of significant ($p \leq 0.1$) predictor variables (e.g., a specific predictor like BMI may be retained in some models and not others). The resulting main model results for the respective Model 2s (here forward referred to as *Full* models) and Model 4s (*Crashworthiness* or *CW* models) are presented herein. Note, occupant sex (female or male) was retained in all models regardless of significance.

Since we are exclusively studying the variable sex, collinearity among other predictors is not relevant as we are not presenting other effects, and obviously sex cannot be expressed as a linear combination of other predictors in our models.

The logistic regression model results are shown in the form of odds ratios. Due to the complex nature of the NASS-CDS/CISS sample survey design, the SURVEYLOGISTIC procedure of SAS Version 9.4 (SAS Institute, Cary, NC) is used in this study. Since we have done multiple (10) imputations of the missing values by HD (ABB) before the logistic regression modeling procedures, the SAS PROC MIANALYZE procedure is used to make the final point and variance (including the p-value) estimates of the OR from 10 individual logistic regression modeling results (Rubin, 1987; Mukhopadhyay, 2016).

We first present the ORs among occupants by sex in overall crashes (*All Crashes*), and then the results in five specific types of crashes: four planar crash types that exclude rollovers (*Frontal impacts, Near-side impacts, Far-side impacts, and Rear impacts*) and non-planar (*Rollover*) crashes. 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).

The following summarizes the inclusion criteria for each set of crash type models:

- **All Crashes**: Includes all crash types (frontal, side, rear, rollover, other) and belted or unbelted occupants in any seating position; occupants were age 13 and over in this and all other crash type models;
- **Frontal**: Belted front row drivers and right front passengers where General Area of Damage for the most severe event (GAD1) = F; no rollover; note, Frontal was limited to front row belted occupants to facilitate comparison to prior studies (e.g., Forman et al., 2019; Brumbelow and Jermakian, 2022);
- **Near-side**: 1st and 2nd row outboard occupants in a GAD1 = L or R where they are seated on the struck- or near-side position (same side as crash); no rollover; both belted and unbelted occupants;
- **Far-side**: Same as near-side, but targeting center-seated occupants or outboard-seated occupants located opposite the struck side of the vehicle;
- **Rear Impact**: Front row occupants involved in GAD1= (B, C, D) crashes; no rollover; both belted and unbelted occupants; and
- **Rollover**: All cases that had any rollover, all occupants, belted and unbelted occupants.

The result is six unique crash type model groupings for each of the 25 injury outcomes. This is expanded further by creating regression models using both the *Full* (pre-crash and crash predictor variables) as well as *CW* (crashworthiness predictors only) sets of predictors, resulting in 300 total models. The female versus male injury ORs produced by the respective models were deemed statistically significant for p-values ≤ 0.05.

Results

The final imputed sample of weighted cases from NASS-CDS 2000 to 2015 and CISS 2017 to 2021 included 79,209,449 (female=37,731,601; male=41,477,848) age 13+ occupants of passenger vehicles. The corresponding injury data is summarized in Table 4 (unweighted injury counts of unimputed sample shown in parentheses). Predictor variable data is summarized in Tables 1 and 2, where both weighted case counts of the imputed sample and unweighted counts of the unimputed sample are shown.

Three hundred (300) multivariable logistic regression models with significant results (global null hypothesis test) were produced. The injury ORs for females versus males for the 300 unique models are presented in Table 5. *Full* models with all predictor variables considered as well as models with only *Crashworthiness* variables are shown. Females show significantly higher odds ($OR > 1.0$; p value ≤ 0.05) for whole body/occupant MAIS 2+ and MAIS 3+ injuries for the *All Crashes* models, though, the MAIS 3+ increase in odds was not significant ($p>0.05$) for the *Crashworthiness* (*CW*) model. Increased odds of MAIS 2+ injuries for females were also significant in *Frontal*, *Far-side*, and *Rollover* crash type models, while MAIS 3+ increase for females was only significant in frontal crashes. For MAIS 4+, the odds were not significantly different for females than males with overall estimates close to 1.0. Similarly, fatal injury odds for females were not significantly different ($p>0.05$) for all crash types, except for the *Far-side* crashworthiness model where females had significantly lower odds ($OR=0.43$, $p<0.05$). In general, the fatal injury odds for females were lower than males. It should also be observed that the increased odds of injury for females (if present), was highest for MAIS 2+ and consistently reduced when moving from less (MAIS 2+) to more serious (MAIS 4+ and fatal) injury outcomes.

Figure 2 shows *Full* model versus *CW*-only predictor variable model female versus male OR results for *All Crashes* and *Frontal* crashes models. In general, both types of models, those that considered all 29 predictor variables (*Full*) and those with the 22 crashworthiness predictor variables (*CW*), had similar ORs. The models that varied the most between the two were the lower extremities in *Frontal* crashes with the *CW* models showing higher odds for leg AIS 2+ and foot/ankle AIS 2+. Conversely, the *CW* model showed lower odds of AIS 3+ thoracolumbar spine injuries.

Table 4. MAIS and body region injury weighted counts for imputed sample by sex for each crash model type (unweighted counts for unimputed sample in parentheses)

		ALL Crashes		Frontal Crashes		Near-Side		Far-Side		Rear		Rollover	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	Total Cases	*41,477,848 (77,263)*	*37,731,601 (67,145)*	*15,172,896 (20,016)*	*14,119,548 (19,588)*	*4,427,659 (7,172)*	*4,481,408 (7,166)*	*3,738,374 (4,722)*	*3,993,733 (5,262)*	*2,352,910 (3,142)*	*2,565,142 (3,546)*	*3,836,032 (8,594)*	*2,640,471 (5,749)*
Whole Body	**MAIS 2+**	2,607,511 (15,164)	2,586,785 (11,818)	670,593 (3,204)	919,120 (3,463)	300,248 (2,144)	303,351 (1,903)	86,404 (547)	195,257 (621)	81,231 (348)	99,279 (285)	512,728 (3,600)	360,049 (2,122)
	MAIS 3+	1,065,301 (9,385)	853,866 (6,501)	205,403 (1,653)	221,475 (1,568)	142,091 (1,543)	132,690 (1,250)	30,333 (303)	45,323 (293)	24,112 (173)	19,924 (119)	222,309 (2,348)	162,099 (1,310)
	MAIS 4+	451,786 (5,353)	285,420 (3,071)	61,896 (660)	45,739 (477)	73,792 (994)	53,980 (733)	14,963 (185)	15,094 (150)	7,396 (105)	9,248 (68)	117,620 (1,527)	69,400 (727)
	Fatal Injury	232,815 (3,338)	119,566 (1,749)	32,909 (367)	17,446 (238)	33,498 (612)	25,325 (424)	7,965 (91)	5,092 (69)	3,343 (71)	2,122 (37)	72,970 (1,025)	32,487 (438)
Body Region AIS 2+	**Head**	918,335 (7,382)	772,874 (4,827)	151,093 (1,119)	225,255 (900)	116,898 (1,141)	126,289 (933)	34,587 (303)	38,150 (264)	32,949 (211)	40,305 (139)	230,365 (1,921)	152,638 (1,061)
	Neck & C-spine	173,081 (1,834)	123,379 (1,296)	24,571 (223)	34,096 (246)	19,214 (249)	20,886 (236)	4,537 (49)	4,381 (53)	4,613 (48)	2,876 (33)	51,972 (603)	30,619 (343)
	Thorax	656,643 (5,712)	528,090 (3,919)	182,582 (1,074)	164,907 (960)	113,779 (1,091)	84,772 (850)	17,764 (220)	40,479 (223)	11,912 (103)	20,670 (79)	125,427 (1,355)	102,422 (752)
	Abdomen	218,359 (2,590)	183,942 (1,915)	46,269 (442)	41,303 (385)	44,202 (569)	34,510 (473)	7,139 (92)	11,620 (109)	7,354 (43)	2,405 (25)	38,209 (518)	38,548 (338)
	Thoracolumbar Spine	200,964 (1,815)	200,210 (1,362)	47,830 (343)	67,368 (331)	20,431 (256)	19,821 (201)	5,188 (58)	16,784 (78)	8,483 (60)	9,655 (52)	65,451 (585)	51,650 (374)
	Torso	963,061 (7,639)	809,547 (5,567)	252,773 (1,467)	257,586 (1,398)	166,525 (1,384)	118,200 (1,123)	24,403 (285)	53,690 (323)	19,628 (152)	30,749 (120)	216,521 (1,890)	159,376 (1,095)
	Knee–Thigh–Hip	374,952 (3,836)	392,972 (3,018)	97,362 (924)	111,968 (809)	50,408 (708)	71,261 (707)	10,199 (97)	63,820 (127)	2,968 (39)	8,558 (43)	45,549 (551)	39,657 (389)
	Leg	136,358 (1,321)	135,465 (1,231)	43,924 (420)	54,502 (497)	15,246 (181)	16,854 (138)	1,875 (23)	1,809 (27)	934 (11)	2,171 (10)	20,507 (184)	14,362 (136)
	Foot & Ankle	162,456 (1,329)	285,463 (1,651)	65,640 (523)	178,742 (829)	6,903 (82)	10,401 (92)	1,482 (24)	7,068 (41)	1,749 (11)	3,765 (15)	14,537 (174)	16,890 (139)
	Upper Extremity	339,869 (2,694)	411,761 (2,612)	141,232 (755)	199,018 (1,017)	23,854 (287)	25,503 (259)	8,020 (61)	26,227 (113)	4,985 (42)	5,469 (37)	58,290 (610)	46,391 (431)
	Lower Extremity	576,167 (5,346)	735,354 (4,885)	167,857 (1,435)	304,163 (1,669)	65,201 (850)	91,753 (859)	12,178 (130)	74,263 (193)	5,248 (59)	14,301 (69)	71,826 (801)	62,782 (581)

		ALL Crashes		Frontal Crashes		Near-Side		Far-Side		Rear		Rollover	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Body Region AIS 3+	**Head**	276,267 (3,412)	172,837 (2,048)	35,111 (405)	28,200 (284)	47,033 (647)	32,822 (479)	7,843 (132)	8,579 (109)	4,464 (77)	4,916 (49)	66,024 (934)	43,712 (507)
	Neck & C-spine	75,570 (839)	47,879 (590)	11,280 (98)	9,507 (97)	6,735 (102)	9,932 (102)	1,171 (15)	1,792 (23)	2,471 (21)	783 (16)	25,088 (278)	12,458 (164)
	Thorax	415,670 (4,581)	327,722 (2,985)	69,743 (716)	83,793 (613)	78,104 (950)	62,814 (717)	13,394 (167)	26,196 (164)	10,284 (92)	4,653 (60)	92,712 (1,117)	74,860 (597)
	Abdomen	96,662 (1,166)	76,071 (841)	17,497 (196)	17,452 (183)	21,712 (280)	14,414 (211)	3,432 (46)	5,181 (41)	4,573 (16)	1,808 (13)	17,323 (234)	15,880 (138)
	Thoracolumbar Spine	46,802 (448)	55,496 (314)	11,878 (90)	18,668 (66)	2,838 (41)	2,063 (26)	407 (9)	11,435 (15)	3,118 (22)	2,552 (19)	17,020 (155)	13,937 (99)
	Torso	473,538 (5,023)	387,341 (3,405)	84,373 (824)	106,872 (728)	86,759 (998)	66,653 (773)	14,472 (181)	29,840 (187)	10,428 (96)	6,745 (68)	108,167 (1,233)	86,312 (672)
	Knee–Thigh–Hip	197,361 (2,467)	150,620 (1,672)	44,734 (579)	36,074 (433)	26,883 (457)	38,065 (397)	4,683 (51)	4,235 (42)	533 (18)	2,989 (10)	25,894 (353)	21,532 (230)
	Leg	56,108 (690)	56,693 (610)	20,794 (233)	24,684 (275)	4,288 (88)	8,810 (64)	187 (7)	738 (15)	251 (4)	82 (2)	5,636 (94)	6,256 (59)
	Upper Extremity	91,716 (950)	97,955 (949)	26,074 (253)	35,937 (348)	8,078 (103)	10,433 (97)	1,930 (22)	3,732 (39)	581 (13)	961 (12)	18,638 (233)	19,443 (181)
	Lower Extremity	238,487 (2,923)	209,322 (2,168)	59,994 (725)	58,858 (655)	31,808 (519)	48,622 (455)	4,876 (58)	5,120 (53)	648 (22)	3,111 (13)	29,910 (422)	27,703 (283)

Further summarizing the results from Table 5 for body region AIS 2+ injuries, the overall trend (*All Crashes* model) shows neck, chest, abdomen, and overall torso injury odds to be lower (OR < 1.0), in some cases significantly ($p<0.05$), for females as compared to males. In contrast, females showed significantly higher upper and lower extremity injury odds, especially for the foot/ankle in *Frontal* crashes.

Body region AIS 3+ injury models produced female versus male ORs that generally showed lower odds for females for head, neck, thorax, and abdomen (findings for head, neck and thorax were statistically significant, $p\leq0.05$) (Table 5). Different than for AIS 2+ upper and lower extremity injuries, females were less likely to have higher odds for AIS 3+ extremity injuries. The exceptions include leg and overall lower extremity injuries in *Near-side* side impact crashes, as well as overall lower extremity in *Rear* crashes and upper extremity in *Near-side* and *Far-side* crashes. In contrast, lower extremity AIS 3+ injury odds were significantly lower for females for *Far-side* side impact crashes and upper extremity AIS 3+ in *Rear* crashes ($p\leq0.05$).

Table 5. Summary table of female vs. male injury odds ratios for 25 injury outcomes across 12 different crash type models. Shown are results for Full (Model 2) and CW (Model 4) models.

		Crash Types											
		All Crashes		**Frontal**		**Near-Side**		**Far-Side**		**Rear**		**Rollover**	
		Full	**CW**	**Full**	**CW**	**Full**	**CW**	**Full**	**CW**	**Full**	**CW**	**Full**	**CW**
Whole Body	**MAIS 2+**	**1.75***	**1.69***	**2.33***	**2.34***	1.14	1.08	**2.20***	**2.68***	0.99	1.00	**2.23***	**2.38***
	MAIS 3+	**1.24***	1.17	**1.56***	**1.51***	1.38	1.3	1.45	1.02	0.46	0.49	1.37	1.66
	MAIS 4+	1.03	0.94	1.00	0.91	0.96	0.9	1.22	0.88	1.04	0.88	1.29	1.37
	Fatal Injury	0.94	0.86	0.98	0.95	1.05	1.09	0.49	**0.43***	0.61	0.42	1.22	1.02
Body Region AIS 2+	**Head**	1.11	1.10	1.73	1.63	0.79	0.77	0.77	0.75	1.23	1.09	1.13	1.13
	Neck & C-spine	0.77	**0.74***	0.94	0.90	1.02	0.69	0.58	0.71	0.66	**0.38***	0.38	0.36
	Thorax	**0.50***	**0.52***	0.54	0.54	**0.56***	**0.53***	0.43	0.70	0.42	0.32	0.71	0.75
	Abdomen	0.77	0.72	**0.46***	**0.45***	0.66	0.68	0.76	0.78	0.42	**0.26***	1.31	1.19
	Thoracolumbar	1.10	1.10	**1.86***	**1.72***	0.61	0.46	2.70	2.00	0.63	0.57	1.07	1.14
	Torso	**0.66***	**0.66***	0.68	0.68	**0.42***	**0.42***	0.78	1.28	0.51	0.58	1.66	1.71
	Knee–Thigh–Hip	0.78	0.87	1.24	1.16	0.41	0.37	3.52	2.76	3.20	0.26	0.45	0.69
	Leg	0.77	0.80	0.63	1.38	2.20	1.73	0.29	0.07	6.18	9.27	1.23	1.19
	Foot & Ankle	**1.66***	**2.01***	**4.42***	**5.00***	1.99	1.26	**7.16***	**6.18***	2.93	2.40	3.82	2.87
	Upper Extremity	**1.75***	**1.72***	**1.96***	1.89	1.72	1.89	**2.43***	1.45	1.25	1.08	1.26	1.18
	Lower Extremity	**1.42***	**1.30***	**1.55***	**1.65***	1.19	1.08	**2.28***	**2.70***	0.88	0.78	1.34	1.31
Body Region AIS 3+	**Head**	0.77	**0.74***	**0.43***	**0.44***	0.83	1.11	2.17	1.69	0.63	0.65	0.82	0.99
	Neck & C-spine	**0.52***	**0.47***	0.41	0.41	0.86	0.53	1.81	2.53	**0.08***	**0.06***	**0.31***	**0.28***
	Thorax	**0.67***	**0.65***	1.53	1.38	**0.56***	**0.53***	**0.35***	**0.39***	**0.10***	**0.10***	0.84	0.85
	Abdomen	0.79	0.73	0.65	0.62	0.61	0.72	0.38	0.34	**0.02***	0.94	1.19	1.59
	Thoracolumbar	1.35	1.26	2.45	1.45	0.32	0.37	2.52	4.40	0.33	0.27	0.85	0.58
	Torso	0.76	**0.71***	1.54	1.35	**0.51***	**0.50***	0.47	0.40	**0.27***	**0.26***	1.21	1.42
	Knee–Thigh–Hip	0.87	0.86	0.92	0.94	0.93	0.78	**0.18***	**0.19***	4.84	6.89	0.53	0.50
	Leg	1.14	1.18	0.99	0.97	2.72	**5.51***	1.26	1.34	1.00	1.00	2.19	0.23
	Upper Extremity	1.26	1.28	1.36	1.36	2.51	**2.43***	**6.44***	**10.2***	**0.00***	**0.01***	0.75	0.89
	Lower Extremity	1.15	1.09	0.92	0.89	**1.65***	1.47	**0.27***	**0.31***	**7.18***	**10.3***	1.10	0.93

*p-value ≤ 0.05

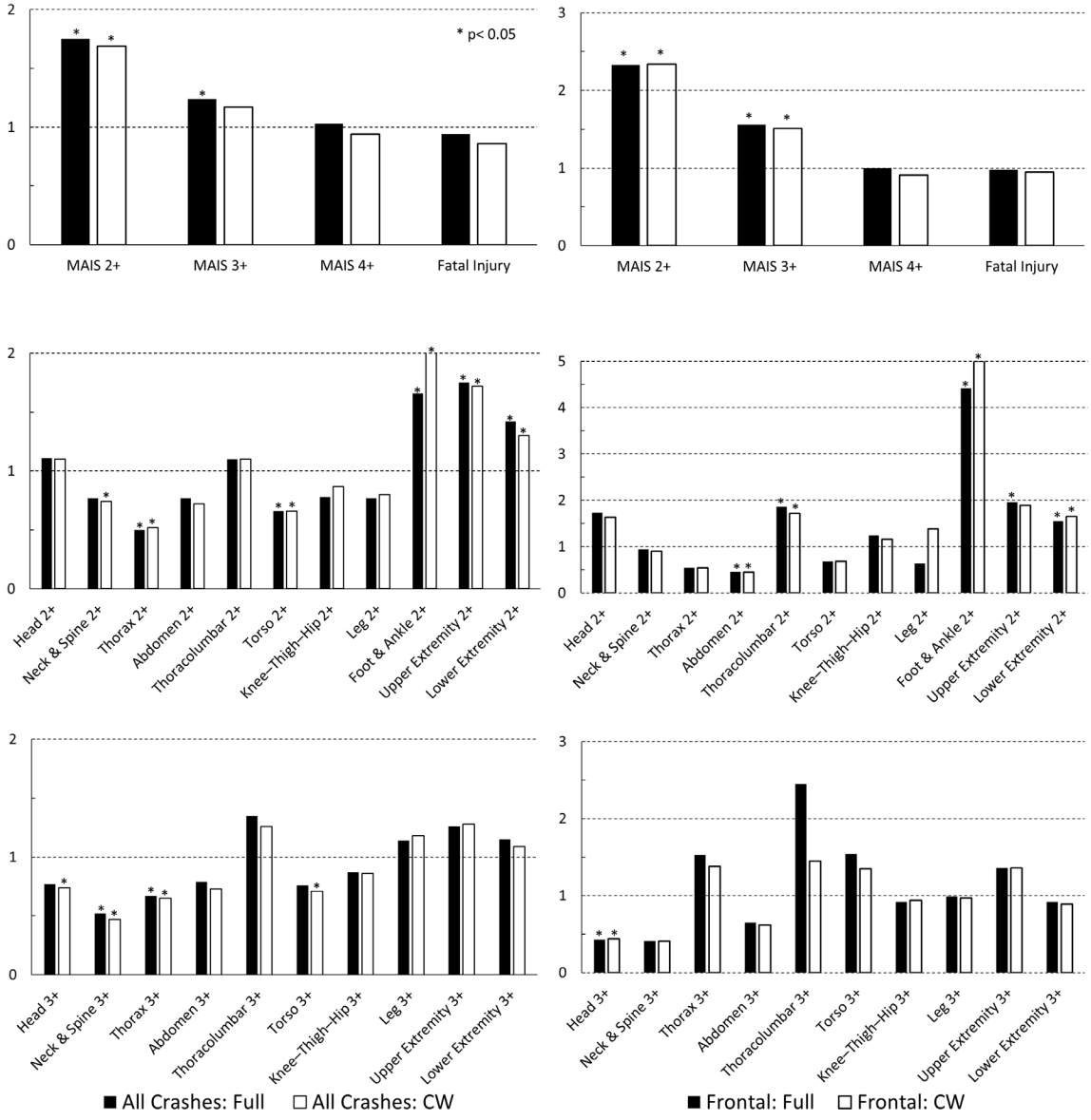

Figure 2. Female vs. male odds ratio comparisons – MAIS, body region AIS 2+, 3+ (All Crashes – Left; Frontal Crashes – Right)

Tables 6 and 7 show the results from a small sample of models that were run with the *All Crashes* sample of crash types for both imputed and unimputed (published sample data with missing values for study variables) versions of the sample. Table 6 presents female versus male injury ORs using the *Full* and *CW*-only sets of predictor variables. In general, the injury outcome ORs for female versus males were similar from the models produced using the imputed and unimputed data samples. However, the odds went from being significantly higher for females to non-significantly higher ($p>0.05$) in three cases (MAIS 3+ and foot/ankle 2+ for *Full* model and foot/ankle 2+ for *CW* model) when comparing ORs derived from the imputed data sample versus unimputed. Table 7 shows the effect on ORs for other predictor variables for both imputed and unimputed samples. The general observation is that the imputation process not only changes the

point estimate of the OR (even though the difference is small for some predictor variables), but also increases the statistical significance of the estimates overall.

Table 6. Comparison of select female vs. male injury odds ratios with and without imputation

	All Crashes			
	Full		CW	
Injury Description	**Imputed Sample**	**No Imputation**	**Imputed Sample**	**No Imputation**
MAIS 2+	1.75*	1.80*	1.69*	1.70*
MAIS 3+	1.24*	***1.17***	1.17	1.11
Head - AIS 2+	1.11	1.20	1.10	1.22
Foot & Ankle - AIS 2+	1.66*	***1.69***	2.01*	***1.68***
Upper Extremity - AIS 2+	1.75*	1.79*	1.72*	1.78*
Thorax - AIS 3+	0.67*	0.63*	0.65*	0.55*

**p*-value ≤ 0.05

Table 7. Comparison of select predictor variable odds ratios with and without imputation

Injury Description	**Predictor Variable**		**All Crashes - Odds Ratios**	
			Imputation	*No Imputation*
MAIS 2+		Vehicle age	**1.02***	1.01
Head AIS 2+	Crash Type	Frontal impact	**0.51***	0.68
		Other	2.1	2.6
		Rollover	0.90	0.86
		Side impact	0.70	0.88
Thorax AIS 3+	Critical Event	Control loss	**2.50***	**3.00***
		Other vehicle in lane	1.32	1.22
		Run off road/turning into path	2.07	2.07
Foot & Ankle AIS 2+	Critical Event	Control loss	0.45	0.72
		Other vehicle in lane	**0.14***	0.76
		Run off road/turning into path	0.33	1.49
Upper Extremity 2+	Crash Type	Frontal impact	**5.35***	2.38
		Other	**5.48***	3.72
		Rollover	**2.98***	1.65
		Side impact	2.51	1.2

**p*-value ≤ 0.05

Table 8 presents a frequency summary of significant and non-significant OR findings, including how often a female was at significantly higher or lower ($p \leq 0.05$) odds of injury as compared to males, as well as how often the difference in odds (whether estimated to be higher or lower) was not statistically significant ($p > 0.05$). Out of the 300 unique logistic regression models, females were found to have significantly higher odds of injury than males 36 times and significantly lower odds of injury 43 times. The remaining 221 estimates for ORs comparing female versus male injury odds were not statistically significant. Of these, there were 103 with higher odds of injury for females versus males, 114 with lower odds of injury for females, and 4 with ORs = 1.00. The set of models that more frequently had significantly higher ORs for females versus males was AIS 2+ injuries in *Frontal* crashes. In contrast, the AIS 3+ *Frontal* models had no significant estimates of increased odds for females. For the non-frontal models (*Near-side*, *Far-*

side, *Rear*, and *Rollover*), there were 27 instances where females had significantly lower odds of injury compared to males versus 12 presenting significantly higher odds for females ($p \leq 0.05$).

Table 8. Frequency comparison regarding significance of female versus male odds of injury estimates for the 300 unique logistic regression models

Crash Type	Injury Models	Models Included (Full + CW, Full - only, CW - only)	No. of Models	Female Odds Significantly Higher p<0.05	Odds Not Signifcantly Higher / Lower p>0.05	Female Odds Significantly Lower p<0.05	Net Difference in Significant Odds Ratio Estimates (*female higher minus lower*)
All Crash Types	All	Full + CW	300	36	221	43	-7
		Full	150	19	262	19	0
		CW	150	17	259	24	-7
All Crashes	Body Region AIS 2+	Full + CW	22	6	11	5	***1***
		Full	11	3	6	2	***1***
		CW	11	3	5	3	0
All Crashes	Body Region AIS 3+	Full + CW	20	0	14	6	-6
		Full	10	0	8	2	-2
		CW	10	0	6	4	-4
Frontal Crashes	Body Region AIS 2+	Full + CW	22	7	13	2	***5***
		Full	11	4	6	1	***3***
		CW	11	3	7	1	***2***
Frontal Crashes	Body Region AIS 3+	Full + CW	20	0	18	2	-2
		Full	10	0	9	1	-1
		CW	10	0	9	1	-1
Non-Frontal Crashes	Body Region AIS 2+	Full + CW	88	5	77	6	-1
		Full	44	3	39	2	***1***
		CW	44	2	38	4	-2
Non-Frontal Crashes	Body Region AIS 3+	Full + CW	80	7	52	21	-14
		Full	40	3	26	11	-8
		CW	40	4	26	10	-6

The aim of this report was to present female versus male injury outcome ORs. However, other predictor variables can be seen to have significant positive and negative influence on injury outcomes. Tables A1 to A12 (Appendix) present the OR results for all 300 models and associated predictor variables.

Table A13 (Appendix) summarizes the frequency of how often each predictor variable was retained in final *Full* and *CW* models. Not including occupant sex, which was retained in all models, delta V and occupant age were retained the most frequently. The most frequently retained pre-crash/environment variables were alcohol/drug involvement and avoidance maneuver.

Table A14 (Appendix) summarizes the possible number of predictor variables retained in each of the 300 models. The average number of predictor variables, as well as maximum and minimum number, is shown for the respective *Full* and *CW* crash type models. The *All Crashes*, *Frontal,* and *Near-side* models, with more overall occupant/crash cases included in their data samples, tended to also have models that included more variables than the models produced from the smaller sample crash types.

Table A15 (Appendix) summarizes the fit of the models using a measure of fit called the concordance index or c-statistic, a commonly used discrimination measure in logistic regression with binary outcomes. In the context of this study, the c-statistic is defined as the proportion among all pairs of occupants having different observed responses where the occupant with the response of "not injured" has a lower predicted probability than the occupant with the response of "injured." Since the c-statistic also gives an estimate of the area under the receiver operating characteristic curve (AUC) when the response is binary and following the general rules of AUC intervals described by Hosmer and Lemeshow (2000), a c-statistic greater than 0.7 is considered *good* model fit and greater than 0.8 indicates *strong* model fit. The current study produced 276 out of 300 models with *good* model fit and 162 with *strong* model fit. Table A16 summarizes the female versus male injury ORs for models with a c-statistic lower than 0.7 (n=24). Sixteen (16) of the 24 models with a c-statistic below 0.7 had females with higher odds of injury (4 ORs were significantly higher, $p \leq 0.05$). If we removed model results with *poor* fit from the overall counts of female versus male injury ORs that were significantly higher or significantly lower, the new counts would be 32 and 41, respectively. Similarly, non-significant injury OR results ($p > 0.05$) would change to females being higher in 91 models and lower in 108.

Table 9 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. Roughly half of the cases are frontal crashes where MAIS 2+ and 3+ and body region AIS 2+ models trend towards having higher injury ORs for females (Table 5). In contrast, regression models developed using the other half of cases (i.e., non-frontal planar crashes and rollovers) produced body region AIS 2+ ORs that trend toward being lower for females (Table 5). Thus, when combining the data from frontal and non-frontal crashes, it is logical why the *All Crashes* models show a more even distribution of significantly higher and lower ORs for AIS 2+ injuries (Table 5). Similarly, the MAIS 2+, 3+, 4+, fatal, and body region AIS 3+ ORs in the *All Crashes* models tend to represent roughly the frequency-adjusted average of the generally higher frontal crash ORs and the lower non-frontal crash ORs.

Table 9. Counts of occupants included in each crash model

	Male	Female	Combined
	Total Occupant Cases		
Frontal	15,172,896	14,119,548	29,292,444
Near-Side	4,427,659	4,481,408	8,909,067
Far-Side	3,738,374	3,993,733	7,732,107
Rear	2,352,910	2,565,142	4,918,052
Rollover	3,836,032	2,640,471	6,476,503
Total	29,527,871	27,800,302	57,328,173

Male	Female	Combined
% of Totals		
51.4%	50.8%	51.1%
15.0%	16.1%	15.5%
12.7%	14.4%	13.5%
8.0%	9.2%	8.6%
13.0%	9.5%	11.3%

Table 10 presents injury counts for the respective CW models by the respective significant and nonsignificant OR model results. For the *All Crashes* model there are more AIS 2+ body region injuries associated with models where females were at significantly lower odds of injury ($p \leq 0.05$). The same is true for AIS 3+ as there are 2.1M total injuries associated with body regions where females have significantly lower odds of injury ($p \leq 0.05$). For planar models, the total AIS 2+ injuries associated with significantly increased odds for females was 927K versus 588K for males. For AIS 3+ there were 491K injuries associated with significantly reduced odds of injury for females versus only 41K that were associated with significantly increased odds. As seen in the many logistic regression model results and given the relative frequency of body region AIS 2+ and 3+ injuries observed between males and females in the full sample of crashes (Figure 3 and Table 4), females often have reduced odds for head, neck, and overall torso injuries while showing overall higher odds for upper and lower extremity injuries.

Table 10. Highlighting total injury counts for injury outcomes from All Crashes and planar models for the CW set of predictors. The counts of total injuries by injury type are mapped to the respective significant and non-significant OR results.

		All Crashes Model				Planar Models (n=4) + Rollover Model			
		OR Higher	OR Lower	OR Higher	OR Lower	OR Higher	OR Lower	OR Higher	OR Lower
		p≤0.05		p>0.05		p≤0.05		p>0.05	
Body Region AIS 2+	Head	-	-	1,691,209	-	-	0	832,605	315,924
	Neck & C-spine	-	296,460	-	-	-	7,489	-	190,276
	Thorax	-	1,184,733	-	-	-	198,551	-	666,163
	Abdomen	-	-	-	402,301	-	97,331	76,757	97,471
	Thoracolumbar	-	-	401,174		115,198	0	139,073	58,390
	Torso	-	1,772,608	-		-	284,725	453,990	560,736
	Knee–Thigh–Hip	-	-	-	767,924	-	-	283,349	218,401
	Leg	-	-	-	271,823	-	-	168,500	3,684
	Foot & Ankle	447,919	-	-		252,932	-	54,245	-
	Upper Extremity	751,630	-	-		-	-	538,989	-
	Lower Extremity	1,311,521	-	-		558,461	-	291,562	19,549
Body Region AIS 3+	Head	-	449,104	-	-	-	63,311	96,277	119,116
	Neck & C-spine	-	123,449	-	-	-	40,800	2,963	37,454
	Thorax	-	743,392	-	-	-	195,445	153,536	167,572
	Abdomen	-	-	-	172,733	-	-	33,203	86,069
	Thoracolumbar	-	-	102,298	-	-	-	42,388	41,528
	Torso	-	860,879	-	-	-	170,585	385,724	44,312
	Knee–Thigh–Hip	-	-	-	347,981	-	8,918	3,522	193,182
	Leg	-	-	112,801		13,098	-	925	57,370
	Upper Extremity	-	-	189,671	-	24,173	1,542	62,011	38,081
	Lower Extremity	-	-	447,809	-	3,759	9,996	80,430	176,465
	Body Region 2+ Totals	**2,511,070**	**3,253,801**	**2,092,383**	**1,442,048**	**926,591**	**588,096**	**2,839,070**	**2,130,594**
	Body Region 3+ Totals	**-**	**2,176,824**	**852,579**	**520,714**	**41,030**	**490,597**	**860,979**	**961,149**

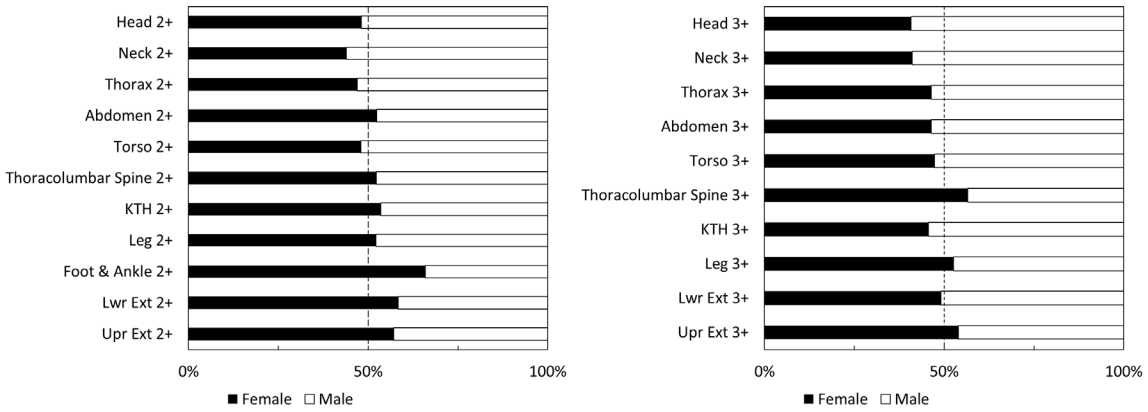

Figure 3. Relative distribution of AIS 2+ and 3+ body region injuries – females versus males

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. These models were produced using both a sample that included all crash types and samples representing five focused subsets of crash and occupant types. The models considered 22 crashworthiness and 7 non-crashworthiness or pre-crash/environment predictor variables. 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 system, and occupant conditions.

The current results in some cases compare well to prior studies that considered only belted, front-row occupants. For the *Frontal* model results (belted drivers, right front passengers in GAD1=F crashes), the current study found females to be at roughly 2.3- and 1.6-times higher odds of MAIS 2+ and 3+ injuries than males, respectively. This is like the 2.4- and 1.7-times higher odds of AIS 2+ and 3+ injuries, respectively, documented by Forman et al. (2019). Like Forman et al., the current study found significantly increased odds of foot and ankle injuries for females with ORs of 4.4 and 5.0 in *Full* and *CW* models, respectively. This compares to the 3.8 times higher odds of ankle injuries for females 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, leg, sternum, and rib fractures, we did not find significantly increased odds for comparable body region injuries. In fact, we found significantly lower odds for abdomen AIS 2+ injuries as well as head AIS 3+. Separately, we observed significantly higher odds of thoracolumbar spine injuries for females (OR=1.9 and 1.7 for *Full* and *CW* models, respectively), which was not a body region included in Forman et al.'s study. Females did not have significantly higher or lower odds of AIS 2+ and 3+ injuries for the remaining body regions evaluated in the current study.

Brumbelow and Jermakian (2022) 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 female with ORs of 3.1 and 1.9 ($p<0.05$), respectively. They found females to have 4.4 times higher odds of lower extremity injuries. This is substantially higher than similar estimates made given the *Frontal* crash models in the current study (ORs of 2.1 and 2.3 for Full and CW models). When including only compatible crashes with airbag 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 ($p>0.05$), and none of their front or side models showed significantly lower odds of injury for females. This contrasts with our findings where females had significantly lower odds of AIS 2+ thorax/torso injuries as well as AIS 3+ head injuries in *Frontal* impact models, and lower thorax and torso injury odds at both AIS 2+ and 3+ severities in *Near-side* crashes and lower thorax AIS 3+, knee-thigh-hip AIS 3+, and overall lower extremity AIS 3+ in *Far-side* crashes.

The differences in the estimated ORs in the current study as compared to Forman et al. (2009) and Brumbelow and Jermakian (2022) 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 2021 CISS, the current study is employing a sample of crashes that has a greater number of newer model year vehicles, which as 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. The *All Crashes – Full Model* found females to be at higher odds of MAIS 2+ injury with an OR of 1.75. Running the same model restricted to belted occupants produced an OR of 1.91. This compares to an OR of 1.49 for unbelted. While the estimates are different, the direction and significance (all significant at p value $\leq$ 0.05) is the same. Finally, the current study also applied a different imputation method to utilize 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.

Regarding fatal injury cases, Noh et al. (2022) reported on the relative risk of fatalities utilizing logistic regression models and paired male/female driver and right front passenger data from the Fatality Analysis Reporting System (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% but was not statistically significant ($p>0.05$). A larger range of model year comparisons that included more older vehicles (MY 2010 to 2020) had a higher relative fatality risk for females versus males with statistical significance ($6.3 \pm 5.4\%$). The current study found the odds of fatal injury to trend toward being slightly lower for females with ORs of 0.94 (95% confidence interval – 0.75, 1.17) for *Full* and 0.86 (0.70, 1.07) for *CW – All Crashes* models, but the findings were not significant ($p>0.05$). Given the case years included in the current study (2000 to 2021), the closest equivalent result in Noh et al. was a 13.5 ± 1.4 percent relative fatality risk increase for females compared to males for case years 2000-2019 (see Table 5 in that study).

It may seem that the current and Noh et al. (2022) studies disagree when it comes to fatal results; however, caution should be taken when directly comparing the findings of the two studies. For one, Noh et al. used FARS and included only vehicles where either the driver and/or the right front passenger died, whereas the current study is based on all crashes (fatal and non-fatal) from NASS-CDS/CISS. Secondly, they looked at different risk metrics (relative risk versus odds ratio 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, respectively, 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 2 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, seat track position, seat position), as was possible in the current study.

To further compare the current and Noh et al. (2022) FARS study results, 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 the Noh et al. The resulting *Full* and *CW* model results produced female versus male fatality ORs of 1.24 (0.85, 1.79) and 1.17 (0.82, 1.66) (or 24% and 17% higher odds for females), respectively, but, like the full crash domain model results, the ORs were not statistically significant ($p>0.05$). This compares with the 13.5±1.4 percent increase in relative fatality risk for females for case years 2000-2019 from Noh et al. We also attempted to replicate the trend found in Noh et al. where the difference in 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 confidence intervals and the differences between the OR estimates for newer versus older model year ranges were not statistically significant ($p>0.05$).

Overall, the current study presents a diverse set of results in comparing female injury odds as compared to males. Table 8 summarized counts of the respective OR results showing females more frequently being at significantly lower (n=43) as opposed to higher (n=36) odds of injury for the 79 of 300 models that produced statistically significant female versus male injury ORs ($p\leq0.05$). The main crash type that presented an exception to this was *Frontal* crashes where females more frequently had significantly higher odds in the case of AIS 2+ body region injuries. The remaining ORs presented in Table 5 were not statistically significant ($p>0.05$) and were relatively evenly split between higher (n=103) and lower (n=114) odds of injury for females versus males.

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 43.4% of cases). Similarly, missing injury data in 2009-2015 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 CDS some of the old vehicle's 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, which could lead to increased bias in the OR estimates we were looking to document in this study. In this case, this would have equated to us using less than 30% of NASS-CDS and CISS cases given the distribution of missing predictor variables over the full data sample.

Another limitation is the sample size for some crash and injury types. Smaller samples for crashes such as rollovers and associated injury counts, coupled with a large selection of predictor variables, results in a greater percentage of non-significant findings. For example, the *All Crashes* models, which includes the complete sample used in this study, produced 20 significant ($p \leq 0.05$) OR estimates out of 50 total models, while *Rollover* only produced four (4) significant models.

There are also limitations related to injury coding. First, NASS-CDS predominantly used AIS 1990/1998 update, while CISS used AIS 2015. In some studies, that shift between AIS versions could result in overestimated injury improvements. However, this issue would affect males and females equally in the current study. Second, there is a tendency for females to have higher odds for lower severity injuries to extremity body regions where there are few corresponding AIS 3+ codes. In contrast, the head, neck, and thorax body region injuries where males had elevated injury odds have many injuries with severities at AIS 3 to 6. As such, the body region/severity odds differences documented in the 300 models produced in this study may not be completely independent of one another.

Another possible limitation is that post-crash factors were not considered in this study other than loosely via the urban/rural variable. It was not possible to determine whether there were post-crash differences in emergency response, treatment, decisions on transport (hospital or not), or other post-crash factors that may not be evenly distributed between females and males.

Another potential limitation of the study relates to the identification, selection, and retention of predictor variables, as well as the reference level that is chosen for categorical variables. To study these potential effects on female versus male (*Sex*) injury ORs, we studied various versions of the modeled results. First, concerning the choice of categorical variable reference levels used in multivariable logistic regression, we looked at *Seat Track Position*. The chosen reference level in final models was *Not adjustable* (less than 2% of weighted counts in *Frontal* crash sample). As a result, *Seat Track Position* was found to be statistically significant ($p \leq 0.1$) in only 2 out of 50 *Frontal* crash injury outcome models. However, if we instead were to choose *Middle position* (27% of weighted *Frontal* crash sample) as the reference level, *Seat Track Position* was found to be statistically significant ($p \leq 0.1$) in 19 out of 50 *Frontal* crash models. However, this example change in reference level selection for *Seat Track Position* did not have a substantial effect on

the estimates or statistical significance of female versus male (*Sex*) injury outcome ORs obtained from the final *Full* and *Crashworthiness (CW)* multivariable logistic regression *Frontal* crash models.

Next, we studied the possible effects of predictor variable selection and retention on *Sex* ORs. The current study did not include occupant height and weight as independent predictor variables, but instead considered Body Mass Index (BMI). Forman et al. (2019) used occupant BMI and height in all models, but not weight. Brumbelow and Jermakian (2022) used occupant height and weight in their models, but not BMI. In both studies, these variables along with sex, delta V, occupant age, and a limited list of other variables were included and retained in all models regardless of whether the variable was shown to be significantly related to the injury outcome being modeled. Recall, the current study only retained predictor variables with p-values of 0.10 and below (*Sex* being the exception).

To address predictor variable selection (e.g., height, weight, and/or BMI) we ran a subset of modeled injury outcomes for both *All Crashes* and *Frontal* crash conditions. Table A17 (Appendix) provides the female versus male OR results of the *Revised* versus *Original* models for 12 injury outcomes for both *Full* and *CW* versions of the *All Crashes* and *Frontal* crash type models (48 total model results). The *Revised* models included occupant height and weight (if found to be significant at p-value ≤ 0.1). Additionally, these models revised the reference level used in multi-variable logistic regression modeling for six predictor variables (*BMI*, *seat track position*, *object contacted*, *crash type*, *pre-impact movement*, and *critical event*).

The female versus male injury OR results presented in Table A17 show generally similar results between *Original* and *Revised* models. While there were some changes in statistical significance, the overall average odds between the two sets of 48 models was virtually unchanged (1.36 for *Original* and 1.33 for *Revised*). Directional changes in odds for *Revised* versus *Original* models showed 24 of 48 models with an increase in the OR, while the other 24 remained unchanged or were reduced. Further, the models did not show an overall improvement in model fit with the average c-statistic remaining at 0.83 and 0.82 in the models, respectively.

Table A18 (Appendix) contrasts predictor variable inclusion in the 48 *Original* and *Revised* models. Regarding occupant size-linked variable retention in the respective *Revised* models, height was retained in 13 of 48 models, weight in 20 of 48, BMI in 24 of 48, and seat-track position in 23 of 48. For BMI and seat-track position this contrasts with the *Original* models where they were retained in 18 of 48 and 3 of 48 models, respectively. Overall, 42 out of 48 *Revised* models retained at least one occupant size variable (*BMI*, *seat track position*, *occupant height*, and/or *occupant weight*). This compares with 21 out of 48 *Original* models that included *BMI* and/or *Seat Track Position* (*occupant height* and *weight* not considered in those models). Of the other variables whose reference levels were changed for multi-variable logistic regression modeling, only *pre-impact movement* had a significant increase in the number of times it was included in versus –models (21 of 24 versus 10 of 24).

To address effects of variable retention (using a p-value cut-off versus no cut-off) we evaluated the female versus male (*Sex*) injury ORs and model fit of all 300 models while using all the *Original* model predictor variables (no occupant height or weight), regardless of p-value. Table A19 (Appendix) shows the resulting ORs for the *Full* and *CW* models (models 1 and 3) where all predictor variables are retained. In 46 of 300 models there was a change in significance of the female versus male injury OR (e.g., statistically significantly higher to not statistically

significant). The averaged OR across all 300 models was largely unchanged (0.10 lower for models 1 and 3 versus 2 and 4). Unsurprisingly, the model fit for the 300 *Full* and *CW* models that included all predictor variables was better than for final models (Table A20 - Appendix), with 291 of 300 models having a c-statistic of ≥ 0.7 versus 276 of 300 for the final *Full* and *CW* models that retained only significant ($p \leq 0.1$) variables. Recall that for the main models presented in this study (models 2 and 4 for *Full* and *CW*, respectively), predictor variables were only retained in the final models if their p-values were ≤ 0.1. In these models, females had significantly higher odds of injury 36 times and significantly lower odds of injury 43 times. The remaining 221 OR estimates were not statistically significant. Of these, there were 103 with higher odds of injury for females versus males, 114 with lower odds of injury for females, and 4 with ORs = 1.00. In contrast, when looking at the OR results for *Full* and *CW* models before dropping predictor variables with p-values > 0.1 (models 1 and 3), there were 32 models where females had significantly higher odds of injury than males, and 53 models where females had significantly lower odds. For the remaining 215 modeled estimates, the *Sex* ORs were not significantly different (p-value > 0.05) between females and males. Of these, there were 107 with higher odds for females and 104 with lower, as well as 4 with ORs = 1.00.

The above efforts to evaluate the effects of variable selection, retention, and general use (e.g., reference level selection for categorical variables) aimed to assess potential limitations of the *Sex* injury OR findings in this study. Overall, the sensitivity to changes in variable selection, retention, and reference levels was minimal and associated findings do not invalidate in any way the overall findings from the main female versus male injury outcome ORs presented in Tables 5 and 8.

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 risk, 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 (NHTSA) 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 represents just one part of that larger effort to identify and then direct further studies towards addressing sex-based differences in crash injury risk.

Conclusions

It is not simple or straightforward to conclude definitively that one sex is at higher risk than the other as it relates to motor vehicle occupant injuries resulting from crashes on public traffic ways. The results of this study suggest that increased or decreased odds of injury for females versus males is dependent on the type of injury outcome, the associated crash type, and other relevant independent variables significantly associated with the respective injury outcomes.

Females were found to be more often at significantly lower odds than to be at significantly higher odds of injury as compared to males across the 300 models considered in this study. In modeled injury outcomes with non-significant female versus male injury odds ratios (i.e., cases where p-value was greater than 0.05), there were approximately equal counts of cases where females were at lower odds of injury than males as compared to being at higher odds.

Some body region injury types require further study to better understand the causes of and possible means to address significantly higher injury odds for females versus males (e.g., lower extremity injuries in frontal crashes like observations in other recent studies). Similarly, further study may be required to understand factors associated with injury outcomes where males had significantly higher odds of injury (or females being significantly lower odds) as documented in Table 5. Several upper body (head, neck, and torso) injury outcomes had significantly higher odds of injury for males as compared to females.

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 2021. 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

Table A-1. Logistic regression predictor variable ORs by injury outcome model for All Crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***1.75****	***1.24****	***1.03***	***0.94***	***1.11***	***0.73***	***0.50****	***0.77***	***1.10***	***0.66****	***0.78***	***0.77***	***1.66****	***1.75****	***1.42****	***0.77***	***0.52****	***0.67****	***0.79***	***1.35***	***0.76***	***0.87***	***1.14***	***1.26***	***1.15***
Alcohol/Drug Use (*No*)	**Yes**	2.03*	2.15*	2.19*	2.54*	2.22*	1.95*	1.81*	1.98*	1.73	1.84*		1.41		1.23		1.51*	1.87*	2.03*	2.01*		2.29*	1.36			1.44*
Avoidance Maneuver (*other/unknown*)	**Any maneuver**	0.63*	0.47*	0.27*	0.16*	0.59*	0.51*	0.37*	0.44*	0.56	0.47*				0.69	0.81	0.34*	0.40*	0.49*	0.34*		0.51*	0.54*		0.81	0.48*
	None	0.73	0.44*	0.32*	0.17*	0.80	0.48*	0.46*	0.40*	0.77	0.60*				0.92	0.78*	0.43*	0.35*	0.53*	0.39*		0.60*	0.60*		0.59*	0.48*
Critical Event (ped/animal/other)	**Control loss**			5.49					3.09	0.53	0.53			0.45	0.91		0.53		2.50*							
	Other vehicle in lane			4.28					3.45	0.11*	0.60			0.14*	1.01		0.46		1.32							
	Run off/turning			5.99*					6.22	0.20*	0.65			0.33	0.75		0.51		2.07							
Pre-impact Movement (other/unknown)	**Avoidance maneuver**					1.39	1.76		0.52	2.54	1.10					1.02		0.23		0.40	0.00*	1.85				
	Change lanes/merge					1.86	0.36		0.96	4.26	2.79*					0.84		1.27		1.02		6.15*				
	Decelerating					0.93	0.13*		0.12*	3.34	1.54					0.99		0.45		0.05*	0.93	1.68				
	Going straight					1.95*	0.50		1.35	2.70*	1.61					1.29		0.81		1.18	1.04	2.04*				
	Negotiating a curve					1.46	0.99		1.89	2.95*	1.40					1.21		1.07		1.79	1.11	1.63*				
	Stopped					0.98	0.08*		1.72	1.32	0.84					0.83		0.26*		1.32	0.04*	1.27				
	Turning					1.58	0.39		1.07	1.52	1.67					1.59		0.56		1.59	0.79	2.24				
Weather (*Normal*)	**Adverse**			1.21									3.24*				1.26				2.78*				1.56*	
Lighting (*Daylight*)	**Dark**						1.95*					2.80*				1.69*					2.28*					
Rural/Urban (*Urban*)	**Rural**	1.37*	1.36*		1.53*							3.05*	2.02*	2.37*											1.22	
Seat Belt Use (*Belted*)	**Unbelted**	2.28*	3.19*	3.55*	2.94*	1.39*	5.65*	2.54*	3.68*	2.67*	2.23*	2.27*	3.04*		1.69*	1.60*	2.42*	4.45*	3.18*	2.22*	3.46*	2.90*	2.23*		1.55*	1.81*
Ejection (*No*)	**Yes**		7.34*			3.73*	5.85*	4.43*		2.98*	4.62*		0.11*		5.62*	2.59*	6.13*	3.87*	2.67*	1.95		3.20*		0.55	2.20*	2.24*
Entrapped (*No*)	**Yes**	3.46*	4.85*	4.29*	3.89*	2.15*	2.06	2.82*	2.00*	4.39	3.21*	7.37*			1.46*	3.23*	3.63*		2.57*	2.46*		2.85*	3.77*	2.29*	2.18*	4.49*
Seating Position (*Driver*)	**Rear passenger**		2.21*	1.91*	1.83			3.89*			2.68*				1.79*			2.63	3.46*			2.62*	4.56*		0.92	4.18*
	RF passenger		1.46*	1.74*	1.78*			2.24*			1.73*				1.79*			1.59	1.77*			1.55*	1.56*		2.27*	1.50*
BMI (<*18.5*)	**18.5-25.0**	1.21					0.63	0.78	0.76	0.53	0.85				1.85*	1.27		0.35	0.55*	0.47*		0.64		4.53*		
	25.0-30.0	1.10					0.45*	0.66*	0.40*	0.53	0.69*				1.64	1.38		0.24	0.44*	0.28*		0.47*		3.54		
	30+	1.58					0.56	0.55*	0.34*	0.38*	0.55*				2.22*	2.00*		0.30	0.46*	0.17*		0.54*		3.67*		
Belt Anchor (*Full Down*)	**Full up**							0.76				1.83		1.81*		1.72			0.59*		3.38*	0.72		1.10	1.11	
	Mid position							0.66				1.87		1.01		1.05			0.42*		0.81	0.48		0.90	1.32	
	No shoulder belt							0.70						1.77		0.80			0.56*		2.86	0.64		3.60*	1.50	
	No upper anchor							0.60				2.89*		1.35		0.95			0.53*		3.70*	0.64*		1.86	1.32	

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**				0.56													0.29							0.31	
	Btw mid & rear				0.80													1.18							0.37	
	Forward most				0.49													1.56							0.25	
	Middle				0.62													1.20							0.34	
	Rear most				0.78													0.46							0.28	
Crash Type (*Rear impact*)	**Frontal impact**	1.84	1.25	0.51*	0.73	0.51*			0.28*	0.76	0.96		5.53*	6.50*	5.35*	2.53*	1.31	1.30		0.19*	0.17*				3.86*	2.01
	Other	2.62*	3.55	0.24*	0.22	2.10			0.20*	2.44	2.48*		2.58	4.59	5.48*	4.88*	0.59	0.77		0.13	0.11				0.00*	
	Rollover	2.47*	1.92*	1.15	1.78	0.90			0.33*	0.92	1.45		3.93	2.66	2.98*	1.17	1.31	2.05		0.13*	0.26				3.75*	1.13
	Side impact	1.71	1.87*	1.40	2.57*	0.70			0.55	0.42	0.95		4.77*	1.31	2.51	1.95	2.52*	2.25		0.30	0.09*				2.98*	2.19
Manner of Collision (*Not Collision*)	**Angle**	0.50	0.52*	0.46*	0.49*	0.88		0.95			0.64			0.38*	0.96			0.44*	0.55*		0.75	0.44*		1.04	0.47*	
	Head-on	1.52	1.23	1.06	0.95	2.70*		0.82			0.80			0.58	0.88			0.18*	0.70		0.56	0.66		1.30	0.90	
	Rear-end	0.31*	0.34*	0.30*	0.41*	0.54*		0.50*			0.40*			0.28	0.45*			0.63	0.55		1.04	0.34*		1.74	0.24*	
	Sideswipe	0.84	0.75	0.75	1.52	1.07		1.93			1.27				2.37*			0.67	1.19		0.20	0.88		0.73	0.75	
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**	2.35						6.98*			7.49*	0.00*	0.00*							0.00*	0.21			0.06	0.00*	
	Vehicle	3.17						3.01			5.37*	0.00	0.00*							0.00*	0.08			0.04	0.00*	
Airbag Deployment (*No*)	**Yes**	1.53*	1.66*							3.03*		0.29*	0.24*		2.40*						2.87*		0.69*	0.84	1.93*	1.70*
Intrusion (*No*)	**Yes**	2.33*	3.03*	2.77*	3.21*			2.27*	2.49*	1.94*	1.97*	4.50*	5.55*	2.50*	1.74*	2.68*		2.17*	2.81*	1.69		2.18*	5.01*	2.63*	2.54*	4.48*
Multiple-impact (*No*)	**Yes**	1.48*	1.70*		1.31*	1.27*	1.97*					1.98					1.59*		1.82*			1.65*				
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**		0.71*	0.57*			0.80	0.60*	0.96	1.34	0.64*				1.28	1.16	0.83	0.49*	0.46*	0.67	1.32	0.47*		4.48*	1.03	1.71
	LT-SUV		0.79	0.67			1.25	0.95	0.76	1.24	0.82				1.13	0.79	0.95	0.60	0.88	0.98	1.07	0.77		1.10	0.68*	0.73
	LT-Vans		1.13	0.41*			1.23	0.82	0.91	0.16*	0.71				0.76	0.58*	0.58	0.96	0.97	0.48*	0.05*	0.85		4.83*	1.28	1.05
	Other/Unknown LT						0.00*	0.64	0.00*		0.33				0.00*	4.85*	0.66	0.00*	1.29	0.00*		1.75		0.00*	0.00*	
Vehicle Vintage (< *2009*)	**2009+**			0.71	0.58*	1.48*		1.84*			1.58*	0.04*	0.02*	0.37*	1.72*						1.97		0.17*	0.02*	0.46	
Weight Ratio (≤*1.0*)	**1.0 – 2.0**	0.80*	0.67*	0.67*		0.91	0.48*			0.49*	0.74*			2.45*	0.79		0.77	0.46*	0.72*	0.78	0.12*	0.62*		0.57	1.16	
	> 2.0	0.56*	0.39	0.21*		0.27*	0.07			2.75	0.98			1.55	0.33		0.67	0.09*	0.35*	0.00*	0.00*	0.33*		3.90	0.00*	
Compatible Crash (*Yes*)	**No**					1.41*			1.12											1.35	0.47		0.88	0.69		
Delta V (kph)		1.06*	1.08*	1.07*	1.07*	1.03*	1.05*	1.04*	1.04*	1.04*	1.05*	1.03*	1.03	1.04*	1.03*	1.04*	1.04*	1.04*	1.05*	1.03*	1.03*	1.06*	1.03*	1.01	1.03*	1.04*
Vehicle Curb Weight (kg)								1.00					1.00*								1.00*		1.00	1.00*		
Occupant Age (years)		1.03*	1.05*	1.04*	1.05*	1.01*	1.06*	1.04*	1.01*	1.05*	1.04*		1.01*	1.02*	1.02*	1.02*	1.03*	1.05*	1.04*	1.02*	1.06*	1.05*	1.01		1.02*	1.02*
Vehicle Age (years)		1.02*									1.01	0.75*	0.75*	0.91*	1.05*					1.03		1.01	0.93*	0.85*	0.99	1.02*
Goodness of model fit: c-statistic		***0.85***	***0.90***	***0.93***	***0.95***	***0.72***	***0.88***	***0.84***	***0.83***	***0.83***	***0.85***	***0.90***	***0.91***	***0.71***	***0.74***	***0.78***	***0.83***	***0.86***	***0.86***	***0.79***	***0.78***	***0.86***	***0.81***	***0.82***	***0.76***	***0.83***

*p-value ≤ 0.05

Table A-2. Logistic regression predictor variable ORs by injury outcome model for All Crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																						
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***1.69****	***1.17***	***0.94***	***0.86***	***1.10***	***0.63****	***0.52****	***0.72***	***1.10***	***0.66****	***0.87***	***0.80***	***2.01****	***1.72****	***1.30****	***0.74****	***0.47****	***0.65****	***0.73***	***1.26***	***0.71****	***0.86***	***1.18***	***1.28***	***1.09***
Seat Belt Use (*Belted*)	**Unbelted**	2.36*	3.28*	4.07*	3.91*	1.44*	6.19*	2.72*	4.52*	2.71*	2.43*	2.48*	2.62*		1.74*	1.50*	2.63*	4.21*	3.64*	2.54*	2.19	3.54*	2.27*		1.57*	1.78*
Ejection (*No*)	**Yes**		8.70*			4.45*	5.30*	4.94*		4.44*	4.64*		0.18*		5.74*	2.60*	6.24*	5.98*	3.34*	2.04*		3.65*		0.57	2.39*	2.42*
Entrapped (*No*)	**Yes**	3.45*	4.85*	4.14*	3.80*	2.32*	1.61	2.93*	1.93*	4.18*	3.24*	8.40*			1.51*	3.03*	3.32*		2.53*	2.46*		3.02*	3.70*	2.23*	2.21*	4.29*
Seating Position (*Driver*)	**Rear passenger**		2.33*	1.78*				3.63*			2.55*				1.84*				3.42*			1.09	4.86*	0.48	0.95	3.75*
	RF passenger		1.43*	1.53*				2.13*			1.68*				1.79*				1.70*			1.48*	1.56*	0.73	2.26*	1.49*
BMI (*<18.5*)	**18.5-25.0**	1.19					0.63	0.81	0.82	0.56	0.95				1.87*	1.24		0.35	0.54*	0.54		0.71		4.96*		
	25.0-30.0	1.09					0.44*	0.67*	0.42*	0.54	0.76				1.69	1.37		0.22	0.44*	0.31*		0.54*		3.71		
	30+	1.56					0.50*	0.55*	0.35*	0.37*	0.59*				2.27*	2.05*		0.29	0.44*	0.19*		0.57*		3.74*		
Belt Anchor (*Full Down*)	**Full up**				0.94			0.77				2.14		1.86*				0.47*	0.59*		3.15*	0.72		1.11	1.13	
	Mid position				0.74			0.66				1.56		1.01				0.49	0.44*		0.84	0.53		0.98	1.30	
	No shoulder belt				0.84			0.62				10.0*		2.07				1.00	0.52*		2.22	0.57*		4.01*	1.46*	
	No upper anchor				0.94			0.56*				3.08*		1.60				0.72	0.54*		3.66*	0.65		2.20	1.29	
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**																					0.39			0.31	
	Btw mid & rear																					0.36*			0.36	
	Forward most																					0.62			0.23	
	Middle																					0.46			0.33	
	Rear most																					0.44			0.29	
Crash Type (*Rear impact*)	**Frontal impact**	1.76	1.26	0.50*	0.57		2.40		0.24*	1.37	1.29		4.12		3.98*	3.78*	0.81	3.23		0.15*					4.49*	
	Other	2.67*	4.31*	0.43	0.44		5.27		0.19	3.70*	4.30*	5.79	2.22		4.59*	9.08*	0.82	2.42		0.13					0.00*	
	Rollover	2.54*	2.28*	1.18	1.83		4.31*		0.30	2.81	1.81	2.96	2.96	4.23	2.29	1.94	0.85	6.12*		0.12*					4.76*	
	Side impact	1.71	1.94*	1.49	2.41*		2.96		0.50	0.84	1.34		2.94	4.81*	1.78	3.11*	1.76	5.68		0.30					3.43*	
Manner of Collision (*Not Collision*)	**Angle**	0.58*	0.43*	0.37*	0.39*	0.87	0.28*	0.49*	0.83		0.67			0.24*	0.52*		0.64*	0.35*	0.42*	0.45	0.75		0.67	0.81	0.48*	0.72*
	Head-on	2.06*	1.27	1.09	1.26	2.70	0.34*	0.53*	1.62*		0.99			1.26	0.49*		1.07	0.20*	0.58*	0.84	0.98		1.32	1.31	0.91	1.01
	Rear-end	0.36*	0.28*	0.18*	0.25*	0.52*	0.23*	0.26*	0.55		0.38*			0.56	0.24*		0.37*	0.47	0.32*	0.35*	2.15		0.57	1.48	0.26*	0.54*
	Sideswipe	0.92	0.67	0.61*	1.32	0.97	0.45*	1.26	1.58		1.35			0.49	1.39		0.61	0.72	1.11	0.83	0.37		1.00	0.60	0.73	0.93
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**										4.82*	0.00*	0.00*		2.36					0.00*	0.25			0.05	0.00*	
	Vehicle										3.40	0.00*	0.00*		5.11*					0.00*	0.11			0.05	0.00*	
Airbag Deployment (*No*)	**Yes**	1.51	1.75*		1.26					2.73*		0.24*	0.26*		2.39*						3.02*		0.65*		2.03*	1.56*
Intrusion (*No*)	**Yes**	2.47*	3.21*	3.04*	3.40*		1.39*	2.47*	2.44*	2.10*	2.05*	3.67*	5.12*	2.18*	1.81*	2.55*	1.41	2.15*	3.08*	1.76		2.67*	4.93*	2.60*	2.57*	4.14*
Multiple-impact (*No*)	**Yes**	1.47*	1.72*	1.36	1.35*	1.49*	1.69*	1.43*			1.41	2.29					1.69*		2.03*			1.85*		1.28		

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																						
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**		0.70*	0.53*			0.64	0.46*	0.84	1.27	0.61*			0.34*	1.29	1.07	0.76	0.42*	0.42*	0.58	0.72	0.46*		4.36*	1.02	1.49
	LT-SUV		0.79	0.67			1.15	0.75	0.77	1.31	0.79			0.55	1.15	0.80	0.89	0.63	0.80	1.00	1.07	0.76		1.16	0.67*	0.67
	LT-Vans		1.04	0.40*			1.03	0.56*	0.74	0.15*	0.62*			0.26	0.75	0.58*	0.63	0.88	0.78	0.46*	0.04*	0.72		4.88*	1.26	0.92
	Other/Unknown LT		9.06*				0.01*	0.50	0.00*		0.30				0.00*	4.09	0.90	0.01*	1.38	0.00*		2.19		0.00*	0.00*	
Vehicle Vintage (< *2009*)	**2009+**	1.25*		0.68	0.49*			2.06*			1.62*	0.06*	0.01*	0.36*	1.68*						1.68		0.17*	0.02*	0.46*	
Weight Ratio (≤*1.0*)	**1.0 – 2.0**	0.84*	0.69*	0.66*	0.53*	0.92	0.60*			0.40*	0.76*	0.53*		2.37*	0.77		0.79	0.50*	0.69*	0.82	0.09*	0.58*		0.58*	1.19	
	> 2.0	0.38*	0.45	0.10	0.09	0.32*	0.03			2.19	0.95	0.02*		1.30	0.53		0.60	0.06*	0.39*	0.00*	0.00*	0.67		2.16	0.00*	
Compatible Crash (*Yes*)	**No**					1.32*			1.36*											1.49			0.86			
Delta V (kph)		1.06*	1.08*	1.08*	1.08*	1.03*	1.06*	1.05*	1.04*	1.05*	1.06*	1.04*	1.03*	1.03*	1.03*	1.04*	1.05*	1.05*	1.05*	1.03*	1.03*	1.06*	1.02*		1.03*	1.04*
Vehicle Curb Weight (kg)																					1.00*		1.00	1.00*		
Occupant Age (years)		1.03*	1.04*	1.04*	1.05*	1.01*	1.06*	1.04*	1.01*	1.05*	1.04*		1.01	1.02*	1.02*	1.01*	1.03*	1.05*	1.04*	1.02*	1.06*	1.05*	1.01		1.02*	1.02*
Vehicle Age (years)		1.02	1.02*					1.04*			1.02	0.76*	0.75*	0.92*	1.05*					1.04		1.01	0.93*	0.85*		1.02*
Goodness of model fit: c-statistic		***0.85***	***0.89***	***0.92***	***0.94***	***0.70***	***0.87***	***0.83***	***0.82***	***0.82***	***0.84***	***0.91***	***0.92***	***0.73***	***0.73***	***0.78***	***0.81***	***0.84***	***0.84***	***0.78***	***0.78***	***0.85***	***0.81***	***0.82***	***0.76***	***0.82***

*p-value ≤ 0.05

Table A-3. Logistic regression predictor variable ORs by injury outcome model for Frontal crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.33****	***1.56****	***1.00***	***0.98***	***1.73***	***0.94***	***0.54***	***0.46****	***1.86****	***0.68***	***1.24***	***0.63***	***4.42****	***1.96****	***1.55****	***0.43****	***0.41***	***1.54***	***0.65***	***2.45***	***1.54***	***0.92***	***0.99***	***1.36***	***0.92***
Alcohol/Drug Use (*No*)	**Yes**	2.13*	2.51*		1.89	3.18*		1.93*	1.95*	2.60*	2.20*								2.79*	2.34*		2.88*	1.69			1.97*
Avoidance Maneuver (*other/unknown*)	**Any maneuver**		0.64	0.42*	0.20*	0.52*			0.52*		0.70			1.20			0.30*		0.94	0.48*						0.65*
	None		0.63	0.33*	0.23*	0.64			0.51*		0.81			3.08*			0.35*		0.49*	0.33*						0.52*
Critical Event (ped/animal/other)	**Control loss**	1.63	2.53							0.10*			1.62			1.86			3.27*		0.02					
	Other vehicle in lane	3.76	4.58*							0.21			0.08			2.53			0.93		1.37					
	Run off/turning	3.31	2.94							0.20*			0.11			2.69*			1.95		0.47					
Pre-impact Movement (other/unknown)	**Avoidance maneuver**		2.72	0.00*	0.00*	0.07*		3.41	0.00*	0.00*	0.44			0.06	8.50*	0.49				0.00*					6.62	
	Change lanes/merge		9.62	2.17	0.59	2.05		1.04	0.27	9.76	0.80			0.10	1.46	0.77				0.67					1.32	
	Decelerating		3.74	1.68	0.00*	0.43		0.33	0.25	3.96	0.60			0.06*	2.64	4.16				0.00*					9.59*	
	Going straight		4.51*	2.13	0.62	2.73*		3.04	0.75	2.43	0.72			0.06*	4.81*	3.44*				0.33					4.26*	
	Negotiating a curve		4.57*	2.96	0.50	3.23*		2.46	0.96	2.16	0.63			0.06*	8.56*	1.68				0.62					4.37	
	Stopped		0.78	0.38	0.19	3.63		0.84	0.12*	0.27	0.15*			0.00*	4.19	0.25				0.04*					0.00*	
	Turning		4.99	1.90	0.34*	3.15		3.81	0.42	1.31	0.85			0.06*	3.00	2.78*				0.33					4.10*	
Weather (*Normal*)	**Adverse**			2.05				0.58						2.81*											1.63	
Lighting (*Daylight*)	**Dark**			1.78		1.39	3.33*					1.57*					1.52*		2.05*		3.33*	2.17*				
Rural/Urban (*Urban*)	**Rural**	1.38*				2.35*						2.12*		2.39*							0.23*					
Ejection (*No*)	**Yes**		5.68*					0.00*	0.00*					0.07*	5.72		2.73	7.81*	0.00*	0.00*	0.00	0.00*		0.00*		
Entrapped (*No*)	**Yes**	3.03*	6.08*	6.82*	5.14*	2.88*		4.01*	5.15*	4.46*	3.24*				2.17*	3.43*	3.24*	1.32	5.33*	7.73*		5.72*	4.50*	2.49*	3.33*	
BMI (<*18.5*)	**18.5-25.0**	1.39*				2.07			0.42	0.25*			6.03					0.11*	0.52	0.19		0.54	2.35			
	25.0-30.0	1.48*				2.33			0.25	0.55			1.30					0.06*	0.47	0.15*		0.46	3.46			
	30+	1.90*				2.15			0.13*	0.36			3.14					0.13*	0.52	0.08*		0.60	3.77			
Belt Anchor (*Full Down*)	**Full up**			1.33		1.37		0.81		1.60		0.90				1.65	1.16	0.34	0.61	1.45	2.67		0.65	1.23	1.42	
	Mid position			3.08*		1.31		0.87		0.99		0.86				0.77	3.33*	0.53	0.61	3.77*	1.04		0.63	1.52	2.99	
	No shoulder belt			2.01		0.60		0.97		6.34		3.33				0.66	1.21	2.75	1.95	1.97	2.08		0.50	5.35	1.07	
	No upper anchor			1.37		1.31		0.66		1.42		3.48*				0.93	1.17	0.75	0.40*	2.15	4.02		1.12	1.91	2.01*	
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**				0.15																					
	Btw mid & rear				0.29																					
	Forward most				0.13																					
	Middle				0.18																					
	Rear most				0.38																					

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Manner of Collision (*Not Collision*)	**Angle**	0.49*	0.28*	0.19*	0.29*	0.73		0.50*	0.35*	0.45	0.43*	1.75		0.18*	2.15*	0.30*	0.45			0.20*	0.97			0.91	0.41*	0.58
	Head-on	1.30*	0.68	0.88	0.93	2.42*		0.62	1.30	0.20	0.44*	3.92*		1.04	1.39	0.85	0.57			1.04	0.71			1.37	0.76	1.14
	Rear-end	0.32*	0.18*	0.06*	0.15*	1.74		0.25*	0.80	0.20*	0.25*	2.35		0.94	0.92	0.70	0.19*			0.34	2.26			0.26	0.19*	0.24*
	Sideswipe	0.84	0.41*	0.66	1.04	0.00*		0.45	1.20	0.14*	0.39*	3.57		0.77	4.71*	0.49	0.41			1.49	0.06*			1.36	0.90	0.79
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**			0.00	0.00*					0.00*		0.00*	0.00*				0.00*				0.27					
	Vehicle			0.00	0.01*					0.00*		0.00	0.00*				0.00*				0.04*					
Airbag Deployment (*No*)	**Yes**			0.54*								0.60	0.13*	2.23	2.91*		0.48*			0.47			0.38*	0.16*	1.57	
Intrusion (*No*)	**Yes**	2.37*	2.80*	2.61*	4.15*		2.28*		1.94*	2.67*	1.74*	3.90*	4.00	2.16*		2.99*	1.79		2.04*			1.85*	6.91*		2.74*	4.21*
Multiple-impact (*No*)	**Yes**			1.84*	1.69*	1.26											2.17*		1.88*			1.73*				
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**		0.74	0.66	1.49		0.96	0.62	0.53		0.62			0.87	0.67	1.38	0.42	0.05*	1.10	0.47		0.89		2.74	1.00	
	LT-SUV		0.60	1.03	0.82		2.56*	0.59	2.47*		0.69			1.01	1.06	0.77	0.80	0.44	0.92	2.33		0.83		0.69	0.37*	
	LT-Vans		0.54*	0.39*	0.64		1.27	0.35*	1.82		0.44*			0.14*	0.71	0.61	1.01	1.02	0.45	0.93		0.44*		0.95	1.12	
	Other/Unknown LT		5.28*	0.00*	0.00*		0.01*	0.00*	0.00*		0.00*				0.00*		0.00*	0.00*	0.00*	0.00*		0.00*		0.00*	0.00*	
Vehicle Vintage (< *2009*)	**2009+**					2.12*		1.97		2.86*	1.94*	0.02*	0.00*	0.35*	1.77*	0.58					4.66*		0.36*	0.01*		
Weight Ratio (≤*1.0*)	**1.0 – 2.0**	0.81	0.69*	0.91	0.86	0.58	0.44		0.43*	0.38*		0.81		3.50*	0.60		0.82	0.32*		0.65	0.03*		0.72	1.73	0.85	0.64
	> 2.0	0.23*	0.43	0.00*	0.00*	0.11*	1.08		0.00*	0.00*		0.03*		1.97	0.27		0.00*	6.02*		0.00*	0.00*		0.04*	2.75	0.08*	0.10*
Compatible Crash (*Yes*)	**No**				1.63	1.27																		1.05		
Delta V (kph)		1.06*	1.08*	1.07*	1.07*	1.03*	1.07*	1.05*	1.04*	1.06*	1.05*	1.03*	1.04*	1.03*	1.05*	1.03*	1.04*	1.08*	1.06*	1.02*	1.04*	1.06*	1.03*	1.02	1.03*	1.05*
Vehicle Curb Weight (kg)			1.00*												1.00*		1.00	1.00*			1.00*			1.00	1.00	
Occupant Age (years)		1.03*	1.05*	1.05*	1.06*		1.08*	1.05*	1.01*	1.06*	1.04*	1.01	1.02	1.04*	1.02*	1.02*	1.03*	1.07*	1.06*	1.03*	1.09*	1.06*		1.02	1.02*	1.02*
Vehicle Age (years)		1.00				1.07*				0.92*		0.73*	0.65*	0.95	1.07*	0.94		0.89*					0.92*	0.80*		
Goodness of model fit: c-statistic		***0.82***	***0.89***	***0.92***	***0.93***	***0.69***	***0.87***	***0.81***	***0.84***	***0.87***	***0.81***	***0.90***	***0.93***	***0.73***	***0.70***	***0.75***	***0.83***	***0.83***	***0.85***	***0.83***	***0.79***	***0.85***	***0.85***	***0.85***	***0.76***	***0.84***

*p-value ≤ 0.05

Table A-4. Logistic regression predictor variable ORs by injury outcome model for Frontal crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.34****	***1.51****	***0.91***	***0.95***	***1.63***	***0.90***	***0.54***	***0.45****	***1.72****	***0.68***	***1.16***	***1.38***	***5.00****	***1.89***	***1.65****	***0.44****	***0.41***	***1.38***	***0.62***	***1.45***	***1.35***	***0.94***	***0.97***	***1.36***	***0.89***
Seat Belt Use (*Belted*)	**Unbelted**																								
Ejection (*No*)	**Yes**		6.93*					0.00*	0.00*								3.00	7.81*	0.00*	0.00*	0.00*	0.00*		0.00*	
Entrapped (*No*)	**Yes**	2.90*	5.65*	6.39*	4.92*	1.95*		3.29*	5.52*	3.59*	3.20*				2.07*	3.83*	3.43*	1.32	3.84*	9.00*		4.75*	4.56*	2.54*	3.12*	
Seating Position (*Driver*)	**Rear passenger**																								
	RF passenger																								
BMI (*<18.5*)	**18.5-25.0**	1.37*				1.82			0.46	0.22*	0.78					1.04		0.11*	0.40	0.25		0.55	2.26			
	25.0-30.0	1.56*				1.95			0.24	0.43	0.82		2.94			1.37		0.06*	0.35*	0.18*		0.44	3.61			
	30+	1.92*				1.95			0.13*	0.28	0.55		5.54			1.67		0.13*	0.41	0.09*		0.57	3.83			
Belt Anchor (*Full Down*)	**Full up**	1.11		1.40		1.45				1.52		0.96		1.41		1.61*	1.18	0.34	0.66	1.36	5.28*		0.64	1.18	1.46	
	Mid position	0.89		2.90*		0.97				1.17		0.89		1.33		0.74	2.78*	0.53	0.64	3.58*	1.37		0.73	1.39	2.98	
	No shoulder belt	0.52		1.69		0.54				5.95		2.98		1.85		0.71	0.87	2.75	1.56	1.24	2.96		0.49	5.57	0.83	
	No upper anchor	1.23		1.28		1.41				1.73		3.30*		1.80*		0.88	1.04	0.75	0.40*	1.69	5.66		1.17	1.88	1.99*	
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**												0.02*													
	Btw mid & rear												0.20													
	Forward most												1.19													
	Middle												0.27													
	Rear most												0.30													
Crash Type (*Rear impact*)	**Frontal impact**																									
	Other																									
	Rollover																									
	Side impact																									
Manner of Collision (*Not Collision*)	**Angle**	0.61	0.32*	0.22*	0.20*	1.12			0.28*	0.43	0.41*	1.97		0.28*	1.72*	0.40*	0.41		0.19*	0.15*	1.17			1.00	0.39*	0.53
	Head-on	1.87*	0.85	1.19	0.98	4.82*			1.36	0.26	0.46*	4.52*		1.35	1.36	0.83	0.62		0.47*	1.09	0.51			1.49	0.68	1.29
	Rear-end	0.40*	0.23*	0.06*	0.11*	0.89			0.69	0.28	0.21*	2.45		0.92	0.79	0.89	0.15*		0.24*	0.24*	3.46			0.25	0.17*	0.23*
	Sideswipe	1.03	0.55*	0.76	1.11	0.75			1.34	0.17*	0.39*	3.56		0.53	4.82*	0.60	0.43		0.56	1.52	0.20			1.50	0.77	0.87
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**			0.00	0.00*					0.00*		0.00*	0.00*				0.00*				0.03*					
	Vehicle			0.00	0.00*					0.00*		0.00*	0.00*				0.00*				0.01*					
Airbag Deployment (*No*)	**Yes**			0.51*								0.59	0.12*		2.88*		0.45*			0.55			0.39*	0.14*	1.71	
Intrusion (*No*)	**Yes**	2.68*	3.23*	2.87*	4.32*		1.95*	2.13*	2.24*	3.06*	1.79*	3.94*	3.75	2.37*		2.96*	1.83		1.96*			2.16*	7.72*		2.89*	4.52*
Multiple-impact (*No*)	**Yes**			1.72*	1.66*	1.41											2.11*									

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Vehicle Body Type (*Passenger cars*)	LT-Pickups		0.75	0.66	1.56	0.65	0.97	0.66	0.51		0.58			0.98	0.68	1.42	0.35	0.05*	1.12	0.46	0.05*	0.86		1.83	1.60	
	LT-SUV		0.62	0.92	0.67	2.31	2.64*	0.62	2.31*		0.68			0.95	1.09	0.73	0.69	0.44	0.86	2.04	0.55	0.93		0.53	0.53*	
	LT-Vans		0.56*	0.43*	0.76	1.51	1.30	0.32*	1.66		0.41*			0.16*	0.70	0.61	1.12	1.02	0.44*	1.23	0.06*	0.39*		0.68	1.59	
	Other/Unknown LT		4.67	0.00*	0.00*	0.00*	0.01*	0.00*	0.00*		0.00*				0.00*	9.16*	0.00*	0.00*	0.00*	0.00*		0.00*		0.00*	0.00*	
Vehicle Vintage (< *2009*)	2009+							2.01		3.29*	1.92*	0.02*	0.00*	0.34*	1.74*	0.55*					4.16		0.35*	0.01*		
Weight Ratio (≤*1.0*)	1.0 – 2.0	0.84		0.89	0.77	0.46	0.37*		0.46*	0.35*		0.82		2.71*	0.63		0.69	0.32*		0.65	0.03*		0.73	1.39	1.06	0.66
	> 2.0	0.26*		0.00*	0.00*	0.13*	0.03		0.00*	0.00*		0.03*		0.99	0.27		0.00*	0.00*		0.00*	0.00*		0.04*	1.99	0.09*	0.11*
Compatible Crash (*Yes*)	No				1.67	1.53*																		1.03		
Delta V (kph)		1.06*	1.08*	1.08*	1.07*	1.03*	1.07*	1.05*	1.04*	1.06*	1.05*	1.03*	1.06*	1.03*	1.05*	1.03*	1.05*	1.08*	1.06*	1.03*	1.05*	1.07*	1.03*	1.02	1.03*	1.05*
Vehicle Curb Weight (kg)			1.00*												1.00*		1.00	1.00*			1.00*					
Occupant Age (years)		1.03*	1.05*	1.05*	1.06*		1.08*	1.04*	1.03*	1.06*	1.04*	1.01	1.03*	1.04*	1.02*	1.02*	1.02*	1.07*	1.05*	1.03*	1.08*	1.05*		1.02	1.02*	1.02*
Vehicle Age (years)						1.06	0.96			0.92*		0.74*	0.68*	0.90*	1.06*	0.93		0.89*					0.92*	0.80*		
Goodness of model fit: c-statistic		***0.81***	***0.88***	***0.90***	***0.92***	***0.67***	***0.86***	***0.81***	***0.83***	***0.87***	***0.81***	***0.90***	***0.93***	***0.72***	***0.70***	***0.76***	***0.82***	***0.84***	***0.85***	***0.82***	***0.81***	***0.84***	***0.85***	***0.85***	***0.76***	***0.83***

*p-value ≤ 0.05

Table A-5. Logistic regression predictor variable ORs by injury outcome model for Near-side crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																								
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Alcohol/Drug Use (*No*)	**Yes**	2.58*	2.54*	3.43*	5.88*	2.32*	2.89*	2.46*	2.36*	4.83*	2.61*					2.01*	1.83*		2.14*	2.35*		2.94*				
Avoidance Maneuver (*other/unknown*)	**Any maneuver**	0.63	0.43*	0.23*	0.31*		0.30*	0.33*	0.52		0.43*					0.38*	0.21*	0.06*	0.34*	0.44		0.52*			0.41	0.22*
	None	0.60*	0.39*	0.22*	0.11*		0.29*	0.43*	0.39*		0.56*					0.42*	0.31*	0.29*	0.47*	0.44		0.53*			0.18*	0.43*
Critical Event (ped/animal/other)	**Control loss**	0.43					0.04*				0.27	0.00*		0.00*			1.14		5.59*	1.96						
	Other vehicle in lane	0.21*					0.02*				0.14	0.00*		0.00*			2.22		1.30	2.20						
	Run off/turning	0.26					0.11*				0.23	0.00*		0.00*			1.90		2.64*	5.70*						
Pre-impact Movement (other/unknown)	**Avoidance maneuver**			0.41	0.03*		0.17	0.54							0.29	1.80	0.15	0.18	1.32	0.00*		1.96			0.00*	
	Change lanes/merge			0.39	0.52		0.00*	0.35							1.10	0.26	0.27	0.01	1.17	0.41		1.18			0.24	
	Decelerating			0.00*	0.00*		0.00*	0.02*							0.00*	0.35	0.00*	0.03	0.03*	0.00*		0.10*			0.00*	
	Going straight			0.64	0.62		0.11*	0.38							0.32	0.51	1.13	0.07*	0.46	1.25		0.82			0.15	
	Negotiating a curve			1.08	1.73		0.22	0.45							0.31	0.61	1.16	0.06*	0.79	2.12		1.36			0.08*	
	Stopped			0.76	0.79		0.01*	0.07*							0.12*	0.36	0.38	0.00*	0.34	0.49		0.37			0.00*	
	Turning			0.82	1.07		0.06*	0.52							0.19	0.68	0.47	0.05*	0.62	0.76		1.03			0.18*	
Weather (*Normal*)	**Adverse**																									
Lighting (*Daylight*)	**Dark**			1.48		1.63			2.86*				0.97		0.97					3.06*					1.88	
Rural/Urban (*Urban*)	**Rural**				2.01*		0.40*								0.64*										4.25*	
Sex (*Male*)	**Female**	1.14	1.38	0.96	1.05	0.79	1.02	0.56*	0.66	0.61	0.42*	0.41	2.20	1.99	1.72	1.19	0.83	0.86	0.56*	0.61	0.32	0.51*	0.93	2.72	2.51	1.65*
Seat Belt Use (*Belted*)	**Unbelted**		2.10*	1.71			4.28*	1.75*			1.38	3.06*					1.90									
Ejection (*No*)	**Yes**		8.90*			8.18*					3.01*				4.79*	2.61*	10.6*		3.17							
Entrapped (*No*)	**Yes**	3.16*	4.65*	2.91*	5.02*	2.09*	3.61*	2.69*	2.21*		2.54*	5.60*			2.38*	4.13*	3.55*	0.41*	2.10*	1.76		2.70*	1.94*	5.23*		4.86*
BMI (*<18.5*)	**18.5-25.0**				0.22	2.79*	0.38		0.10		0.54			0.00*			0.90	0.29		0.13*			1.22		0.71	
	25.0-30.0				0.23	2.83*	0.29*		0.11		0.26*			0.00*			0.32*	0.17		0.19			0.54		2.04	
	30+				0.34	2.17	0.18*		0.09		0.23*			0.00*			0.57	0.13		0.01*			0.28		2.78*	
Belt Anchor (*Full Down*)	**Full up**		0.69	0.44*	0.94			0.81							2.42										1.33	
	Mid position		0.56	0.84	2.27			0.46							1.74										0.38	
	No shoulder belt		0.51*	0.60	0.96			0.56*							2.92*										2.85*	
	No upper anchor		1.01	1.01	2.11			0.91							1.60										1.47	

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**	0.56	0.39	0.28*	0.22		0.07*	0.16*		0.07*	0.22*			0.04*	0.51	0.19*	0.22*	0.03*		0.17	0.36		0.14*		0.35	0.14*
	Btw mid & rear	1.31	0.90	0.80	0.58		0.10*	0.28		0.15	0.36			0.04*	0.52	0.28*	0.82	0.07*		0.29	0.11		0.19*		0.35	0.25*
	Forward most	0.66	0.38	0.50	0.18		0.22	0.26		0.38	0.33			0.00	0.06*	0.32	0.16*	0.15		1.14	0.00*		0.27		0.05*	0.34
	Middle	0.82	0.77	0.37	0.35		0.09*	0.25*		0.08*	0.26*			0.05*	0.44	0.39	0.26*	0.08*		0.38	0.31		0.19*		0.36	0.33
	Rear most	1.18	0.83	0.41	0.25*		0.08*	0.21*		0.21	0.41			0.10*	0.60	0.35	0.21*	0.04*		0.32	0.10		0.41		1.03	0.33
Manner of Collision (*Not Collision*)	**Angle**							1.43							0.31*			0.12*							0.13*	0.71
	Head-on							1.92							0.00			0.00							0.00	0.85
	Rear-end							3.50							0.71			0.00*							0.00	0.53
	Sideswipe							2.75							0.21*			0.03*							0.06*	0.89
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**			0.02*	0.15*		0.00*	0.00*	0.00*							0.04*	0.00*		0.00*	0.00*		0.00*	0.00*			
	Vehicle			0.01*	0.08*		0.00*	0.00*	0.00*							0.02*	0.00*		0.00*	0.00*		0.00*	0.00*			
Airbag Deployment (*No*)	**Yes**	1.76*	1.78*									0.32*			4.95*	2.32*						1.16	0.69*		5.40*	1.44
Intrusion (*No*)	**Yes**	3.10*	3.55*	5.77*	5.44*	1.46		2.77*	7.68*	5.04*	2.06*					7.19*		8.69*	3.74*	8.50*		3.13*	5.50*			
Multiple-impact (*No*)	**Yes**	1.94*	2.54*	1.63			1.62	1.77*			1.57*		1.38	2.37				1.52	1.62					2.88*	1.97	1.45
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**	0.40*	0.25	0.41	0.13*	0.91	0.96	0.22*	2.21						0.30*		0.42	0.07*	0.26*	0.68	1.40	0.31*			0.24	
	LT-SUV	1.34	0.62	0.92	0.21*	1.56	0.63	1.40	0.46						0.71		0.66	0.43	1.19	1.54	0.08*	0.72			1.06	
	LT-Vans	0.91	0.58	0.61	0.23*	1.63	1.14	0.42	1.14						0.37*		0.27	0.45	0.46	1.02	0.97	0.42*			0.18*	
	Other/Unknown LT	0.01*	0.01*	0.00*	0.00*	0.79	0.00*	0.24	0.00*						0.00*		1.47	0.00*	0.63	0.00*		1.00			0.00*	
Vehicle Vintage (< *2009*)	**2009+**			0.39*	0.27*							0.01*	0.00*	0.32	0.47*			1.49					0.05*	0.07*	0.05*	
Weight Ratio (≤*1.0*)	**1.0 – 2.0**			0.76			0.41*	0.63*	1.09		0.60*						1.43		0.66	2.34*	0.10*	0.59	1.47		2.24*	
	> 2.0			0.06*			0.00*	0.00*	0.00*		0.47						0.00*		0.00*	0.00*	0.00*	0.00*	0.00*		0.14	
Compatible Crash (*Yes*)	**No**														0.64										0.45*	
Delta V (kph)		1.10*	1.10*	1.10*	1.11*	1.04*	1.04*	1.05*	1.05*	1.07*	1.07*	1.07*	1.02	1.08*	1.04*	1.06*	1.05*	1.04*	1.06*	1.05*	1.07*	1.08*	1.03*	1.02	1.04*	1.06*
Vehicle Curb Weight (kg)									1.00*			1.00	1.00*							1.00*						
Occupant Age (years)		1.03*	1.05*	1.06*	1.06*	1.02*	1.06*	1.04*	1.02*	1.04*	1.04*	1.00	1.01	1.02	1.03*	1.02*	1.05*	1.06*	1.03*	1.04*	1.02	1.04*	1.01*		1.02*	1.01*
Vehicle Age (years)		0.97*	0.97	0.93*	0.94					0.96	0.96*	0.73*	0.57*				0.91*				0.81		0.91*			
Goodness of model fit: c-statistic		***0.87***	***0.91***	***0.93***	***0.95***	***0.74***	***0.86***	***0.84***	***0.79***	***0.78***	***0.84***	***0.95***	***0.93***	***0.77***	***0.72***	***0.82***	***0.81***	***0.84***	***0.84***	***0.74***	***0.72***	***0.85***	***0.72***	***0.73***	***0.71***	***0.75***

*p-value ≤ 0.05

Table A-6. Logistic regression predictor variable ORs by injury outcome model for Near-side crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***1.08***	***1.30***	***0.90***	***1.09***	***0.77***	***0.69***	***0.53****	***0.68***	***0.46***	***0.42****	***0.37***	***1.73***	***1.26***	***1.89***	***1.08***	***1.11***	***0.53***	***0.53****	***0.72***	***0.37***	***0.50****	***0.78***	***5.51****	***2.43****	***1.47***
Seat Belt Use (*Belted*)	**Unbelted**	1.67*	2.46*	2.17*			4.39*	1.82*			1.71*	3.22*					2.69					1.64		1.48		
Ejection (*No*)	**Yes**		9.89*			7.99*					3.43*		4.14	0.02	4.81*	3.32*	10.6*					3.21*				
Entrapped (*No*)	**Yes**	3.26*	4.75*	3.30*	3.50*	2.14*	3.42*	2.56*	2.15		2.78*	6.49*			2.40*	4.40*	3.91*		2.22*	1.89		3.14*	1.72	6.28*		4.85*
BMI (*<18.5*)	**18.5-25.0**					2.65*	0.41*		0.10		0.50							0.29					0.82		0.88	
	25.0-30.0					2.79*	0.26*		0.11		0.23*							0.10*					0.38		2.97	
	30+					2.08*	0.15*		0.09		0.20*							0.12					0.18		2.95*	
Belt Anchor (*Full Down*)	**Full up**		0.66	0.38*			0.28*								1.82		0.90	0.09*							1.34	0.63
	Mid position		0.53	0.76			0.32*								1.61		0.64	0.54							0.44	0.83
	No shoulder belt		0.46*	0.51			0.39								2.31*		0.39*	0.18							2.65*	0.83
	No upper anchor		0.94	0.89			1.80								1.57		1.62	1.80							1.46	1.01
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**	0.65	0.44	0.35*	0.20*		0.30	0.19*		0.09*	0.22*			0.01*	0.52	0.21*	0.31	0.13*		0.15	0.17			0.07	0.36	0.18*
	Btw mid & rear	1.46	0.95	0.87	0.46		0.46	0.32		0.18	0.38			0.00*	0.59	0.28*	0.98	0.27		0.21	0.05			0.46	0.28	0.31
	Forward most	0.64	0.36	0.54	0.16		0.75	0.28		0.54	0.33			0.00	0.06*	0.29	0.18*	1.21		0.51	0.00*			0.12*	0.03*	0.37
	Middle	0.92	0.74	0.40	0.30		0.30	0.26*		0.11*	0.28*			0.02	0.51	0.40	0.33*	0.22		0.22	0.22			0.26	0.39	0.34
	Rear most	1.21	0.77	0.42	0.19*		0.28	0.21*		0.30	0.39			0.02	0.69	0.35	0.29*	0.13		0.23	0.05			0.43	0.82	0.37
Manner of Collision (*Not Collision*)	**Angle**														0.31*		0.66	0.11*			0.25				0.11*	
	Head-on														0.00		0.32	0.00			0.00*				0.00	
	Rear-end														0.87		0.12	0.00*			0.05				0.00	
	Sideswipe														0.34*		0.63	0.04*			0.05				0.05*	
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**			0.02*	0.05*			0.00*				0.00*					0.00*			0.00*			0.00*			
	Vehicle			0.01*	0.01*			0.00*				0.00*					0.00*			0.00*			0.00*			
Airbag Deployment (*No*)	**Yes**	1.88*	1.91*									0.33*	0.41	3.46*	4.10*	2.46*						1.40			4.60*	1.52
Intrusion (*No*)	**Yes**	3.03*	3.62*	6.87*	7.88*	1.36		3.04*	7.72*	5.09*	2.13*			5.81*		7.54*		7.26*	4.61*	9.99*		3.13*	4.95*			
Multiple-impact (*No*)	**Yes**	2.11*	2.64*	1.59		1.52	2.97*	1.82*			1.65*			0.74			1.92	2.34*	1.68		0.24			3.39*	1.96	1.47
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**	0.45*	0.27*	0.35*	0.19*		0.46	0.18*			0.50			0.01*	0.26*	0.42*	0.35	0.02*	0.29*		0.75	0.37*			0.20	
	LT-SUV	1.34	0.63	0.87	0.32*		0.73	1.22			0.82			1.25	0.63	0.86	0.57	0.38	1.04		0.06*	0.74			0.87	
	LT-Vans	0.84	0.52	0.56	0.20*		0.60	0.48			0.41			0.00*	0.50	0.88	0.18	0.39	0.42*		0.47	0.39*			0.19*	
	Other/Unknown LT	0.01*	0.02*	0.05*	0.06*		0.02*	0.54			0.70				0.00*		1.41	0.00*	1.04			2.39			0.00*	

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	**MAIS 3+**	**MAIS 4+**	**Fatal**	**Head 2+**	**Neck & C-spine 2+**	**Thorax 2+**	**Abdo-men 2+**	**Thoraco-lumbar Spine 2+**	**Torso 2+**	**KTH 2+**	**Leg 2+**	**Foot/Ankle 2+**	**Upr Ext 2+**	**Lwr Ext 2+**	**Head 3+**	**Neck & C-spine 3+**	**Thorax 3+**	**Abdo-men 3+**	**Thoraco-lumbar Spine 3+**	**Torso 3+**	**KTH 3+**	**Leg 3+**	**Upr Ext 3+**	**Lwr Ext 3+**
Vehicle Vintage (*< 2009*)	**2009+**				0.27*							0.02*	0.00*	0.04*				3.13					0.05*	0.04*	0.09*	
Weight Ratio (*≤1.0*)	**1.0 – 2.0**			0.85	0.92		0.28*	0.70	1.34		0.58*						1.40	0.41*	0.64	1.98	0.06*	0.60	1.13		2.77*	0.82
	> 2.0			0.09*	0.13*		2.31	0.00*	9.62*		0.60						0.00*	4.46	1.83	0.00*	0.00*	0.92	0.00*		0.29	1.61
Compatible Crash (*Yes*)	**No**								1.39					1.07							0.21		0.65		0.52*	
Delta V (kph)		1.10*	1.11*	1.11*	1.13*	1.04*	1.06*	1.06*	1.05*	1.07*	1.08*	1.07*	1.02	1.09*	1.04*	1.06*	1.07*	1.05*	1.07*	1.06*	1.08*	1.08*	1.04*	1.01	1.05*	1.07*
Vehicle Curb Weight (kg)									1.00*		1.00*		1.00*	1.00						1.00*						
Occupant Age (years)		1.03*	1.05*	1.05*	1.05*	1.02*	1.06*	1.04*	1.02	1.04*	1.04*	1.01		1.08*	1.03*	1.02*	1.05*	1.07*	1.02*	1.03*	1.02	1.04*	1.01*		1.02*	1.02*
Vehicle Age (years)		0.97*	0.97	0.94*	0.95*						0.96*	0.74*	0.58*	0.84*			0.92*				0.80		0.91*			
Goodness of model fit: c-statistic		***0.86***	***0.90***	***0.92***	***0.93***	***0.73***	***0.83***	***0.82***	***0.78***	***0.76***	***0.82***	***0.94***	***0.94***	***0.81***	***0.73***	***0.81***	***0.78***	***0.79***	***0.82***	***0.73***	***0.71***	***0.84***	***0.71***	***0.74***	***0.69***	***0.75***

*p-value ≤ 0.05

Table A-7. Logistic regression predictor variable ORs by injury outcome model for Far-side crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.20****	***1.45***	***1.22***	***0.49***	***0.77***	***0.58***	***0.43***	***0.76***	***2.70***	***0.78***	***3.52***	***0.29***	***7.16****	***2.43****	***2.28****	***2.17***	***1.81***	***0.35****	***0.38***	***2.52***	***0.47***	***0.18****	***1.26***	***6.44****	***0.27****
Alcohol/Drug Use (*No*)	**Yes**		3.69*	3.57*	3.16*			1.55			2.19*				0.98				2.45*			2.52*				
Avoidance Maneuver (*other/unknown*)	**Any maneuver**	0.23*	0.20*	0.13*	0.07*		0.08	0.17*	0.17*		0.37*	0.06*	0.38		0.20*	0.36	0.07*		0.26*	0.04*		0.34*			3.04	0.35
	None	0.48	0.20*	0.10*	0.02*		0.10*	0.12*	0.14*		0.32*	3.48	6.29		0.22*	3.08*	0.32*		0.36	0.16*		0.34			1.34	0.33*
Critical Event (ped/animal/other)	**Control loss**		0.24				0.13		0.15*								0.29			0.00*		0.22				
	Other vehicle in lane		0.26				0.01*		0.23								0.38			0.00*		0.08				
	Run off/turning		0.47				0.02*		0.10*								0.54			0.00*		0.22				
Pre-impact Movement (other/unknown)	**Avoidance maneuver**				0.00*	0.64									0.00*		0.00*	0.02								
	Change lanes/merge				0.12	0.04	0.00*								0.00*		0.68	0.00*								
	Decelerating				0.00*	0.18	0.00*								0.00*		0.00*	0.00*								
	Going straight				0.37	0.68	1.81								0.03*		0.20*	0.00*								
	Negotiating a curve				0.17*	0.51	0.63								0.03*		0.42	0.01*								
	Stopped				0.00*	0.48	0.00*								0.00*		6.92	0.00*								
	Turning				0.21	0.34	0.29								0.01*		0.11*	0.00								
Weather (*Normal*)	**Adverse**	0.35*				0.40	0.19*						2.22		0.95	0.27	0.21*							0.54		0.42
Lighting (*Daylight*)	**Dark**	3.53*			0.39			3.01*			2.68*										0.19*		0.93	3.76		
Rural/Urban (*Urban*)	**Rural**	2.33*						5.63*			3.42*								2.70	0.14*						
Ejection (*No*)	**Yes**																									
Entrapped (*No*)	**Yes**		7.58*			8.91*		9.81*		6.51*												5.91*			0.98	2.17
BMI (<*18.5*)	**18.5-25.0**	0.80	0.18*			0.32*		0.57							1.53			1.24				0.19*				0.05*
	25.0-30.0	0.96	0.22*			0.40		0.62							1.10			0.22				0.26				0.04*
	30+	2.49	0.26*			0.32		0.16							5.74			0.40				0.25				0.07*
Belt Anchor (*Full Down*)	**Full up**	1.68	0.73		0.51	0.68		0.53	0.54							5.44*		0.11	0.56	0.61		0.54				
	Mid position	1.30	0.45		0.09*	3.66*		0.52	0.27							0.28		0.00	0.32	0.00		0.27				
	No shoulder belt	6.09*	0.24*		0.69	1.05		3.47*	0.54							0.67		0.00	0.10*	1.15		0.10*				
	No upper anchor	0.75	1.21		0.47	1.14		0.52	1.05							0.51		0.13	0.45	3.18		0.56				
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**						0.02*					0.17			0.23	0.13	0.12	0.00		0.05						0.33
	Btw mid & rear						0.01*					0.34			0.60	0.08*	0.17	0.03		0.06						0.13
	Forward most						0.03					0.24			0.51	0.12	0.04	0.00		1.92						0.19
	Middle						0.10					2.82			1.03	0.21	0.86	0.30		0.10						0.83
	Rear most						0.05*					0.39			0.92	0.03*	0.39	0.04		0.03*						0.11*

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Manner of Collision (*Not Collision*)	**Angle**		0.21*		0.10*	0.77					1.00	0.01*				0.05*		0.01*	0.07*			0.27				
	Head-on		0.07		0.00	0.10					0.07	0.19				0.01		0.00	0.00			0.00				
	Rear-end		0.22		0.00*	0.94					0.11	0.38				0.03*		0.00*	0.16			0.35				
	Sideswipe		1.71		0.50	1.46					6.82*	0.04				0.22		0.46	0.92			2.14				
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**																									
	Vehicle																									
Airbag Deployment (*No*)	**Yes**	1.53*	1.63		0.37*	0.48*						0.17		0.84	1.12					4.00						3.32*
Intrusion (*No*)	**Yes**	3.86*			6.26*			5.04*	6.02*		8.08*			0.56		4.76*					0.00*					
Multiple-impact (*No*)	**Yes**	2.23*																								
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**					1.50	6.15	0.25		3.26							1.16			0.00*						
	LT-SUV					2.21	8.26*	0.97		3.93*							0.94			1.78						
	LT-Vans					0.07*	0.00*	2.93*		1.47							0.02*			0.00*						
	Other/Unknown LT					0.21	0.00*	1.09												0.00*						
Vehicle Vintage (< *2009*)	**2009+**	2.72*				2.43						0.03*		0.46	3.78*						2.05				0.24	
Weight Ratio (≤*1.0*)	**1.0 – 2.0**														2.24						1.21				3.76	
	> 2.0														0.00*						0.00*				0.00*	
Compatible Crash (*Yes*)	**No**				2.08																					1.88
Delta V (kph)		1.08*	1.13*	1.13*	1.15*	1.04*	1.14*	1.08*	1.08*	1.12*	1.09*	1.02	1.12	1.13*	1.03	1.06*	1.09*		1.12*	1.12*	1.04	1.11*	1.08*	1.03	1.10*	1.08*
Vehicle Curb Weight (kg)					1.00*														1.00	1.00*				1.00		
Occupant Age (years)		1.02*	1.07*	1.06*	1.06*	1.01	1.08*	1.06*	1.04*	1.04	1.06*	0.98	1.07*	1.05*	1.02*	1.03*	1.03*	1.01	1.09*	1.08*	1.06*	1.09*	1.07*	1.10*	1.03*	1.06*
Vehicle Age (years)		1.07*							1.17*		1.06*	0.73*		0.99		1.09			1.05			1.06*		1.00		1.10
Goodness of model fit: c-statistic		**0.78**	**0.90**	**0.93**	**0.96**	**0.72**	**0.88**	**0.84**	**0.82**	**0.80**	**0.82**	**0.80**	**0.81**	**0.70**	**0.68**	**0.69**	**0.82**	**0.70**	**0.85**	**0.88**	**0.76**	**0.86**	**0.76**	**0.75**	**0.77**	**0.80**

*p-value ≤ 0.05

Table A-8. Logistic regression predictor variable ORs by injury outcome model for Far-side crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																								
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.68****	***1.02***	***0.88***	***0.43****	***0.75***	***0.71***	***0.70***	***0.78***	***2.00***	***1.28***	***2.76***	***0.07***	***6.18****	***1.45***	***2.70****	***1.69***	***2.53***	***0.39****	***0.34***	***4.40***	***0.50***	***0.19****	***1.34***	***10.2****	***0.31****
Ejection (*No*)	**Yes**																									
Entrapped (*No*)	**Yes**	6.79*	8.71*		3.80*	7.78*					6.30*						8.92*					8.50*				3.50
BMI (*<18.5*)	**18.5-25.0**		0.20*			0.39*		0.29*			0.79		0.00						0.23*							0.05*
	25.0-30.0		0.26*			0.48		0.36			0.92		0.00*						0.30*							0.03*
	30+		0.32			0.35		0.05*			0.34		0.00*						0.18*							0.07*
Belt Anchor (*Full Down*)	**Full up**	2.23	0.88		0.56	0.72	0.28	0.48							0.56	7.83		0.22	0.65		3.16	0.60				
	Mid position	1.24	0.39		0.11	3.35*	0.13	0.28*							0.15	0.33		0.00	0.31		0.00*	0.21				
	No shoulder belt	6.08*	0.20*		0.33	0.75	0.20	1.12								0.75		0.00*	0.14*		0.00*	0.12*				
	No upper anchor	0.92	1.06		0.48	1.04	0.38	0.36*							0.47	0.77		0.11	0.43		1.95	0.60				
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**		0.55	0.40			0.07						0.00			0.12*	0.09*	0.04		0.05*						0.59
	Btw mid & rear		0.32	0.22*			0.02*						0.01			0.11*	0.21	0.05		0.09						0.17
	Forward most		0.27	0.31			0.07						0.00			0.23	0.03*	0.00		0.25						0.18
	Middle		1.28	0.81			0.21						0.01			0.50	0.60	0.92		0.13						1.00
	Rear most		0.32	0.49			0.13						0.05			0.06*	0.35	0.29		0.07						0.16
Manner of Collision (*Not Collision*)	**Angle**		0.14*		0.09*	0.72	0.11	0.11*			0.55					0.12	0.39	0.01*	0.06*	0.40		0.20*			0.21	
	Head-on		0.15		0.00	0.07	0.00	0.02			0.14					0.01	0.20	0.00	0.00	2.22		0.00			0.00	
	Rear-end		0.04*		0.00*	0.52	0.00*	0.29			0.27					0.09	0.00*	0.00*	0.27	0.00		0.25			0.00*	
	Sideswipe		1.24		0.76	1.72	0.61	4.43			6.65*					0.19	1.23	0.23	1.10	0.37		2.13			0.90	
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**																									
	Vehicle																									
Airbag Deployment (*No*)	**Yes**				0.34*	0.43*									2.69*					5.72*						2.75*
Intrusion (*No*)	**Yes**	3.85*			5.27*											3.35										
Multiple-impact (*No*)	**Yes**	3.10*		2.12											1.26						0.27			1.69		0.53
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**					1.33	3.05			4.35				4.72	3.74		0.97			0.00*						
	LT-SUV					2.17	4.40*			5.19*				0.31	1.06		0.80			2.47						
	LT-Vans					0.13*	0.00*			1.15				0.09	1.52		0.01*			0.00*						
	Other/Unknown LT					0.18	0.00*								0.00*		3.14			0.00						
Vehicle Vintage (*< 2009*)	**2009+**	4.62*		0.20*	0.49*	3.73*						0.58														

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	**MAIS 3+**	**MAIS 4+**	**Fatal**	**Head 2+**	**Neck & C-spine 2+**	**Thorax 2+**	**Abdo-men 2+**	**Thoraco-lumbar Spine 2+**	**Torso 2+**	**KTH 2+**	**Leg 2+**	**Foot/Ankle 2+**	**Upr Ext 2+**	**Lwr Ext 2+**	**Head 3+**	**Neck & C-spine 3+**	**Thorax 3+**	**Abdo-men 3+**	**Thoraco-lumbar Spine 3+**	**Torso 3+**	**KTH 3+**	**Leg 3+**	**Upr Ext 3+**	**Lwr Ext 3+**
Weight Ratio (≤*1.0*)	**1.0 – 2.0**			0.44	0.48										1.81						1.77	0.62			8.25	
	> 2.0			0.00	0.00*										0.00*						0.00*	0.00*			0.00*	
Compatible Crash (*Yes*)	**No**				1.31	1.59				0.23*														0.42		
Delta V (kph)		1.07*	1.14*	1.14*	1.15*	1.04*	1.15*	1.10*	1.10*	1.14*	1.08*	0.98	1.15	1.12*	1.04*	1.06*	1.07*	1.12*	1.12*	1.09*	1.08*	1.12*	1.09*	1.04	1.11*	1.09*
Vehicle Curb Weight (kg)			1.00*		1.00*								0.99	1.00		1.00				1.00				1.00	1.00		
Occupant Age (years)		1.01	1.08*	1.07*	1.05*	1.01	1.06*	1.08*	1.03*	1.04	1.06*	0.97*	1.19	1.05*	1.02	1.01	1.03*	1.03	1.09*	1.05*	1.13*	1.09*	1.07*	1.09*	1.02*	1.05*
Vehicle Age (years)		1.10*	1.03			1.04		1.04	1.20*		1.07*	0.81*	0.65	1.00	1.05				1.06*	1.26*		1.06*		0.95		
Goodness of model fit: c-statistic		***0.76***	***0.87***	***0.90***	***0.94***	***0.73***	***0.85***	***0.83***	***0.78***	***0.77***	***0.81***	***0.46***	***0.93***	***0.70***	***0.67***	***0.66***	***0.84***	***0.77***	***0.84***	***0.83***	***0.74***	***0.86***	***0.76***	***0.77***	***0.75***	***0.78***

*p-value ≤ 0.05

Table A-9. Logistic regression predictor variable ORs by injury outcome model for Rear crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																								
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***0.99***	***0.46***	***1.04***	***0.61***	***1.23***	***0.66***	***0.42***	***0.42***	***0.63***	***0.51***	***3.20***	***6.18***	***2.93***	***1.25***	***0.88***	***0.63***	***0.08****	***0.10****	***0.02****	***0.33***	***0.27****	***4.84***	***1,00***	***0.00****	***7.18****
Alcohol/Drug Use (*No*)	**Yes**			5.43*		2.24	2.61					1.45								0.03	1.39			1.00		
Avoidance Maneuver (*other/unknown*)	**Any maneuver**	0.31	0.19*		0.06*	0.73	0.25	0.14	0.00*		0.73								0.50			0.35		0.99		
	None	0.32*	0.14*		0.13*	1.52	0.04*	0.13*	0.10*		0.14*								0.05*			0.11*		0.99		
Critical Event (ped/animal/other)	**Control loss**																1.54									
	Other vehicle in lane																0.01*									
	Run off/turning																0.05									
Pre-impact Movement (other/unknown)	**Avoidance maneuver**					3.34																				
	Change lanes/merge					3.99																				
	Decelerating					0.90																				
	Going straight					0.64																				
	Negotiating a curve					1.30																				
	Stopped					0.44																				
	Turning					1.93																				
Weather (*Normal*)	**Adverse**		4.11*			0.65	0.23			3.86					0.22		1.14							0.99	0.06*	
Lighting (*Daylight*)	**Dark**			0.17*		0.38*	1.50			1.54	1.45					1.66	0.55			0.97				0.99	0.33	0.09*
Rural/Urban (*Urban*)	**Rural**			0.94			3.72*		0.32			0.73			0.62				1.58				0.41	0.99		0.03
Seat Belt Use (*Belted*)	**Unbelted**	1.73	4.66*			1.41	3.98				2.65	6.72	0.44	3.83					1.45			6.03*		1.00		
Ejection (*No*)	**Yes**		5.68*			1.36																		0.99		
Entrapped (*No*)	**Yes**	7.79*			3.25				0.57									0.00*	0.53							
BMI (<*18.5*)	**18.5-25.0**						0.33								0.29									0.99		
	25.0-30.0						0.23								0.66									0.99		
	30+						0.30								0.36									0.99		
Belt Anchor (*Full Down*)	**Full up**		2.49	1.91																						
	Mid position		0.89	0.88																						
	No shoulder belt		1.66	4.09																						
	No upper anchor		7.23*	6.49																						

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																								
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**					0.21	1.93																	1.00		
	Btw mid & rear					0.37	5.73																	1.00		
	Forward most					0.30	1.85																	0.99		
	Middle					0.49	6.99																	1.00		
	Rear most					1.05	7.66																	0.99		
Manner of Collision (*Not Collision*)	**Angle**				0.14	2.03		0.09*			0.27															
	Head-on				0.00*	1.19		0.00*			0.00*															
	Rear-end				0.28	0.60		0.18			0.75															
	Sideswipe				0.24	0.27		6.46			5.59															
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**		0.04*	0.27													0.00*									
	Vehicle		0.39	0.28													0.03									
Airbag Deployment (*No*)	**Yes**	3.05*	5.56*			3.27*			0.01			0.01*										9.18*		0.99		
Intrusion (*No*)	**Yes**					1.61																		1.00		3.03
Multiple-impact (*No*)	**Yes**	1.98*	2.23				3.01							1.42		0.31*							0.06	1.00		0.21
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**					1.14	0.87										0.43	0.36				0.15				
	LT-SUV					0.60	0.14										0.20*	0.00*				0.09*				
	LT-Vans					0.21*	0.14*										0.43	0.19				0.07*				
	Other/Unknown LT					0.13	0.00*										1.79	0.00*				3.15				
Vehicle Vintage (< *2009*)	**2009+**				0.10*		0.15*					0.00*												0.99	0.00*	0.00*
Weight Ratio (≤*1.0*)	**1.0 – 2.0**		0.21*	0.29							2.59					0.85	0.61	2.88								
	> 2.0		0.00*	0.00*							0.00*					0.00*	0.00*	0.00*								
Compatible Crash (*Yes*)	**No**	2.02*					1.16		4.41			0.47							0.84					0.99		0.21
Delta V (kph)		1.06*	1.08*	1.12*	1.08*	1.05*	1.07*	1.05	1.15*	1.08*	1.08*	1.04	1.06	0.99	1.11*	1.03	1.07*	1.11*	1.05	1.17*	1.09*	1.09*	1.02	1.00	0.95	1.08*
Vehicle Curb Weight (kg)				1.00		1.00*	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00		1.00		0.99*				1.00	1.00	1.00	1.00
Occupant Age (years)		1.03*	1.03	1.04	1.10*	1.08*	1.08*	1.01	0.86*	1.04	1.02	1.02	1.05	0.99	1.04*	1.02*	1.03*	1.05*	1.04	0.87*	1.05*	1.03	0.99	1.00	1.03	0.96
Vehicle Age (years)							0.91	1.03	1.49*	1.10		0.68	1.20*	1.23		1.13*	0.91		0.92	2.03		1.11	1.13	1.00	0.94	0.98
Goodness of model fit: c-statistic		***0.79***	***0.86***	***0.86***	***0.75***	***0.71***	***0.83***	***0.83***	***0.87***	***0.83***	***0.84***	***0.96***	***0.54***	***0.65***	***0.82***	***0.59***	***0.78***	***0.81***	***0.78***	***0.73***	***0.81***	***0.86***	***0.73***	***1.00***	***0.72***	***0.86***

*p-value ≤ 0.05

Table A-10. Logistic regression predictor variable ORs by injury outcome model for Rear crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***1.00***	***0.49***	***0.88***	***0.42***	***1.09***	***0.38****	***0.32***	***0.26****	***0.57***	***0.58***	***0.26***	***9.27***	***2.40***	***1.08***	***0.78***	***0.65***	***0.06****	***0.10****	***0.94***	***0.27***	***0.22****	***6.89***	***1.00***	***0.01****	***10.3****
Seat Belt Use (*Belted*)	**Unbelted**		3.15			1.47				1.58	1.17			2.94			9.04*					3.16		1.00		0.36
Ejection (*No*)	**Yes**		5.53			0.46		0.68								5.72				0.00*				0.99		
Entrapped (*No*)	**Yes**	5.86			2.60	1.48										9.29*		0.00*				1.12				
BMI (*<18.5*)	**18.5-25.0**																	0.34						1.00		
	25.0-30.0																	0.25						1.00		
	30+																	0.07*						0.99		
Belt Anchor (*Full Down*)	**Full up**		1.99	1.64	2.34		0.47	1.40				0.45							0.66		1.71					
	Mid position		0.84	1.01	0.85		0.30	1.97				0.22							1.16		0.17					
	No shoulder belt		1.90	3.97	0.14		0.72	0.45				2.88							0.21		0.00*					
	No upper anchor		7.17*	5.08	0.72		0.59	2.00				3.71							2.38		0.07*					
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**																							1.00		
	Btw mid & rear																							1.00		
	Forward most																							1.00		
	Middle																							1.00		
	Rear most																							0.99		
Manner of Collision (*Not Collision*)	**Angle**		0.13		0.08						0.08				0.00*										0.00*	
	Head-on		1.89		0.00*						0.00*				0.00*										0.00*	
	Rear-end		1.65		0.08*						0.37				0.09*										0.02*	
	Sideswipe		2.04		0.04						8.98				0.01*										0.00*	
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**			0.40																						
	Vehicle			0.87																						
Airbag Deployment (*No*)	**Yes**	3.28*	4.17*	4.17*		2.71			0.04	6.55*						1.57				0.22				1.00		0.46
Intrusion (*No*)	**Yes**					1.23		2.55			0.28		2.11									0.30	5.28	1.00		
Multiple-impact (*No*)	**Yes**	2.03*	3.09			1.22					2.72*	0.14*	0.91		2.53*	0.22*			7.10*	0.25			0.12*	1.00		
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**					0.68									0.00*		0.44	0.17								
	LT-SUV					0.41									0.76		0.15*	0.00*								
	LT-Vans					0.27*									0.22		0.15	0.15								
	Other/Unknown LT					0.16									2.77		0.68	0.00*								

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	**MAIS 3+**	**MAIS 4+**	**Fatal**	**Head 2+**	**Neck & C-spine 2+**	**Thorax 2+**	**Abdo-men 2+**	**Thoraco-lumbar Spine 2+**	**Torso 2+**	**KTH 2+**	**Leg 2+**	**Foot/Ankle 2+**	**Upr Ext 2+**	**Lwr Ext 2+**	**Head 3+**	**Neck & C-spine 3+**	**Thorax 3+**	**Abdo-men 3+**	**Thoraco-lumbar Spine 3+**	**Torso 3+**	**KTH 3+**	**Leg 3+**	**Upr Ext 3+**	**Lwr Ext 3+**
Vehicle Vintage (< *2009*)	**2009+**				0.06*		0.32									0.22*						2.89		0.99	0.00*	0.00*
Weight Ratio (≤*1.0*)	**1.0 – 2.0**		0.33	0.47					1.27		2.47*							3.44				0.43				
	> 2.0		0.00*	0.00*					0.01*		0.00*							0.00*				0.02				
Compatible Crash (*Yes*)	**No**	2.08*				2.06		2.04	3.30	1.24	1.85		2.11	5.87		1.30						3.35	0.26	0.99		
Delta V (kph)		1.06*	1.08*	1.11*	1.09*	1.04*	1.09*	1.05	1.14*	1.08*	1.08*	1.01	1.06	1.02	1.10*	1.02	1.08*	1.12*	1.06*	1.08*	1.09*	1.07*	1.01	1.00	0.93	1.07
Vehicle Curb Weight (kg)						1.00*		1.00	1.00*	0.99	1.00	0.99*	0.99	1.00			1.00*		0.99*	0.99*	1.00	0.99*	0.99	1.00	1.00	0.99
Occupant Age (years)		1.02*	1.04*	1.04	1.11*	1.01	1.05*	1.02	1.01*	1.05*	1.03	0.99	1.06	0.98	1.06*	1.00	1.09*	1.06*	1.04	0.82	1.04	1.05*	0.97	1.00	1.03	0.94
Vehicle Age (years)		1.07*				0.98		1.09	1.63*	1.11	1.11	1.11	1.18	1.19		1.07	0.84*	1.01		2.13	1.52*	1.20*	1.08	0.99		1.06
Goodness of model fit: c-statistic		***0.78***	***0.85***	***0.86***	***0.74***	***0.68***	***0.81***	***0.80***	***0.83***	***0.89***	***0.79***	***0.72***	***0.56***	***0.67***	***0.76***	***0.64***	***0.85***	***0.80***	***0.79***	***0.76***	***0.82***	***0.80***	***0.76***	***1.00***	***0.69***	***0.75***

*p-value ≤ 0.05

Table A-11. Logistic regression predictor variable ORs by injury outcome model for Rollover crashes (Full Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.23****	***1.37***	***1.29***	***1.22***	***1.13***	***0.38***	***0.71***	***1.31***	***1.07***	***1.66***	***0.45***	***1.23***	***3.82***	***1.26***	***1.34***	***0.82***	***0.31****	***0.84***	***1.19***	***0.85***	***1.21***	***0.53***	***2.19***	***0.75***	***1.10***
Alcohol/Drug Use (*No*)	**Yes**	2.28*	4.36*	4.76*				3.38*	4.02*		3.12*	3.64		0.19	2.15	1.67	5.25*					4.23*		0.46		
Avoidance Maneuver (*other/unknown*)	**Any maneuver**	0.49*	0.21*	0.25*	0.20*		0.09*			0.28	0.47*						0.48	0.26*		0.14*		0.25*	0.17*		0.57	0.54
	None	0.90	0.54	0.57*	0.28*		0.21*			2.08	1.12						0.26*	0.29		1.18		1.15	0.43		0.25*	0.36*
Critical Event (ped/animal/other)	**Control loss**		0.21*	2.85						1.10	0.32					0.19									0.08*	
	Other vehicle in lane		0.09*	0.82						0.05*	0.13					0.55									0.02*	
	Run off/turning		0.12*	0.96						0.13	0.19					0.53									0.05*	
Pre-impact Movement (other/unknown)	**Avoidance maneuver**		0.71	0.00*	0.00*		1.42																			
	Change lanes/merge		3.55	0.04*	0.46		0.96										0.00*									
	Decelerating		2.25	0.66	0.00*		0.00*										1.81									
	Going straight		0.44	1.44	2.34		0.10*										2.59									
	Negotiating a curve		0.42	1.41	1.92		0.02*										1.74									
	Stopped		0.02*	0.26	0.21		0.01*										2.29									
	Turning		0.27	0.68	0.88		0.08*										5.21									
Weather (*Normal*)	**Adverse**				0.66					2.89	2.24*			0.86	0.63		4.27*						0.46			1.03
Lighting (*Daylight*)	**Dark**							2.51*			2.76*			3.61	1.16				4.74*			3.07*	3.50*			
Rural/Urban (*Urban*)	**Rural**		3.35*	2.28*							2.59*	0.52	3.43	2.54				3.56*	1.78			1.82			1.93	
Seat Belt Use (*Belted*)	**Unbelted**	4.94*	4.21*	6.85*	6.53*	3.01*		4.07*	6.21*		2.60*		0.56	0.46	2.54*	0.79			5.42*	4.75*		3.40*				1.60
Ejection (*No*)	**Yes**					3.07*	4.47*	6.18*		3.90*	2.53*								6.76*	5.35*		4.28*				3.71*
Entrapped (*No*)	**Yes**				2.24	2.54*		1.25			1.22			0.58	1.73							1.31			2.20*	2.62*
BMI (*<18.5*)	**18.5-25.0**			3.17		0.22*	0.02*	0.39	1.03		0.36					0.22*			0.61			0.31*			0.24*	0.44
	25.0-30.0			3.00		0.08*	0.02*	0.42	0.72		0.58					0.18*			0.63			0.56			0.69	0.66
	30+			1.55		0.11*	0.01*	0.21	0.84		0.65					0.14*			0.49			0.44			0.47	0.26*
Belt Anchor (*Full Down*)	**Full up**	1.21	0.22*	0.25*			0.19*	0.19*											0.13*			0.27			0.31*	
	Mid position	1.54	0.54	0.39			1.31	1.24											0.17*			0.44			1.67	
	No shoulder belt	0.37*	0.64	0.27*			0.09*	0.23											0.28			0.20			4.31*	
	No upper anchor	1.16	0.45*	0.50			0.08*	0.28											0.17			0.23*			2.59*	

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes																							
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**		0.44	0.34				0.17		0.13						0.18			0.15*	0.05		0.37				
	Btw mid & rear		0.60	0.58				0.13		0.10*						0.89			0.30	0.59		0.54				
	Forward most		0.41	0.28				0.18		0.21*						0.39			0.38	0.71		0.33				
	Middle		0.69	0.73				0.50		0.40						0.41			0.79	0.75		1.45				
	Rear most		0.74	0.56				0.48		0.30						0.65			1.43	0.31		0.99				
Manner of Collision (*Not Collision*)	**Angle**	0.64	0.67	2.68	0.92		0.06*		1.09						0.82		2.18		1.04							0.61
	Head-on	1.24	2.24	1.18	0.47		0.56		0.17						1.08		4.92*		1.04							1.65
	Rear-end	0.31	0.17*	0.77	0.66		0.02*		0.37						0.40		0.58		1.03							0.38
	Sideswipe	1.69	1.06	2.04	1.58		0.85		1.07						1.98		0.79		3.38							1.43
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**																			0.07						
	Vehicle																			0.04						
Airbag Deployment (*No*)	**Yes**	2.01	1.67*	1.59				1.98		6.47*		0.23*			2.09*	2.34*	1.34	1.89	2.28*					0.13*	3.12*	
Intrusion (*No*)	**Yes**	1.93*		2.05*	3.48*										1.98	4.33*							2.54		3.43*	4.24*
Multiple-impact (*No*)	**Yes**		0.14*	0.13*	0.14*		0.00*											0.16*	0.04*							0.11
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**			0.46		0.54	0.98		0.25							0.37*	0.36*									0.25*
	LT-SUV			0.32		0.44*	0.83		0.28*							0.70	0.73									0.36*
	LT-Vans			0.24*		0.23*	0.11*		0.52							1.11	0.23*									0.65
	Other/Unknown LT			0.00*		0.00*	0.00*		0.00*							0.00*	0.00*									0.00*
Vehicle Vintage (< *2009*)	**2009+**							2.59*	0.20*			0.00*		0.14*	0.23*								0.04*			
Weight Ratio (≤*1.0*)	**1.0 – 2.0**					1.66		1.93	8.04*					5.07*					0.88	4.88		0.85				
	> 2.0					0.15*		0.00*	0.00*					0.00*					0.01*	0.00*		0.01*				
Compatible Crash (*Yes*)	**No**		0.68	2.30*						0.44		1.06		0.48	1.42						2.10					
Delta V (kph)		1.06*	1.07*	1.05*	1.05*	1.02*	1.06*	1.07*	1.02	1.02	1.06*	1.02	1.02	1.10*	1.03*	1.06*	1.02	1.00	1.05*	1.03	0.99	1.05*	1.01	1.03	1.00	1.03*
Vehicle Curb Weight (kg)										1.00*	1.00	1.00*	1.00*	0.99*										0.99*		
Occupant Age (years)		1.03*	1.05*	1.03*	1.02	1.01	1.07*	1.05*	1.00	1.03	1.03*	1.00	0.98	0.97	1.02*	1.01	1.00	1.01	1.04*	1.00	1.01	1.04*	0.98	0.98	1.01	1.01
Vehicle Age (years)		1.05*					1.12*	1.06	1.07	1.04	1.04	0.74*	1.05	1.01		1.10*	1.02				1.05	1.02	0.88*	0.95		
Goodness of model fit: c-statistic		***0.77***	***0.79***	***0.81***	***0.86***	***0.64***	***0.80***	***0.77***	***0.72***	***0.70***	***0.74***	***0.92***	***0.70***	***0.74***	***0.67***	***0.74***	***0.73***	***0.62***	***0.72***	***0.75***	***0.62***	***0.75***	***0.79***	***0.72***	***0.63***	***0.79***

*p-value ≤ 0.05

Table A-12. Logistic regression predictor variable ORs by injury outcome model for Rollover crashes (CW Models)

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes															Odds Ratios of Various Injury Severity Outcomes									
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Sex (Male)	***Female***	***2.38****	***1.66***	***1.37***	***1.02***	***1.13***	***0.36***	***0.75***	***1.19***	***1.14***	***1.71***	***0.69***	***1.19***	***2.87***	***1.18***	***1.31***	***0.99***	***0.28****	***0.85***	***1.59***	***0.58***	***1.42***	***0.50***	***0.23***	***0.89***	***0.93***
Seat Belt Use (*Belted*)	**Unbelted**	6.09*	4.79*		5.81*	3.01*		5.79*	9.20*	4.09*	4.78*	3.12	0.10	0.18	1.88*		3.14*	7.03*	6.44*			5.76*	2.18			
Ejection (*No*)	**Yes**					3.07*		7.03*			4.34*			5.93		2.70			5.42*			3.46		0.30		4.61*
Entrapped (*No*)	**Yes**	2.04*	2.28¥	1.95*	2.15	2.54*					1.66				1.90			3.78*		2.85		1.80		0.30	1.95	2.68*
BMI (*<18.5*)	**18.5-25.0**			3.69*		0.22*	0.11*	0.55			0.37					0.15*					0.05*	0.40			0.31	0.34*
	25.0-30.0			3.65		0.08*	0.06*	0.53			0.49					0.13*					0.10*	0.48			0.72	0.42
	30+			2.00		0.11*	0.05*	0.26			0.49					0.13*					0.02*	0.38			0.55	0.19*
Belt Anchor (*Full Down*)	**Full up**	1.34	0.23*	0.24*			0.19*	0.17*	6.52*						0.70				0.16*						0.29*	0.32
	Mid position	1.64	0.33	0.19*			0.91	0.92	2.31						1.77				0.15*						1.59	1.00
	No shoulder belt	0.38	0.49	0.21*			0.91	0.41	1.09						0.83				0.39						3.58	1.11
	No upper anchor	1.45	0.47*	0.49			0.14*	0.35	2.82						1.16				0.20						3.37*	0.86
Seat Track Position (*Not adjustable*)	**Btw fwd & mid**		0.35*	0.31			0.40	0.26		0.13						0.19*			0.16*	0.03*						
	Btw mid & rear		0.47	0.54			0.60	0.22		0.12						0.95			0.27	0.69						
	Forward most		0.28*	0.15*			0.01*	0.35		0.16*						0.61			0.44	0.69						
	Middle		0.59	0.56			0.79	0.96		0.79						0.41			1.03	1.00						
	Rear most		1.07	0.68			0.30	1.02		0.39						0.68			1.72	0.54						
Manner of Collision (*Not Collision*)	**Angle**		0.32*	1.28	1.49		0.19*	0.60	1.20							1.04	2.26		0.72	0.10*		0.97				0.49
	Head-on		1.30	0.62	0.83		0.87	0.90	0.20							5.75*	3.74*		0.75	0.01*		1.00				2.14
	Rear-end		0.13*	0.31*	0.63		0.07*	0.53	0.30							1.22	0.68		0.84	0.32		1.10				0.38
	Sideswipe		1.02	0.51	1.59		1.29	1.54	0.89							1.04	0.30		2.61	0.33		5.72*				1.14
Object Contacted (*non-fixed/other/unk*)	**Fixed Obj**																			0.15						
	Vehicle																			1.33						
Airbag Deployment (*No*)	**Yes**		2.41*	2.09*			2.60	2.57		5.54*	2.20*	0.27	0.21		2.38*	2.42*	2.27	1.66	2.62*			2.09	0.38		3.19*	
Intrusion (*No*)	**Yes**	2.16*	2.03*	2.35*	3.00*					2.30*		4.05			2.02*	3.52*							2.65		4.01*	3.14*
Multiple-impact (*No*)	**Yes**			0.27*	0.27*									0.00*					0.06	0.05*						
Vehicle Body Type (*Passenger cars*)	**LT-Pickups**			0.48	0.34	0.54	1.32		0.25	0.42					1.50	0.29*	0.27*	1.34		1.68	1.21		0.20*			0.14*
	LT-SUV			0.33	0.29*	0.44*	0.76		0.28*	0.30					1.35	0.50	0.55	2.58		2.25	0.07*		0.27*			0.27*
	LT-Vans			0.21*	0.30	0.23*	0.38		0.36	0.35					0.49	0.98	0.10*	3.30		0.26	0.00*		0.25			0.41
	Other/Unknown LT			0.00*	0.00*	0.00*	0.04*		0.00*						0.00*	0.00*	0.00*	0.12*		0.01*			0.57			0.00*

Predictor Variable (*reference level*)	Levels	Odds Ratios of Various Injury Severity Outcomes															Odds Ratios of Various Injury Severity Outcomes									
		MAIS 2+	MAIS 3+	MAIS 4+	Fatal	Head 2+	Neck & C-spine 2+	Thorax 2+	Abdo-men 2+	Thoraco-lumbar Spine 2+	Torso 2+	KTH 2+	Leg 2+	Foot/Ankle 2+	Upr Ext 2+	Lwr Ext 2+	Head 3+	Neck & C-spine 3+	Thorax 3+	Abdo-men 3+	Thoraco-lumbar Spine 3+	Torso 3+	KTH 3+	Leg 3+	Upr Ext 3+	Lwr Ext 3+
Vehicle Vintage (< *2009*)	**2009+**			0.29*				2.73*	0.19*		0.51*	0.00*	0.01*	0.10	0.29*		0.15*						0.03*	0.00*		
Weight Ratio (≤*1.0*)	**1.0 – 2.0**	0.87				1.66	0.39	1.65	5.40*					4.16	0.60			0.12*	0.80	2.22	0.20	0.79			0.29*	
	> 2.0	0.30				0.15*	0.42	0.01*	0.00*					0.00*	0.00*			2.97	0.01*	0.00*	0.00*	0.02*			0.00*	
Compatible Crash (*Yes*)	**No**		0.60*	2.05	2.20					0.50			1.57	0.27*	1.34			1.22			2.39			0.80		
Delta V (kph)		1.07*	1.06*	1.07*	1.06*	1.02*	1.05*	1.07*	1.03	1.03	1.05*	1.02*	1.01	1.10*	1.04*	1.05*	1.04*	1.00	1.05*	1.03	0.97	1.05*	1.02*	1.01	1.01	1.03*
Vehicle Curb Weight (kg)										1.00*	1.00	1.00*	0.99*	0.99			1.00				1.00*			0.99		
Occupant Age (years)		1.03*	1.05*	1.03*	1.02	1.01	1.03	1.04*		1.03*	1.03*	1.01	0.97	0.95*	1.02*	1.01	1.01	1.01	1.03*	1.00	1.01	1.04*	1.00	1.00	1.01	1.02*
Vehicle Age (years)		1.05	1.08*				1.11*	1.08*	1.06*	1.07	1.03	0.73*	0.83*			1.11*	1.00		1.05	1.05	1.06*	1.05	0.88*	0.87		1.07
Goodness of model fit: c-statistic		***0.76***	***0.76***	***0.78***	***0.80***	***0.64***	***0.67***	***0.75***	***0.71***	***0.70***	***0.74***	***0.92***	***0.89***	***0.74***	***0.75***	***0.75***	***0.71***	***0.72***	***0.71***	***0.74***	***0.73***	***0.73***	***0.80***	***0.89***	***0.66***	***0.76***

*p-value ≤ 0.05

Table A-13. Predictor variable inclusion percentage by model type

		% of Modeles with Listed Predictor Variable													
		Full Models							Crashworthiness Models						
	Predictor Variable	*All Models*	All Crashes	Frontal	Near-side	Far-side	Rear	Roll	*All Models*	All Crashes	Frontal	Near-side	Far-side	Rear	Roll
Pre-Crash / Environment	Alcohol/Drug Involvement	50%	76%	52%	60%	32%	28%	52%							
	Light Conditions	29%	16%	32%	28%	28%	44%	28%							
	Adverse Weather	23%	20%	16%	0%	36%	32%	32%							
	Pre-impact Movement	31%	40%	52%	48%	24%	4%	20%							
	Avoidance Maneuver	60%	80%	44%	64%	72%	44%	56%							
	Pre-crash Critical Event	24%	32%	28%	32%	24%	4%	24%							
	Rural vs. Urban Crash Location	27%	28%	20%	16%	20%	36%	40%							
Crashworthiness	Occupant Sex	100%	100%	100%	100%	100%	100%	100%	*100%*	100%	100%	100%	100%	100%	100%
	Occupant Seat Belt Use	57%	92%		28%		44%	64%	*59%*	92%		40%		36%	68%
	Occupan BMI	37%	52%	40%	44%	32%	12%	44%	*34%*	52%	48%	28%	28%	8%	40%
	Occupant Age	97%	92%	92%	96%	100%	100%	100%	*95%*	92%	92%	92%	100%	100%	96%
	Occupant Seat Position	48%	48%						*44%*	44%					
	Seat Track Position	27%	12%	4%	72%	32%	12%	32%	*26%*	8%	4%	72%	36%	4%	32%
	Shoulder Belt Anchor	33%	36%	56%	24%	44%	8%	32%	*42%*	40%	60%	32%	48%	32%	40%
	Occupant Entrapment	54%	84%	76%	80%	28%	20%	36%	*57%*	84%	76%	76%	32%	24%	52%
	Crash Type	72%	72%						*68%*	68%					
	Manner of Collision	41%	60%	76%	20%	36%	16%	40%	*49%*	80%	76%	20%	52%	20%	48%
	Delta V	99%	100%	100%	100%	96%	100%	100%	*99%*	96%	100%	100%	100%	100%	100%
	Object Contacted	21%	36%	28%	44%	0%	12%	4%	*16%*	32%	28%	28%	0%	4%	4%
	Multiple Impacts	29%	36%	24%	52%	4%	32%	28%	*37%*	52%	16%	60%	24%	48%	20%
	Intrusion at Occupant Location	49%	84%	72%	60%	32%	12%	32%	*53%*	92%	76%	64%	12%	28%	44%
	Airbag Deployment at Occupant Loc.	39%	44%	40%	36%	36%	28%	52%	*41%*	44%	36%	40%	20%	40%	64%
	Occupant Ejection	32%	68%	48%	28%	0%	12%	36%	*34%*	68%	40%	36%	0%	24%	36%
	Vehicle Body Type	46%	72%	68%	64%	24%	20%	28%	*53%*	76%	76%	64%	28%	16%	56%
	Vehicle Curb Weight	29%	20%	28%	16%	16%	68%	24%	*31%*	12%	20%	20%	32%	68%	32%
	Veh Weight Ratio	43%	68%	76%	48%	12%	24%	28%	*51%*	76%	72%	60%	24%	24%	52%
	Compatible Crash	18%	24%	12%	8%	8%	28%	28%	*25%*	16%	12%	20%	16%	48%	40%
	Vehicle Vintage: MY 2009+	36%	52%	48%	40%	28%	24%	24%	*37%*	52%	44%	32%	20%	28%	44%
	Vehicle Age	50%	48%	44%	44%	40%	64%	60%	*57%*	52%	44%	44%	56%	72%	72%

Table A-14. Predictor variable frequency by model type

		Number of Predictor Variables in Each Model				
	Crash Types	***Possible***	**Average**	**% of Possible**	**Max**	**Min**
Full Models (n=150)	**All Crashes**	***29***	15.9	54.9%	21	12
	Frontal	***26***	12.8	49.1%	16	7
	Near-side	***27***	12.5	46.4%	18	7
	Far-side	***26***	9.0	34.8%	14	4
	Rear	***27***	9.3	34.4%	19	4
	Rollover	***27***	11.4	42.4%	18	5
Crasworthiness (CW) Models (n=150)	**All Crashes**	***22***	13.3	60.4%	17	10
	Frontal	***19***	10.2	53.7%	14	6
	Near-side	***20***	10.3	51.4%	14	5
	Far-side	***19***	7.3	38.3%	12	4
	Rear	***20***	8.2	41.2%	14	5
	Rollover	***20***	10.4	52.0%	14	9

Table A-15. Summary of model fit for final Full and CW models

		Goodness of Model Fit - C-statistic					
	Crash Types	**Average**	**Max**	**Min**	**<0.5**	**≥0.7**	**≥0.8**
Full Models (n=150)	**All Crashes**	0.83	0.95	0.71	0	25	18
	Frontal	0.83	0.93	0.69	0	24	19
	Near-side	0.82	0.95	0.71	0	25	14
	Far-side	0.80	0.96	0.68	0	23	15
	Rear	0.79	1.00	0.54	0	22	14
	Rollover	0.74	0.92	0.62	0	20	4
	All Models				*0*	*139*	*84*
Crasworthiness (CW) Models (n=150)	**All Crashes**	0.83	0.94	0.70	0	25	18
	Frontal	0.83	0.93	0.67	0	24	20
	Near-side	0.81	0.94	0.69	0	24	13
	Far-side	0.78	0.94	0.46	1	22	11
	Rear	0.78	1.00	0.56	0	20	11
	Rollover	0.75	0.92	0.64	0	22	5
	All Models				*1*	*137*	*78*

Table A-16. Summary of female vs. male injury OR significance in models with c-statistic below 0.7

	Female vs. Male OR			
Model	**Sig. Higher**	**Higher**	**Lower**	**Sig. Lower**
Full	2	5	3	1
CW	2	7	3	1

Table A-17. Summary table of female vs. male injury odds ratios for selection of injury outcomes for All Crashes and Frontal - Full (Model 2) and CW (Model 4). Shown are Original models and Revised model results. Shaded cells highlight a change in significance from Original to Revised.

			All Crashes				Frontal			
			Full		CW		Full		CW	
			Original	Revised	Original	Revised	Original	Revised	Original	Revised
Whole Body		MAIS 2+	**1.75***	**2.02***	**1.69***	**1.95***	**2.33***	**2.68***	**2.34***	**2.66***
		MAIS 3+	**1.24***	**1.32***	1.17	**1.25***	**1.56***	**1.56***	**1.51***	**1.51***
		MAIS 4+	1.03	1.10	0.94	1.00	1.00	1.00	0.91	0.96
		Fatal Injury	0.94	0.92	0.86	0.94	0.98	0.56	0.95	0.57
Body Region	AIS 2+	Head	1.11	**1.46***	1.10	1.40	1.73	**2.02***	1.63	**2.52***
		Thorax	**0.50***	**0.51***	**0.52***	**0.52***	0.54	0.54	0.54	0.54
		Leg	0.77	0.76	0.80	0.82	0.63	0.53	1.38	1.13
		Foot & Ankle	**1.66***	1.4	**2.01***	1.75	**4.42***	**2.51***	**5.00***	**3.29***
		Upper Extremity	**1.75***	**1.75***	**1.72***	**1.71***	**1.96***	**1.89***	1.89	**1.90***
		Lower Extremity	**1.42***	**1.62***	**1.30***	**1.55***	**1.55***	**1.47***	**1.65***	**1.54***
	AIS 3+	Head	0.77	0.96	**0.74***	0.91	**0.43***	**0.49***	**0.44***	**0.48***
		Thorax	**0.67***	**0.62***	**0.65***	**0.60***	1.53	1.38	1.38	1.40

*p-value ≤ 0.05

Table A-18. Predictor variable inclusion in Original and Revised models: (A) Full – All Crashes; (B) Full – Frontal Crashes; (C) CW – All Crashes; (D) CW – Frontal Crashes. Shaded cells represent a change in variable inclusion between Original and Revised models.

(A)

	Predictor Variable Inclusion - Full Models - All Crashes																							
	MAIS 2+		**MAIS 3+**		**MAIS 4+**		**Fatal**		***Head 2+***		**Thorax 2+**		**Leg 2+**		***Foot/ Ankle 2+***		**Upr Ext 2+**		**Lwr Ext 2+**		**Head 3+**		**Thorax 3+**		***Variable Inclusion Count***	
Predictor Variable	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	*Orig*	*Revised*
Alcohol/Drug Use	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	***10***	***10***
Avoidance Maneuver	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	***10***	***10***
Critical Event*					x	x		x		x					x	x	x	x			x		x	x	***5***	***6***
Pre-impact Movement *		x				x		x	x	x				x				x	x	x		x		x	***2***	***9***
Weather					x	x							x	x							x	x			***3***	***3***
Lighting																x		x	x						***1***	***2***
Rural/Urban	x	x	x	x			x	x					x	x	x	x									***5***	***5***
Sex	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Ejection		x	x	x		x		x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	***8***	***11***
Entrapped	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	***10***	***10***
BMI*	x	x				x		x		x	x			x			x	x	x	x			x	x	***5***	***8***
Belt Anchor											x	x		x	x	x		x	x				x	x	***4***	***5***
Seat Track Position*		x					x							x		x				x		x			***1***	***5***
Manner of Collision	x	x	x	x	x	x	x	x	x	x	x	x			x		x			x			x	x	***9***	***8***
Object Contacted*	x	x									x	x	x							x					***3***	***3***
Airbag Deployment	x	x	x	x									x	x			x			x					***4***	***4***
Intrusion	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x		x	x	x	***10***	***11***

(A)

	Predictor Variable Inclusion - Full Models - All Crashes																									
	MAIS 2+		**MAIS 3+**		**MAIS 4+**		**Fatal**		***Head 2+***		**Thorax 2+**		**Leg 2+**		***Foot/ Ankle 2+***		**Upr Ext 2+**		**Lwr Ext 2+**		**Head 3+**		**Thorax 3+**		***Variable Inclusion Count***	
Multiple-impact	x	x	x	x			x		x	x											x	x	x	x	***6***	***5***
Vehicle Body Type			x	x	x	x		x			x	x				x	x	x	x	x	x		x	x	***7***	***8***
Vehicle Vintage		x			x	x	x	x	x		x	x	x	x	x	x	x			x					***7***	***7***
Weight Ratio	x	x	x	x	x	x		x	x	x					x	x	x			x	x	x	x	x	***8***	***9***
Compatible Crash									x	x															***1***	***1***
Delta V	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Vehicle Curb Weight											x		x												***2***	***0***
Occupant Age	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Vehicle Age	x	x										x	x	x	x	x	x			x					***4***	***5***
Occupant Height*	NA		NA		NA		NA		NA	x	NA		NA		NA	x	NA		NA		NA	x	NA		***NA***	***3***
Occupant Weight*	NA	x	NA	x	NA	x	NA	x	NA		NA		NA		NA	x	NA	x	NA		NA		NA		***NA***	***6***
Total Predictors - Model	***17***	***21***	***17***	***17***	***16***	***19***	***15***	***19***	***15***	***16***	***17***	***17***	***15***	***16***	***12***	***14***	***19***	***15***	***14***	***21***	***14***	***15***	***17***	***19***	***188***	***209***

* New reference level; ** New variable

(B)

Predictor Variable	MAIS 2+		MAIS 3+		MAIS 4+		Fatal		Head 2+		Thorax 2+		Leg 2+		Foot/ Ankle 2+		Upr Ext 2+		Lwr Ext 2+		Head 3+		Thorax 3+		*Variable Inclusion Count*	
	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	*Orig*	*Revised*
Alcohol/Drug Use	x	x	x	x		x	x	x	x	x	x	x											x	x	**6**	**7**
Avoidance Maneuver		x	x	x	x	x	x		x	x					x	x					x	x	x	x	**7**	**7**
Critical Event*	x	x	x	x						x		x	x	x					x	x			x		**5**	**6**
Pre-impact Movement *		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x		x	**8**	**12**
Weather					x	x					x	x			x	x									**3**	**3**
Lighting					x	x			x	x											x	x	x	x	**4**	**4**
Rural/Urban	x	x							x	x					x	x									**3**	**3**
Sex	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**12**	**12**
Ejection		x	x	x		x		x		x	x	x			x	x	x			x	x	x	x	x	**6**	**10**
Entrapped	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	**10**	**10**
BMI*	x					x			x	x			x	x		x							x	x	**4**	**5**
Belt Anchor					x	x			x	x	x	x		x		x		x	x		x	x	x	x	**6**	**8**
Seat Track Position*		x					x			x										x		x		x	**1**	**5**
Manner of Collision	x	x	x	x	x	x	x	x	x		x	x			x	x	x	x	x	x	x	x			**10**	**9**
Object Contacted*					x		x	x		x		x	x			x		x			x	x			**4**	**6**
Airbag Deployment					x	x							x	x	x		x			x	x	x			**5**	**4**
Intrusion	x	x	x	x	x	x	x	x					x		x	x		x	x		x	x	x	x	**9**	**8**
Multiple-impact					x	x	x	x	x	x											x	x	x	x	**5**	**5**
Vehicle Body Type			x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	**9**	**11**
Vehicle Vintage									x	x	x	x	x	x	x	x	x	x	x	x					**6**	**6**

(B)

	Predictor Variable Inclusion - Full Models - Frontal Crashes																									
	MAIS 2+		**MAIS 3+**		**MAIS 4+**		**Fatal**		**Head 2+**		**Thorax 2+**		**Leg 2+**		**Foot/ Ankle 2+**		**Upr Ext 2+**		**Lwr Ext 2+**		**Head 3+**		**Thorax 3+**		***Variable Inclusion Count***	
Weight Ratio	x	x	x	x	x	x	x	x	x	x					x	x	x			x	x	x			**8**	**8**
Compatible Crash							x	x	x	x												x			**2**	**3**
Delta V	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**12**	**12**
Vehicle Curb Weight			x	x													x			x	x				**3**	**2**
Occupant Age	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	**11**	**11**
Vehicle Age	x								x	x			x	x	x	x	x	x	x	x					**6**	**5**
Occupant Height***	NA		NA		NA		NA	x	NA		NA		NA		NA	x	NA	x	NA		NA		NA		**NA**	**3**
Occupant Weight***	NA	x	NA		NA		NA		NA	x	NA		NA		NA	x	NA	x	NA		NA		NA		**NA**	**4**
Total Predictors - Model	***12***	***14***	***14***	***14***	***16***	***18***	***15***	***14***	***16***	***20***	***12***	***14***	***10***	***11***	***15***	***17***	***13***	***12***	***12***	***15***	***16***	***18***	***14***	***15***	**165**	**182**

* New reference level; ** New variable

(C)

	Predictor Variable Inclusion - CW Models - All Crashes																									
	MAIS 2+		**MAIS 3+**		**MAIS 4+**		**Fatal**		**Head 2+**		**Thorax 2+**		**Leg 2+**		**Foot/ Ankle 2+**		**Upr Ext 2+**		**Lwr Ext 2+**		**Head 3+**		**Thorax 3+**		**Variable Inclusion Count**	
Predictor Variable	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	*Orig*	*Revised*
Sex	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Ejection		x	x	x		x		x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	***8***	***11***
Entrapped	x	x	x	x	x	x	x	x	x	x	x	x					x		x	x	x	x	x	x	***10***	***9***
BMI*	x	x				x		x		x	x			x			x		x	x			x	x	***5***	***7***
Belt Anchor							x				x	x		x	x	x		x					x	x	***4***	***5***
Seat Track Position*		x						x		x				x		x				x		x			***0***	***7***
Manner of Collision	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x			x	x	x	x	x	***10***	***10***
Object Contacted*												x	x				x			x				x	***2***	***3***
Airbag Deployment	x	x	x	x			x	x					x	x			x			x					***5***	***5***
Intrusion	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	***11***	***11***
Multiple-impact	x	x	x	x	x	x	x	x	x	x	x	x									x	x	x	x	***8***	***8***
Vehicle Body Type			x	x	x	x		x			x	x			x	x	x	x	x	x	x		x	x	***8***	***8***
Vehicle Vintage	x	x			x	x	x	x		x	x	x	x	x	x	x	x			x					***7***	***8***
Weight Ratio	x	x	x	x	x	x	x	x	x	x					x	x	x			x	x	x	x	x	***9***	***9***
Compatible Crash									x	x															***1***	***1***
Delta V	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Vehicle Curb Weight																									***0***	***0***
Occupant Age	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Vehicle Age	x	x	x	x							x	x	x	x	x	x	x	x		x					***6***	***7***
Occupant Height **	NA		NA		NA		NA		NA	x	NA		NA		NA	x	NA		NA		NA	x	NA		***NA***	***3***
Occupant Weight **	NA	x	NA	x	NA		NA	x	NA		NA		NA		NA	x	NA	x	NA		NA		NA		***NA***	***5***
Total Predictors - Model	***14***	***16***	***15***	***15***	***13***	***15***	***13***	***16***	***10***	***15***	***15***	***16***	***11***	***12***	***10***	***13***	***17***	***10***	***10***	***18***	***12***	***13***	***14***	***16***	***154***	***175***

* New reference level; ** New variable

(D)

	Predictor Variable Inclusion - CW Models - Frontal Crashes																									
	MAIS 2+		**MAIS 3+**		**MAIS 4+**		**Fatal**		**Head 2+**		**Thorax 2+**		**Leg 2+**		**Foot/ Ankle 2+**		**Upr Ext 2+**		**Lwr Ext 2+**		**Head 3+**		**Thorax 3+**		***Variable Inclusion Count***	
Predictor Variable	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	Orig	Revised	*Orig*	*Revised*
Sex	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Ejection		x	x	x		x		x			x	x									x	x	x	x	***4***	***7***
Entrapped	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	***10***	***10***
BMI*	x					x			x	x				x					x				x	x	***4***	***4***
Belt Anchor	x	x			x	x		x	x	x				x	x	x		x	x		x	x	x	x	***7***	***9***
Seat Track Position*		x				x				x			x	x						x		x			***1***	***6***
Manner of Collision	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	***10***	***10***
Object Contacted*					x		x			x			x			x		x		x	x	x			***4***	***5***
Airbag Deployment					x	x				x			x	x			x			x	x	x			***4***	***5***
Intrusion	x	x	x	x	x	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x	x	***10***	***11***
Multiple-impact					x	x	x	x	x	x											x	x		x	***4***	***5***
Vehicle Body Type			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	***10***	***11***
Vehicle Vintage											x	x	x	x	x	x	x	x	x	x					***5***	***5***
Weight Ratio	x	x			x	x	x	x	x	x					x	x	x			x	x	x			***7***	***7***
Compatible Crash							x	x	x	x												x			***2***	***3***
Delta V	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	***12***	***12***
Vehicle Curb Weight			x	x													x			x	x	x			***3***	***3***
Occupant Age	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	***11***	***11***
Vehicle Age									x	x			x	x	x	x	x	x	x	x					***5***	***5***
Occupant Height **	NA		NA		NA		NA	x	NA	x	NA		NA		NA	x	NA	x	NA		NA		NA		***NA***	***4***
Occupant Weight **	NA	x	NA		NA		NA	x	NA	x	NA		NA		NA	x	NA	x	NA		NA		NA		***NA***	***5***
Total Predictors - Model	***9***	***10***	***9***	***9***	***12***	***14***	***11***	***13***	***11***	***15***	***8***	***8***	***9***	***11***	***10***	***12***	***11***	***12***	***11***	***14***	***14***	***16***	***10***	***11***	***125***	***150***

* New reference level; ** New variable

Table A-19. Summary table of female vs. male injury odds ratios for 25 injury outcomes across 12 different crash type models. Shown are results for Full (Model 1) and CW (Model 3) models. Highlighted cells (46 of 300) indicate a change in OR significance versus final Full (Model 2) and CW (Model 4) results that only include significant (p≤0.1) predictor variables.

		Crash Types											
		All Crashes		Frontal		Near-Side		Far-Side		Rear		Rollover	
		Model 1	Model 3	Model 1	Model 3	Model 1	Model 3	Model 1	Model 3	Model 1	Model 3	Model 1	Model 3
Whole Body	MAIS 2+	1.79*	1.73*	2.37*	2.36*	1.19	1.17	1.92*	2.02*	1.41	1.29	1.50	1.72
	MAIS 3+	1.24	1.18	1.56*	1.49*	1.44*	1.36	1.12	1.00	0.45*	0.35	1.22	1.51
	MAIS 4+	0.98	0.93	1.02	0.98	0.84	0.85	0.93	0.81	0.98	0.93	1.13	1.24
	Fatal Injury	0.81	0.78*	0.96	1.07	1.05	1.14	0.21*	0.22*	0.55*	0.49*	1.20	1.05
Body Region AIS 2+	Head	1.16	1.13	1.74*	1.82*	1.04	0.99	0.85	0.74	1.21	1.36	0.96	0.96
	Neck & C-spine	0.69	0.59†	0.78	0.75	1.31	1.21	0.13	0.15	0.14*	0.42	0.24	0.35
	Thorax	0.51*	0.50*	0.55	0.52	0.52*	0.51*	0.66	0.66	0.23	0.08*	0.54	0.57
	Abdomen	0.76	0.72	0.52*	0.48*	0.74	0.75	0.82	0.74	0.00*	0.00	1.53	1.31
	Thoracolumbar	1.08	1.08	1.69	1.59	0.66	0.55	1.39	1.30	0.37	1.00	1.17	1.02
	Torso	0.67†	0.67†	0.69	0.66	0.48*	0.45*	0.76	0.90	0.73	0.49	1.18	1.46
	Knee–Thigh–Hip	0.74	0.73	1.34	1.32	0.51	0.38	3.52	7.89	3.20	0.26	7.98	0.40
	Leg	0.84	0.91	1.45	1.47	2.20	8.27	0.00	0.02	0.00	0.13	0.96	1.27
	Foot & Ankle	2.05*	2.13*	4.16*	4.51*	7.09	0.69	1.06	6.18*	0.13	0.07	3.82	3.06
	Upper Extremity	1.75*	1.69*	2.04*	1.93*	2.04	1.99	1.44	0.97	1.60	0.73	1.28	1.35
	Lower Extremity	1.40*	1.43*	1.57*	1.63*	1.07	1.03	1.83	1.54	0.81	0.78	1.37	1.28
Body Region AIS 3+	Head	0.78	0.75*	0.45*	0.48*	0.97	0.99	3.10*	2.10*	0.09*	0.30	0.86	0.93
	Neck & C-spine	0.49*	0.46*	0.40*	0.43	1.13	0.95	1.96	2.17	0.02*	0.06*	0.05*	0.16*
	Thorax	0.61*	0.61*	1.53	1.35	0.54*	0.52*	0.29*	0.36*	0.01	0.02*	0.65*	0.70
	Abdomen	0.80	0.72	0.65	0.61	0.70	0.69	0.15	0.23	0.27	0.00*	1.92	1.72
	Thoracolumbar	1.15	1.07	1.50	1.16	0.49	0.45	4.17	4.40	0.65	5.01	0.03	0.46
	Torso	0.74*	0.74*	1.77*	1.46	0.58*	0.55*	0.35*	0.43*	0.18*	0.12*	0.89	1.32
	Knee–Thigh–Hip	1.01	0.97	0.96	1.07	1.26	1.01	0.29	0.15	0.05*	0.01*	0.41	0.56
	Leg	1.34	1.38	1.06	1.16	2.64	3.41	1.26	1.34	1.00	1.00	0.00*	0.00
	Upper Extremity	1.29	1.33	1.38	1.48	2.35	2.35	6.44*	10.2*	0.00*	0.00*	0.57	0.71
	Lower Extremity	1.20	1.17	1.02	1.02	1.73*	1.59*	0.52	0.34	0.28	10.3*	1.42	1.21

* p-value ≤ 0.05

Table A-20. Model fit (c-statistic) for Full (Model 1) and CW (Model 3) models

		Goodness of Model Fit - C-statistic					
	Crash Types	**Average**	**Max**	**Min**	**<0.5**	**≥0.7**	**≥0.8**
Full Models (n=150)	**All Crashes**	0.83	0.95	0.72	0	25	19
	Frontal	0.84	0.94	0.69	0	24	20
	Near-side	0.83	0.98	0.72	0	25	18
	Far-side	0.87	1.00	0.69	0	24	22
	Rear	0.89	1.00	0.69	0	24	23
	Rollover	0.83	1.00	0.65	0	24	15
	All Models				*0*	*146*	*117*
Crasworthiness (CW) Models (n=150)	**All Crashes**	0.83	0.94	0.71	0	25	18
	Frontal	0.83	0.93	0.67	0	24	20
	Near-side	0.82	0.96	0.70	0	25	15
	Far-side	0.84	1.00	0.66	0	23	19
	Rear	0.87	1.00	0.69	0	24	23
	Rollover	0.80	0.97	0.64	0	24	10
	All Models				*0*	*145*	*105*

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