Using Police-Reported Rear-crash Data to Assess IIHS's Whiplash Prevention Evaluation

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Abstract Recent studies linking Insurance Institute for Highway Safety (IIHS) rear-impact sled test results to real-world outcomes have relied on insurance claim data. This study instead used police-reported front-to-rear crash data to corroborate prior findings and to examine additional injury risk factors unavailable in the insurance dataset. Drivers coded B, C, or O on the KABCO scale (non-incapacitating injury, possible/minor injury, or uninjured, respectively) were included, with injuries defined as B or C codes. There were 291,999 crashes in 18 US states that involved rear-struck vehicles with one of 40 tested seat designs. Linear regression showed police-reported injury rates were strongly correlated with previously reported insurance injury claim rates. Among other factors, logistic regression estimated significantly higher police-reported injury risk ($p \leq 0.05$) for drivers who were female or who were driving vehicles that were older, that were lighter than the striking vehicle, that were struck by pickups or SUVs, or that were struck by vehicles driven by older or male drivers. The effect of struck driver age was nonlinear. While controlling for other effects, the overall IIHS seat evaluation sled test score was a significant predictor of injury ($p < 0.001$).

Keywords Consumer ratings, Crashworthiness, Rear impacts, Seat performance, Whiplash.

I. INTRODUCTION

Rear-impact crashes account for between one-quarter and one-third of all motor vehicle crashes (MVCs) in the US and a similar proportion of crashes resulting in injury [1]. Whiplash injuries are particularly common in these crashes, with over 1 million estimated to occur annually in the US alone [2]. New Car Assessment programmes worldwide include rear-impact whiplash assessments in their overall ratings using a variety of crash pulses and evaluation methods. Prior research has demonstrated the relationship between outcomes in several of these tests and the rate of injury claims in insurance datasets [3-7]. While recent data are unavailable, between 1999 and 2008 neck injury claim rates decreased 39% [4].

From 2004 to 2022, the Insurance Institute for Highway Safety (IIHS) relied on a single 16 km/h sled test for each seat design in its vehicle seat/head restraint evaluation. Ratings were assigned based on a combination of static geometry, upper neck shear force and tension, T1 X-acceleration, and time to head contact with the head restraint. Vehicle manufacturers updated their seat designs to improve test performance, and multiple studies demonstrated a direct link with reduced injury risk [4][6]. By 2022, nearly all tested seats earned a Good rating. Despite this fleet-wide improvement in whiplash protection, insurance claims data indicated that meaningful injury rate differences remained among the newest Good-rated seats [7]. This prompted IIHS to suspend its rear-impact evaluation and launch a research programme aimed at defining an assessment to provide additional correlation with real-world outcomes. The research included testing seats using three different crash pulses while evaluating a wider range of dummy measurements than those used in the original rating programme.

IIHS introduced its upgraded seat and head restraint evaluation, called the Whiplash Prevention Evaluation, in 2025 [8]. The new programme evaluates performance across two crash severities using six dummy metrics for each test. It also provides a framework for manufacturers to submit virtual test results after validating to physical test conditions. The rating procedure was informed by sled tests of 40 seat designs and their relationship to insurance injury claim rates. An initial study of mid-size cars and mid-size SUVs [7] helped identify the best-candidate dummy metrics and crash pulses. A follow-up study [9] added a test series of small SUVs and was used to verify that the final rating procedure produced results that correlated with the field injury outcomes.

All previous studies linking IIHS seat test performance to real-world injury outcomes have relied on insurance claims data, specifically the number of personal injury protection (PIP) or bodily injury claims relative to property damage liability (PDL) claims in rear-impact crashes [3-4][6-7][9]. Two early studies supplemented these data with

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manual review of detailed claim files, enabling focused analyses of neck injury and controls for driver sex and age [3-4]. This approach was labour-intensive and limited sample sizes to 5,000–10,000 cases. More recent studies used broader PIP-to-PDL ratios without detailed driver information, enabling samples of 200,000–600,000 [6][9], albeit at the cost of reduced demographic detail. While [6] evaluated age and sex by assuming the driver assigned to each vehicle on the insurance policy was operating the vehicle at the time of the crash, the studies using the expanded research test results have not included these variables [7][9].

The present study aims to verify the real-world relevance of the updated IIHS seat rating system using an alternative data source: police-reported crash records from multiple US states. These data include driver age and sex, crash circumstances, and information about both the struck and striking vehicles, allowing the analysis of potential injury risk factors not measurable in insurance datasets. Although police-reported injuries do not specify the injured body region, prior research indicates that ¾ of occupants injured in rear impacts have whiplash injuries [10] and ⅔ report it as their most serious injury [11]. This predominance of whiplash in rear-impact crashes makes overall rates of minor injury a plausible proxy for whiplash outcomes, providing an opportunity to examine whether police-reported injury patterns align with previously observed insurance claim injury patterns and whether both datasets similarly reflect differences in seat performance.

II. METHODS

IIHS Rear-impact Sled Tests

As reported by [9], IIHS has conducted rear-impact sled tests on 40 different seats from mid-size cars, mid-size SUVs, and small SUVs using both a 16 and 24 km/h pulse. Using an evaluation procedure released in 2025 [8], results from the two tests are combined into a single demerit score ranging from 0 to 18, which serves as the basis for assigning an overall seat rating. Designs with 0–3, 4–6, 7–9, or 10–18 demerits are rated Good, Acceptable, Marginal, or Poor, respectively. While other research has quantified differences in the predictive value of specific injury metrics and pulse severities [7][9], in the current analyses the total demerit score was used as the primary measure of seat test performance and was included as a continuous predictor in the statistical models of injury outcome. One of the 40 tested seats had no matching crash data, while two of the seat designs were used in two unique vehicle models each, producing a total of 41 vehicle models with a tested seat and available crash data. Vehicles and demerit scores are shown in Table I.

Police-reported Crash Data

Police-reported crash data were obtained from 18 US states: Connecticut, Delaware, Florida, Iowa, Illinois, Kansas, Louisiana, Maryland, Michigan, Minnesota, Missouri, North Dakota, New Jersey, Nevada, Ohio, Pennsylvania, South Dakota, Tennessee, Utah, Wisconsin, and Wyoming. These states were all those with crash databases containing coded information on crash type, vehicle impact location, speed limit, driver age and sex, and sufficient detail from vehicle identification numbers to identify vehicles equipped with one of the seat designs evaluated in the IIHS sled tests.

The analysis was restricted to front-to-rear crashes in which the rear-struck vehicle was equipped with a tested seat design. Only crashes with complete data for both vehicles were included. Driver injury status for the struck vehicle was based on the police-reported KABCO injury scale. Drivers coded as B (non-incapacitating injury), C (possible or minor injury), or O (no injury) were retained for analysis.

Injury Rate Comparisons

Linear regression was used to evaluate the relationship between police-reported injury rates and insurance injury claim rates reported in [9]. Injury rates were calculated at the vehicle model level by combining all applicable model years equipped with the same tested seat design and aggregating crashes across all included states. The police-reported injury rates were calculated as the number of B- or C-level injuries out of all drivers with a B, C, or O code. As in [9], insurance injury claim rates were calculated as the number of PIP claims divided by the number of PDL claims. Only models with at least 1,000 PDL claims were included, and regression models were weighted by the total number of PDL claims.

Multivariable Injury Risk Modelling

Logistic regression was used to assess the effects of seat test performance and other factors on the odds of driver injury (B or C level) in the police-reported crash dataset. In addition to the IIHS demerit score, covariates included crash state, posted speed limit, driver age and sex for both the striking and struck vehicles, the logarithm of the ratio of the struck-to-striking vehicle curb weights, and vehicle type for both vehicles. Crash state was included to account for differences in crash reporting practices as well as road type, terrain and other environmental factors that could influence crash severity. Speed limit, striking vehicle driver demographics [12-13], and vehicle type and curb weight were included based on their potential to affect impact severity. The struck vehicle type was one of the specific series with IIHS sled tests (mid-size cars, mid-size SUVs, or small SUVs), while the striking vehicle type was categorised more generally as car, SUV, minivan, pickup, or full-size van. Terms were included to estimate two-way interaction effects between the types of vehicles involved in the crash.

TABLE I
VEHICLES TESTED IN THE IIHS WHIPLASH PREVENTION EVALUATION AND INCLUDED IN FIELD CRASH ANALYSES

Model years	Vehicle	IIHS demerit score	Model years	Vehicle	IIHS demerit score
	Mid-size cars			*Small SUVs*	
2013–2019	Ford Fusion	4	2019–2024	Audi Q3	3
2013–2017	Honda Accord	2	2023–2024	BMW X1	9
2015–2019	Hyundai Sonata	4	2024–2024	Buick Encore	5
2014–2021	Mazda 6	3	2024–2024	Chevrolet Equinox	4
2013–2019	Nissan Altima	6	2021–2024	Ford Bronco Sport	12
2015–2019	Subaru Legacy	2	2023–2024	Honda CR-V	4
2015–2019	Subaru Outback	2	2022–2024	Hyundai Ioniq 5	3
2012–2017	Toyota Camry	4	2024–2024	Hyundai Tucson	10
2012–2022	Volkswagen Passat	6	2022–2024	Jeep Compass	5
	Mid-size SUVs		2022–2024	Kia Sportage	5
2018–2021	Chevrolet Traverse	3	2023–2025	Mazda CX-50	11
2011–2021	Dodge Durango	2	2020–2024	Mercedes-Benz GLB Class	5
2018–2019	Ford Explorer	2	2022–2024	Mitsubishi Outlander	8
2016–2021	Honda Pilot	4	2021–2024	Nissan Rogue	8
2013–2018	Hyundai Santa Fe	4	2025–2025	Subaru Forester	1
2014–2021	Jeep Cherokee	8	2019–2024	Toyota RAV4	2
2011–2021	Jeep Grand Cherokee	2	2022–2024	Volkswagen Taos	4
2018–2020	Kia Sorento	3	2019–2024	Volvo XC40	6
2016–2021	Mazda CX-9	3			
2015–2021	Nissan Murano	5			
2019–2021	Subaru Ascent	6			
2014–2019	Toyota Highlander	4			
2018–2021	Volkswagen Atlas	5			
2018–2021	Volkswagen Tiguan	4			

Several previous studies have reported a nonlinear relationship between age and injury risk in rear impacts [3][6][14-19]. To explore this possibility, natural cubic splines were used to estimate the effect of driver age in the struck vehicle. Regression splines allow parameter effects to be estimated using a continuous risk function without assuming a linear relationship with the outcome [20-21]. Splines were calculated using the “splines” package in the R programming language [22]. Boundary knots were set at the 5th and 95th quantiles (ages 20 and 70 years) and interior knots at the 35th and 65th quantiles (34 and 48 years) following the recommendation of [20] when transition points are unknown beforehand. These knots define the join points of the polynomial functions comprising the overall cubic spline. Terms were also included to estimate two-way interaction effects between the sex and age of the driver of the rear-struck vehicle.

Two additional logistic regression models were used to assess whether certain drivers may benefit more from the IIHS Whiplash Prevention Evaluation. The first model included an interaction between IIHS demerits and the sex of the struck driver, and the second also added an interaction between demerits and the age of the struck driver. These models were otherwise identical to the primary model described above. Statistical significance for all models was evaluated using an α level of 0.05.

III. RESULTS

There were 291,999 police-reported front-to-rear crashes in 18 states that met inclusion criteria. Summary statistics are shown in Table II and the number of crashes by IIHS test demerits are shown in the Appendix. The overall rate of police-reported injury was 17.9%. Linear regression using data from vehicles with at least 1,000 PDL claims showed a strong correlation between the police-reported injury rate for each vehicle model and the injury claim rate from insurance data ($r2 = 0.74$, $p < 0.001$; Fig. 1).

TABLE II
SUMMARY OF POLICE-REPORTED CRASHES

Continuous variables		25th percentile	50th percentile	75th percentile
IIHS test demerits		2	4	5
Speed limit		35	45	50
Curb weight ratio (striking / struck)		0.81	0.98	1.17
Struck-vehicle driver's age		30	41	53
Striking-vehicle driver's age		23	32	47
Categorical variables		**Percent**		
Struck-vehicle driver: B/C injury		17.9%		
Struck-vehicle driver: female		57.0%		
Striking-vehicle driver: female		42.9%		
Struck vehicle type	Mid-size car	57.2%		
	Mid-size SUV	39.2%		
	Small SUV	3.6%		
Striking vehicle type	Car	53.8%		
	Minivan	3.7%		
	Pickup	13.5%		
	SUV	27.2%		
	Van	1.8%		

Logistic regression was used to study factors affecting the risk of injury in the police-reported crashes. While controlling for driver, vehicle, and crash characteristics, an increase of 1 demerit in the IIHS Whiplash Prevention Evaluation was estimated to increase the odds of the driver sustaining a B or C injury by 3.9% ($p < 0.001$). Table III shows results of the primary model except for state differences and the estimates for age and sex of the struck driver. As the individual spline basis coefficient estimates used to model driver age have no direct interpretation on their own, the injury risk predicted by the model for female and male drivers of different ages in otherwise identical crash conditions is shown in Fig. 2. Likelihood ratio tests indicated that the age effect was nonlinear ($p<0.001$) and that the interaction between driver sex and age was significant ($p<0.001$). Female drivers had higher estimated injury risk than males at all ages. Estimated risk increased with age for both female and male drivers until around 50 years (for females) or 60 years (for males) and then declined for females and remained relatively constant for males (Fig. 2).

Other factors that increased the risk of driver injury in the rear-struck vehicle included a higher curb weight ratio (striking/struck), crashes on roads with higher speed limits, and crashes with a striking-vehicle driver who was older or male (Table III). These estimates reflect the isolated effect of factors that can be correlated. For example, crashes on roads with higher speed limits involved striking-vehicle drivers who were younger on average (result not shown).

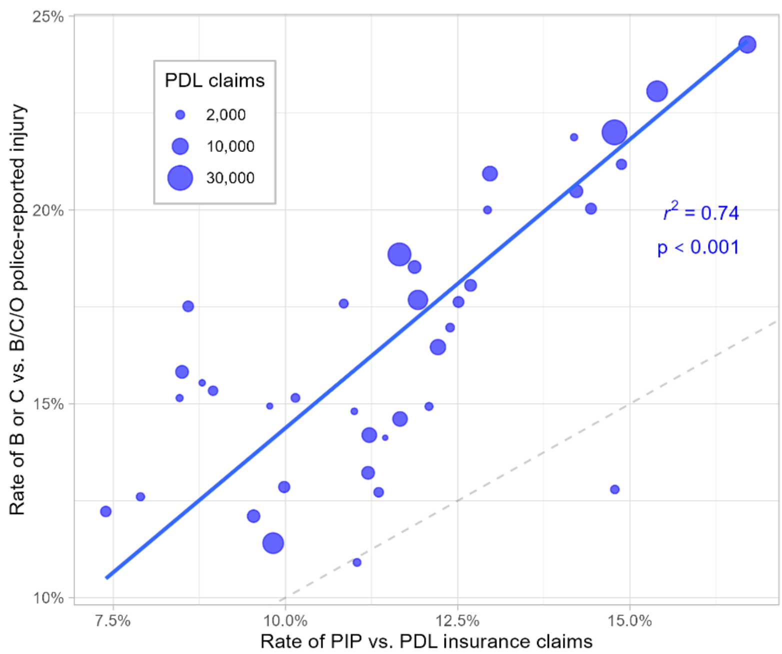

Fig. 1. Linear regression between police-reported injury rate and insurance injury claim rate for vehicles with 1,000 or more PDL claims; weighted by number of PDL claims. Dashed 1:1 line for reference.

TABLE III

RESULTS OF PRIMARY LOGISTIC REGRESSION MODEL OF B OR C INJURY

Covariate	Unit / reference	Estimate	Standard error	*p* value
IIHS test demerits	+1	0.0388	0.00285	<0.001
Curb weight ratio, striking vs struck vehicle; log	+1	0.32	0.0303	<0.001
Speed limit	+5 mph	0.0373	0.00208	<0.001
Struck vehicle: mid-size SUV	vs car	−0.386	0.0174	<0.001
Struck vehicle: small SUV	vs car	−0.231	0.0386	<0.001
Striking vehicle: minivan	vs car	0.023	0.0351	0.51
Striking vehicle: pickup	vs car	0.0107	0.0225	0.63
Striking vehicle: SUV	vs car	0.000	0.0168	1.00
Striking vehicle: van	vs car	0.0637	0.0462	0.17
Striking-vehicle driver's age	+1 year	0.0013	0.000301	<0.001
Striking-vehicle driver: male	vs female	0.0406	0.0105	<0.001
Interaction: struck mid-size SUV × striking minivan	–	0.0755	0.0555	0.17
Interaction: struck mid-size SUV × striking pickup	–	0.266	0.0307	<0.001
Interaction: struck mid-size SUV × striking SUV	–	0.154	0.0248	<0.001
Interaction: struck mid-size SUV × striking van	–	0.184	0.0726	0.01
Interaction: struck small SUV × striking minivan	–	0.000	0.146	1.00
Interaction: struck small SUV × striking pickup	–	0.0819	0.0807	0.31
Interaction: struck small SUV × striking SUV	–	0.0705	0.061	0.25
Interaction: struck small SUV × striking van	–	0.121	0.171	0.48

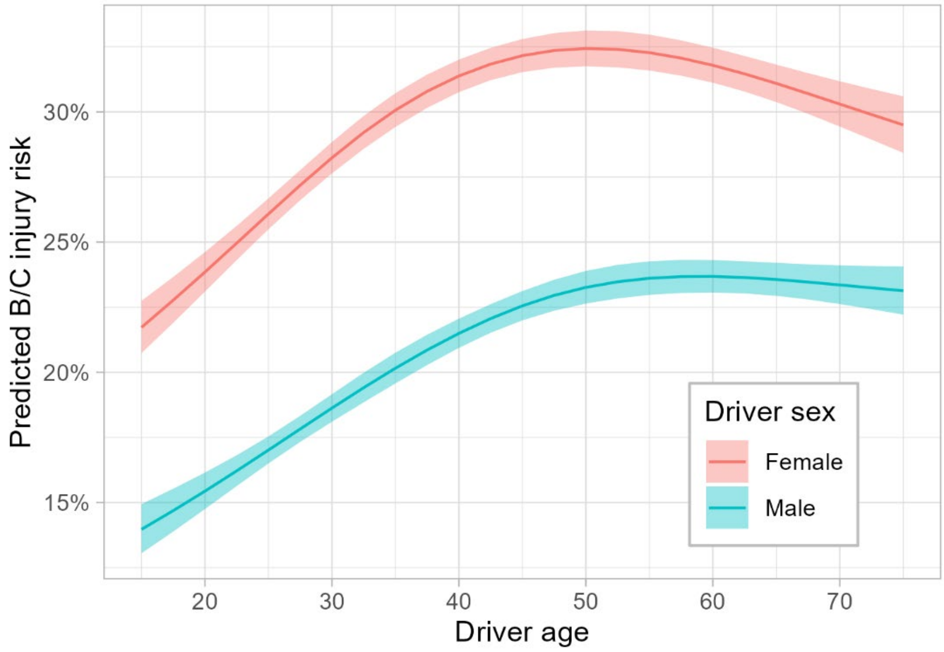

Fig. 2. Predicted injury risk with 95% confidence interval by age and sex of the struck driver in otherwise identical crashes. *Note:* injury risk predicted for these factors: crash on 45 mph (72 km/h) road in Florida, two cars with same curb weight, striking-vehicle driver being a 40-year-old female, struck vehicle seat with 4 demerits.

Many of the interaction effect estimates between striking and struck vehicle type were statistically significant (Table III); to aid interpretation, predicted injury risks are presented graphically (Fig. 3). Even after controlling for curb weight ratio, drivers of cars had higher overall injury risk than drivers of small or mid-size SUVs, while the risk for car drivers was less sensitive to the type of striking vehicle. Risk in small and mid-size SUVs was lowest when the striking vehicle was a car; risk was higher for striking minivans, SUVs, pickups, and full-size vans.

Two additional logistic regression models were used to study whether the updated IIHS evaluation is more strongly associated with injury risk for certain drivers. The first model included all the covariates from the primary model as well as an interaction term between the IIHS test demerits and the sex of the struck driver. Results indicated that the effect of demerits on injury risk was stronger for females than for males (Table IV and Fig. 4). The second model also included an interaction term between IIHS test demerits and the age of the struck driver. As with the primary model, the age effect was included using cubic splines. A likelihood ratio test found no evidence that adding the interaction term between age and demerits improved model fit (p = 0.90), suggesting that increasing test demerits raised injury risk similarly for drivers of all ages.

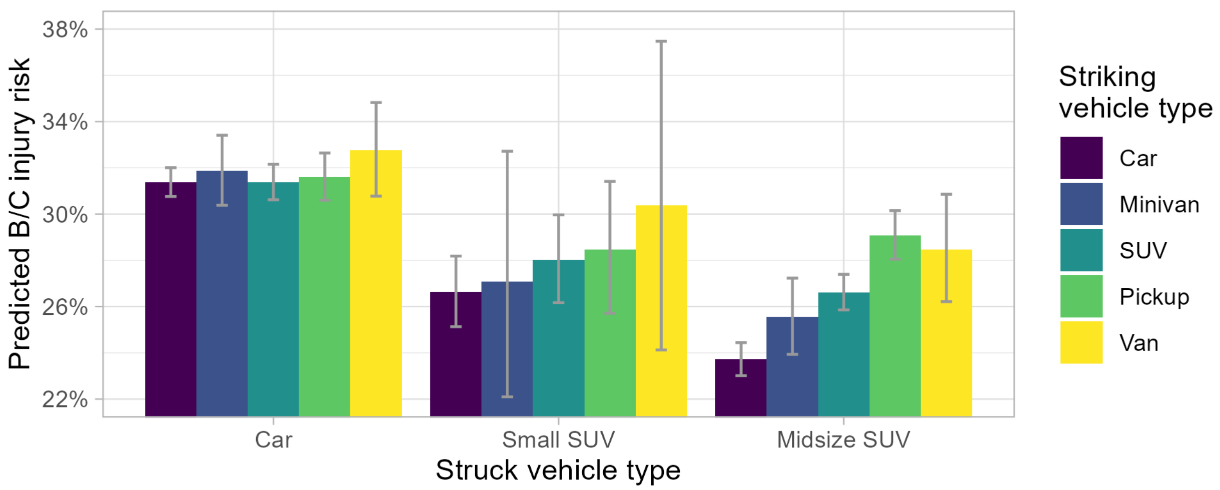

Fig. 3. Predicted injury risk with 95% confidence interval by type of striking and struck vehicle in otherwise identical crashes. *Note:* injury risk predicted for these factors: crash on 45 mph (72 km/h) road in Florida, vehicles with same curb weight, both drivers being 40-year-old females, struck vehicle seat with 4 demerits.

TABLE IV
ESTIMATED EFFECTS OF IIHS TEST DEMERITS ON B OR C INJURY OUTCOME BY DRIVER SEX

Covariate	Unit / reference	Estimate	Standard error	*p* value
IIHS test demerits, female drivers	+1	0.0447	0.0035	<0.001
IIHS test demerits, male drivers	+1	0.028	0.00474	<0.001
IIHS test demerits × male	–	−0.0166	0.00583	0.004

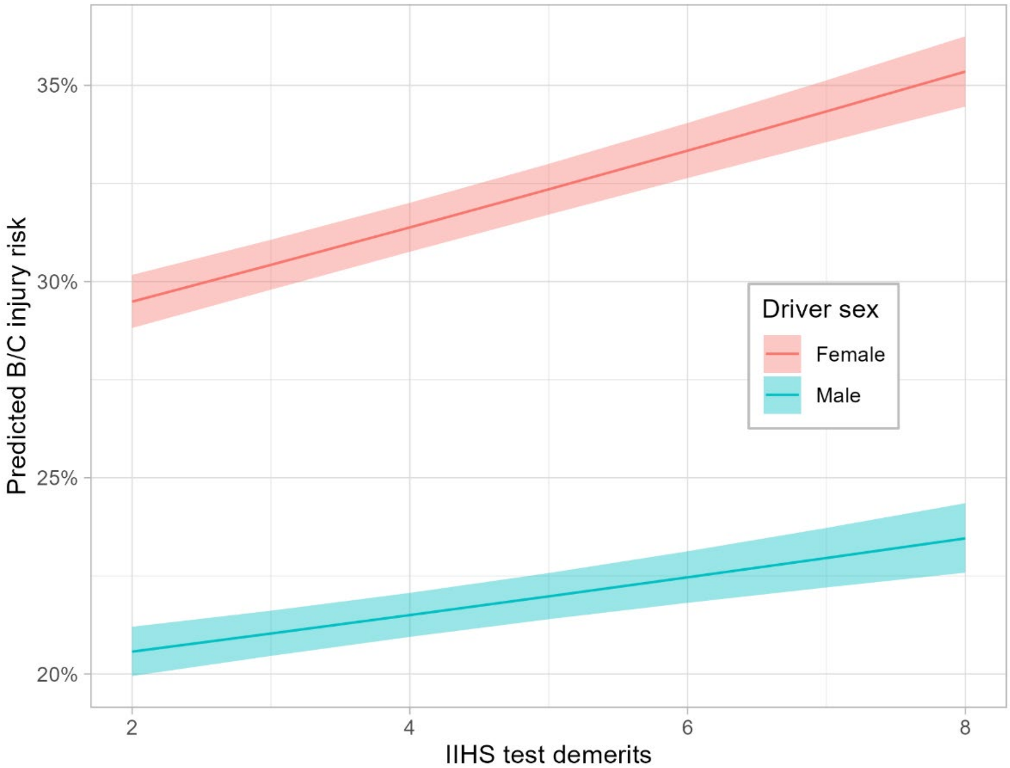

Fig. 4. Predicted injury risk with 95% confidence interval by IIHS test demerits and sex of the driver in otherwise identical crashes. *Note:* injury risk predicted for these factors: crash on 45 mph (72 km/h) road in Florida, two cars with same curb weight, striking-vehicle driver being a 40-year-old female, struck-vehicle driver being 40 years old.

IV. DISCUSSION

IIHS has recently introduced its Whiplash Prevention Evaluation programme to further delineate among existing seat designs [8]. A separate study [9] has shown that performance in the updated evaluation is correlated with field crash injury outcomes using insurance claim rates. The current study strengthens evidence for the relevance of the IIHS evaluation by demonstrating that it also predicts police-reported injury outcomes. A 1 demerit increase was associated with an estimated 2.2% increase in the insurance injury claim rate [9] and with a 3.9% increase in the odds of a B or C police-reported injury.

More generally, to our knowledge this is the first study to establish a relationship between police- and insurance-reported injury on a vehicle model level (Fig. 1). Despite the different ways injuries are defined and documented in these two data sources, B- and C-level police-reported injuries align closely with insurance injury claims in rear-impact crashes. This alignment is evidence for the reliability of both outcome measures, strengthening confidence in research that relies on either insurance claim data or police-reported B/C injuries in this crash mode.

Beyond confirming the relevance of seat test performance, the police-reported crash data provided opportunities to explore rear-impact injury factors, such as driver demography, details about the striking vehicle and its driver, and speed limit, that were not available in the insurance data. Demographic analyses indicated that female drivers are at greater risk of injury in rear impacts than males of the same age (Fig. 2). This is consistent with many prior studies [3][6][14-19], although most of these did not report specific injury risk differences for drivers in rear impacts. According to [4], female drivers had a 44% higher risk of neck injury than males in rear-impact crashes. Reference [5] reported a 38% higher risk for females in the newest vehicles studied (1998 and later models). While neither of these accounted for the possibility of unique age-related differences for females and males, the results are similar to our estimates at the age of 40, which produce a 46% higher predicted risk for females in the crash conditions shown in Fig. 2. Promisingly, we also found that reducing demerits in the IIHS evaluation should be especially effective at reducing female risk. The magnitude of the demerit effect for females was around 75% larger than that for males. Previous studies also have found that other seat evaluations are more strongly related to female than to male injury outcomes [4][6]. However, estimated injury risk in the best-performing vehicles remains elevated for females relative to males (Fig. 4), highlighting the potential for virtual testing to support the development of targeted, female-specific countermeasures in the future [23].

Our finding that the effect of age on rear-impact injury risk is nonlinear (Fig. 2) is not typical of most crash injury outcomes. To assess whether this could be explained by injury coding differences, we fit an additional regression model including A-level injuries. The results were similar (Fig. A2), suggesting the nonlinear effect is robust. In fact, this nonlinearity is consistent with a large body of prior research. Similar nonlinear patterns have been reported in insurance claims data from Quebec [15], Sweden [14], and the USA [3][6]; in hospital injury data from the UK [18]; and in internal crash databases from vehicle manufacturers in Sweden [16][19] and Germany [17]. Although the reasons for declining injury risk at older ages remain uncertain, one possibility proposed by [19] is that age-related increases in neck stiffness may reduce the likelihood of certain injury types. Other factors must also contribute, as injury risk clearly rises through mid-adulthood before decreasing again. Further research is needed to understand how age-related physiological changes influence injury susceptibility. This work may also help to clarify the underlying whiplash mechanisms relevant for drivers of all ages.

Vehicle compatibility plays a major role in rear-crash injury risk, but the underlying mechanisms appear to be complex and influenced by multiple factors. Overall, injury risk increased with the mass difference between the striking and struck vehicles, aligning with previous findings [4]. For rear-struck cars, this mass difference appeared to have a stronger effect than the striking vehicle type (Fig. 3). However, SUV drivers had significantly lower injury risk than car drivers, even in crashes with similar mass disparity. Furthermore, the risk of injury for SUV drivers appeared to be more sensitive to the type of striking vehicle than to typical mass difference (Fig. 3 and Table III). For example, mid-size SUV drivers had an estimated 32% higher injury odds when struck by a pickup than when struck by a car of the same mass, while the median curb weight ratio difference for these vehicle types would increase the estimated injury odds by 16%. Although these findings do not allow firm conclusions, one possibility is that underride of the struck vehicle's rear structure may reduce crash pulse severity and associated injury risk. This could explain why cars, which are less likely to be underridden due to their lower ground clearance, show less sensitivity to the type of striking vehicle, whereas higher-riding SUVs are more affected.

Limitations

Police-reported data do not specify injury type or affected body region. Although prior research indicates that whiplash accounts for most rear-impact injuries [10-11], many drivers classified with a police-reported B or C injury likely did not sustain whiplash. The inclusion of these non-whiplash cases is a limitation, but it is more likely to weaken the observed relationship between the IIHS evaluation and real-world injury outcomes than to result in an overestimate.

This study is also limited by the number of seat designs that have been tested using the updated IIHS protocol. To date, crash-involved vehicles with evaluated seats are almost all mid-size cars or mid-size SUVs. Small SUVs also have been tested, but these were more recent models and made up less than 4% of the police-reported crash data. Relatedly, the range of demerit scores for evaluated seats was relatively narrow; while demerit scores from 0 to 18 are possible, 93% of the field crash data involved vehicles with 2 to 6 demerits (Fig. A1). As more vehicles are evaluated over the coming years, it will be important to ensure the link between test performance and injury outcome remains meaningful.

V. CONCLUSION

The new IIHS Whiplash Prevention Evaluation is a strong predictor of real-world injury outcomes in a multi-state dataset of police-reported rear-impact crashes. Police-reported injury rates align closely with insurance injury claim rates for the same vehicle models, strengthening confidence in both data sources and in the real-world relevance of the evaluation. Beyond validating the link between sled test performance and injury risk, this study quantified the effect of other factors not available in the insurance claims data. Female drivers exhibited higher injury risk than males at all ages, and improved seat performance was estimated to yield greater benefits for females. The models also corroborate nonlinear age effects previously detected in other crash data and indicate that vehicle compatibility affects injury risk in complex ways. Together, these findings reinforce the relevance of the updated IIHS programme and identify risk factors to monitor as more seat designs are evaluated.

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VIII. APPENDIX

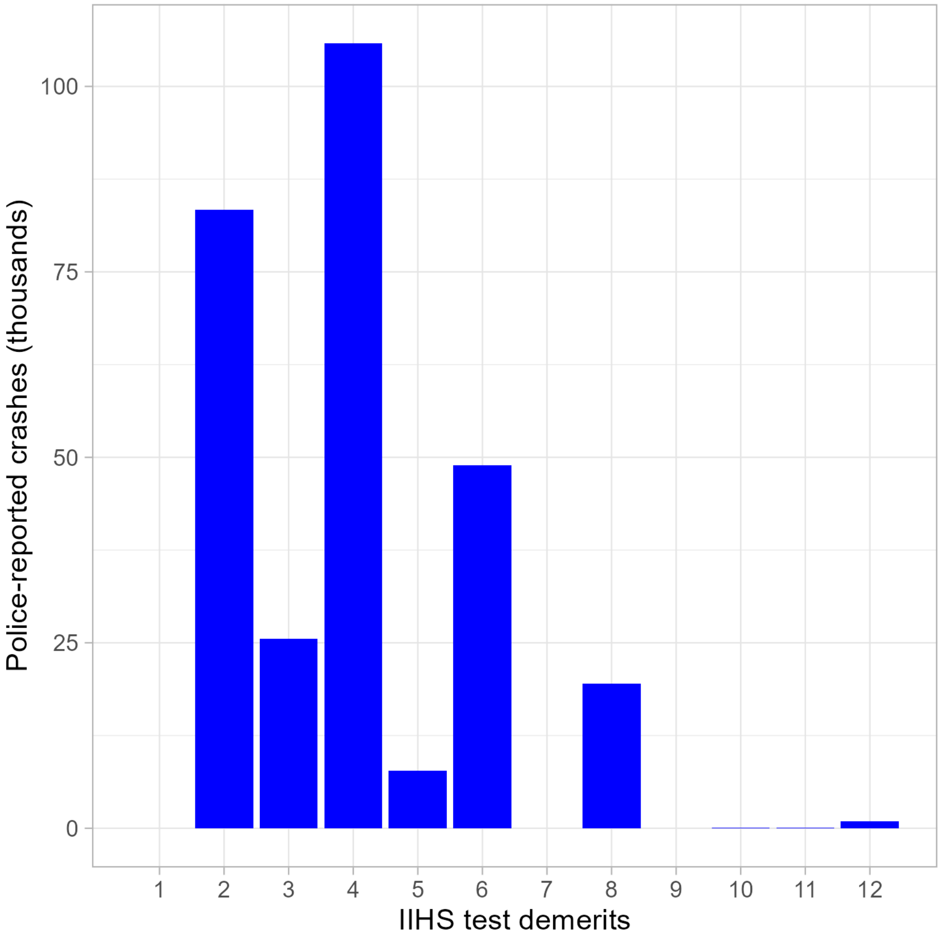

Fig. A1. Number of police-reported crashes by IIHS test demerits.

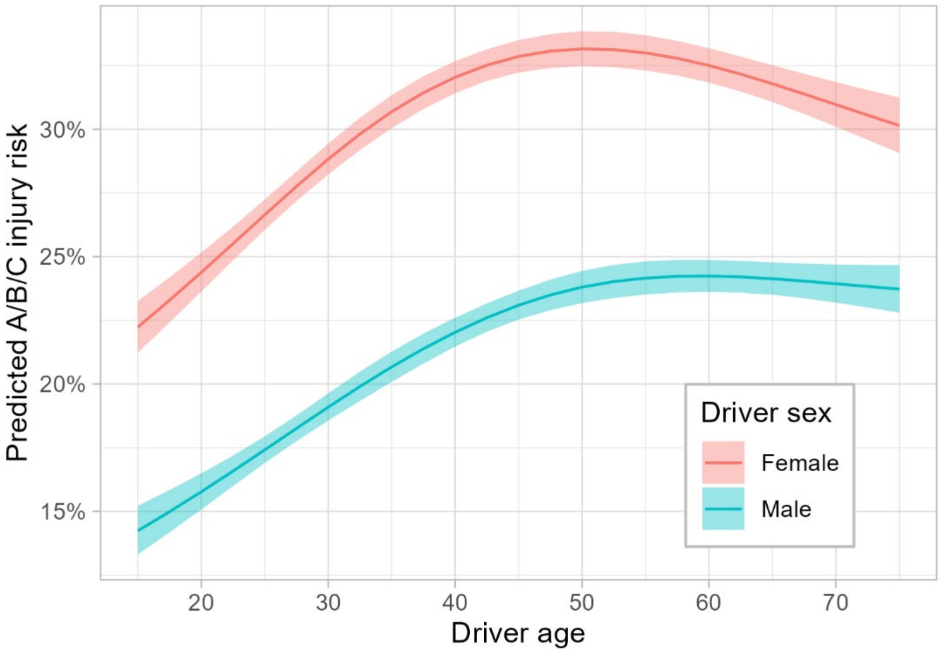

Fig. A2. Predicted A/B/C injury risk with 95% confidence interval by age and sex of the struck driver in otherwise identical crashes. Note: injury risk predicted for these factors: crash on 45 mph (72 km/h) road in Florida, two cars with same curb weight, striking-vehicle driver being a 40-year-old female, struck vehicle seat with 4 demerits.