Identification of Influential Factors Among Fatalities of Restrained First-Row Occupants in Recent Frontal Crashes

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Abstract This study conducted detailed case reviews of fatally injured belted drivers and front row passengers in frontal crashes in the United States. Cases were identified using the NHTSA's NASS-CDS, CISS, and CIREN databases. Although this study includes model year 2000 and newer vehicles, greater emphasis was placed on evaluating newer vehicles. A consensus panel reviewed each case and assigned influential factors that contributed to the fatal outcome. The influential factors included characteristics such as exceedingly severe, limited structural engagement, narrow object impact, heavy vehicle underride, and occupant specific factors. These categories generally aligned with prior studies and allowed case reviewers to characterise the fatalities in terms of high-level, crashworthiness-related themes. Results indicate that conditions of limited structural engagement and exceedingly severe are still the most common factors among fatally injured belted occupants in frontal crashes. Occupant specific factors, especially among female occupants, stood out more prominently in this study.

Keywords Case review, crashworthiness, fatal, frontal impact, vulnerable occupant.

I. INTRODUCTION

The most recent data from the United States (US) showed a 10% increase in traffic fatalities in 2021 compared to 2020, with 42,939 deaths occurring, the highest count since 2005 [1]. The number of injured persons increased more than 9% year-on-year to 2.5 million. Further examination of data from the Fatality Analysis Reporting System (FARS) indicates that fatalities of restrained, non-ejected occupants of light vehicles are most common where the subject vehicle's initial plane of contact is the front [2]. The proportion of restrained, non-ejected occupant fatalities occurring with an initial front plane impact has increased from 52% in 2012 to 59% in 2021. To address the increasing number of fatalities and serious injuries on roads, the United States Department of Transportation (DOT) implemented the National Roadway Safety Strategy (NRSS), with an emphasis on its objectives focusing on safer people, safer roads, safer vehicles, safer speeds, and post-crash care [3]. Given the prevalence of frontal crash fatalities, even among restrained occupants, in combination with the extensive testing and evaluation in the configuration, further exploration of field occurrence is necessary to identify potential paths for countermeasures.

The DOT's National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS) had conducted prior studies into publicly available field data collected by the NHTSA to assess factors that contribute to fatalities in frontal collisions [4-6]. The general approach by Bean *et al*. [4] and Brumbelow and Zuby [5] was similar, though each study had unique inclusion criteria. High crash severity was established as the primary causal factor for 37 of 121 fatalities examined in the NHTSA study of restrained front-row occupants in frontal crashes [4]. Among crashes deemed not overly severe, the authors concluded that the most common factors leading to fatalities were limited structural engagement (28 horizontal or 36 vertical), oblique impact direction (28), and elevated occupant age (30). The IIHS study of 96 fatal occupants also identified restraint/occupant factors and structural factors, concluding that small overlap, underride, and higher-severity moderate overlap configurations could be addressed with full-scale crash testing [5]. A similar IIHS study by Sherwood *et al*. concluded the intrusion resulting from small overlap and oblique frontal crashes was strongly related to injury severity [7]. The findings ultimately led to a new IIHS small-overlap frontal crash test, which was introduced in 2012 [8]. NHTSA undertook a test development program to target oblique frontal crashes, which culminated in a proposed update to its New Car Assessment Program (NCAP) in 2015 [9-10].

More than a decade has passed since the NHTSA and IIHS studies of fatal frontal crashes [4-10]. Federal Motor Vehicle Safety Standards (FMVSS Nos. 214 and 226) addressing side-impact and ejection mitigation have driven

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restraint enhancements with potential to affect occupant protection in some frontal crash conditions [11]. Further, NHTSA updated its NCAP testing program and rating system, starting in vehicle model year 2011, which motivated vehicle manufacturers to implement improved frontal crash protection. Finally, the US vehicle fleet includes vehicles with structure and restraint enhancements in response to the IIHS small overlap test. A 2021 study by Parenteau *et al.* [12] examined a set of 37 fatal crashes to observe advanced restraint system performance, using an approach similar to that used by Bean *et al*. [4]. The authors found 15 of the 37 fatalities occurred with delta-Vs above 64 km/h, and about a third were over 65 years of age [12]. They did not observe many cases involving oblique impact and notably did not include any fatalities with heavy truck crash partners. A 2023 IIHS report includes analysis of fatality risk in small overlap frontal crashes conducted with FARS data [13]. Vehicles achieving *Good* and *Acceptable* ratings in the small overlap frontal crash test were found to have 12% and 11% lower death risks, respectively, compared to vehicles receiving a *Poor* rating. While FARS data do not contain sufficient detail to specifically identify small overlap frontal crashes, the observation provides an encouraging outcome of the efforts to target high-risk frontal crash types identified in the preceding studies.

Given the crashworthiness improvements prompted by prior in-depth case analysis, the ongoing frontal crash problem warrants periodic updates following a similar approach. NHTSA conducts detailed crash investigations through the Crash Investigation Sampling System (CISS) and the Crash Injury Research and Engineering Network (CIREN). Prior to the introduction of CISS in 2016, NHTSA conducted in-depth investigations as part of the National Automotive Sampling System's Crashworthiness Data System (NASS-CDS). The CISS includes several enhancements to the collection methods used in NASS-CDS, including additional requirements for documenting injury causation coding. The data collected in these investigative systems allow researchers the opportunity to evaluate factors not discernible from records-based data. Specifically, researchers can examine causal factors relating to the people/occupants involved in these fatal collisions, the roadways these fatalities are occurring on, the vehicle and restraint designs, and even information about emergency responder response times and lifesaving efforts, ultimately aligning with the Department's NRSS. This study was undertaken to determine whether frontal crash fatalities in the field were occurring due to the continuation of previously identified vehicle and occupant factors or whether new factors may have emerged.

II. METHODS

This study conducted detailed case reviews of fatally injured belted drivers and outboard front row passenger occupants in frontal crashes of airbag-equipped vehicles. Cases selected for review were identified using three NHTSA databases: NASS-CDS, CISS, and CIREN. This study is a follow-on from the work conducted by Bean *et al.* [4] and by Rudd [6] and does not include the NASS-CDS or CIREN cases assessed under those studies. The CISS superseded the NASS-CDS data collection program when it was retired. Therefore, case years for NASS-CDS are 2012–2015, for CISS are 2017–2021, and CIREN are 2005–2022. Case data were queried from publicly available data tables for NASS-CDS, CISS, and CIREN (2005–2016). Case data for CIREN 2017–2022 were queried from an internal database. All cases are available for examination in NHTSA's internet-based Crash Viewer [13]. Although the nature of this follow-on study includes vehicles as old as the 2000 model year, greater emphasis for the Results and Discussion sections of this paper will be on the fatalities that occurred in newer vehicles that are more likely to reflect updated crashworthiness considerations (i.e. model year 2012 and newer).

Data Selection

Eligible fatal occupants for this study included drivers or front-row right passengers in a model year 2000 or newer, frontal airbag-equipped light passenger vehicle with a highest-severity frontal crash event. All belt-restrained occupants in these seating positions were considered, regardless of demographics such as age, sex, weight, etc. Frontal impacts were defined as having a principal direction of force (PDOF) between 0° and 40° *or* 320° and 360° for the highest-ranked crash event for the subject vehicle. The collision deformation classification (CDC) damage plane for the highest-ranked crash event was required to be either 1) *Front* or 2) *Left Side/Right Side* with a CDC longitudinal/lateral location (specific horizontal location) of *Side Front*. The fatally injured occupant was secured by their lap and shoulder belt. The aim of the study was to focus on occupants with frontal airbag protection, but case inclusion did not require a frontal airbag deployment for the highest ranked (frontal) crash event. Occupants who were completely ejected were excluded from the study.

Case Review

After fatally injured occupants were identified through the data selection process, each case was assigned to an individual panel member, selected from an expert panel of 13 engineers and research support within NHTSA's Office of Vehicle Safety Research. Each individual evaluated their assigned cases and compiled relevant evidence from NHTSA's Crash Viewer [13] for later discussion during a panel review. Consistent with the case review methods specified by Bean *et. Al* [4], the panel jointly analysed case summaries, photographs, occupant injuries, and select vehicle and crash specific variables for every case. For cases where detailed injuries were documented, the analysis considered body region and type of injury. Occupant comorbidities were also assessed to determine whether they may have contributed to the occupant's fatal outcome. Ratings from the US NCAP frontal test (relevant to the occupant's seating position), the IIHS moderate overlap test, and the IIHS small overlap test were also noted for the case vehicle, when tested.

All the compiled data were recorded into a standard case review template designed to enable consistent documentation by all panel members for this study. Completion of the template included a narrative assessment and preliminary assignment of up to three factors contributing to the fatal outcome. Selection of a factor was based on its necessity in producing the fatal outcome, and incidental factors not essential for the fatal outcome were not assigned. Occupant-specific factors, such as elevated age or obesity, were only assigned in instances where the condition was deemed influential to the occupant's fatal outcome. As an example, a decedent's age or obesity would not have been considered imperative for a fatality involving underride of a heavy goods vehicle resulting in fatal head injuries from windshield header intrusion.

Following the preliminary individual case assessments, the panel met to review and discuss each case, using the compiled evidence and preliminary assessments prepared by the individual member. The team then reached a consensus on the most influential factors for each case. The factors and their definitions are listed in Appendix Table AI. To enable a more direct comparison to the findings in Rudd [6], the influential factors were categorised into more generalized groups matching the assignments in that study. The mapping of the factors is indicated in Table AI with many mapping one-to-one and others dependent on specific case details.

Cases were not excluded from this study based on the presence of non-frontal crash events, such as rollover or fire. Rather, the review processes evaluated case evidence and the panel agreed whether a non-frontal event caused the fatality. For example, if the only coded cause of death for an occupant was designated as smoke inhalation, the case was excluded from the study. In cases where the non-frontal event could not be ruled out as a contributory factor, its role was considered accordingly.

III. RESULTS

Querying the NASS-CDS, CISS, and CIREN databases using the criteria established above identified 204 occupants for inclusion in this study. After exclusion of 16 fatalities deemed non-frontal, the case review process considered 64 NASS-CDS, 94 CISS, and 30 CIREN occupants (Table I). Justifications for exclusions are given in Table AII. Additional case details are provided in Tables AIII, AIV, and AV. The factors indicated in Table AIII align with those in Rudd [6] while those in Tables AIV and AV are the influential factors specific to this study and defined in Table AI. This study assessed 188 fatally injured driver and front right passenger occupants in 178 vehicles that were model year 2000 and newer (Fig. 1). One crash included a fatality from two different case vehicles and 10 crashes included two qualifying fatalities within the same vehicle.

TABLE I
NUMBER OF QUALIFYING CRASHES, VEHICLES, AND OCCUPANTS BY DATABASE

	NASS-CDS	CISS	CIREN	Total
Cases	62	86	29	177
Vehicles	62	87	29	178
Occupants	64	94	30	188

Over 40% of the fatally injured occupants in this study were drivers or right front passengers in vehicles that were model year 2007 or older (Fig. 1). The objects most frequently contacted by the occupant's vehicle were another vehicle, at 69%, followed by fixed objects, including poles and trees, at 20% (Fig. 2). Of the 188 fatally injured occupants in this study, 117 were male and 71 were female. Male drivers accounted for 58% of fatalities, followed by female drivers at 27% (Fig. 3). Of the 15% of occupants who were right front passengers, over twice as many females were fatally injured compared to males.

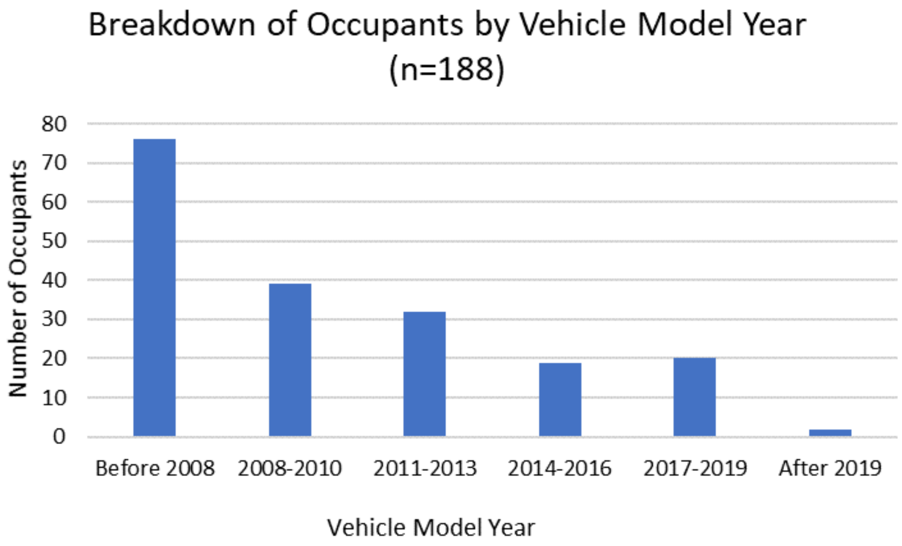

Fig. 1. Distribution for the fatally injured occupant's vehicle by model year.

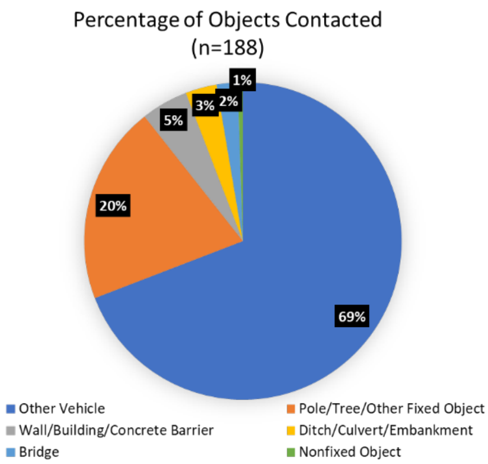

Fig. 2. Type and percentage breakdown of objects contacted by the fatally injured occupant's vehicle in the frontal crash event.

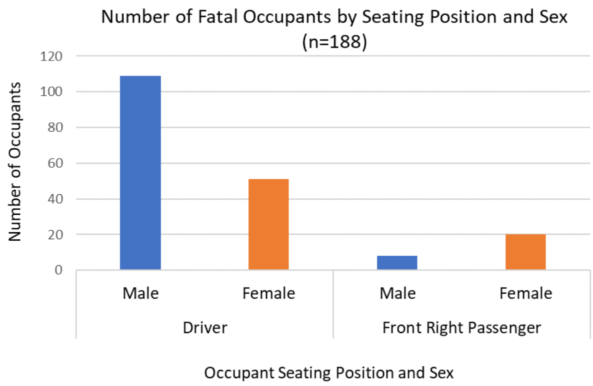

Fig. 3. Counts of all fatal occupants by seating position and sex.

Average occupant age was 54 years. The youngest and oldest case occupants were 18 and 97 years of age, respectively. Eighteen percent of occupants were at least 76 years of age (Fig. 4). The largest number of male fatalities was in the 56-65 age group with 25 occupants, while the largest number of female fatalities was in the 66-75 age group with fifteen occupants. Nearly 40% of occupants had a Body Mass Index (BMI) of 30 or higher (rounded to the nearest whole number), which is considered obese, regardless of sex (Fig. 5).

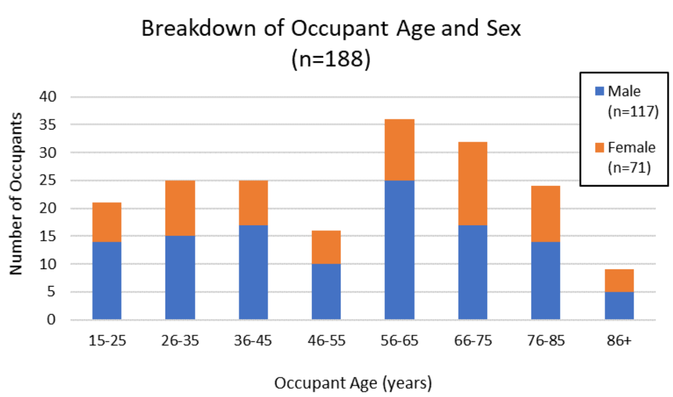

Fig. 4. Age and sex distribution for all fatally injured occupants.

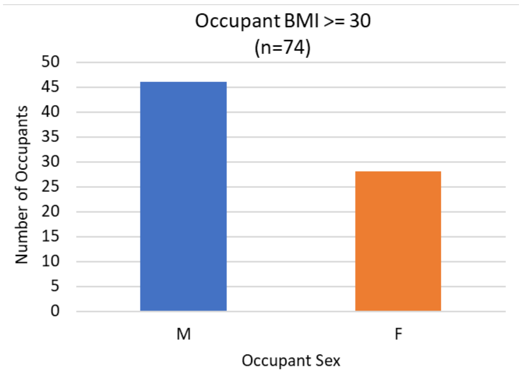

Fig. 5. Breakdown of obese (BMI >= 30) occupants by sex.

As described in the Methods section, every case analysed was assigned up to three influential factors considered contributory to cause of the occupant's fatal outcome (Fig. 6). The most common influential factors were *exceedingly severe* for 82 occupants, *case to partner incompatibility* for 50 occupants, and *limited structural engagement* for 48 occupants. The factors are indicated in Table AIV for NASS-CDS and CISS cases and Table AV for CIREN cases.

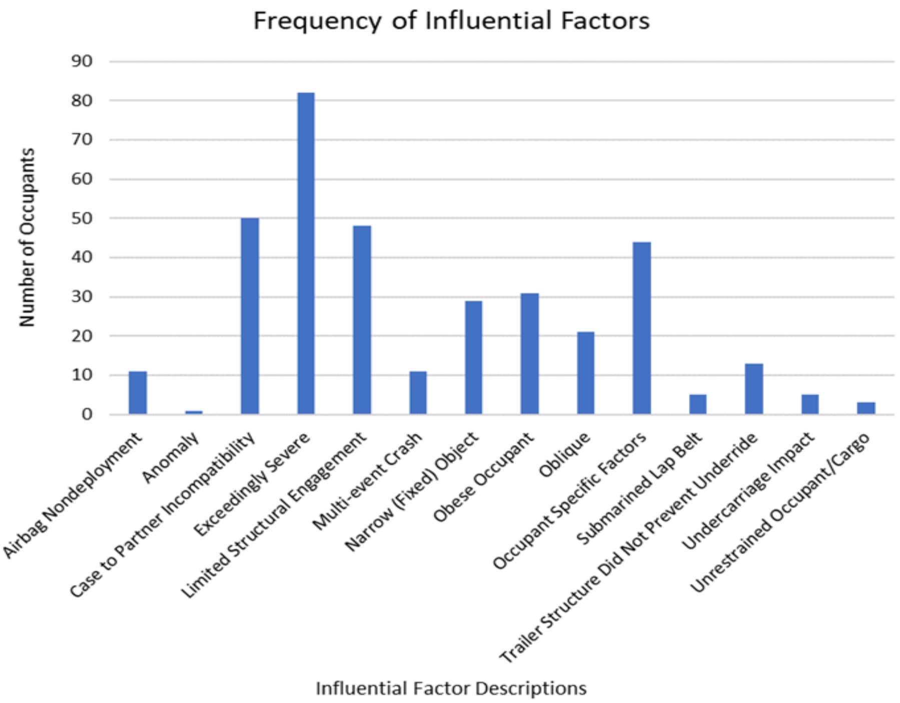

Fig. 6. Frequency of influential factors contributing to the fatal outcomes of the assessed occupants. Note that each occupant may have multiple factors assigned.

The percentage comparisons between MY 2011 and older vehicles (MY scope considered by Rudd [6]) and MY 2012 and newer vehicles by influential factor are represented in Fig. 7. Newer model year vehicles were designated the *limited structural engagement* factor 7% less than older vehicles. *Case to partner incompatibility* is 5% higher for occupants in newer compared to older vehicles. Newer vehicles were 4% higher for the *exceedingly severe* and *obese occupant* factors. *Occupant specific factors* between older and newer vehicles is comparable, within 1% difference. *Airbag nondeployment*, *submarined lap belt*, *trailer structure did not prevent underride*, and *undercarriage impact* were assigned as factors to eleven, five, thirteen, and five occupants, respectively. Notably, all occupants where *airbag nondeployment* were coded as an influential factor were in model year vehicles that were 2012 or older. There were no occupants in newer model year vehicles coded with an *undercarriage impact* factor. Four of the five *submarined lap belt* factors were assigned to occupants in MY 2012 and newer vehicles.

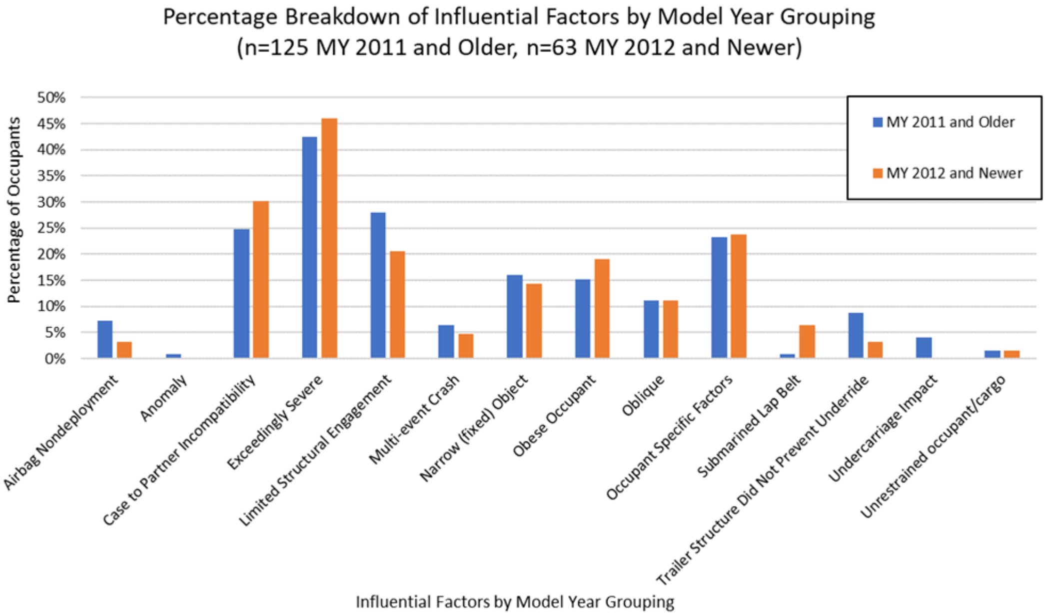

Fig. 7. Percentage of occupants assigned influential factors by model year grouping. Note that each occupant may have multiple factors assigned.

Categorising by occupant sex, *exceedingly severe* was the most dominant factor for both males and females, at 46% and 39%, represented in Fig. 8. *Occupant specific factors* had a higher female percentage compared to males, at 32% of females and 18% of males. Females also had a higher percentage of the *obese occupant* factor compared to males, at 21% compared to 14%. Percentage of male occupants was higher for the *limited structural engagement* (28%) and *narrow (fixed) object* (19%) factors compared to females (21% and 10%).

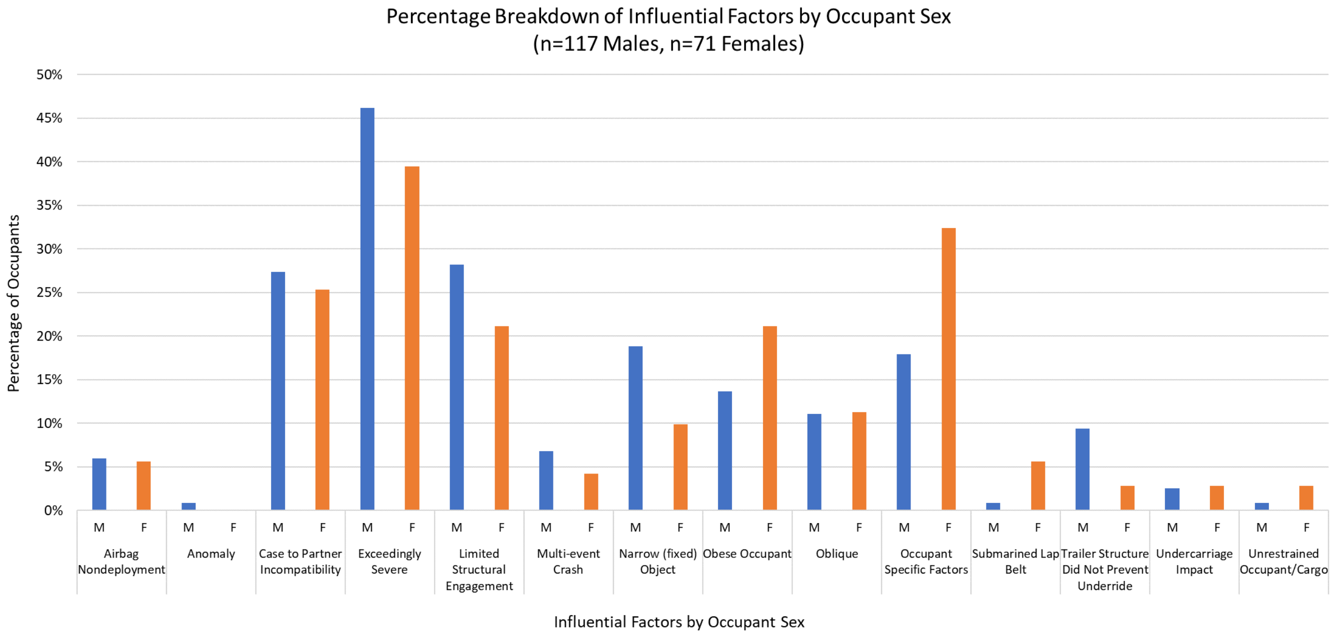

Fig. 8. Percentage of occupants assigned influential factors by sex. Note that each occupant may have multiple factors assigned.

Figures 9 and 10 show the breakdown of vehicles that were tested in the NCAP frontal test, IIHS moderate overlap test, and/or IIHS small overlap test. Vehicle model year groupings separate the older model years from the newer model years, which are the focus for this study. Over 82% of case occupants were in a vehicle that had a 4- or 5-star NCAP Frontal Crash Test Rating, and 88% were in a vehicle that received a score of *Acceptable* or

Good on the IIHS moderate overlap test. As represented in Table II, the number of case occupants in vehicles that were *Not Tested* to the IIHS small overlap test is notable at 74%. There were 49 occupants in vehicles tested to the IIHS small overlap test.

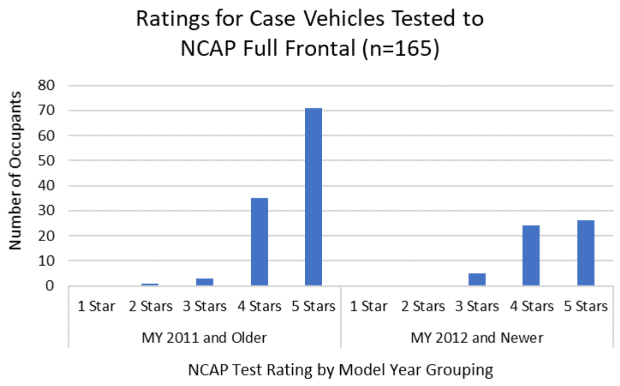

Fig. 9. Model year grouping (old vs. new) and ratings breakdown for fatally injured occupants in vehicles tested to the NCAP full frontal test.

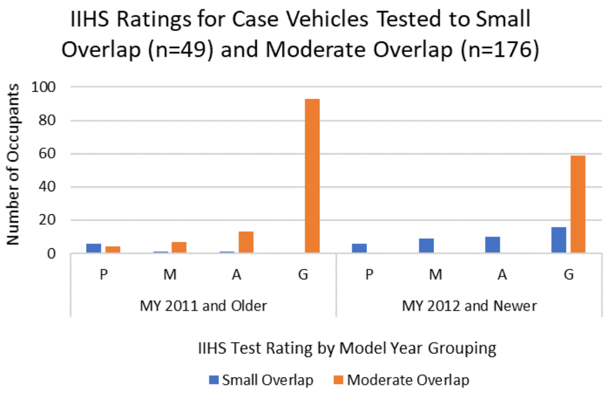

Fig. 10. Model year grouping (old vs. new) and IIHS ratings breakdown for fatally injured occupants in vehicles tested to the Small Overlap and Moderate Overlap tests.

TABLE II
NUMBER OF OCCUPANTS IN VEHICLES NOT TESTED TO IIHS/NCAP TESTS

	IIHS Small Overlap	IIHS Moderate Overlap	NCAP Frontal
MY 2011 and Older (125 vehicles)	117 (94%)	8 (6%)	15 (12%)
MY 2012 and Newer (63 vehicles)	22 (18%)	4 (3%)	8 (6%)

Sixteen occupants were in a vehicle that received a *Good* rating on the IIHS Small Overlap Test and eleven occupants were in a vehicle that received an *Acceptable* rating. The influential factors assigned for these 27 occupants is represented in Fig. 11. None of the occupants in *Good* or *Acceptable* rated vehicles had an influential factor assigned for *airbag nondeployment*, *anomaly*, *undercarriage impact*, *trailer structure did not prevent underride*, or *unrestrained occupant/cargo*. *Exceedingly severe* was the highest influential factor, assigned for 48% of occupants in vehicles that received a *Good* or *Acceptable* small overlap test rating. *Narrow (fixed) object* and *occupant specific factors* were both assigned for 22% of occupants in vehicles that received these ratings. *Limited structural engagement*, a factor that involves crash conditions similar to the small overlap test, was assigned as an influential factor for four occupants, three of whom had one additional influential factor assigned.

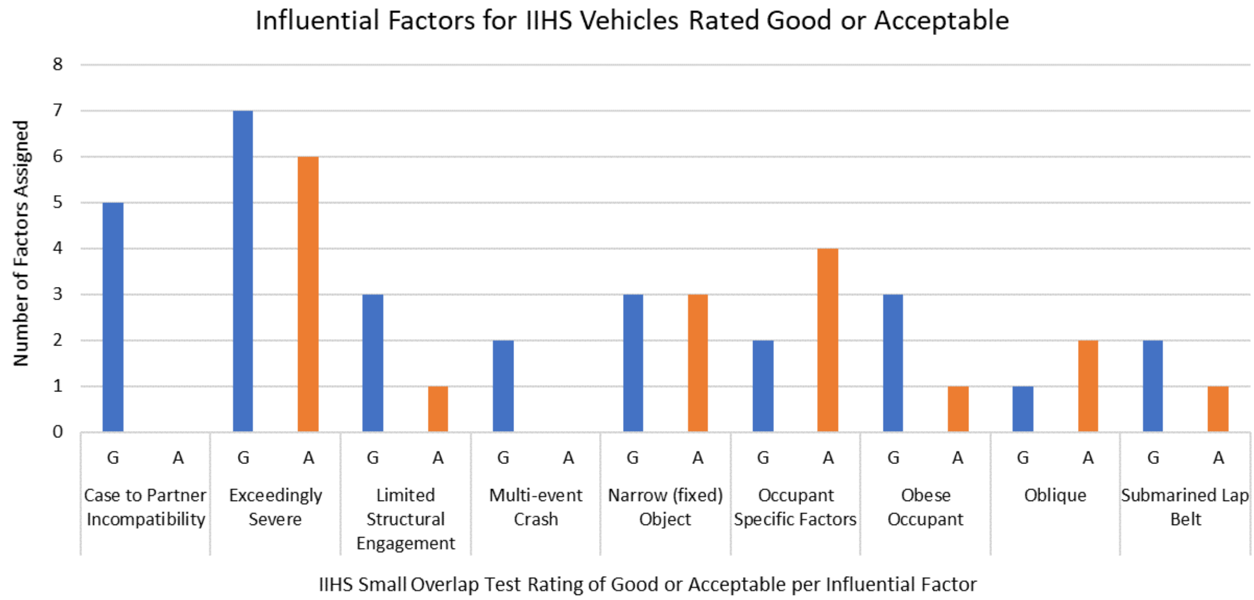

Fig. 11. Breakdown of influential factors assigned for occupants in vehicles that received a rating of *Good* or *Acceptable* on the IIHS Small Overlap Test. Note that each occupant may have multiple factors assigned.

IV. Discussion

Overall, this review of fatalities of restrained front-row occupants in frontal crashes highlights similar factors as prior studies. The most prominent factor was exceedingly severe, followed by case to partner incompatibility, limited structural engagement, and occupant specific factors. A larger proportion of crashes in this study (over 40%) were determined to have a high crash severity that outweighed structural, restraint or occupant factors.

There is no entirely objective threshold to assign exceedingly severe as a factor, though guidance for this classification is defined in Table AI. The review team selected this factor for crashes where the crash energy was considered to be beyond what production vehicles and restraint systems can reasonably manage. Regardless of overlap and structural engagement, these crashes produced notable intrusions and resulted in occupants overloading restraints such that contact with non-forgiving structures or sub-optimal restraint interaction was inevitable. An example is 2013-43-038-1-1[1] (Fig. 12), where the case vehicle's estimated travel speed was 153 km/h before leaving the roadway and striking a tree. The impact caused the vehicle to pitch upward such that the header and roof also deformed from tree contact. Even absent catastrophic intrusion, restraints may not have managed occupant ride-down with speed changes greater than those common in crash tests. The case vehicle in CIRENID 432 (Fig. 13) did not experience a reduction in occupant compartment volume, but the young female driver submarined the lap belt in the high delta-V crash (76 km/h longitudinal indicated by event data recorder, EDR). The 2016 Honda Civic received top ratings in crash tests and experienced a full-width engagement in this crash.

A unique circumstance among the exceedingly severe crashes was that of a wrong-way driver on the roadway leading to a head-on crash, which was confirmed in eleven crashes. This generally exposes both vehicles to an overly severe crash condition since the travel speeds on divided highways tend to be higher. Alcohol influence was a common feature in these wrong way cases. These crashes highlight issues relevant to the safer roads, safer speeds and safer people objectives of the NRSS, more so than safer vehicles given the engineering challenges of managing such severity.

[1] References to specific NASS-CDS or CISS occupants are given as YEAR-PSU-CASE-VEHICLE NUMBER-OCCUPANT NUMBER

Fig. 12. Front crush for 2013-43-038-1-1 with high travel speed into a tree.

Fig. 13. Occupant's seating position in CIRENID 432, which was considered Exceedingly Severe based on the EDR-calculated speed change.

Crash configuration remained a prominent factor in the outcome of the examined crashes. The extent of structural engagement, primarily in the horizontal sense, frequently led to significant intrusion of the occupant compartment. There were fewer trailer underride cases in this dataset compared to Bean *et al.* [4], though similar outcomes were observed with intrusion to the greenhouse portion generally producing head injuries. Trailer structure did not prevent underride of twelve subject vehicles for thirteen case occupants. Case number 2019-17-031-1 involved fatalities of both the driver and front right passenger after impacting the rear of a cargo trailer. Half of the case vehicles under-rode the rear of the trailer, while the remaining half of the case vehicles under-rode the trailer's side. A lack of evidence for the struck trailers prevented assessment of underride guard performance. Cases with limited structural engagement suffered similar problems as in prior studies. This study resulted in fewer crashes with *oblique* as a factor compared to Bean *et al.* [4], but the role played was generally the same, with notable intrusion or poor occupant interaction with the airbag.

Impacts with medium and heavy trucks that did not involve trailer underride were captured as *case to partner incompatibility*. This factor was expanded in this study to also include compatibility issues between passenger cars or light trucks with substantial mass and/or height differences. Case number 2019-14-003-1-1 involved a modified (increased ground clearance) 2017 Ford F-150 which overrode the 2017 Dodge Caravan case vehicle, imparting maximum severity head and thorax injuries to the Caravan's driver. *Case to partner incompatibility* was a common theme in this study, similar to prior studies involving heavy goods vehicles, and remains a challenging problem to solve given the combined effects of mass, geometry, and stiffness differences for light versus heavy vehicle impacts.

Similar to the prior studies, *occupant specific factors* were commonly cited in this group of fatal crashes. Many of these cases involved the decedents surviving the crash but later dying of complications; their deaths were not specifically tied to any crash injuries. This number would probably be higher were it not for missing or limited medical information in some cases, noted as such in Appendices AIV. One unique observation was that *occupant specific factors* was the most common factor among the CIREN cases, assigned for sixteen CIREN case occupants. This is likely due to a combination of CIREN's case inclusion bias and the extensive medical information capable of providing more insight on the cause of death. CIREN includes relatively few case subjects who expire at the crash scene based on its case acquisition process, so a high proportion of fatalities in CIREN die of complications during treatment rather than specific injuries sustained in the crash. Half of the CIREN occupants assigned *occupant specific factors* had it as the sole influential factor, while the other half of these CIREN occupants had one additional influential factor applied. For these occupants, although occupant specific factors played a role in the occupant's fatal outcome, other crash characteristics were also deemed influential.

The decedents in this study were mostly male (62%), which tracks with findings from FARS over the past 10 years (average 61%). The influential factors were shown by decedent's sex in Fig. 8 and the most notable difference is the greater proportion of females with occupant specific factors. The differences in the crash- or vehicle-specific factors were not as pronounced. Of note, and related to the bias in CIREN toward occupant specific factors, within CISS and NASS-CDS, males outnumbered females two-to-one. However, in CIREN fatalities, females outnumbered males by a factor of 1.5. This outcome warrants further examination to look at other occupant factors and injury outcomes.

While 39% of the decedents in this study qualified as obese, the reviewers found the *obese occupant* factor to be applied for less than half (42%) of those occupants. Obesity was identified as a factor when restraints were overloaded or judged to not be positioned correctly. Occupant BMI would not play much of a role in a crash with significant intrusion, such as a trailer underride. While a broad spectrum of occupant sizes should be considered when designing safety systems, it appears that occupant factors related to elevated age and reduced tolerance to injury demand greater attention among fatal frontal crashes. Among the occupants 70 years or older, 62% had *occupant specific factors* identified.

Other factors observed, but not present in many cases, were *multi-event crashes* or imparted with a vertical component through an *undercarriage impact*. Uncertainties regarding occupant response and restraint performance introduced with these crash types cast some doubt on the overall assessment of the affected cases. For multi-event crashes, primarily those without EDR information, questions about restraint deployment timing arose. In terrain impacts, an uncertain amount of vertical deceleration often masks the true severity of the impact given the structural response of the vehicle or absence of normal acceleration measurement by the EDR. The five *undercarriage impact* factor assignments were observed to only be present for vehicles that were MY 2011 and older.

Unlike prior studies, airbag deployment was not used as an exclusion factor for this study and therefore is included within the 188-occupant case count. This was intended to allow for exploration of fatal field data into instances where airbag deployment would have been expected based on crash configuration, crash severity, and/or occupant injury outcome. In this study, there were twelve occupants in vehicles where airbag deployment was expected, yet the airbag did not deploy. Of these twelve occupants, eleven had *airbag nondeployment* coded as a factor that contributed to the occupant's fatal outcome. *Airbag nondeployment* was not coded as a factor for case number 2014-08-029-3-1, when a school bus completely overrode the case vehicle (a 2011 Nissan Altima) such that none of the vehicle's structural frame rails were engaged. Therefore, the unusual crash circumstances for this case instead categorised this crash as *anomaly*. Failure to reinstall the airbag was determined to be the cause for airbag nondeployment in case number 2015-49-005-1-1. There were nine occupants in this study where airbag deployment was coded as *Unknown*, which are noted for the respective occupant in Table AIV.

Slightly more than half of the decedents received no treatment at a medical facility. Most cases in this study lacked sufficient information to assess the role played by emergency response in the fatalities. One notable CIREN case, CIRENID 360208690, involved a vehicle that left the roadway and struck a tree down a slight embankment. The EMS notification did not occur until over ten hours after the crash. While rare, this individual may have survived the thoracic injuries had treatment been delivered sooner post-crash. There is insufficient information in this dataset to identify shortcomings related to post-crash care.

One of the primary motivations for this study was to examine whether the nature of frontal crash fatalities of restrained occupants has changed because of design changes implemented since prior similar studies. One aspect of this was to look at newer vehicles with structures and restraints aimed at meeting more recent test protocols. Brumbelow *et al*. cited collapse of the occupant compartment, subsequent to reduced structural engagement and high crash severity, as the most promising problem to address through crashworthiness testing [5]. The most notable new test protocol aimed specifically at crash conditions identified in prior studies is the IIHS small overlap frontal test. Despite including case data from as recent as the 2022 calendar year, two-thirds of the occupants in this study were in vehicles that were older than the 2012 model year. About a quarter of occupants in this study were in case vehicle models that have been subjected to the IIHS small overlap test. An analysis of those receiving *Good* or *Acceptable* ratings showed that exceedingly severe was the most common influential factor. Five cases cited *limited structural engagement* as a factor, two of which involved notable intrusion to the occupant compartment causing head injuries from A-pillar contact (2020-14-068-1-1 and 2020-30-066-2-1). Crash severity and conditions in both of those cases deviated from the small overlap test condition. Even with newer crashworthiness designs, vehicle frontal structures and occupant compartments continue to suffer from injurious collapse in higher-severity frontal crashes or with partial overlap/engagement conditions.

When considering the findings of this study in the context of the classification groups presented by Rudd [6], the influential factors assigned in this study were categorised into groups like those in the 2013 study to assess any shifts in the main factors (Table III). Note that for this study, up to three factors were permitted per case, with

67 fatalities coded with one factor, 107 with two factors, and 14 with three factors. Comparatively, Rudd [6] assigned a maximum of two factors per case, with 153 fatalities coded with one factor and 34 fatalities with two factors[2]. Notable differences are a higher percentage of cases considered exceedingly severe, as well as more involving a narrow impact, occupant factors, or other factors. While the definition of *exceedingly severe* was slightly revised from the prior study [6], the nearly 50% increase suggests a need to emphasize solutions to the scenarios that lead to such crashes rather than a focus on vehicle crashworthiness. This study found narrow impacts to be a factor twice as much as in Rudd [6], but the overall relevance is still relatively low at 15%. Occupant factors were cited twice as much in this study compared to the prior study and were present in a third of the cases. The prevalence of this factor warrants further study to determine how engineering, behavioural, or post-crash care approaches could improve outcomes.

TABLE III
FREQUENCY OF FACTOR CATEGORISATION

	Number of Fatalities	Exceedingly Severe	Corner/ Oblique	Heavy Vehicle	Narrow Impact	Occupant Vulnerability/Factors	Other
Rudd 2013 [6]	189	55 (29%)	67 (35%)	40 (21%)	14 (7%)	45 (24%)	6 (3%)
Current Study	188	82 (44%)	64 (34%)	44 (23%)	29 (15%)	68 (36%)	36 (19%)

The most notable limitation is that this is a convenience study of fatalities, designed as a follow-on to Rudd [6]. It is not a census study, nor is it a nationally representative sampling of fatal frontal crashes. Three different databases were used with varying extents of detail regarding injuries. Some fatalities in NASS-CDS and CISS did not include comprehensive injury documentation due to external factors, such as non-cooperative medical facilities or conduct of external-only autopsies, which often fail to identify critical injuries. Though less common, some case vehicles in NASS-CDS and CISS were not subjected to a complete standard NHTSA investigation and documentation of the vehicle's condition may have lacked some evidence necessary for the team's assessment. Some CISS investigations from the 2020 case year were limited based on restrictions imposed during the COVID-19 pandemic. Table AIV indicates nineteen cases where there was insufficient injury information documented to evaluate the occupant's outcome, or where missing vehicle information (e.g., crush measurements, interior/exterior photos, etc.) prohibited a comprehensive assessment of crash severity and fatal injury causation. Though CIREN cases are built upon comprehensive medical documentation, certain data elements, such as comorbidities or drug and alcohol laboratory results, are not released to the public. In cases where complications or comorbidities are implicated in a CIREN case subject's demise, that information is available in the SAS file.

For fatal crashes where the crash partner was a non-applicable vehicle (i.e., buses or medium/heavy trucks), very little detail was available for the non-applicable vehicle except in some cases with on-scene photographs. For CIREN cases, complete inspection of crash partner vehicles, even when an applicable body type, only occurs when an occupant of that vehicle has also provided consent to participate in the study. Differences in case inclusion among the studies, namely that CIREN collects relatively few scene fatalities, is also worth noting given the greater number of cases with occupant factors identified.

One of the primary objectives was examine factors associated with fatalities of restrained occupants in frontal crashes of newer vehicles. Despite several additional years of data compared to the Rudd [6] study from 2013, most of the case vehicles in this study were too old to feature designs optimized to the more stringent crashworthiness criteria. This presented challenges when trying to assess how well more stringent testing criteria affect real-world performance.

Finally, the methodology employed may impart bias given the subjective nature of some factor assignments. The consensus approach was used to solicit multiple opinions and to improve overall consistency in the factor assignments. Even though the case template and consensus review process were designed to minimize subjectivity and bias, the overall case assessment of this study is a product of this research team's consensus review process.

[2] Two fatalities in Rudd [6] had zero factors assigned.

V. CONCLUSIONS

Precedent NHTSA studies involving fatal frontal collisions with restrained occupants occurred prior to fleet penetration of vehicles equipped to meet updated crashworthiness standards and criteria. Examples of these improvements include enhancements to side curtain airbags to meet FMVSS Nos. 214 and 226 requirements, which subsequently provide additional occupant protection in oblique and limited engagement of frontal impacts, and the addition of structural components to enhance vehicle performance in the IIHS small overlap test. Occupant compartment intrusion secondary to limited front overlap, high-severity, or heavy partner vehicle impacts remains a common issue among fatal frontal crashes of restrained occupants examined in this study. Occupant vulnerability, even when crash conditions are otherwise not severe, represents a notable portion of fatal crash victims examined in this study. Not only do vulnerable occupants have lower injury tolerance to crash loading, they frequently sustain treatable injuries but die of complications in the hospital. This study identifies new opportunities and priorities for prevention of occupant fatalities in frontal crashes.

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VIII. APPENDIX

TABLE AI

DEFINITIONS FOR INFLUENTIAL FACTORS

Factor	Definition	Map to Factors in Rudd [6]
Anomaly	Unusual crash circumstances that may not be captured by current vehicle crashworthiness designs or standards	Heavy Vehicle
Case to Partner Incompatibility	Significant mass and/or height mismatch between the subject case vehicle and the contacted partner vehicle; includes impacts involving the front of medium and heavy trucks as well as compatibility issues between passenger cars/light trucks	Corner Oblique Exceedingly Severe Heavy Vehicle
Exceedingly Severe	Occupant deceleration exceeds capabilities of the restraint system; likely a fatal event even if the crash had been a full-frontal with good structural performance; generally considered with delta-V above 56 km/h, though additional crash considerations may supersede a coded delta-V designation	Exceedingly Severe
Limited Structural Engagement	The crash is offset from vehicle centre and may not have fully engaged the subject vehicle's structural components	Corner/Oblique
Obese Occupant	Occupant's Body Mass Index (BMI) is ≥ 30, rounded to the nearest whole number; occupant may have bottomed out airbag and/or had poor seat-belt engagement during the crash event	Occupant Vulnerability/ Factors
Oblique	Crash occurs at an angle, with the PDOF specified between 30 and 40 degrees or 310 and 320 degrees	Corner/Oblique
Narrow (fixed) Object	The subject vehicle has limited structural engagement as a result of contact with a fixed object such as a pole, tree, or other narrow fixed object; based on the location of engagement, the restraint system's deployment timing may have been altered, increasing risk for occupant injury	Narrow Impact
Trailer Structure Did Not Prevent Underride	Vehicle underrides the rear or side of a tractor trailer (heavy goods vehicle); if a rear trailer guard is present, the impact exceeds the guard's design limitations, possibly reducing its effectiveness	Heavy Vehicle
Occupant Specific Factors	Occupant's elevated age (>=70 years old), body stature and habitus, medical condition/comorbidity, restraint use, seat positioning, or unusual posture increases their risk for injuries during a crash event; this factor is an expansion on the "vulnerable occupant" factor defined in Rudd [6]	Occupant Vulnerability/Factors
Undercarriage Impact	The underside of the vehicle comes into contact with an embankment, ditch, etc., which may increase the occupant's risk for injury; the impact may impart a vertical force loading condition to the occupant, cause the occupant to become out of position when they engage the restraint system, and may affect the deployment timing for restraint systems	Other

Airbag Nondeployment	Based on provided case evidence, frontal airbag deployment was expected to mitigate injury during the relevant crash event; however, the airbag did not deploy which may have contributed to the occupant’s fatal outcome	Other
Multi-event Crash	The vehicle experienced a series of crash events which increased their vulnerability to injury; to be included in this factor, an occupant may have sub-optimally engaged their restraint systems because they were out of position from a prior event, or their restraint systems had deployed in the prior event	Other
Submarined Lap Belt	Sufficient case evidence exists to indicate that the occupant’s fatal injuries were caused by the lap portion of the seat belt engaging their abdomen during the crash event	Other
Unrestrained Occupant/Cargo	An unbelted occupant or loose cargo potentially load the occupant during the crash event, increasing their risk for injury	Other

TABLE AII
CASES EXCLUDED FROM STUDY (N=28)

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Reason for Exclusion
2012	8	144	-	1	1	Cause of death attributed to rollover event
2012	49	107	-	2	1	Cause of death attributed to side impact event
2012	74	73	-	2	1	Cause of death attributed to rollover event
2013	11	123	-	1	1	Cause of death attributed to rollover event
2013	11	123	-	1	2	Cause of death attributed to rollover event
2013	45	141	-	1	1	Cause of death attributed to vehicle fire
2014	45	106	-	1	1	Minor vehicle crash deformation and minor injuries coded; cause of death attributed to factors unrelated to frontal crash event
2014	75	57	-	1	1	Cause of death attributed to occupant factors unrelated to frontal crash event
2018	17	64	-	1	1	Multi crash event that included multiple severe rollovers and post-crash fire; cause of death not attributed to frontal collision
2018	27	70	-	1	1	Fatal ruled disease
2020	11	95	-	1	1	Fatal ruled disease
2020	13	59	-	1	1	Fatal ruled disease
2020	48	73	-	1	1	Cause of death attributed to right side impact
2020	73	4	-	2	1	Cause of death attributed to occupant factors unrelated to frontal crash event
2021	24	130	-	1	2	Shoulder belt wrapped behind occupant’s back; fatality attributed to shoulder belt misuse
-	-	-	983	1	1	Cause of death attributed to side impact event

TABLE AIII

INCLUDED NASS-CDS, CISS, AND CIREN CASES FOR STUDY (N=188)

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	Exceedingly Severe	Narrow Impact	Corner/Oblique	Heavy Vehicle	Occupant Vulnerability/ Factors	Other
2012	6	73	-	1	1	22	F	20	11	4	2011	Volkswagen Jetta			✓			
2012	9	20	-	2	*2	77	F	U	13	3	2010	Ford Edge					✓	
2012	9	69	-	1	1	57	M	35	11	5	2005	Honda Accord					✓	✓
2012	11	136	-	1	1	21	M	24	11	5	2005	Dodge Neon	✓			✓		
2012	13	60	-	2	1	37	M	39	11	4	2007	Ford Focus			✓			
2012	43	33	-	1	1	38	M	31	11	1	2003	Honda Pilot		✓	✓			
2012	43	140	-	1	*‡1	28	F	23	11	2	2009	Toyota Corolla	✓					
2012	43	194	-	2	1	55	F	34	11	3	2007	Lexus ES-350			✓			
2012	43	200	-	1	†1	22	M	21	11	6	2008	Dodge Caliber	✓	✓	✓			
2012	43	200	-	1	2	29	M	24	13	6	2008	Dodge Caliber	✓	✓	✓			
2012	48	68	-	1	2	28	F	39	13	5	2005	Chevrolet Malibu			✓		✓	
2012	49	63	-	1	1	67	F	26	11	5	2007	Honda Accord		✓			✓	
2012	49	160	-	2	1	31	M	28	11	6	2010	Hyundai Sonata	✓			✓		
2012	73	87	-	1	1	35	F	39	11	3	2004	Chevrolet Venture		✓	✓			
2012	76	88	-	1	2	23	M	27	13	4	2007	Dodge Charger				✓		✓
2012	76	154	-	1	1	88	M	28	11	5	2006	Ford F-150					✓	✓
2012	78	95	-	2	†1	73	M	25	11	7	2010	Mercury Mariner	✓		✓	✓		
2012	78	95	-	2	2	64	F	25	13	7	2010	Mercury Mariner	✓		✓	✓		
2012	79	82	-	1	‡1	21	F	21	11	2	2004	Acura TSX	✓			✓		
2013	2	81	-	1	1	42	M	U	11	6	2004	Dodge Dakota	✓			✓		
2013	5	117	-	1	1	69	M	34	11	3	2010	Honda Fit			✓	✓		
2013	13	112	-	1	†1	84	M	32	11	2	2007	Buick Terraza				✓	✓	✓
2013	43	2	-	1	1	47	F	23	11	3	2008	Ford Fusion		✓	✓			
2013	43	38	-	1	1	43	M	32	11	3	2006	Acura TL	✓	✓				
2013	43	161	-	1	1	49	M	39	11	4	2004	Ford Focus	✓			✓		
2013	45	138	-	2	1	68	M	28	11	4	2007	Kia Optima	✓					✓
2013	48	10	-	2	1	57	M	37	11	5	2007	Chevrolet Silverado			✓		✓	
2013	48	76	-	1	1	53	F	27	11	1	2013	Kia Soul	✓					
2013	49	7	-	1	1	41	M	38	11	4	2010	Volkswagen Passat			✓		✓	
2013	49	85	-	1	1	57	M	34	11	6	2007	Mazda CX-7	✓					
2013	49	105	-	1	1	23	M	26	11	6	2007	Toyota Corolla	✓					
2013	72	188	-	1	1	22	M	U	11	7	2012	Chevrolet Sonic		✓				✓
2013	73	52	-	1	1	86	M	33	11	5	2005	Buick Lesabre			✓		✓	
2013	73	106	-	1	1	64	F	37	11	5	2006	Honda Civic					✓	✓
2013	73	125	-	1	1	61	F	39	11	3	2008	Chevrolet Malibu				✓	✓	
2013	75	86	-	1	1	64	M	27	11	7	2009	Hyundai Sonata		✓	✓			
2013	76	101	-	2	1	47	M	24	11	3	2010	Ford Focus			✓			
2013	78	93	-	1	2	76	M	30	13	2	2010	Buick Lacrosse			✓		✓	
2013	79	92	-	1	1	23	M	30	11	4	2007	Toyota Tacoma			✓			
2013	81	157	-	1	1	90	M	23	11	6	2012	Ford Edge				✓		
2014	8	29	-	3	1	28	M	38	11	4	2011	Nissan Altima				✓		
2014	11	57	-	1	1	56	F	34	11	5	2005	Lincoln Town Car					✓	
2014	45	71	-	2	1	72	M	41	11	5	2007	Kia Amanti					✓	

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	Exceedingly Severe	Narrow Impact	Corner/Oblique	Heavy Vehicle	Occupant Vulnerability/ Factors	Other
2014	48	75	-	1	*1	61	M	43	11	3	2007	Ford Ranger					✓	
2014	48	108	-	1	1	60	F	39	11	4	2012	Dodge Caravan		✓	✓			
2014	73	67	-	2	1	48	F	U	11	4	2012	Ford Fiesta	✓					
2014	75	58	-	1	1	67	F	25	11	7	2007	Lexus ES-350	✓			✓		
2014	76	97	-	1	1	26	M	26	11	2	2009	Hyundai Accent	✓		✓			
2014	81	111	-	1	1	20	F	49	11	5	2014	Kia Soul				✓	✓	
2015	5	133	-	1	1	65	M	27	11	6	2015	Ford F-250			✓	✓		
2015	11	7	-	2	1	33	M	26	11	5	2008	Pontiac G6	✓		✓			
2015	11	60	-	1	1	76	F	27	11	3	2013	Volkswagen Passat	✓				✓	
2015	12	45	-	1	1	28	M	28	11	4	2008	Chevrolet Impala	✓	✓				
2015	12	63	-	2	1	57	M	26	11	5	2006	Dodge Caravan			✓			✓
2015	45	99	-	2	*†2	29	M	26	13	4	2011	Chevrolet Impala						✓
2015	49	5	-	1	1	29	F	47	11	6	2007	Chevrolet SIlverado					✓	✓
2015	49	68	-	1	2	32	M	U	13	6	2008	Chevrolet Impala	✓					✓
2015	49	130	-	1	1	40	M	20	11	6	2013	Toyota Corolla				✓		
2015	73	35	-	1	1	79	M	24	11	3	2012	Toyota RAV-4		✓			✓	
2015	73	44	-	1	*1	63	M	35	11	4	2011	Toyota Camry		✓			✓	
2015	75	22	-	1	*1	73	M	U	11	4	2013	Toyota Prius						✓
2015	75	23	-	1	1	20	M	21	11	2	2010	Honda Fit				✓		
2015	75	60	-	1	2	22	M	24	13	1	2007	Jeep Cherokee		✓				
2015	78	8	-	1	1	90	F	19	11	3	2006	Ford Fusion			✓			
2017	11	35	-	1	‡1	75	M	16	11	3	2012	Hyundai Elantra	✓					
2017	11	35	-	2	‡1	56	M	41	11	3	2007	Kia Sorento	✓				✓	
2017	13	10	-	2	‡1	36	M	29	11	6	2007	Mitsubishi Galant	✓					
2017	17	86	-	1	1	72	M	30	11	4	2008	Honda Accord					✓	✓
2017	20	49	-	1	1	43	M	27	11	5	2002	Pontiac Grand Prix				✓		
2017	26	75	-	1	*1	65	M	26	11	7	2009	Hyundai Sonata					✓	
2017	28	39	-	1	1	65	M	36	11	1	2007	Chevrolet Aveo	✓			✓		
2018	11	25	-	1	†‡1	36	M	46	11	3	2012	Jeep Liberty	✓			✓		
2018	11	48	-	1	1	56	M	29	11	3	2003	Honda Accord	✓		✓			
2018	11	54	-	2	1	71	M	24	11	3	2001	Dodge Ram			✓		✓	
2018	13	47	-	1	1	25	M	33	11	3	2003	Acura CL			✓			
2018	14	57	-	2	*1	73	M	U	11	7	2014	Toyota Corolla	✓					
2018	17	109	-	1	1	56	F	31	11	5	2015	Jeep Cherokee	✓		✓			
2018	18	51	-	1	1	60	M	24	11	6	2010	Nissan 370Z	✓			✓		
2018	18	51	-	1	2	64	F	25	13	3	2010	Nissan 370Z	✓			✓		
2018	20	89	-	1	*1	60	M	32	11	3	2006	Chevrolet Silverado	✓	✓				✓
2018	21	84	-	1	1	57	M	26	11	6	2015	Lexus ES-350	✓		✓			
2018	23	87	-	1	1	37	M	27	11	3	2000	Volkswagen New Beetle	✓					
2018	25	27	-	1	1	53	F	23	11	3	2003	Jeep Liberty	✓					
2018	25	27	-	1	2	80	F	36	13	3	2003	Jeep Liberty	✓					
2018	26	94	-	1	1	82	M	31	11	3	2000	Toyota Avalon	✓			✓	✓	
2018	26	94	-	1	1	75	F	U	13	7	2000	Toyota Avalon	✓			✓		
2018	27	19	-	1	1	64	F	25	11	4	2003	Toyota Matrix			✓			
2018	29	26	-	2	†‡1	38	M	36	11	6	2003	Jeep Liberty	✓		✓			

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	Exceedingly Severe	Narrow Impact	Corner/Oblique	Heavy Vehicle	Occupant Vulnerability/ Factors	Other
2018	30	44	-	1	1	68	M	40	11	3	2005	Chevrolet Malibu		✓	✓			
2018	33	78	-	2	1	27	M	34	11	5	2012	Honda Civic	✓		✓			
2019	12	79	-	3	†1	30	F	U	11	7	2014	Chevrolet Traverse	✓			✓		
2019	13	20	-	2	2	65	F	37	13	3	2014	Toyota Sienna					✓	
2019	14	3	-	1	1	33	M	35	11	6	2017	Dodge Grand Caravan						✓
2019	14	43	-	4	1	42	M	27	11	6	2016	Hyundai Accent	✓					
2019	14	43	-	4	2	21	F	23	13	3	2016	Hyundai Accent	✓					
2019	16	22	-	1	1	72	F	U	11	3	2017	Kia Forte					✓	
2019	17	31	-	1	1	76	M	1	11	3	2004	Dodge Ram 1500	✓			✓		
2019	17	31	-	1	2	76	F	30	13	3	2004	Dodge Ram 1500	✓			✓		
2019	19	80	-	1	1	41	M	U	11	7	2017	Nissan Altima	✓			✓		
2019	22	79	-	1	1	75	F	28	11	5	2008	Honda CR-V			✓		✓	
2019	25	85	-	2	1	51	M	1	11	3	2016	Toyota Corolla	✓				✓	
2019	26	27	-	1	1	72	M	23	11	5	2012	Toyota Prius			✓		✓	
2019	28	24	-	2	1	91	M	21	11	5	2004	Buick LeSabre				✓	✓	
2019	31	26	-	2	1	67	F	31	11	3	2008	Honda Accord	✓					✓
2019	31	26	-	2	2	40	F	37	13	4	2008	Honda Accord	✓					
2019	31	30	-	1	1	31	M	23	11	3	2008	Ford Focus				✓		
2019	31	54	-	1	1	78	M	U	11	5	2003	Chrysler Town and Country			✓			✓
2019	32	107	-	1	1	58	M	28	11	5	2009	Infiniti G37	✓	✓				
2019	33	89	-	1	1	59	M	33	11	1	2006	Ford F-150	✓	✓				
2019	48	59	-	1	1	75	M	28	11	3	2010	Toyota Camry				✓		
2019	59	38	-	1	1	56	F	24	11	5	2002	Chevrolet Trailblazer			✓		✓	
2019	77	38	-	2	1	97	F	21	11	3	2012	Honda Fit			✓		✓	
2020	10	38	-	1	*1	66	M	U	11	7	2019	Chevrolet Colorado			✓	✓		
2020	11	98	-	1	1	55	M	U	11	7	2011	GMC Sierra			✓			✓
2020	12	82	-	2	1	18	M	U	11	7	2005	GMC Sierra			✓	✓		
2020	14	68	-	1	1	63	M	30	11	5	2018	Ford F-150		✓	✓			
2020	16	55	-	2	‡1	23	M	22	11	3	2017	Chevrolet Malibu	✓					
2020	21	51	-	1	1	66	M	48	11	3	2006	Pontiac G6	✓			✓	✓	
2020	21	137	-	1	1	35	M	22	11	6	2020	Nissan Sentra	✓			✓		
2020	23	3	-	1	*2	40	F	U	13	7	2006	Jeep Grand Cherokee						✓
2020	24	90	-	2	1	53	M	42	11	4	2003	Honda Civic	✓				✓	
2020	24	165	-	1	1	35	F	26	11	5	2004	Mitsubishi Lancer				✓		✓
2020	24	176	-	1	1	33	M	27	11	6	2010	Mitsubishi Outlander	✓			✓		
2020	26	49	-	1	*1	29	F	35	11	7	2011	Hyundai Sonata	✓				✓	
2020	30	66	-	2	‡1	23	F	19	11	5	2014	Volkswagen Passat			✓			
2020	31	40	-	1	*1	55	M	U	11	7	2014	Dodge Ram 1500		✓				
2020	32	135	-	2	†1	37	M	30	11	5	2012	Mercedes-Benz Sprinter				✓		✓
2020	32	154	-	1	1	25	M	28	11	5	2016	Kia Sorento						✓
2020	33	29	-	2	1	36	F	25	11	4	2019	Toyota Camry			✓			
2020	33	36	-	1	*1	29	F	35	11	3	2017	Honda Accord					✓	
2020	66	11	-	2	1	72	M	30	11	7	2019	Toyota RAV4	✓		✓			
2020	66	14	-	1	1	22	M	U	11	7	2018	Ford Focus	✓		✓			
2020	73	43	-	1	1	85	M	28	11	3	2003	Chevrolet Silverado	✓	✓				

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	Exceedingly Severe	Narrow Impact	Corner/Oblique	Heavy Vehicle	Occupant Vulnerability/ Factors	Other
2020	73	97	-	1	1	85	F	45	11	3	2003	Cadillac Deville			✓		✓	
2020	77	62	-	1	1	71	F	39	11	3	2013	Honda Civic	✓				✓	
2021	11	22	-	1	1	45	M	32	11	4	2006	Audi A4	✓	✓	✓			
2021	12	66	-	1	*2	18	M	U	13	7	2018	Nissan Sentra		✓				
2021	12	70	-	1	1	45	M	32	11	7	2003	Ford F-150	✓			✓		
2021	13	125	-	2	‡1	34	M	U	11	7	2011	Kia Soul	✓		✓			
2021	19	98	-	1	1	19	F	U	11	7	2002	Jeep Liberty			✓	✓		✓
2021	19	159	-	2	1	37	F	38	11	6	2019	Chevrolet Cruze	✓				✓	
2021	19	159	-	2	2	45	F	40	13	3	2019	Chevrolet Cruze	✓				✓	
2021	20	101	-	1	*†1	29	M	21	11	6	2020	Ford Ranger						✓
2021	20	133	-	2	1	59	M	27	11	7	2008	Toyota Highlander	✓		✓	✓		
2021	21	92	-	1	1	81	F	30	11	2	2012	Chrysler 200			✓		✓	
2021	21	166	-	2	1	79	M	28	11	3	2014	Audi A6			✓		✓	
2021	22	1	-	1	1	82	M	26	11	6	2018	Chevrolet Silverado			✓			✓
2021	24	115	-	1	1	73	F	24	11	6	2017	Volkswagen Jetta	✓	✓				
2021	24	130	-	1	1	51	M	30	11	6	2015	Volkswagen CC	✓				✓	
2021	26	161	-	2	1	47	M	36	11	5	2002	Ford Focus			✓			
2021	28	104	-	1	1	86	F	U	11	7	2018	Chevrolet Cruze			✓		✓	
2021	30	109	-	1	1	61	M	28	11	5	2017	Mazda MX-5	✓		✓	✓		
2021	32	141	-	1	*1	66	F	U	11	2	2010	Toyota Camry		✓				✓
2021	52	26	-	1	2	85	M	30	13	6	2009	Subaru Tribeca					✓	✓
2021	66	87	-	2	1	65	M	1	11	3	2004	Ford F-150			✓	✓		
2021	76	73	-	1	*1	59	M	U	11	7	2000	Jeep Cherokee			✓			
2021	77	79	-	2	2	71	F	30	13	2	2019	Mercedes-Benz GLC-Class					✓	✓
2021	77	97	-	1	*1	65	M	31	11	1	2001	Toyota Corolla						✓
-	-	-	136213	1	1	80	M	29	11	5	2004	Chevrolet Malibu		✓			✓	
-	-	-	159342	1	1	83	M	27	11	4	2001	Ford E-Series Van					✓	✓
-	-	-	317594589	1	1	39	F	48	11	6	2009	Hyundai Sonata	✓					
-	-	-	317791120	1	1	69	F	25	11	6	2008	Chevrolet Aveo	✓					
-	-	-	340682130	1	1	58	M	36	11	4	2011	Chevrolet Impala	✓				✓	
-	-	-	352233424	1	2	68	F	49	13	5	2011	Toyota Camry					✓	
-	-	-	352362600	1	1	74	M	37	11	5	2008	GMC Sierra	✓				✓	✓
-	-	-	357137500	2	1	38	F	23	11	5	2000	Pontiac Grand Prix			✓			
-	-	-	357137514	1	1	51	M	29	11	5	2002	Honda CR-V		✓				
-	-	-	359861836	2	2	74	F	22	13	3	2002	Toyota Avalon					✓	✓
-	-	-	360258996	1	1	90	M	27	11	3	2012	Ford Focus					✓	
-	-	-	360259001	1	2	79	F	28	13	4	2012	Ford Focus					✓	
-	-	-	360325067	1	2	27	F	20	13	4	2012	Subaru Impreza	✓					
-	-	-	425504920	1	1	62	M	38	11	3	2012	Ford Focus		✓			✓	
-	-	-	431382835	1	1	71	M	30	11	4	2006	Honda Civic/CRX, del Sol	✓				✓	
-	-	-	431587536	1	1	82	M	25	11	5	2008	Ford Focus			✓		✓	
-	-	-	431587997	1	1	80	F	21	11	5	2002	Lexus RX300					✓	
-	-	-	431890626	1	1	83	F	27	11	3	2015	Honda Fit					✓	
-	-	-	588552417	1	1	87	F	23	11	5	2010	Honda Civic			✓		✓	
-	-	-	588814168	1	2	44	F	39	13	3	2013	Acura RDX					✓	✓

Case Year	PSU	Case	CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	Exceedingly Severe	Narrow Impact	Corner/Oblique	Heavy Vehicle	Occupant Vulnerability/ Factors	Other
-	-	-	588852888	1	1	68	F	27	11	4	2014	Toyota Camry	✓	✓				
-	-	-	842003315	1	1	79	F	27	11	4	2000	Ford Taurus					✓	✓
-	-	-	852122288	1	2	65	F	47	13	6	2006	Scion tC					✓	
-	-	-	852127792	1	1	50	M	33	11	5	2005	Hyundai Accent	✓					
-	-	-	116	1	1	85	M	29	11	3	2010	Lexus ES-350					✓	
-	-	-	157	1	1	69	F	17	11	5	2014	Volkswagen Tiguan					✓	
-	-	-	432	1	‡1	25	F	27	11	4	2016	Honda Civic	✓					✓
-	-	-	661	1	1	41	M	39	11	6	2019	Chevrolet Corvette	✓				✓	
-	-	-	678	1	1	51	F	40	11	3	2011	Dodge Caliber					✓	
-	-	-	952	1	‡2	32	F	24	13	4	2019	Nissan Rogue	✓		✓			✓
							M=Male F=Female	U=Unknown	11=Driver 13=Passenger									

*Case evidence to categorise fatality considered "insufficient." Indicated cases are missing evidence such as vehicle measurements, medical information, or photos, which may have limited the ability to assign factors
†Unknown airbag deployment
‡Confirmed “wrong way” crash

TABLE AIV

NASS-CDS AND CISS CASE TEST RATINGS AND FACTOR CATEGORISATION (N=158)

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2012	6	73	1	1	22	F	20	11	4	2011	Volkswagen Jetta	4	G	N				✓										
2012	9	20	2	*2	77	F	U	13	3	2010	Ford Edge	4	G	N									✓					
2012	9	69	1	1	57	M	35	11	5	2005	Honda Accord	5	G	N					✓					✓				
2012	11	136	1	1	21	M	24	11	5	2005	Dodge Neon	4	M	N			✓					✓						
2012	13	60	2	1	37	M	39	11	4	2007	Ford Focus	5	G	N		✓		✓										
2012	43	33	1	1	38	M	31	11	1	2003	Honda Pilot	5	G	N						✓	✓							
2012	43	140	1	*‡1	28	F	23	11	2	2009	Toyota Corolla	4	G	N			✓											
2012	43	194	2	1	55	F	34	11	3	2007	Lexus ES-350	5	G	P				✓		✓								
2012	43	200	1	†1	22	M	21	11	6	2008	Dodge Caliber	5	G	N			✓	✓			✓							
2012	43	200	1	2	29	M	24	13	6	2008	Dodge Caliber	5	G	N			✓	✓			✓							
2012	48	68	1	2	28	F	39	13	5	2005	Chevrolet Malibu	5	G	N				✓	✓									
2012	49	63	1	1	67	F	26	11	5	2007	Honda Accord	5	G	N							✓		✓					
2012	49	160	2	1	31	M	28	11	6	2010	Hyundai Sonata	5	G	N			✓					✓						
2012	73	87	1	1	35	F	39	11	3	2004	Chevrolet Venture	4	P	N				✓			✓							
2012	76	88	1	2	23	M	27	13	4	2007	Dodge Charger	5	G	N		✓									✓			
2012	76	154	1	1	88	M	28	11	5	2006	Ford F-150	5	N	N									✓	✓				
2012	78	95	2	†1	73	M	25	11	7	2010	Mercury Mariner	5	G	N		✓	✓			✓								
2012	78	95	2	2	64	F	25	13	7	2010	Mercury Mariner	5	G	N		✓	✓			✓								
2012	79	82	1	‡1	21	F	21	11	2	2004	Acura TSX	5	G	N		✓	✓											
2013	2	81	1	1	42	M	U	11	6	2004	Dodge Dakota	3	P	N		✓	✓											
2013	5	117	1	1	69	M	34	11	3	2010	Honda Fit	5	G	P		✓		✓										
2013	13	112	1	†1	84	M	32	11	2	2007	Buick Terraza	5	G	N		✓							✓		✓			
2013	43	2	1	1	47	F	23	11	3	2008	Ford Fusion	5	G	N				✓			✓							
2013	43	38	1	1	43	M	32	11	3	2006	Acura TL	5	G	N			✓				✓							
2013	43	161	1	1	49	M	39	11	4	2004	Ford Focus	5	G	N		✓	✓											
2013	45	138	2	1	68	M	28	11	4	2007	Kia Optima	5	G	N			✓								✓			

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2013	48	10	2	1	57	M	37	11	5	2007	Chevrolet Silverado	4	G	N				✓	✓									
2013	48	76	1	1	53	F	27	11	1	2013	Kia Soul	4	G	P			✓											
2013	49	7	1	1	41	M	38	11	4	2010	Volkswagen Passat	4	G	N				✓	✓									
2013	49	85	1	1	57	M	34	11	6	2007	Mazda CX-7	5	G	N			✓											
2013	49	105	1	1	23	M	26	11	6	2007	Toyota Corolla	5	G	N			✓											
2013	72	188	1	1	22	M	U	11	7	2012	Chevrolet Sonic	5	G	M							✓				✓			✓
2013	73	52	1	1	86	M	33	11	5	2005	Buick Lesabre	4	G	N				✓	✓				✓					
2013	73	106	1	1	64	F	37	11	5	2006	Honda Civic	5	G	N					✓					✓				
2013	73	125	1	1	61	F	39	11	3	2008	Chevrolet Malibu	5	G	N		✓			✓									
2013	75	86	1	1	64	M	27	11	7	2009	Hyundai Sonata	5	G	N				✓			✓							
2013	76	101	2	1	47	M	24	11	3	2010	Ford Focus	4	G	N		✓		✓										
2013	78	93	1	2	76	M	30	13	2	2010	Buick Lacrosse	5	G	N						✓			✓					
2013	79	92	1	1	23	M	30	11	4	2007	Toyota Tacoma	5	G	N				✓		✓								
2013	81	157	1	1	90	M	23	11	6	2012	Ford Edge	3	G	N								✓						
2014	8	29	3	1	28	M	38	11	4	2011	Nissan Altima	4	G	N	✓													
2014	11	57	1	1	56	F	34	11	5	2005	Lincoln Town Car	5	G	N					✓				✓					
2014	45	71	2	1	72	M	41	11	5	2007	Kia Amanti	N	G	N									✓					
2014	48	75	1	*1	61	M	43	11	3	2007	Ford Ranger	5	A	N					✓									
2014	48	108	1	1	60	F	39	11	4	2012	Dodge Caravan	4	G	P				✓			✓				✓			
2014	73	67	2	1	48	F	U	11	4	2012	Ford Fiesta	4	G	M		✓	✓											
2014	75	58	1	1	67	F	25	11	7	2007	Lexus ES-350	5	G	P			✓					✓						
2014	76	97	1	1	26	M	26	11	2	2009	Hyundai Accent	5	A	N			✓	✓										
2014	81	111	1	1	20	F	49	11	5	2014	Kia Soul	5	G	N		✓			✓									
2015	5	133	1	1	65	M	27	11	6	2015	Ford F-250	N	N	N		✓		✓										
2015	11	7	2	1	33	M	26	11	5	2008	Pontiac G6	5	G	N		✓	✓			✓								
2015	11	60	1	1	76	F	27	11	3	2013	Volkswagen Passat	5	G	A			✓						✓					
2015	12	45	1	1	28	M	28	11	4	2008	Chevrolet Impala	5	A	N			✓				✓							
2015	12	63	2	1	57	M	26	11	5	2006	Dodge Caravan	5	A	N				✓							✓			

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2015	45	99	2	*†2	29	M	26	13	4	2011	Chevrolet Impala	N	G	N		✓												
2015	49	5	1	1	29	F	47	11	6	2007	Chevrolet SIlverado	4	G	N					✓						✓			
2015	49	68	1	2	32	M	U	13	6	2008	Chevrolet Impala	5	A	N			✓								✓			
2015	49	130	1	1	40	M	20	11	6	2013	Toyota Corolla	4	G	N		✓												
2015	73	35	1	1	79	M	24	11	3	2012	Toyota RAV-4	4	G	N							✓		✓					
2015	73	44	1	*1	63	M	35	11	4	2011	Toyota Camry	4	G	N					✓		✓							
2015	75	22	1	*1	73	M	U	11	4	2013	Toyota Prius	4	G	N												✓		
2015	75	23	1	1	20	M	21	11	2	2010	Honda Fit	5	G	P								✓						
2015	75	60	1	2	22	M	24	13	1	2007	Jeep Cherokee	5	G	N							✓							
2015	78	8	1	1	90	F	19	11	3	2006	Ford Fusion	4	A	N		✓		✓										
2017	11	35	1	‡1	75	M	16	11	3	2012	Hyundai Elantra	N	G	A			✓											
2017	11	35	2	‡1	56	M	41	11	3	2007	Kia Sorento	5	G	N			✓		✓									
2017	13	10	2	‡1	36	M	29	11	6	2007	Mitsubishi Galant	4	G	N		✓	✓											
2017	17	86	1	1	72	M	30	11	4	2008	Honda Accord	5	G	N					✓				✓	✓				
2017	20	49	1	1	43	M	27	11	5	2002	Pontiac Grand Prix	4	G	N								✓						
2017	26	75	1	*1	65	M	26	11	7	2009	Hyundai Sonata	5	G	N									✓					
2017	28	39	1	1	65	M	36	11	1	2007	Chevrolet Aveo	5	A	N		✓	✓											
2018	11	25	1	†‡1	36	M	46	11	3	2012	Jeep Liberty	N	G	N		✓	✓											
2018	11	48	1	1	56	M	29	11	3	2003	Honda Accord	N	G	N			✓	✓										
2018	11	54	2	1	71	M	24	11	3	2001	Dodge Ram	4	P	N						✓			✓					
2018	13	47	1	1	25	M	33	11	3	2003	Acura CL	N	N	N				✓										
2018	14	57	2	*1	73	M	U	11	7	2014	Toyota Corolla	5	G	M		✓	✓											
2018	17	109	1	1	56	F	31	11	5	2015	Jeep Cherokee	4	G	M			✓	✓										
2018	18	51	1	1	60	M	24	11	6	2010	Nissan 370Z	N	N	N		✓	✓											
2018	18	51	1	2	64	F	25	13	3	2010	Nissan 370Z	N	N	N		✓	✓											
2018	20	89	1	*1	60	M	32	11	3	2006	Chevrolet Silverado	N	N	N			✓				✓					✓		
2018	21	84	1	1	57	M	26	11	6	2015	Lexus ES-350	5	G	N			✓	✓										
2018	23	87	1	1	37	M	27	11	3	2000	Volkswagen New Beetle	4	G	N			✓											

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2018	25	27	1	1	53	F	23	11	3	2003	Jeep Liberty	5	M	N			✓											
2018	25	27	1	2	80	F	36	13	3	2003	Jeep Liberty	4	M	N			✓											
2018	26	94	1	1	82	M	31	11	3	2000	Toyota Avalon	N	G	N		✓	✓						✓					
2018	26	94	1	1	75	F	U	13	7	2000	Toyota Avalon	N	G	N		✓	✓											
2018	27	19	1	1	64	F	25	11	4	2003	Toyota Matrix	N	G	N				✓										
2018	29	26	2	†‡1	38	M	36	11	6	2003	Jeep Liberty	5	G	N			✓	✓										
2018	30	44	1	1	68	M	40	11	3	2005	Chevrolet Malibu	5	G	N				✓			✓							
2018	33	78	2	1	27	M	34	11	5	2012	Honda Civic	5	G	N			✓	✓										
2019	12	79	3	†1	30	F	U	11	7	2014	Chevrolet Traverse	5	G	N		✓	✓											
2019	13	20	2	2	65	F	37	13	3	2014	Toyota Sienna	3	G	M									✓					
2019	14	3	1	1	33	M	35	11	6	2017	Dodge Grand Caravan	4	G	P		✓												
2019	14	43	4	1	42	M	27	11	6	2016	Hyundai Accent	4	G	P		✓	✓											
2019	14	43	4	2	21	F	23	13	3	2016	Hyundai Accent	4	G	P		✓	✓											
2019	16	22	1	1	72	F	U	11	3	2017	Kia Forte	4	G	G									✓					
2019	17	31	1	1	76	M	1	11	3	2004	Dodge Ram 1500	5	G	N			✓					✓						
2019	17	31	1	2	76	F	30	13	3	2004	Dodge Ram 1500	5	G	N			✓					✓						
2019	19	80	1	1	41	M	U	11	7	2017	Nissan Altima	5	G	G		✓	✓											
2019	22	79	1	1	75	F	28	11	5	2008	Honda CR-V	5	G	N						✓			✓					
2019	25	85	2	1	51	M	1	11	3	2016	Toyota Corolla	5	G	M			✓		✓									
2019	26	27	1	1	72	M	23	11	5	2012	Toyota Prius	4	G	N				✓					✓					
2019	28	24	2	1	91	M	21	11	5	2004	Buick LeSabre	N	G	N								✓	✓					
2019	31	26	2	1	67	F	31	11	3	2008	Honda Accord	5	G	N		✓	✓											✓
2019	31	26	2	2	40	F	37	13	4	2008	Honda Accord	5	G	N		✓	✓											
2019	31	30	1	1	31	M	23	11	3	2008	Ford Focus	4	G	N		✓												
2019	31	54	1	1	78	M	U	11	5	2003	Chrysler Town and Country	4	A	N				✓								✓		
2019	32	107	1	1	58	M	28	11	5	2009	Infiniti G37	5	G	A			✓				✓							
2019	33	89	1	1	59	M	33	11	1	2006	Ford F-150	5	G	N			✓				✓							
2019	48	59	1	1	75	M	28	11	3	2010	Toyota Camry	5	G	N								✓						

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2019	59	38	1	1	56	F	24	11	5	2002	Chevrolet Trailblazer	3	M	N				✓					✓					
2019	77	38	2	1	97	F	21	11	3	2012	Honda Fit	4	G	P				✓					✓					
2020	10	38	1	*1	66	M	U	11	7	2019	Chevrolet Colorado	5	G	G		✓		✓										
2020	11	98	1	1	55	M	U	11	7	2011	GMC Sierra	4	A	N				✓								✓		
2020	12	82	2	1	18	M	U	11	7	2005	GMC Sierra	4	M	N		✓		✓										
2020	14	68	1	1	63	M	30	11	5	2018	Ford F-150	5	G	G				✓			✓							
2020	16	55	2	‡1	23	M	22	11	3	2017	Chevrolet Malibu	5	G	G		✓	✓											
2020	21	51	1	1	66	M	48	11	3	2006	Pontiac G6	5	G	N		✓	✓		✓									
2020	21	137	1	1	35	M	22	11	6	2020	Nissan Sentra	3	G	G		✓	✓											
2020	23	3	1	*2	40	F	U	13	7	2006	Jeep Grand Cherokee	5	G	N										✓				✓
2020	24	90	2	1	53	M	42	11	4	2003	Honda Civic	5	G	N			✓		✓									
2020	24	165	1	1	35	F	26	11	5	2004	Mitsubishi Lancer	4	G	N		✓									✓			
2020	24	176	1	1	33	M	27	11	6	2010	Mitsubishi Outlander	5	G	N		✓	✓											
2020	26	49	1	*1	29	F	35	11	7	2011	Hyundai Sonata	4	G	M			✓		✓									
2020	30	66	2	‡1	23	F	19	11	5	2014	Volkswagen Passat	5	G	A				✓										
2020	31	40	1	*1	55	M	U	11	7	2014	Dodge Ram 1500	4	G	N							✓							
2020	32	135	2	†1	37	M	30	11	5	2012	Mercedes-Benz Sprinter	N	N	N								✓						
2020	32	154	1	1	25	M	28	11	5	2016	Kia Sorento	5	G	G												✓		
2020	33	29	2	1	36	F	25	11	4	2019	Toyota Camry	5	G	G		✓				✓								
2020	33	36	1	*1	29	F	35	11	3	2017	Honda Accord	3	G	G					✓									
2020	66	11	2	1	72	M	30	11	7	2019	Toyota RAV4	3	G	G			✓	✓										
2020	66	14	1	1	22	M	U	11	7	2018	Ford Focus	5	G	A			✓			✓								
2020	73	43	1	1	85	M	28	11	3	2003	Chevrolet Silverado	N	N	N			✓				✓							
2020	73	97	1	1	85	F	45	11	3	2003	Cadillac Deville	4	G	N				✓					✓					
2020	77	62	1	1	71	F	39	11	3	2013	Honda Civic	4	G	G			✓		✓				✓					
2021	11	22	1	1	45	M	32	11	4	2006	Audi A4	4	G	N			✓	✓			✓							
2021	12	66	1	*2	18	M	U	13	7	2018	Nissan Sentra	4	G	G							✓							
2021	12	70	1	1	45	M	32	11	7	2003	Ford F-150	4	P	N			✓					✓						

Case Year	PSU	Case	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Object	Trailer Structure Did Not Prevent Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondeployment	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
2021	13	125	2	‡1	34	M	U	11	7	2011	Kia Soul	4	G	P			✓	✓										
2021	19	98	1	1	19	F	U	11	7	2002	Jeep Liberty	5	M	N		✓		✓								✓		
2021	19	159	2	1	37	F	38	11	6	2019	Chevrolet Cruze	5	G	N			✓		✓									
2021	19	159	2	2	45	F	40	13	3	2019	Chevrolet Cruze	5	G	N			✓		✓									
2021	20	101	1	*†1	29	M	21	11	6	2020	Ford Ranger	4	G	G												✓		
2021	20	133	2	1	59	M	27	11	7	2008	Toyota Highlander	5	G	N		✓	✓	✓										
2021	21	92	1	1	81	F	30	11	2	2012	Chrysler 200	4	G	N					✓	✓			✓					
2021	21	166	2	1	79	M	28	11	3	2014	Audi A6	5	G	N				✓		✓			✓					
2021	22	1	1	1	82	M	26	11	6	2018	Chevrolet Silverado	5	G	M		✓		✓										
2021	24	115	1	1	73	F	24	11	6	2017	Volkswagen Jetta	4	G	G			✓				✓							
2021	24	130	1	1	51	M	30	11	6	2015	Volkswagen CC	N	G	M			✓		✓									
2021	26	161	2	1	47	M	36	11	5	2002	Ford Focus	4	G	N				✓		✓								
2021	28	104	1	1	86	F	U	11	7	2018	Chevrolet Cruze	5	G	N		✓				✓			✓					
2021	30	109	1	1	61	M	28	11	5	2017	Mazda MX-5	N	N	N		✓	✓			✓								
2021	32	141	1	*1	66	F	U	11	2	2010	Toyota Camry	5	G	N							✓					✓		
2021	52	26	1	2	85	M	30	13	6	2009	Subaru Tribeca	5	G	N									✓			✓		
2021	66	87	2	1	65	M	1	11	3	2004	Ford F-150	5	G	N						✓		✓						
2021	76	73	1	*1	59	M	U	11	7	2000	Jeep Cherokee	3	M	N				✓		✓								
2021	77	79	2	2	71	F	30	13	2	2019	Mercedes-Benz GLC-Class	5	G	G					✓								✓	
2021	77	97	1	*1	65	M	31	11	1	2001	Toyota Corolla	4	A	N									✓			✓		
						M=Male F=Female	U=Unknown	11=Driver 13=Passenger				N=Not Tested	N=Not Tested	N=Not Tested														

*Case evidence to categorise fatality considered insufficient. Indicated cases are missing evidence such as vehicle measurements, medical information, or photos, which may have limited the ability to assign factors
†Unknown airbag deployment
‡Confirmed “wrong way” crash

TABLE AV

CIREN CASE TEST RATINGS AND FACTOR CATEGORISATION (N=30)

CIREN ID	Vehicle	Occupant	Age	Sex	BMI	Seating Position	MAIS	Model Year	Make and Model	NCAP Rating	IIHS Moderate Overlap Rating	IIHS Small Overlap Rating	Anomaly	Case to Partner Incompatibility	Exceedingly Severe	Limited Structural Engagement	Obese Occupant	Oblique	Narrow (Fixed) Obj.	Trailer Structure Did Not Prev. Underride	Occupant Specific Factors	Undercarriage Impact	Airbag Nondepl.	Multi-event Crash	Submarined Lap Belt	Unrestrained Occupant/Cargo
136213	1	1	80	M	29	11	5	2004	Chevrolet Malibu	4	G	N							✓		✓					
159342	1	1	83	M	27	11	4	2001	Ford E-Series Van	N	N	N									✓		✓			
317594589	1	1	39	F	48	11	6	2009	Hyundai Sonata	5	G	N		✓	✓											
317791120	1	1	69	F	25	11	6	2008	Chevrolet Aveo	5	A	N			✓											
340682130	1	1	58	M	36	11	4	2011	Chevrolet Impala	N	G	N			✓		✓									
352233424	1	2	68	F	49	13	5	2011	Toyota Camry	2	G	N					✓									
352362600	1	1	74	M	37	11	5	2008	GMC Sierra	5	G	N			✓		✓								✓	
357137500	2	1	38	F	23	11	5	2000	Pontiac Grand Prix	N	A	N				✓										
357137514	1	1	51	M	29	11	5	2002	Honda CR-V	5	G	N							✓							
359861836	2	2	74	F	22	13	3	2002	Toyota Avalon	4	G	N									✓			✓		
360258996	1	1	90	M	27	11	3	2012	Ford Focus	5	G	A									✓					
360259001	1	2	79	F	28	13	4	2012	Ford Focus	4	G	A									✓					
360325067	1	2	27	F	20	13	4	2012	Subaru Impreza	4	G	N		✓	✓											
425504920	1	1	62	M	38	11	3	2012	Ford Focus	4	G	A					✓		✓							
431382835	1	1	71	M	30	11	4	2006	Honda Civic/CRX, del Sol	5	G	N			✓						✓					
431587536	1	1	82	M	25	11	5	2008	Ford Focus	4	G	N						✓			✓					
431587997	1	1	80	F	21	11	5	2002	Lexus RX300	4	G	N									✓					
431890626	1	1	83	F	27	11	3	2015	Honda Fit	5	G	A									✓					
588552417	1	1	87	F	23	11	5	2010	Honda Civic	5	G	N						✓			✓					
588814168	1	2	44	F	39	13	3	2013	Acura RDX	N	G	N					✓				✓				✓	
588852888	1	1	68	F	27	11	4	2014	Toyota Camry	5	G	A			✓				✓							
842003315	1	1	79	F	27	11	4	2000	Ford Taurus	5	G	N									✓		✓			
852122288	1	2	65	F	47	13	6	2006	Scion tC	5	A	N									✓					
852127792	1	1	50	M	33	11	5	2005	Hyundai Accent	5	N	N		✓	✓											
116	1	1	85	M	29	11	3	2010	Lexus ES-350	5	G	P									✓					
157	1	1	69	F	17	11	5	2014	Volkswagen Tiguan	4	G	M									✓					
432	1	‡1	25	F	27	11	4	2016	Honda Civic	5	G	G			✓										✓	
661	1	1	41	M	39	11	6	2019	Chevrolet Corvette	N	N	N			✓		✓									
678	1	1	51	F	40	11	3	2011	Dodge Caliber	4	G	N									✓					
952	1	‡2	32	F	24	13	4	2019	Nissan Rogue	4	G	A			✓			✓							✓	
				M=Male F=Female	U=Unkown	11=Driver 13=Passenger				N=Not Tested	N=Not Tested	N=Not Tested														

‡Confirmed wrong way crash