



Insurance Institute for Highway Safety  
Highway Loss Data Institute

# Differences in injury risk between male and female vehicle occupants

Data on Equitable Occupant Protection UNECE ad hoc group

31 Mar 2022

Jessica Jermakian

Vice President, Vehicle Research

Matt Brumbelow

Senior Research Scientist

[iihs.org](https://www.iihs.org)

# Saving lives. Preventing harm.

---

## IIHS-HLDI mission:

To reduce deaths, injuries and property damage from motor vehicle crashes through **research and evaluation** and through **education** of consumers, policymakers and safety professionals.



**45 staff members**



**73 staff members**

TRUSTED REVIEWS: Slow Cookers, Washer & Dryers, TVs Under \$1,200, Home WIFI Speakers

CR Consumer Reports®

THE BEST MATTRESS FOR YOUR MONEY

TOP PICKS FROM \$245 TO \$1,500

PLUS OUR FIRST-EVER PILLOW RATINGS

WORTH THE SPLURGE?

- > Peloton Treadmill
- > Samsung Galaxy Fold
- > Mercedes-Benz GLC

WHY CARS ARE LESS SAFE FOR WOMEN

How did that happen?

MAKING A BETTER BURGER

Best & Worst Fast-Food Choices

ROAD REPORT

## Making Cars Safer for Women

Women are at higher risk of injury or death in a car crash, and yet auto safety testing is still geared almost exclusively toward men. Why have safety regulators and automakers continued to ignore women—and what must be done to provide better protection?

by Keith Berry

THE FACE of a crash test dummy looks eerily vacant. With indents instead of eyes, a pointy nose, and permanently pinched lips, it appears remarkably expressionless—especially considering it's about to hurtle toward a stationary barrier at speeds as high as 40 mph. You might assume from its lack of distinguishing features that a crash test dummy is an avatar for all humanity. But despite the blank faces, most of the dummies used in automotive crash tests by the government and the insurance industry—the tests that determine whether a car gets a coveted five-star

safety rating or is named a top safety pick—represent a very specific man. Even though female and male bodies react differently in crashes, an average adult female crash test dummy simply does not exist, despite the fact that women obviously drive to work, take road trips, and ride in cars with friends. That absence has set the course for four decades' worth of car safety designs, with deadly consequences.

Although the majority of Americans killed or injured in car crashes are male, the raw data masks the fact that females are actually at greater risk of

death or injury when a crash occurs. Data from the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA) show that males drive more miles than females and are more likely to engage in risky behavior, such as speeding, driving under the influence of alcohol, and not wearing a seat belt. But a study from NHTSA shows that a female driver or front passenger who is wearing her seat belt is 17 percent more likely than a male to be killed when a crash takes place. And a 2009 study from the University of Virginia (UVA)

shows that for a female occupant, the odds of being injured in a frontal crash are 73 percent greater than the odds for a male occupant. That's controlling for occupant age, height, and body mass index, in addition to collision severity and vehicle model year.

These alarming numbers suggest an urgent safety issue, but the problem is neither new nor unfamiliar to regulators and automakers. "These same trends have been observed in many, many studies in the past," says Jason Forman, Ph.D., who is a principal scientist with the Center for Applied

BioMechanics at UVA and led that 2009 survey of injury disparities.

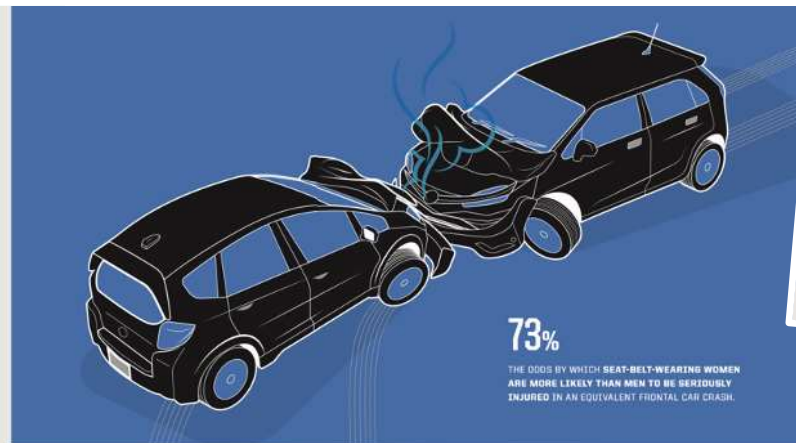
In fact, researchers have understood since at least the early 1980s that male and female bodies perform differently in crashes, but the vast majority of automotive safety policy and research is still designed to address the body of the so-called 50th percentile male—currently represented in crash tests by a 175-pound, 5-foot-9-inch dummy that was first standardized in the 1970s. (Today, the average American man is about 20 pounds heavier.)

Regulators asked for a female dummy

in 1980, and a group of automakers petitioned for one in 1996, but it took until 2002 for NHTSA to put one in the car. Even then, it's just a scaled-down version of a male dummy that represents only the smallest 5 percent of women by the standards of the mid-1970s—so small that it can work double-duty as a 12- or 13-year-old child. Furthermore, no dummy takes into account the biological differences between male and female bodies.

In frontal crash tests performed by both NHTSA and the Insurance Institute for Highway Safety (IIHS),

## Females are at increased risk of injury and death in crashes compared with males



'MAKING CARS EQUALLY SAFE FOR MEN AND WOMEN IS NOT AN INSURMOUNTABLE TASK. BUT IF WE DON'T TAKE ACTION NOW, WOMEN WILL CONTINUE TO BE AT A DISADVANTAGE.'

EMILY THOMAS, PH.D.,  
AUTOMOTIVE SAFETY ENGINEER  
AT CONSUMER REPORTS' AUTO  
TEST CENTER



'NHTSA IS FAILING IN ITS MISSION IF WOMEN ARE ALMOST 75 PERCENT MORE LIKELY THAN MEN TO DIE OR RECEIVE A SERIOUS INJURY WHEN THEY ARE INVOLVED IN AN AUTOMOBILE CRASH.'

REPRESENTATIVES KATHY  
CASTOR (D-FLA., ABOVE) AND JAN  
SCHAKOWSKY (D-ILL.) IN A LETTER  
TO NHTSA LAST NOVEMBER

IIHS  
HLDI



When will women's safety on the road matter as much as men's?

Medium

Where are all the female crash test dummies?



Best of 2019  
The deadly truth about a world built for men - from stab vests to car crashes

KOMONEWS

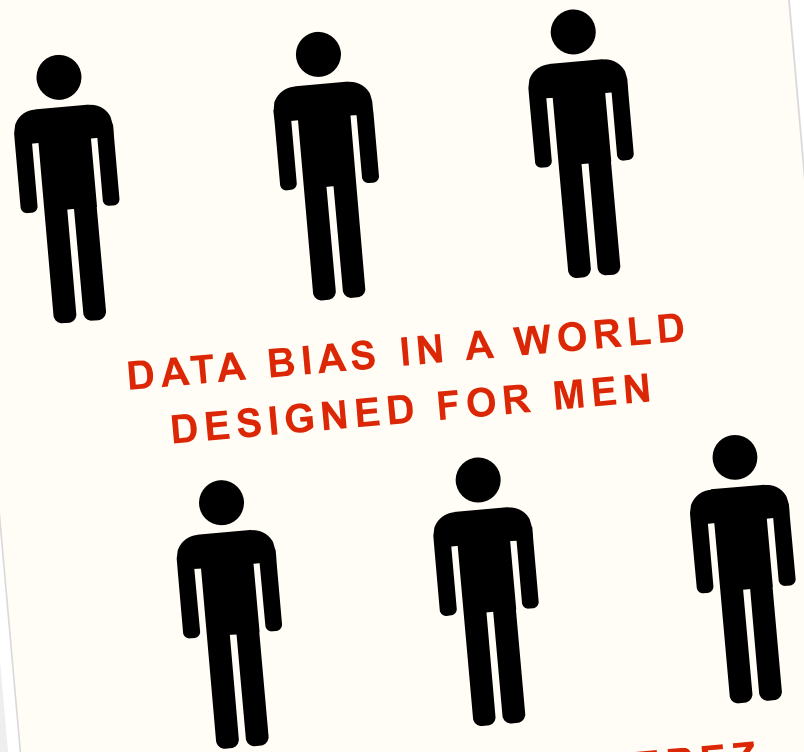
Is vehicle crash test gender bias putting female drivers at risk?

Forbes

Dummies Used In Motor Vehicle Crash Tests Favor Men And Put Women At Risk, New Report Says



# INVISIBLE WOMEN

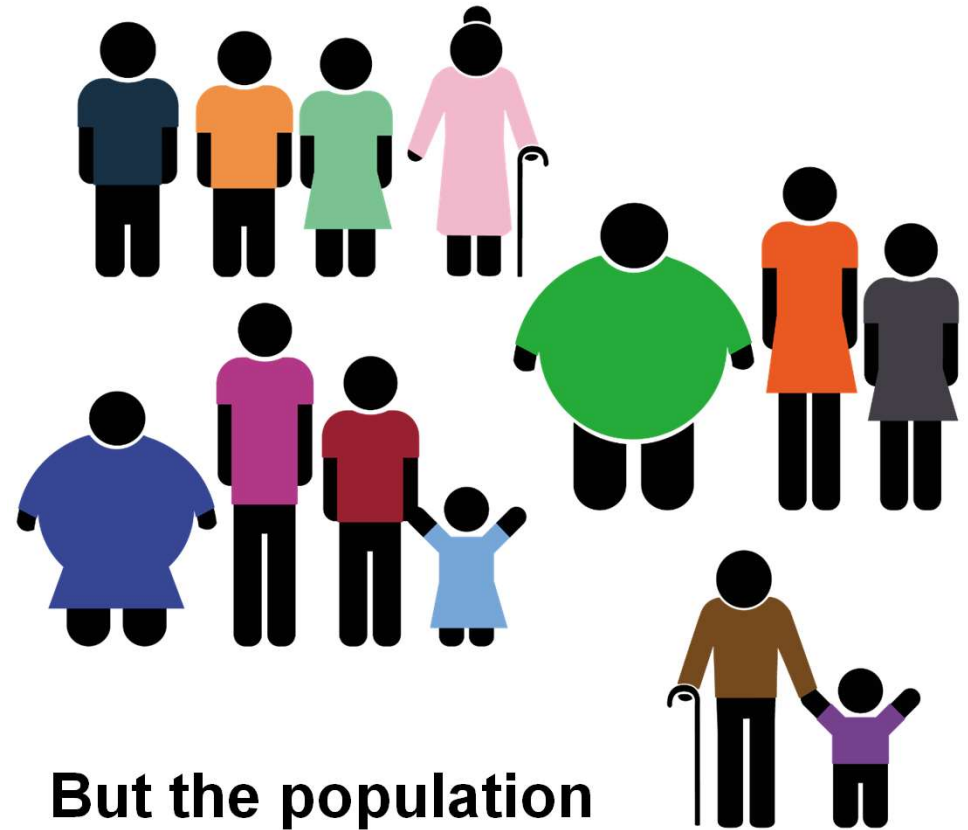


DATA BIAS IN A WORLD DESIGNED FOR MEN

CAROLINE CRIADO PEREZ



**A crash test =  
one crash with one dummy**



**But the population  
is much more diverse**

## Our vehicle ratings account for factors important for protection of occupants of different sizes and shapes

Dummy injury measures



Structural performance



Restraints/dummy kinematics





# UVA research shows increased risk to females

Difference in front crash injury risk compared with males

TRAFFIC INJURY PREVENTION  
2019, VOL. 20, NO. 6, 607-612  
<https://doi.org/10.1080/15389588.2019.1630825>

## Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisions

Jason Forman<sup>a</sup>, Gerald S. Poplin<sup>a</sup>, C. Greg Shaw<sup>a</sup>, Timothy L. McMurry<sup>a</sup>, Kristin Schmidt<sup>a</sup>, Joseph Cecilia Sunnevang<sup>b</sup>

<sup>a</sup>Center for Applied Biomechanics, University of Virginia, Charlottesville, Virginia; <sup>b</sup>Autoliv Research, Vårgårda, Sweden

### ABSTRACT

**Objective:** As vehicle safety technologies and evaluation procedures advance, it is pertinent to periodically evaluate injury trends to identify continuing and emerging priorities for intervention. This study examined detailed injury distributions and injury risk trends in belted occupants in frontal automobile collisions (10 o'clock to 2 o'clock) using NASS-CDS (1998–2015).

**Methods:** Injury distributions were examined by occupant age and vehicle model year (stratified at pre- and post-2009). Logistic regression models were developed to examine the effects of various factors on injury risk (by body region), controlling for delta-V, sex, age, height, body mass index (BMI), vehicle model year (again stratified at 2009).

**Results:** Among other observations, these analyses indicate that newer model year vehicles (model year [MY] 2009 and later) carry less risk of Abbreviated Injury Scale (AIS) 2+ and AIS 3+ injury compared to older model year vehicles, with odds ratios of 0.69 (AIS 2+) and 0.45 (AIS 3+). The largest reductions in risk between newer model year vehicles and older model year vehicles occur in risk of lower extremities and in the risk of skull fracture. There is no statistically significant change in risk of AIS 3+ rib fracture or sternum injury between model year categories. Females are at greater risk of AIS 2+ and AIS 3+ injury compared to males, with increased risk across most injury types.

**Conclusions:** For belted occupants in frontal collisions, substantial reductions in injury risk have been realized in many body regions in recent years. Risk reduction in the thorax has lagged other body regions, resulting in increasing prevalence among skeletal injuries in newer model year vehicles (especially in the elderly). Injuries also remain common in the arm and hand/wrist for all age ranges studied. These results provide insight into where advances in the field have made gains in occupant protection and what injury types remain to be addressed.



Check for updates

Table 1. Imputed multivariate logistic regression model results (all frontal crashes; odds ratios) for various injury outcomes.<sup>a</sup>

Model	Delta-V (km/h)	Female	Age (years)	Height (cm)	BMI (kg/m <sup>2</sup> )	2009+ MY
AIS 2+	1.09**	2.42**	1.02**	1.00	1.05**	0.69*
AIS 3+	1.11**	1.73**	1.04**	1.00	1.03**	0.45**
Skull fracture	1.07**	0.47*	1.01	1.01	1.01	0.37*
Brain, moderate	1.07**	1.76*	1.00	1.01	1.01	1.47
Brain, severe	1.07**	0.44	1.03**	1.01	1.03*	1.47
Brain, any	1.07**	1.60*	1.00	1.01	1.03*	0.45
C-spine	1.02**	1.99**	1.00	0.98	1.01	1.41
Abdomen	1.06**	2.06**	1.00	0.99	1.06**	0.70*
Knee-thigh-hip	1.08**	1.89*	1.01**	1.00	1.07**	0.71*
Knee	1.06**	1.79*	1.00	0.99	1.06**	0.44*
Leg	1.09**	2.29**	1.03**	1.00	1.07**	0.36**
Ankle	1.08**	3.80**	1.01**	1.03*	1.08**	0.65
LE <sup>b</sup>	1.07**	3.05**	1.00	1.02**	1.08**	0.40**
Sternum	1.08**	1.57	1.04**	1.01	0.98	1.03
Rib fracture	1.10**	2.14*	1.08**	0.98	1.01	0.49*
Rib fractures, 3+				1.00	1.04*	0.67

<sup>a</sup>N = 31,254 (weighted = 14,532,617); AIS 2+ unless otherwise noted. See Appendix C, Table C2 for confidence intervals.  
<sup>b</sup>LE = general lower extremity (encompassing KTH, leg, ankle, and all other lower extremity codes).

\*P < .05.

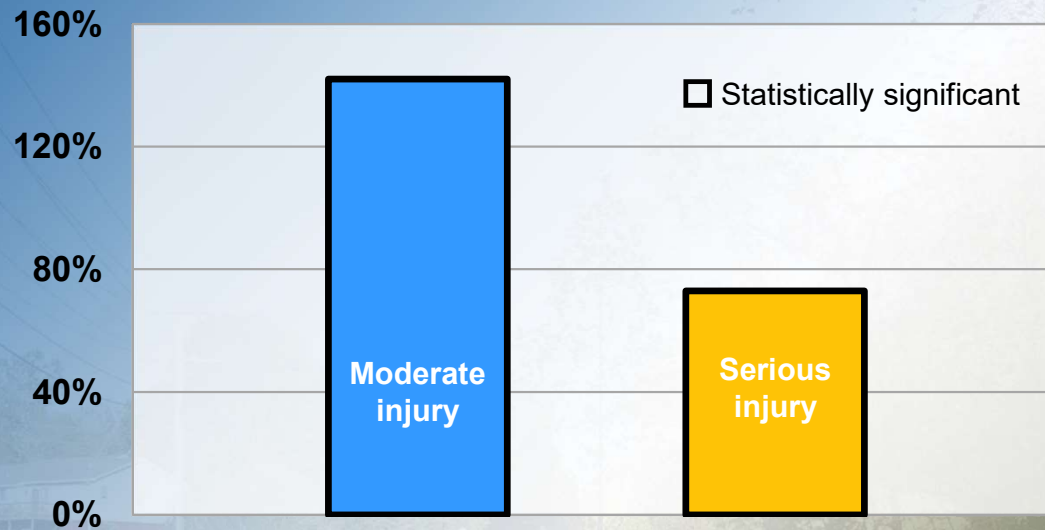
\*\*P < .001.

adjustment for confounders such as occupant age, belt use, crash type, they found that newer vehicles (MY 2009 and later) carry less risk of Abbreviated Injury Scale (AIS) 2+ and AIS 3+ injury compared to older model year vehicles, with odds ratios of 0.69 (AIS 2+) and 0.45 (AIS 3+).

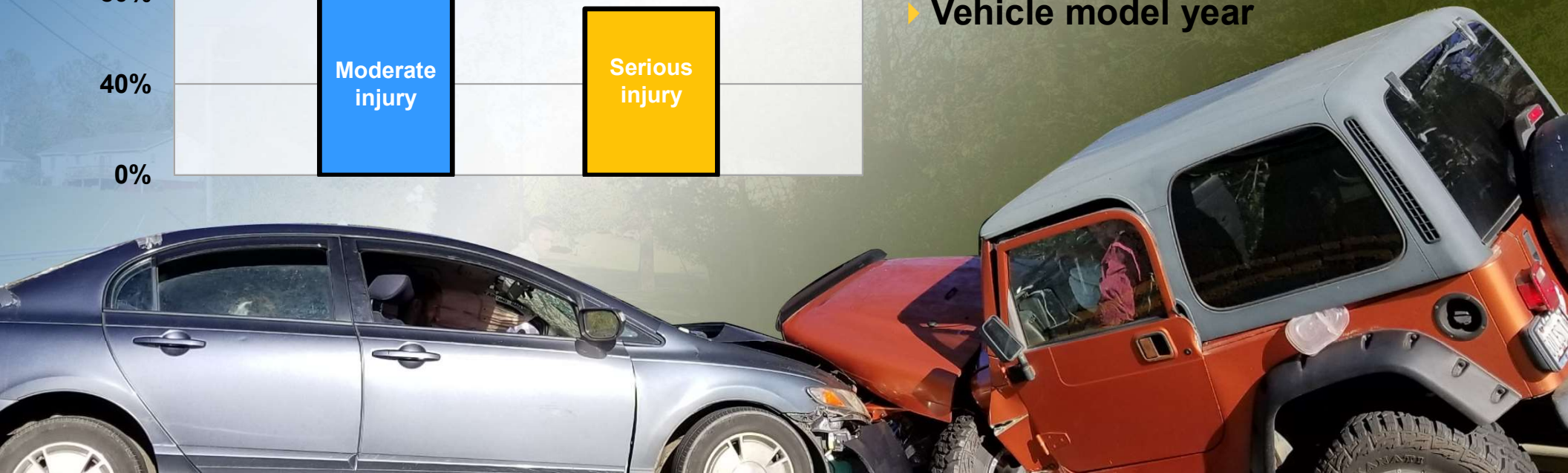


# UVA research shows increased risk to females

Difference in front crash injury risk compared with males



- ▶ Occupant factors
- ▶ Estimated crash severity
- ▶ Vehicle model year



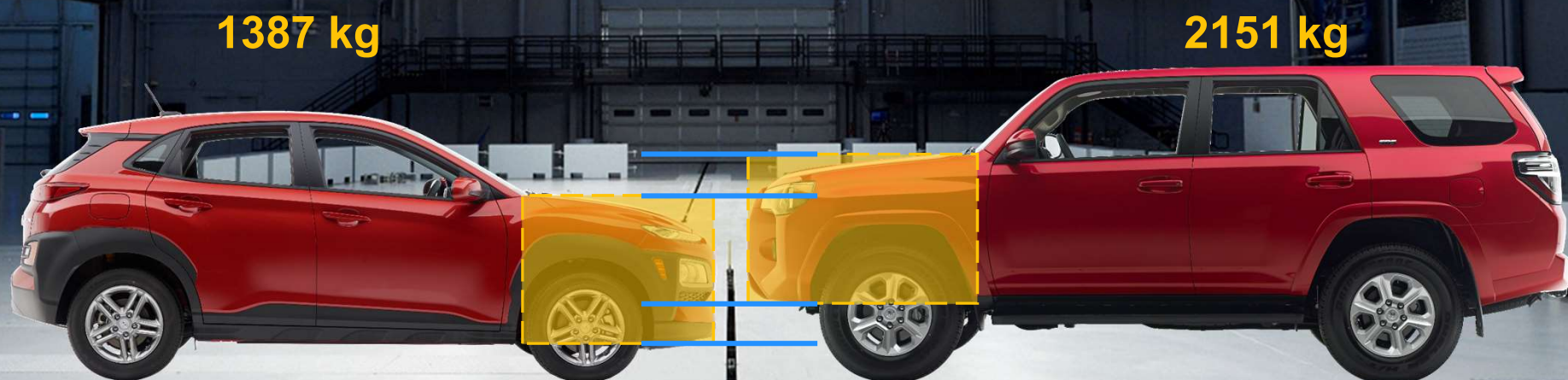


**Other exposure differences affect crash severity and injury risk**





## Other exposure differences affect crash severity and injury risk





# Other exposure differences affect crash severity and injury risk

## Crash configuration with partner vehicle



## Crashworthiness of vehicles



Good



Acceptable



Marginal



Poor

# Difference in front crash injury risk for females compared with males

TRAFFIC INJURY PREVENTION  
<https://doi.org/10.1080/15389588.2021.2004312>



Check for updates

## Injury risks and crashworthiness benefits for females and males: Which differences are physiological?

Matthew L. Brumbelow and Jessica S. Jermakian

Vehicle Research Center, Insurance Institute for Highway Safety, Ruckersville, Virginia

### ABSTRACT

**Objective:** Previous research has found elevated injury risk for females relative to males in passenger vehicle crashes but has not accounted for ways the crashes themselves differ between these populations. Vehicle curb weight, ride height, safety rating, airbag deployment, and crash configuration all influence injury outcome and often are not well-represented by delta-V alone. This study evaluated the effect of occupant sex on injury risk in front and side crashes while limiting or controlling for non-physiological crash differences. Additionally, the effects of crashworthiness improvements are compared for females and males.

**Methods:** NASS-CDS cases from 1998–2015 calendar years involving a belted driver in a front crash or a struck-side driver or right front passenger in a side crash were analyzed. Case vehicle model years were 1989–2016. Logistic regression was used to estimate the risk of MAIS  $\geq 2$  and MAIS  $\geq 3$  injury outcomes for females relative to males as well as the change in risk due to improved crashworthiness. Sex-based differences in occupant age, mass, and stature; crash test rating; delta-V; crash configuration; and vehicle-to-vehicle compatibility were considered either through case selection or the inclusion of additional regression covariates.

**Results:** Before controlling for crash and vehicle differences, female drivers in front crashes had higher estimated overall and body-region-specific risks of MAIS  $\geq 2$  and MAIS  $\geq 3$  injury, as consistent with previous findings. After accounting for such differences, all ratios of injury odds for females relative to males were reduced. Females remained at higher risk of MAIS  $\geq 2$  injury (OR, 2.23; 95% CI, 1.42–3.51), especially extremity injury, but had similar odds for MAIS  $\geq 3$  non-extremity injury (OR, 0.98; 95% CI, 0.56–1.7). While controlling for crash differences in side impacts, none of the estimated injury risk differences by sex were significant at the  $p \leq 0.05$  level. Estimated benefits of improved crashworthiness were similar or greater for females than for males for most injury outcomes.

**Conclusions:** Female-specific crashworthiness improvements may be required to provide additional protection against AIS 2 extremity injury. Much of the remaining discrepancy in sex-based injury risk can be attributed differences between vehicles and crashes, not to physiological differences. Addressing these differences will require other types of countermeasures.

### ARTICLE HISTORY

Received 17 February 2021  
Accepted 4 November 2021

### KEYWORDS

injury risk; crash analysis;  
crashworthiness; consumer  
ratings; sex-based  
differences

### Introduction

Fatal crash rates are higher for males than females regardless of how they are measured—per capita, per miles traveled, or per licensed driver—(Insurance Institute for Highway Safety 2019; Mayhew 2003) but the gaps are narrowing as more females are licensed and spend more time driving (Mayhew 2003). Still, females accounted for fewer than 30% of crash deaths in 2018 in the United States (Insurance Institute for Highway Safety 2019). For crashes of all severities, females have lower rates of crashes per licensed driver but higher rates per miles traveled (Massie et al. 1995; 1997; Li et al. 1998; Ferguson and Braitman 2006; Bose et al. 2011). Males are involved in more crashes involving risk-taking behaviors such as speeding and impairment (Romano et al. 2008;

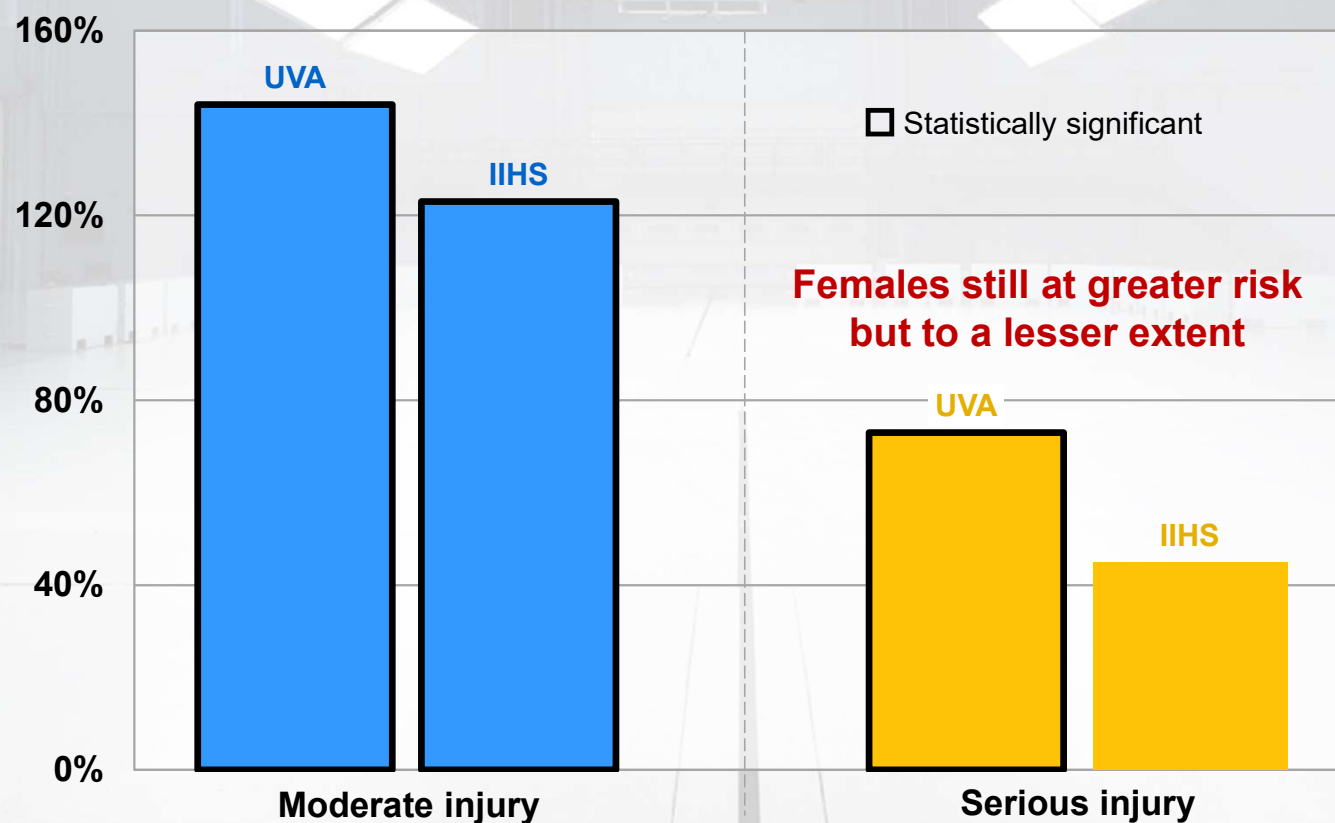
Insurance Institute for Highway Safety 2019) and tend to be involved in more severe crashes overall (Li et al. 1998).

After adjusting for crash severity and other factors, studies show females are at increased risk of fatal injury compared with males. In double-pair comparison studies, young females (20–35 years) have an increased fatality risk of 20 to 28% compared with young males in similar crashes, although the discrepancy decreases with age and is eliminated or reversed by middle age (Evans 2001; Kahane 2013; Abrams and Bass 2020). Using a different method, Evans and Gerrish (2001) found unbelted young females have an increased fatality risk of 22% compared with unbelted males, a similar magnitude as found using the double-pair method. When considering serious injuries, multivariate logistic regression studies using National Automotive Sampling

- ▶ NASS CDS 1998-2015
- ▶ Belted drivers in frontal crashes in vehicles model year 1989+
- ▶ Comparison of injury risk in “compatible” crashes:
  - airbag deployment
  - vehicle-to-vehicle crashes restricted on striking vehicle type and mass differential, no underride/override
- ▶ Covariates:
  - $\Delta V$ , driver age, height, mass
  - good IIHS moderate overlap rating, crash partner type

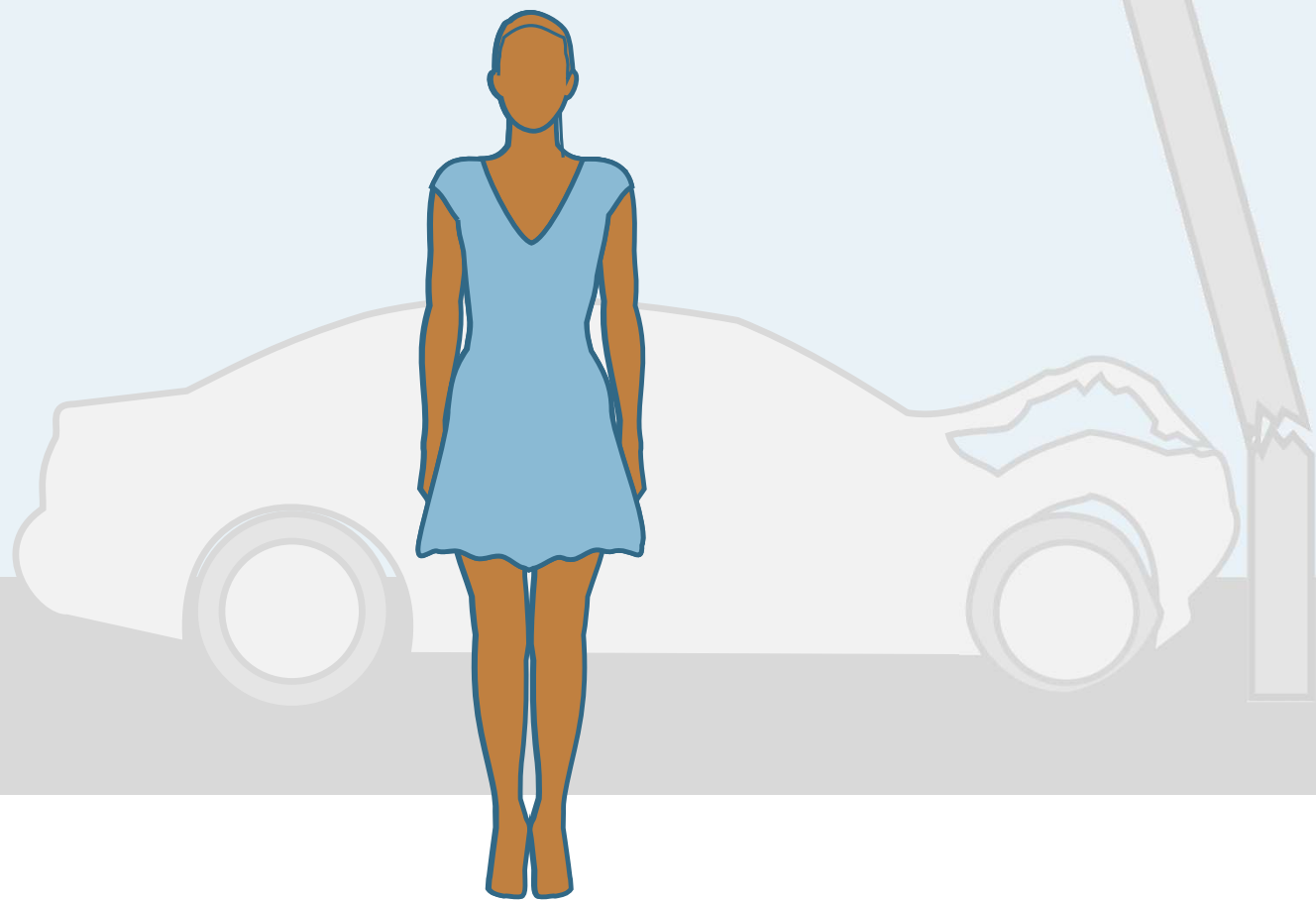
# Difference in front crash injury risk compared with males

UVA findings vs. IIHS findings





## Types of injury risk

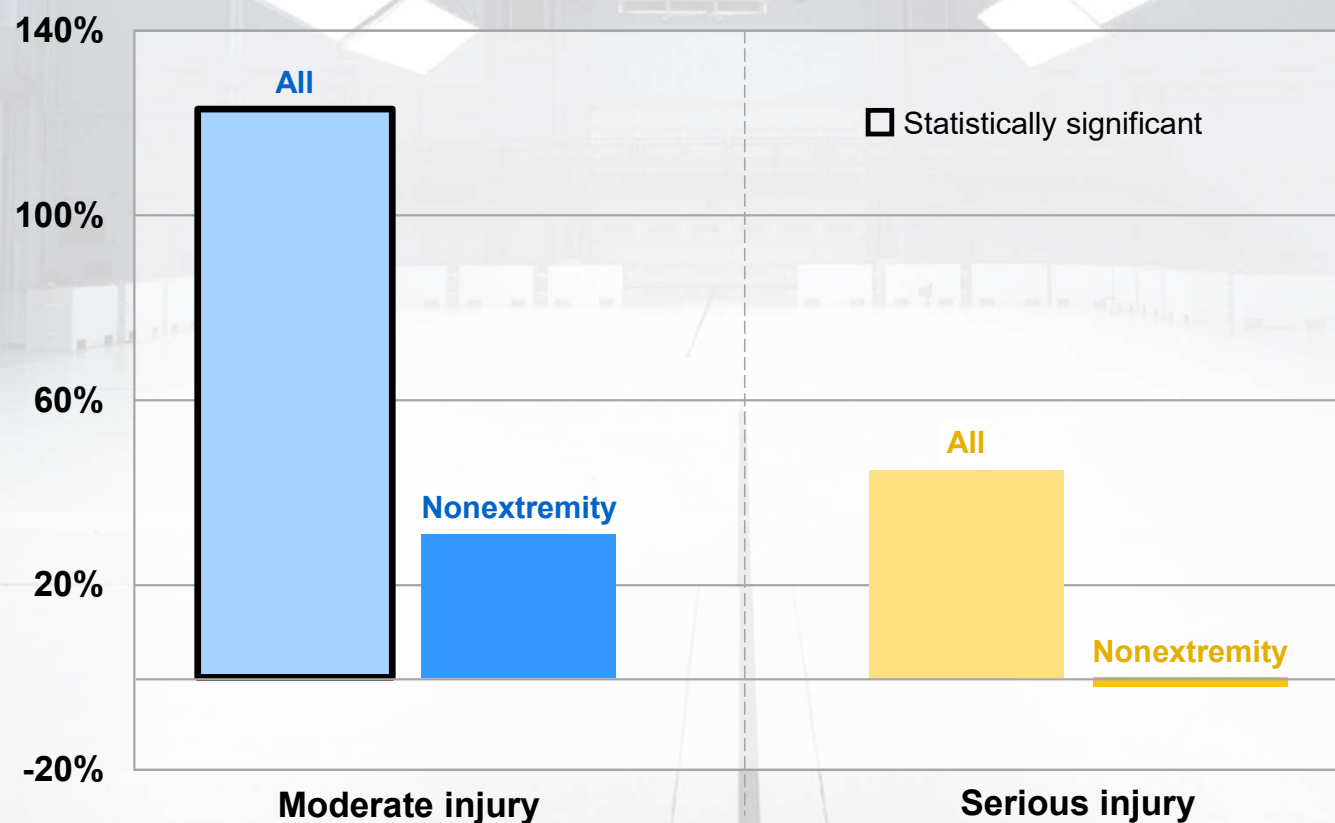


All injuries

Nonextremity injuries

# Difference in injury risk for females compared with males

Front crashes



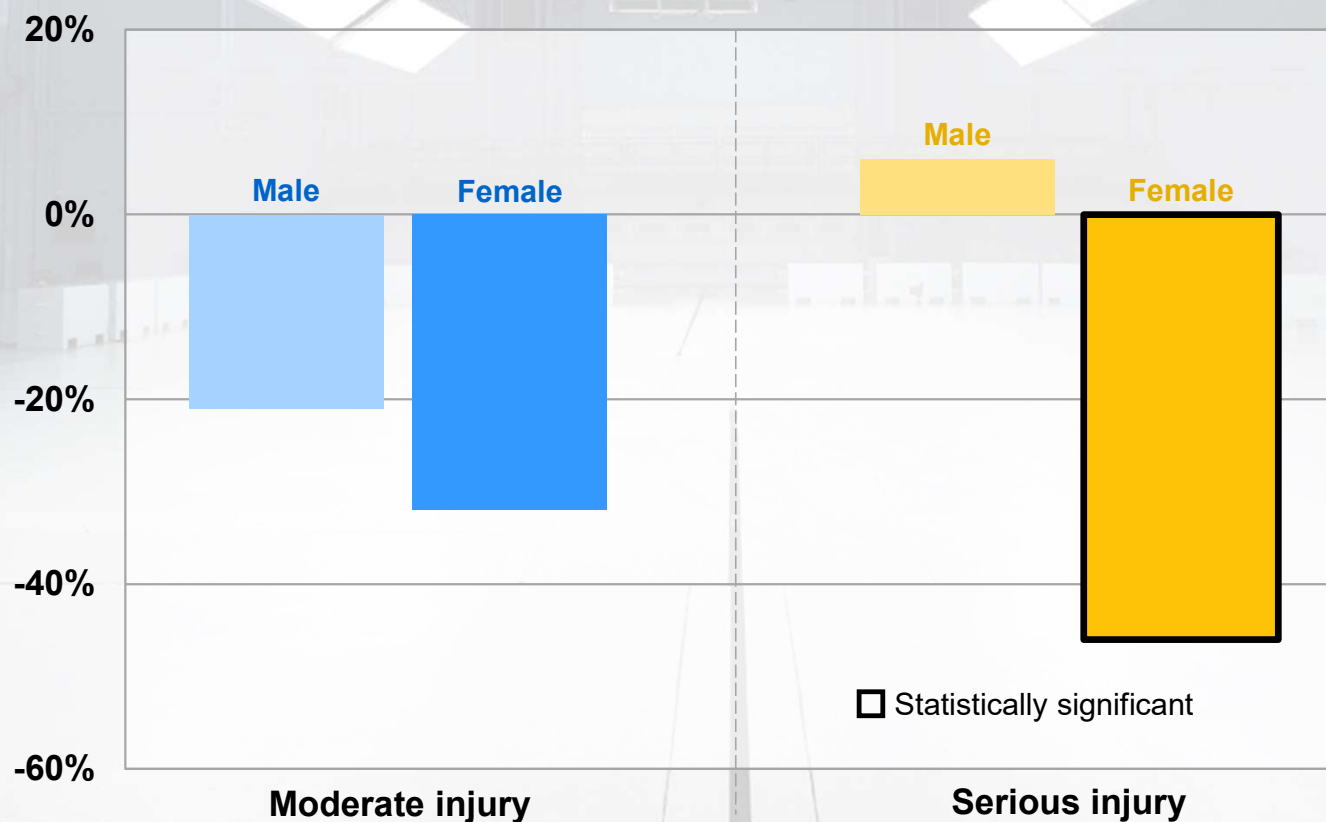
**Have vehicle improvements benefited males and females equally?**





# Difference in injury risk for good-rated vs. other vehicles

Front crashes





## Summary

- ▶ Some good news:
  - Females and males have similar risk of serious nonextremity injuries in front crashes
  - Crashworthiness improvements have benefited both sexes, perhaps females more
  
- ▶ Is there more we can do?
  - Some increased risk to females is due to sex-based differences in crash exposure
  - Females are at higher risk of extremity injuries
  - More data needed to understand injury risk in side impact crashes



Insurance Institute for Highway Safety  
Highway Loss Data Institute

More information at [iihs.org](https://www.iihs.org) and on our social channels:



[/iihs.org](https://www.iihs.org)



[@iihs\\_autosafety](https://www.instagram.com/iihs_autosafety)



[@IIHS\\_autosafety](https://twitter.com/IIHS_autosafety)



[IIHS](https://www.youtube.com/IIHS)

## **Jessica Jermakian**

Vice President, Vehicle Research

[jjermakian@iihs.org](mailto:jjermakian@iihs.org)

## **Matt Brumbelow**

Senior Research Engineer

[mbrumbelow@iihs.org](mailto:mbrumbelow@iihs.org)

**[iihs.org](https://www.iihs.org)**