NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Female Crash Fatality Risk Relative to Males for Similar Physical Impacts

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Agenda

- Purpose of the study
- Data
- Methodology
- Main results
- Conclusions

Purpose of the Study

- Assess female crash fatality risk relative to males for similar physical impacts.
- Examine the effect of sex on driver-side or right front passenger-side occupant fatalities in fatal crashes.
  - NHTSA study (Kahane, 2013)
  - Update a part of the previous study by adding recent fatal crash data
- Evaluate the effect of recent vehicle safety improvement.
- Investigate the extent to which newer vehicles with modern occupant protection systems reduce the difference in fatality risk between females and males as compared to the older vehicles without those systems.

Data

- Data 1: FARS 1975-2019
  - Cars and LTVs where there was a driver and a RF passenger, and at least one of them died.
  - Model year: 1960-2020
  - Belt use status and air bag availability is the same for driver and RF passenger.
  - Occupant ages: 16-96
  - ➔ Used for Logistic Regression Models for various vehicle groups

    ❖ Vehicle Groups (independent models for each vehicle group):
      - Vehicle Type, Model Year, Occupant Protection Type, Impact Type
      - Combination of these groups (~ 100 groups).
- Data 2: FARS 2001-2019
  - Cars and LTVs where there was a driver and a RF passenger, and at least one of them died.
  - Occupant ages: 16-96
  - Model years, belt use status, and air bags availability were not considered.
  - ➔ Used for Double-pair comparison

Methodology

- Step 1: Logistic Regression Models
  - Two models: a driver model and a RF passenger model
    - Response variable is the fatal status of the driver or RF passenger
    - 8 Independent variables are formed based on driver’s and RF passenger’s ages and sexes.
  - Make formula to predict probabilities of driver’s and RF passenger’s fatalities.
- Step 2: Double-Pair Comparison
  - Estimate driver’s and RF passenger’s fatalities.
  - Estimate female fatality risk relative to males using double-pair comparison.
    (Percentage difference in fatality risk between females and males)
  - Double-pair comparison estimates the effect of sex separately from the other effects on fatalities such as crash severity, risky driving behavior, and so on.
- Step 3: Variance Estimation
  - FARS is one realization (a sample) from a super-population.
  - Jackknife variance estimation
  - 95% Confidence Interval

Methodology (Logistic Regression Models)

- Example Scenario:
  - Female driver fatality risk relative to male drivers for cars with air bags and unbelted occupants
- Logistic Regression Models
  - Fit two models for this vehicle group (cars with air bags and unbelted occupants) from FARS 1975-2019
  - Make formulas to predict probabilities of driver's and RF passenger's fatalities.

$$E\_FATAL1 = \frac{exp(Z1)}{1 + exp(Z1)}$$

$$E\_FATAL3 = \frac{exp(Z3)}{1 + exp(Z3)}$$

Z1: log-odds of a driver fatality from the driver model

Z3: log-odds of a RF passenger fatality from the RF passenger model

Methodology (Double-Pair Comparison) - Drivers

- Double-pair comparison provides a causal interpretation of the sex effect (i.e. does being a female cause you to have a higher risk of dying than being a male?).
- Apply formulas predicting probabilities of driver's and RF passenger's fatalities to the FARS 2001-2019 dataset.
  - For each vehicle in the dataset, calculate
    - Probabilities of driver's and RFP's fatality **had the driver been a female**.
    - Probabilities of driver's and RFP's fatality **had the driver been a male**.
  - Aggregate probabilities over all vehicles in the dataset to estimate
    - Driver fatalities and RFP fatalities when drivers are females.
    - Driver fatalities and RFP fatalities when drivers are males.
- Calculate two fatality ratios:

$$r1 = \text{(Driver fatalities/RFP fatalities), when drivers are females.}$$
$$r2 = \text{(Driver fatalities/RFP fatalities), when drivers are males.}$$

  - Here, **RF passengers are control characteristics**.
- Estimate female driver fatality risk relative to male drivers as

$$R(\%) = \left(\frac{r1}{r2} - 1\right) \times 100$$

Methodology (Double-Pair Comparison) - Drivers

- The actual estimate of the example:
  - Aggregation of probabilities produces estimated fatalities
    - $\sum \text{driver fatality probability when the driver is female} = 395{,}850$
    - $\sum \text{RFP fatality probability when the driver is female} = 375{,}686$
    - $\sum \text{driver fatality probability when the driver is male} = 371{,}907$
    - $\sum \text{RFP fatality probability when the driver is male} = 407{,}621$
  - The estimated female driver fatality relative to male drivers for cars with air bags and unbelted occupants is 15.5%.

$$R(\%) = \left(\frac{r1}{r2} - 1\right) \times 100 = \left(\frac{395{,}850/375{,}686}{371{,}907/407{,}621}\right) \times 100 = 0.155$$

Methodology (Double-Pair Comparison) – RF Passengers

- Apply formulas predicting probabilities of driver's and RF passenger's fatalities to the FARS 2001-2019 dataset.
  - For each vehicle in the dataset, calculate
    - Probabilities of driver's and RFP's fatality **had the RFP been a female**.
    - Probabilities of driver's and RFP's fatality **had the RFP been a male**.
  - Aggregate probabilities over all vehicles in the dataset to estimate
    - Driver fatalities and RFP fatalities when RFPs are females.
    - Driver fatalities and RFP fatalities when RFPs are males.
- Calculate two fatality ratios:

$r1 =$ (RFP fatalities/Driver fatalities), when RFPs are females.

$r2 =$ (RFP fatalities/ Driver fatalities), when RFPs are males.

  - Here, **drivers are control characteristics**.
- Estimate female RFP fatality risk relative to male RFPs as

$$R(\%) = \left(\frac{r1}{r2} - 1\right) \times 100$$

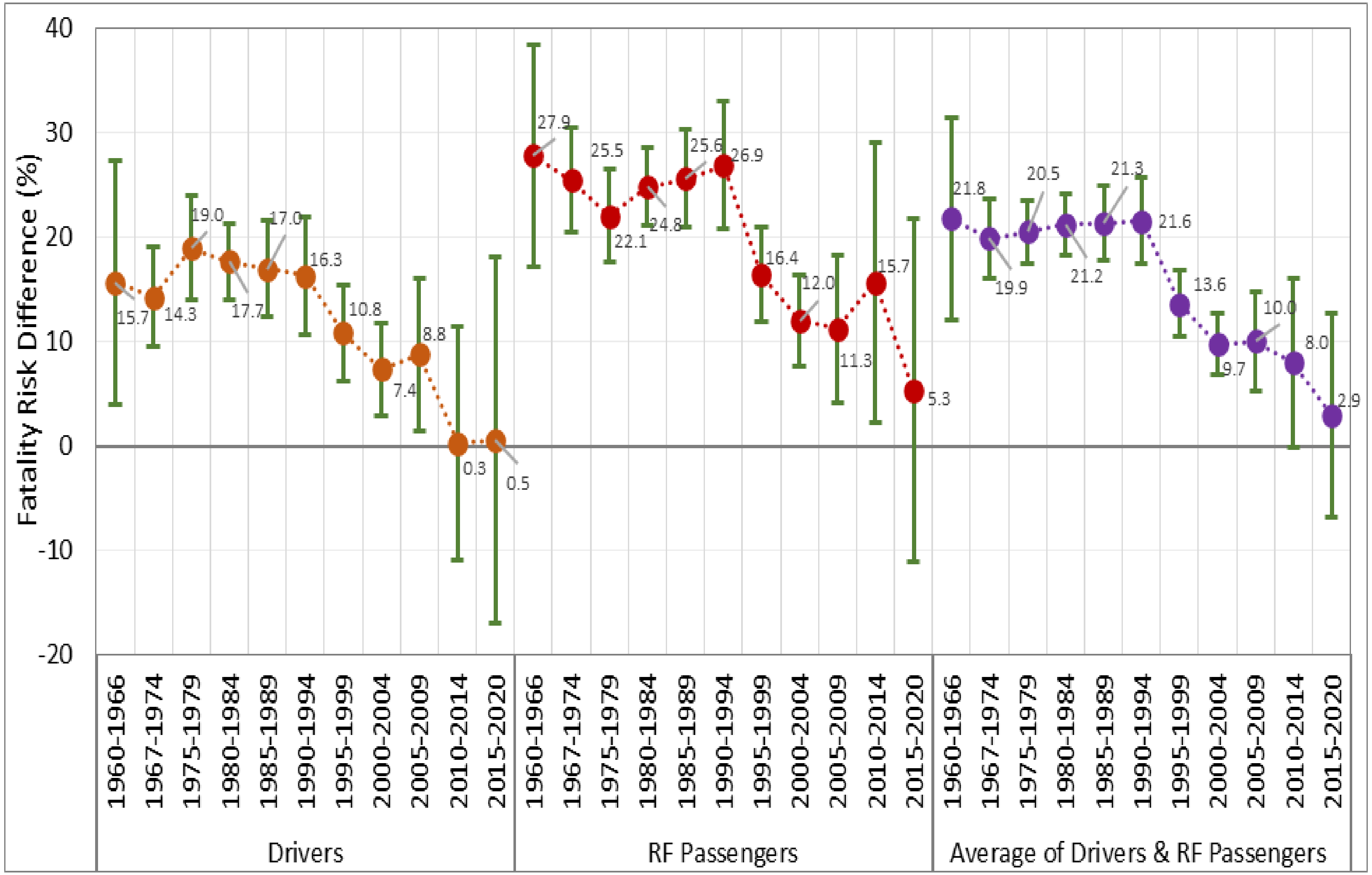
Methodology (Double-Pair Comparison) – RF Passengers

- The actual estimate of the example:
  - Aggregation of probabilities produces estimated fatalities
    - $\sum$ driver fatality probability when the RFP is female $= 76{,}482$
    - $\sum$ RFP fatality probability when the RFP is female $= 87{,}556$
    - $\sum$ driver fatality probability when the RFP is male $= 82{,}643$
    - $\sum$ RFP fatality probability when the RFP is male $= 82{,}422$
  - The estimated female RFP fatality relative to male RFP for cars with air bags and unbelted occupants is 14.8%.

$$R(\%) = \left(\frac{r1}{r2} - 1\right) \times 100 = \left(\frac{87{,}556/76{,}482}{82{,}422/82{,}643}\right) \times 100 = 0.148$$

Results by Model Years (Trends)

- Female fatality risk relative to males reduces steadily for later model years.
- Small sample sizes for later model years create wide confidence intervals.



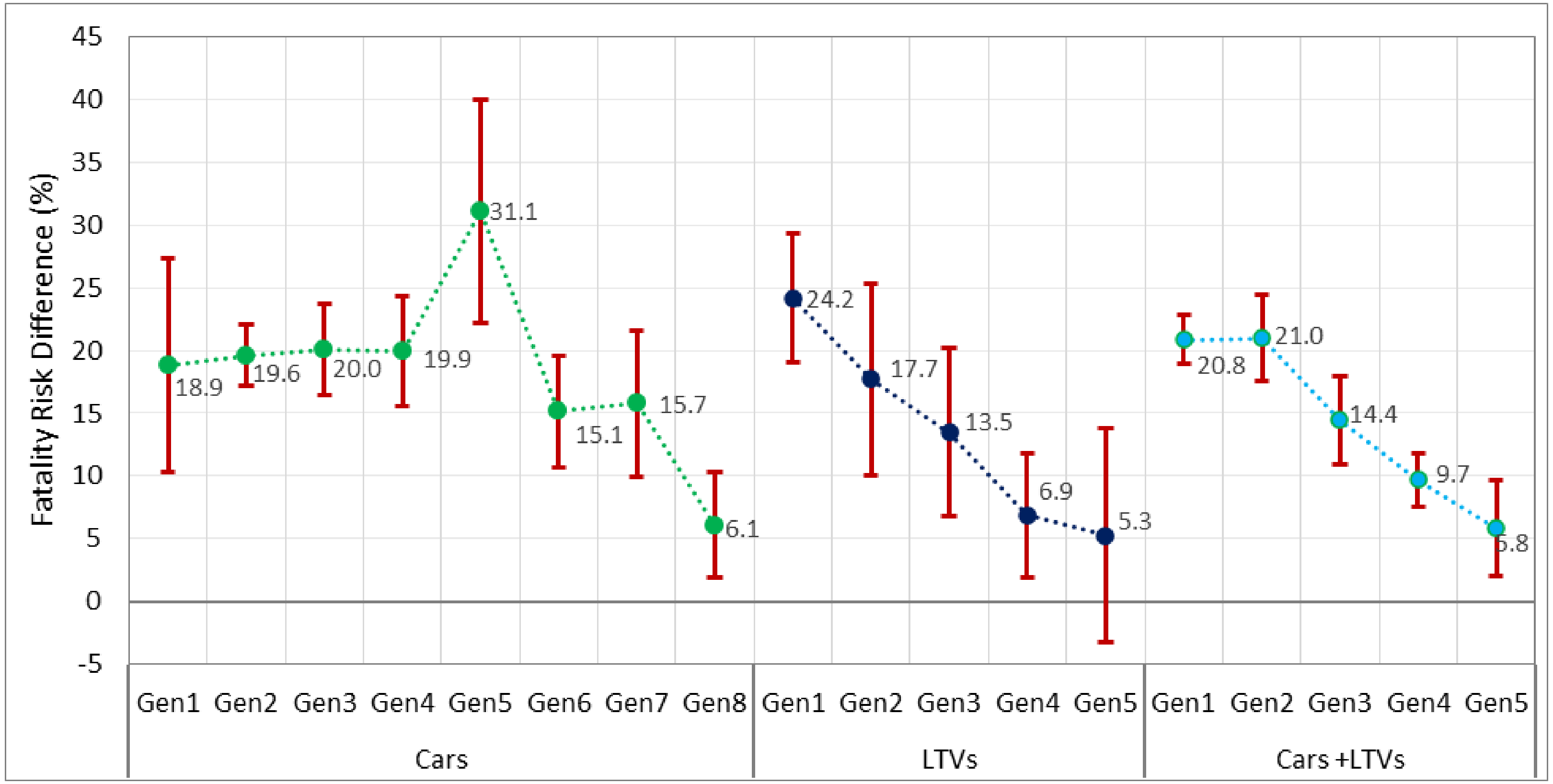
Results by Model Years (Comparison)

- Female fatality risk relative to males is significantly reduced in newer MY vehicles compared to older MY vehicles
  - MY 2010-2020 vs MY 1960-2009 reduces by **-9.8 ± 6.7** % for belted occupants.
  - MY 2000-2020 vs MY 1960-1999 reduces by **-5.9 ± 4.9** % for unbelted occupants.

Comparison of Model Years	Unbelted			Belted			All (Unbelted + Belted)		
2010-2020 vs. 1960-2009	-11.9	±	14.1	**-9.8**	**±**	**6.7**	**-12.0**	**±**	**5.5**
2010-2020 vs. 1960-1999	-12.3	±	14.2	**-13.6**	**±**	**7.0**	**-13.6**	**±**	**5.6**
2010-2020 vs. 1980-1989	-13.8	±	14.3	**-13.8**	**±**	**8.1**	**-15.0**	**±**	**6.0**
2010-2020 vs. 1990-1999	-8.9	±	14.6	**-12.5**	**±**	**7.1**	**-11.2**	**±**	**5.9**
2000-2020 vs. 1960-1999	**-5.9**	**±**	**4.9**	**-12.3**	**±**	**3.8**	**-10.6**	**±**	**2.5**
2000-2020 vs. 1980-1989	**-7.4**	**±**	**5.4**	**-12.5**	**±**	**5.6**	**-12.0**	**±**	**3.3**
2000-2020 vs. 1990-1999	-2.5	±	6.0	**-11.2**	**±**	**3.9**	**-8.2**	**±**	**3.2**

Results by Occupant Protection Type (Trends)

- In cars, air bags (Gen6-Gen8) reduces female fatality risk relative to males.
- In LTVs female fatality risk relative to males decreases with newer generations of occupant protection.



Generations of Car Occupants	Generations of LTV or Car+ LTV Occupants
Gen1: Unbelted, pre-MY 1968, no energy-absorbing (EA) steering columns	Gen1: Unbelted, without air bags
Gen2: Unbelted, MY 1969-1982 cars	Gen2: Belted, without air bags
Gen3: Unbelted, MY 1983-1996, no air bags	Gen3: Unbelted, with dual air bags (no on-off switches for LTVs)
Gen4: 3-pt. belted occupants of cars without air bags	Gen4: Belted, with dual air bags (no on-off switches for LTVs)
Gen5: 2-pt. lap/automatic shoulder belted occupants of cars without air bags	Gen5: Belted, with dual air bags, pretensioners, load limiters (LTV MY ≥ 2007)
Gen6: Unbelted occupants of cars with dual air bags	
Gen7: Belted, with dual air bags, no pretensioners/load limiters	
Gen8: Belted, with dual air bags, pretensioners, load limiters	

Results by Occupant Protection Type (Comparison)

- Modern occupant protection technologies significantly reduce the female fatality risk relative to males.
  - Dual air bags reduce by **-6.4 ± 4.0** % for unbelted occupants.
  - Dual air bags further reduce by **-11.3 ± 4.1** % for belted occupants.
  - Dual air bags, pretensioners, and load limiters reduce by **-15.2 ± 5.2** % for belted occupants.

Comparison of Occupant Protection Types	Drivers & RFP		
Unbelted with dual air bags vs. Unbelted without air bags	-6.4	±	4.0
Belted with dual air bags vs. Belted without air bags	-11.3	±	4.1
Belted with dual air bags, pretensioners and load limiters vs. Belted without air bags	-15.2	±	5.2

Conclusions

- The incremental female fatality risk relative to males reduces steadily for later model year vehicles.
- New vehicle designs have significantly decreased female fatality risk relative to males.
  - Air bags significantly reduce the relative female fatality risk for both belted and unbelted occupants.
  - The latest occupant protection technologies (dual air bags, pretensioners, and load limiters) most significantly reduce the relative female fatality risk for belted occupants.
- The report can be downloaded from this link:

https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813358