

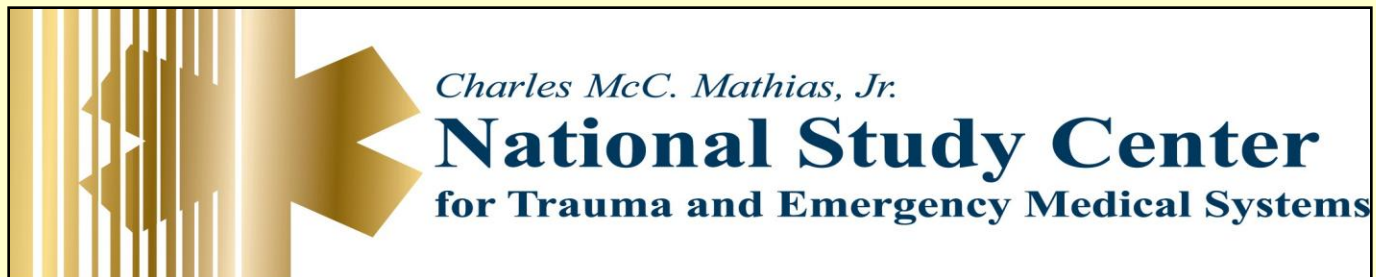


Assessing Effects Of Changes in Airbag Regulations On Risk Of Frontal Deaths among Drivers and Right-front Passengers: Two Approaches

Elisa R. Braver, PhD

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It takes a village to study airbags . . .the UMB team



Joe Kufera



Karen Volpini



Marge Scerbo



Mel Alexander



Joe Lloyd



Elisa Braver

Purpose of studies

- Compare sled-certified airbags with first-generation airbags
 - Deaths among drivers & right-front passengers in frontal crashes



Data Sources

- **Deaths (frontal crash)**: Fatality Analysis Reporting System (FARS), 1998-2005
- National Automotive Sampling System (NASS), 1998-2004
 - **Police-Reported Frontal Crashes**: General Estimates System (GES)



Occupant Restraint Data Collection

- **Airbag and seat belt features**
 - Repeated contacts with manufacturers, including provision of sample vehicle identification numbers
 - NHTSA public data (NASS/CDS manual, www.safercar.gov, Buying a Safer Car)
 - Built a database of features and made further corrections

Overview of Two Approaches: Frontal Crashes

I. First approach: FARS only

- Matched pairs of drivers involved in fatal head-on collisions

II. Second approach: FARS and GES

- Driver deaths per:
 - Drivers involved in police-reported frontal crashes
- Right-front passenger deaths per:
 - Passengers in frontal crashes



Study Population

Eligibility

- Frontal crashes (11, 12, 1 o'clock impact point or front or front corner general area of damage)
- Passenger vehicles (cars, pickups, SUVs, minivans)
- Standard frontal airbags (included models with driver-only airbags for driver analyses)
- Vehicles with first-generation airbags: model years 1994-97
- Vehicles with sled-certified airbags: model years 1998-2005 (identified as sled-certified by auto makers, NHTSA)
- **NOTE:** Examined vehicles equipped with airbags, did not confine analysis to vehicles reported as having deployed airbags.

Study Population: Ineligible

Exclusions

- Rollovers following initial frontal impact
- Cargo vans/very large passenger vans
- Specific model years that had *running changes* in sled-certified status
- Certification as advanced & compliant (CAC) with FMVSS 208
- Vehicles not sled-certified after model year 1997
- Any Mercedes-Benz (reason: advanced features but not sled-certified)

Matched-pair cohort studies



- Have group that experienced the same event (crash)
- Match pairs within group (occupants in same vehicle in crash or involvement in same crash)
- Compute matched-pair risk ratio
- Advantage: able to use data when do not know numbers of pairs where both survived or both escaped injury (FARS, hospitalized motorists)

Head-On Collisions

- Rationale: Drivers of vehicles in head-on collisions generally will experience similar degrees of kinetic energy when:
 - No vehicle weight or structure/stiffness mismatch
 - Both drivers belted or both unbelted



Matched-pair cohort analyses

- Fatal 2-vehicle head-on collisions between vehicles with 1st generation and sled-certified airbags during 1998-2005
- First-generation airbags: reference group for computing risk ratios
- Simple stratified analyses
- Multivariate analyses using conditional Poisson regression

Matched-pair cohort study: 2,035 driver pairs

1st GEN DIED

		1 st GEN DIED	
		Yes	No
SLED-CERT DIED	Yes	172	554
	No	846	(463+?)

$$\text{Risk ratio} = \frac{(172 + 846)}{(172 + 554)}$$

=0.71 (95% confidence interval 0.65-0.78)

What does this mean?

- Risk ratio of 0.71 → drivers of sled-certified vehicles had 29% lower risk of dying in head-on collision than first-generation drivers.
- Other factors that affect risk of death were not considered – so estimate is crude.

Multivariate models

- All vehicles: airbag generation, vehicle type, belt status, age (15-59 vs. 60+)
 - Tested interaction terms to determine if airbag effects varied by category: airbag by belt status, vehicle type, age, gender
 - Partly accounted for vehicle age by separating sled model years 1998-99, 2000-01, 2002-05
- Only cars: airbag generation, belt status, age (15-59 vs. 60+), passenger car size
 - Tested interaction terms: airbag by belt status, car size, age
 - Partly accounted for vehicle age by separating sled model years 1998-99, 2000-01, 2002-05

Multivariate models and adjusted RR* & 95% CI for driver deaths by age, vehicle type, belt status

Variable	Model 1 (crude)	Model 2	Model 3
Sled airbag	0.71 (0.65-0.78)	0.87 (0.77-0.98)	0.96 (0.80-1.15)
Co-variables' effects		Adjusted fatality risk	Adjusted fatality risk
Age 60+		2.81 (2.24-3.52)	2.80 (2.23-3.51)
Unbelted		3.09 (2.52-3.78)	3.14 (2.56-3.86)
Pickup/SUV		0.22 (0.18-0.28)	0.27 (0.20-0.35)
Minivan		0.72 (0.50-1.05)	0.65 (0.40-1.06)
Interaction terms:			
Sled by Pickup/SUV		—	0.72 (0.52-1.01)
Sled by Minivan		—	1.32 (0.61-2.86)
N of matched pairs	1,572	1,400	1,400

*Reference groups: first-generation airbag, ages 15-59, belted, cars

Understanding potential interaction between sled-certified airbags & vehicle type

- Pickups, first-generation: 48% of drivers died in head-on collisions.
- Pickups, sled-certified: 27% of drivers died in head-on collisions.

vs.

- Cars, first-generation: 73% of drivers died in head-on collisions.
- Cars, sled-certified: 64% of drivers died in head on collisions.

Addressing newer vehicle age and improved vehicle designs: adjusted RR* & 95% CI for driver deaths by model year, age, vehicle type, belt status

Variable	Model 2	Model 5	Model 6
Sled airbag (all)	0.87 (0.77-0.98)		
Model years 98-99		0.92 (0.76-1.10)	1.02 (0.81-1.28)
Model years 00-01		0.81 (0.66-1.00)	0.89 (0.70-1.14)
Model years 02-05		0.87 (0.68-1.12)	0.96 (0.72-1.27)
<u>Co-variables' effects</u>	Adjusted risk	Adjusted risk	Adjusted risk
Age 60+	2.81 (2.24-3.52)	2.81 (2.24-3.53)	2.80 (2.24-3.52)
Unbelted	3.09 (2.52-3.78)	3.07 (2.50-3.76)	3.12 (2.54-3.83)
Pickup/SUV	0.22 (0.18-0.28)	0.22 (0.18-0.27)	0.27 (0.20-0.35)
Minivan	0.72 (0.50-1.05)	0.73 (0.50-1.06)	0.65 (0.40-1.07)
Interaction terms:			
Sled by Pickup/SUV	—	—	0.72 (0.52-1.0)
Sled by Minivan	—	—	1.34 (0.62-2.88)
N of matched pairs	1,400	1,400	1,400

***Reference groups: first-generation airbag, ages 15-59, belted, cars**

CAR-CAR HEAD-ON COLLISIONS ONLY: adjusted RR* & 95% CI for driver deaths by model year, age, belt status, car size

Variable	Model 1C (crude)	Model 2C	Model 3C
Sled airbag (all)	0.90 (0.76-1.06)	1.04 (0.85-1.29)	
Model years 98-99			1.25 (0.91-1.71)
Model years 00-01			0.87 (0.61-1.24)
Model years 02-05			0.99 (0.64-1.53)
<u>Co-variables' effects</u>		Adjusted fatality risk	Adjusted fatality risk
Age 60+		3.38 (2.27-5.03)	3.45 (2.31-5.16)
Unbelted		3.54 (2.45-5.12)	3.50 (2.42-5.06)
Small cars		4.64 (2.92-7.38)	4.76 (2.98-7.60)
Midsized cars		2.06 (1.28-3.32)	2.04 (1.26-3.29)
N of matched pairs	503	437	437

***Reference groups: first-generation airbag, ages 15-59, belted, large cars**

PAIR COMBINATIONS: Ages 15-59 with same belt status by vehicle type

Variable	N of pairs	Risk ratio	95% CI
Ages 15-59, same belt status (both)	492	0.72	(0.61-0.86)
Belted (both)	390	0.70	(0.58-0.85)
Unbelted (both)	102	0.81	(0.57-1.15)
Cars, same belt status (both)	151	0.92	(0.69-1.24)
Pickup/SUV, same belt status (both)	80	0.75	(0.50-1.13)

*Reference groups: first-generation airbag

PAIR COMBINATIONS: Ages 60+ or gender by belt status

Variable	N of pairs	Risk ratio	95% CI
Ages 60+, same belt status (both)	35	0.75	(0.40-1.38)
Men, belted (both)	221	0.86	(0.67-1.11)
Men, unbelted (both)	76	1.02	(0.68-1.54)
Women (both, any belt status)	232	0.62	(0.48-0.80)
Women, belted (both)	118	0.54	(0.37-0.78)

***Reference groups: first-generation airbag**

Matched-pair cohort analysis of 2-vehicle head-on collisions

- Limitations:
 - Small numbers in some categories.
 - Conditional Poisson regression can → overly wide confidence intervals.
 - Unable to study height/weight of drivers.
 - Too few vehicles with seat belt pretensioners and load limiters to control for their presence.



Matched-pair cohort analysis of 2-vehicle head-on collisions

- Strengths:
 - Excellent measure of restraint performance (head-on collisions).
 - Similar crash forces in head-on collisions.
 - Used sled-certification, not simply model year 1998+.
 - Control for confounding effects of driver age, vehicle type/collision partner, belt use, car size.
 - Fatal crashes are high-severity events, so this study is relevant to concerns about protectiveness of sled-certified airbags in high-severity crashes

Summary of Findings: Matched-Pair Cohort Study of Fatal Head-on Collisions

- Most evidence: sled-certified airbags have not reduced protectiveness of frontal airbags among drivers, including unbelted drivers and men.
- No significant differences in protection by driver age.
- Suggestive evidence: Female drivers and drivers of pickup trucks may receive more protection.
- Inconsistent findings concerning later models versus earlier models of sled-certified vehicles.

Driver and Right-Front Passenger Deaths per Involvements in Frontal Police-Reported Crashes

FARS and GES



Vehicle Type: Driver Deaths per Drivers Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
TOTAL	10,545	44,649	11,470	54,999	0.89 (0.74-1.08)
Pickup	1,941	6,439	2,780	10,848	0.87 (0.70-1.08)
SUV	876	4,919	1,408	10,358	0.80 (0.64-0.99)
Minivan	499	2,275	480	2,875	0.75 (0.61-0.92)
Car	7,229	31,016	6,802	30,918	0.95 (0.78-1.16)

***Reference group: drivers of first-generation vehicles**

Car Size: Driver Deaths per Drivers Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
Car (all)	7,229	31,016	6,802	30,918	0.95 (0.78-1.16)
Small	3,125	13,249	2,732	12,521	0.93 (0.77-1.14)
Midsized	2,194	10,337	2,166	11,025	0.94 (0.77-1.16)
Large	1,910	7,430	1,813	7,342	0.96 (0.77-1.19)

***Reference group: drivers of first-generation vehicles**

VEHICLE AGE: Driver Deaths per Drivers Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Model year	FG deaths	FG involved (no wgt)	Sled deaths	Sled involved (no wgt)	Risk ratio (95% CI)
1994-97	10,545	44,659			—
1998-99			5,154	22,096	0.98 (0.80-1.19)
2000-01			4,126	21,037	0.84 (0.70-1.01)
2002-04			2,190	11,866	0.82 (0.67-0.99)

***Reference group: drivers of first-generation vehicles (model years 94-97)**

Driver Age & Sex: Driver Deaths per Drivers Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
Age					
15-59	7,966	39,260	8,635	48,298	0.89 (0.73-1.08)
60-74	1,482	3,119	1,614	4,049	0.86 (0.72-1.04)
75+	1,078	1,416	1,202	1,712	0.97 (0.78-1.20)
Gender					
Female	3,452	20,626	3,533	25,223	0.84 (0.69-1.03)
Male	7,092	23,662	7,937	29,383	0.91 (0.76-1.10)

***Reference group: drivers of first-generation vehicles**

Advanced Airbag Features: Driver Deaths per Drivers Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Advanced features	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
Dual stage inflator	—	—	1,160	6,342	0.78 (0.62-0.99)
Dual stage or others*	—	—	1,958	10,578	0.81 (0.65-1.00)
None**	10,545	44,649	9,512	44,421	0.91 (0.76-1.10)

*Other advanced features: buckle sensor, occupant position sensor, weight sensor

***Reference group: drivers of first-generation vehicles**

Summary of Driver Findings: Deaths per Involvement in Police-Reported Frontal Crash

- No evidence of increased risk from sled-certified airbags.
- Later model years and advanced airbag features: suggestive of decreased risk.
- SUVs, minivans, maybe pickups: may benefit more than cars.
- Oldest drivers (75+): no increase or decrease in risk – whereas drivers in younger age groups had non-significant decreases in risk.
- Non-significant decrease among female drivers.

Right-Front Passengers in Frontal Police-Reported Crashes FARS and GES



Child RF Passenger Age: Deaths per RF Passenger Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
0-4	101	142	41	152	0.35 (0.24-0.52)
5-9	76	357	45	424	0.54 (0.41-0.70)
10-12	29	340	25	408	0.68 (0.52-0.88)
13-14	34	354	33	442	0.75 (0.56-1.00)

***Reference group: RF passengers of first-generation vehicles**

Adult RF Passenger Age: Deaths per RF Passenger Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
15-59	1,484	5,724	1,807	7,941	0.89 (0.73-1.08)
60-74	303	529	394	762	0.92 (0.74-1.15)
75+	381	325	521	450	1.05 (0.76-1.42)

***Reference group: RF passengers of first-generation vehicles**

RF Passenger Sex: Deaths per RF Passenger Involved in Police-Reported Crashes by Airbag Generation, 1998-2004

Variable	FG deaths	FG involved (no weight)	Sled deaths	Sled involved (no weight)	Risk ratio (95% CI)
Female	1,336	4,632	1,543	6,379	0.84 (0.69-1.01)
Male	1,082	3,352	1,335	4,524	0.95 (0.78-1.15)

*Reference group: RF passengers of first-generation vehicles

Summary of Right-Front Passenger Findings: Deaths per Involvement in Police-Reported Crash

- Most evidence: no increased risk from sled-certified airbags.
- Dramatic decrease in risk among child passengers in sled-certified vehicles.
- Oldest passengers (75+): no increase or decrease in risk – whereas other adult passengers had non-significant decreases in risk.
- Non-significant decrease among female passengers.

What about restraint use?

- GES: Reports 90%+ belt use; this is higher than observational surveys (80%), so likely overreported. Police usually rely on self-reports of surviving occupants.
- FARS: 2 - 5% higher use among drivers of sled-certified vehicles killed in crashes compared with drivers of first-generation vehicles.
- FARS right-front passengers:
 - Children: 6 – 17% higher use rates among those killed in sled-certified vehicles.
 - Adults: 2 – 4% higher use rates among those killed in sled-certified vehicles.
- Rough calculations:
 - IF restraint use differences among those killed in crashes reflect differences among all involved in crashes, and
IF restraints decrease risk of dying by 50%:
 - THEN: Decreased risks observed among child passengers are so large that higher belt use cannot explain all of these decreases.

Limitations of FARS/GES Analysis

- Recording of right-front passengers may be incomplete in GES – about 60% are uninjured.
- Belt use overreported by police so cannot control for belt use using GES denominator.
- Some observed decreases in risk for sled-certified vehicles might be due to higher belt use rates. Dramatic decreases among children: likely not due to belt use differentials.
- No guarantee that crash severities were similar between airbag generations, but speed limit distributions were similar.
- Unlike FARS, do not have cross checking of vehicle registrations and license records.

Strengths

- Helps answer key question: what is likelihood of dying if get into a police-reported crash?
- FARS: captures almost all fatal crashes in US
- GES: relatively large sample that represents all police-reported crashes.
- GES represents geography, roadway mileage, population, traffic density.
- Included all eligible vehicles, including those that were missing vehicle identification numbers (about 40% of GES vehicles).

Summary of Analyses

Group	Population	Risk Ratios (Sled vs. FG)	Comments
Driver deaths	Matched-pairs, head-on crashes	0.87	Females ↓ risk, Pickups ↓ risk
	Drivers in crashes (GES)	0.89	Non-significant decreases in risk for females, pickups; larger decreases for SUVs & minivans
RFPassenger deaths	RF Passengers in crashes	0.89 (all) 0.35 (ages 0-4)	Dramatic ↓ risk for children. Children still must be seated in rear to avoid airbag-induced injuries and deaths.

Summaries of findings for sled-certified vehicles by age, gender, vehicle type, model year, advanced airbag features

Variable	Matched-pair (fatal head-on crashes)	Deaths per involvement in police-reported crash
Gender	Female drivers may benefit	Non-significant decrease in female occupant risk
Age	No difference observed in protectiveness of sled-certified airbags	Children: large decrease in risk; ages 75+: no change; younger adults: possible small decrease
Vehicle type	Pickup drivers: may benefit more than car drivers	SUVs and minivans: may benefit more than cars; possible benefit for pickups
Model year	Improvement for model years 2000-01, not 02-05	Later model years (sled) had decreased risks
Advanced features	N/A	Appear to provide better protection; need more scrutiny

Discussion

- Findings vary by methods used
- Overall: little evidence of increased fatality risk for sled-certified airbags; potential reduced risk in some groups.
 - Evidence of markedly decreased fatality risk among child right-front passengers.
- Future research
 - Examine mortality experience of vehicles equipped with advanced airbags.
 - Need further scrutiny of non-fatal injuries by airbag generation using a variety of databases.



Contact Information

National Study Center for Trauma & EMS
University of Maryland, Baltimore
701 W. Pratt St., Rm. 526
Baltimore, MD 21201

Telephone: (410) 328-7491
ebraver@som.umaryland.edu

