IIHS head restraint ratings and insurance injury claim rates

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ABSTRACT
Objectives: The Insurance Institute for Highway Safety (IIHS) rates front seat/head restraint designs using a combination of static and dynamic measurements following RCAR-IIWPG procedures. The purpose of this study was to determine whether vehicles with better IIHS-rated seats/head restraints had lower injury risk in rear-end collisions and how the effect of better rated seats interacted with driver gender and age.

Methods: The presence of an associated insurance injury claim was determined for rear-impact crashes using 2001–2014 model year cars and SUVs. Logistic regression was used to compare injury risk for vehicles with good, acceptable, and marginal IIHS-rated seats/head restraints with poor-rated seats/head restraints. Analyses were run by gender and driver age and also by the rate of more severe injury claims.

Results: Injury rates were 11.2% lower for vehicles with seats/head restraints rated good compared to vehicles with seats/head restraints rated poor. The percentage reduction for good-versus poor-rated seats was greater for females (12.7%) than males (8.9%). Comparing good-versus poor-rated seats, driver ages 15–24 had the largest reduction at 19.8%, followed by 10.7% for driver ages 45–64 and 10.4% for driver ages 25–44.

Conclusions: Seats/head restraints with better IIHS ratings are associated with lower injury rates in rear-impact collisions than seats rated poor. The reductions in injury rates were strongest for females and for young-to-middle-age drivers. The strong reductions in injury rates for these groups are encouraging given their high initial injury rates.

Introduction
Whiplash injuries are the most frequently reported type of automobile injury in the United States. A 2007 estimate by the Insurance Research Council found that insurance claims in which a neck sprain is the most serious injury cost automobile insurers about $8.8 billion annually and comprised 25% of injury dollars paid. The NHTSA estimated that between 1988 and 1996 there were more than 800,000 whiplash injuries annually at a cost of $8 billion. Whiplash injuries in Europe are estimated to cost 10 billion euros a year (Richter et al. 2000). In Japan, 44% of traffic-related injuries involved neck injury (Watanabe et al. 2000).

Some occupants of vehicles involved in rear-impact crashes suffer injuries to the neck. These can range in severity from only experiencing mild pain to ruptures of ligaments or fractures of the cervical vertebrae. Minor neck injuries are by far the most common and are typically associated with muscle strain, which usually results in pain lasting several days. In some cases, the pain may persist when it is related to neurological injury. Various anatomical sites and mechanisms of injury have been investigated to explain the neurological symptoms, but so far there is little consensus among researchers about the symptom's etiology. Regardless of the specific nature or severity of neck injury following rear crashes, they are thought to result from the differential motion between the head and torso. When a vehicle is struck in the rear and driven forward, its seats accelerate the occupants’ torsos forward. Unsupported, an occupant's head will lag behind this forward torso movement, and the differential motion causes the neck to bend and stretch. The higher the torso acceleration, the more sudden the motion, the higher the forces on the neck, and the more likely a neck injury is to occur. This motion, known as whiplash, also is used to describe the resulting neck injuries.

Not all rear-impact crashes result in whiplash. Even in severe crashes, injuries can be avoided if there is little or no movement of the head relative to the torso. Good head restraints move the occupant's head forward with the torso, helping to prevent neck injury. Neck protection in a crash is influenced by seat design elements, starting with ensuring that the head restraint is at least as high as the center of the occupant's head and reducing the distance between the occupant's head and the restraint. Reducing the force of the seat pushing on the back also has been shown to be effective (Farmer et al. 2003).

Federal regulations establish geometric requirements for head restraints in front seats for vehicles manufactured after September 1, 2010. Front seats in passenger vehicles are required to have a backset of 2.2 inches or less and a distance of 29.5 inches or more from an occupant's hip to the top of the head restraint. Adjustable restraints also must lock in place. No maximum backset distance was required under the previous rule. Head restraints installed in rear seats must meet the 29.5-inch height requirement for vehicles manufactured after September 1, 2011.
Past efforts to reduce whiplash injury risk with better vehicle seat design have been successful. O’Neill et al. (1972) showed that the presence of a head restraint reduced neck injury risk in rear crashes following a 1969 federal mandate requiring them for all front outboard seats in vehicles sold in the United States. Between 1995 and 2003, the Insurance Institute for Highway Safety (IIHS) rated head restraints based on static measures of their geometry to encourage head restraints that could be adjusted to the head height of taller occupants and fit closer to the backs of all seat occupants’ heads. Farmer et al. (1999) reported 24% lower neck injury rates in rear-struck vehicles with seats that had geometry rated good by IIHS compared to those rated poor. A 2005 study by the Highway Loss Data Institute (HLDI) showed that this reduction in neck injury rates translated to an 11–19% reduction in the rate of insurance claims for any injury in rear-struck cars for good-rated geometry seats compared to poor-rated seats. In 2005, the IIHS augmented its seat and head restraint evaluation with a dynamic test simulating a rear crash resulting in a velocity change of 10 mph. A 2008 study found that neck injury rates in vehicles with head restraints rated good based on this new evaluation were 15% lower than in vehicles with poor-rated head restraints in rear-end crashes (Farmer et al. 2008). A stronger effect was seen in long-term injuries (lasting 3 or more months), with injury rates 35% lower in vehicles with good-rated head restraints compared to poor head restraints.

Gender has been shown to be a significant factor in rear-impact injuries. Many studies have found a higher injury rate in females than males (Chapline et al. 2000; Dolinis 1997; Farmer et al. 1999, 2008; Jakobsson 2004; Kihlberg 1969; Krafft et al. 2003; Magg et al. 1990; Morris and Thomas 1996; Narragon 1965; O’Neill et al. 1972; Otremski et al. 1989; Richter et al. 2000; Storvik et al. 2009; Temming and Zobel 1998; Thomas et al. 1982). Injury risk in these studies ranged from about 1.5 to 3.0 times higher for females than males. Injuries in females also were more likely to persist long term, with 55% of females compared to 38% of males developing long-term symptoms from whiplash injuries (Krafft 1998).

Females’ higher injury rates compared to males may be attributed to several physical differences. Compared to males, female neck muscles are not as strong and the neck is more slender relative to the head (Foust et al. 1973; States et al. 1972; Vasavada et al. 2001, 2008). Cross-section dimensions of the male cervical spine are larger than for females (Stemper et al. 2008, 2009; Vasavada et al. 2008). These studies also found greater segmental support area in the spine for males than females. Despite the higher risk for females, interventions that have reduced whiplash risk have often been found to be more effective for women than men (Chapline et al. 2000; Farmer et al. 2003; O’Neill et al. 1972; States et al. 1972; Thomas et al. 1982).

In the current study, insurance injury rates are related to head restraint evaluations. The results update and expand on earlier studies. The initial 2005 HLDSI study used head restraint ratings based only on static geometric measurements, whereas the current study utilizes the newer IIHS seat ratings incorporating dynamic measurements. The current analyses also were able to control for additional vehicle and driver factors. With more than 600,000 real-world crash observations, the scale of the study is significantly larger than prior studies.

Methods

Data sources

Thirty-six insurers currently supply automobile insurance coverage and loss data to HLDSI, accounting for more than 80% of privately insured passenger vehicles in the United States. Data from personal injury protection (PIP) losses and property damage liability (PDL) losses were used in the study. PIP covers medical payments for those injured in crashes with the insured vehicle without regard to fault. The PIP payments may be for the driver or other occupants of the vehicle. PIP coverage is available in 17 states (Delaware, Florida, Hawaii, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, New Jersey, New York, North Dakota, Oregon, Pennsylvania, Texas, Utah, and Washington). Michigan was excluded due to differences in its first-party physical damage insurance laws. The monetary benefit under PIP coverage is set by state law and varies from $2,500 to unlimited. PDL covers the physical damage to the not-at-fault (generally struck) vehicle in a multiple-vehicle crash. PDL coverage has no deductible or minimum threshold for which a claim can be filed, but some minor damage may be resolved without insurance involvement and would not be present in the database.

Whiplash injuries are associated with the passengers in a rear-struck vehicle. Generally this occurs when the front of one vehicle strikes the rear of another vehicle, such as a vehicle failing to stop in time to avoid hitting a car stopped at a light or due to traffic. To closely match this crash type, the study used only rear-impact PDL claims. The point of impact information was supplied by the damage estimation services CCC Information Services Inc. and Mitchell International. These data were linked to HLDSI data by vehicle identification number and crash date.

The study vehicles were 2001–2014 model year cars and SUVs up to 5 years old. Only vehicles with head restraint ratings were included. In total, there were 1,754 vehicle series and model year combinations with 603,755 rear-impact PDL claims. Only PDL claims for vehicles with corresponding PIP coverage were used.

Head restraint ratings

IIHS rates front seat/head restraint designs using a combination of static and dynamic measurements following RCAR-IWPG procedures. The geometric rating is determined based on the backset and height of the head restraint (Figure A1, see online appendix). A 50th percentile male manikin is used for the measurements. For seats receiving a good or acceptable geometric rating, a dynamic sled test is run to simulate a vehicle being struck in the rear by a vehicle of the same weight going 20 mph. A BioRID dummy is used to measure how well the seat supports the torso, neck, and head (Davidsson 2000). The dynamic test criteria are time to head restraint contact, torso acceleration, maximum neck shear force, and maximum neck torque force. The static and dynamic rating are then combined to produce an overall rating of good, acceptable, marginal, or poor. IIHS does not rate rear-seat head restraints.

Analysis methods

Logistic regression was used to model the effect of better IIHS-rated seats on injury rates (ratio of the number of PIP claims
The analyses were run in SAS using the PROC LOGISTIC procedure. All models controlled for available vehicle and rated driver factors: vehicle damage amount, vehicle type, curb weight, model year, vehicle age, rated driver age, gender, marital status, insurance risk category, vehicle garaging state, and vehicle density per square mile (garaging county). A rated driver is the one assigned to a vehicle by an insurer and is typically considered to represent the greatest loss potential for the insured vehicle. Although this is generally the primary driver of the vehicle, the actual driver at the time of the crash is unknown (the information is not available in the HLID database). Risk ratios were estimated from the odds ratios using a method by Zhang and Yu (1998). The 95% confidence intervals also were converted by the same method.

In estimating the relationship between head restraint rating and injury rates, the IIHS rating was treated as the independent variable, with the rating of poor used as the reference value. Analyses were run on all claims, by gender, by rated driver age, and by the rate of more severe injury claims (≥ $2,000). Focusing on higher dollar injury claims eliminates many potential minor claims for cuts and abrasions, resulting in claims more likely to involve whiplash injuries and claims that might require long-term treatment. The higher injury claim amount was restricted due to the low PIP limits in some states ($2,500 in Maryland and Texas). A list of the number of PDL and PIP claims used in the study by head restraint rating, rated driver gender, and rated driver age is given in Table 1. In rear-impact PDL claims the overall injury claim rate was 12.1%, and it was 7.4% for PIP claims ≥ $2,000.

A second set of logistic regressions was run to assess the effect of better rated seats on the likelihood that an injury claim is at least $2,000 given that a paid injury claim had occurred. This measure approximates the likelihood an injury will be a long-term injury requiring multiple payments resulting in a high dollar loss amount. These analyses were included in the study to provide a more direct comparison with other studies using injured occupants as the study population.

### Table 1. Number of PDL and PIP claims by category.

| Category          | Number of PDL claims | Number of injury claims | Number of claims ≥ $2,000 | Injury rate | Injury rate of claims ≥ $2,000 |
|-------------------|----------------------|-------------------------|---------------------------|-------------|--------------------------------|
| All               | 603,755              | 72,922                  | 44,424                    | 0.121       | 0.074                          |
| Good-rated seats  | 265,499              | 30,190                  | 18,441                    | 0.114       | 0.069                          |
| Acceptable-rated seats | 67,239       | 8,601                   | 5,226                     | 0.128       | 0.078                          |
| Marginal-rated seats | 155,996       | 19,668                  | 12,118                    | 0.126       | 0.078                          |
| Poor-rated seats  | 115,021              | 14,463                  | 8,639                     | 0.126       | 0.075                          |
| Female            | 266,302              | 34,509                  | 19,794                    | 0.130       | 0.074                          |
| Male              | 174,836              | 17,665                  | 10,575                    | 0.101       | 0.060                          |
| Unknown           | 162,617              | 20,748                  | 14,055                    | 0.128       | 0.086                          |
| Ages 15–24        | 63,018               | 6,937                   | 3,836                     | 0.110       | 0.061                          |
| Ages 25–44        | 267,430              | 34,926                  | 20,902                    | 0.131       | 0.078                          |
| Ages 45–64        | 210,370              | 25,578                  | 16,216                    | 0.122       | 0.077                          |
| Ages 65–99        | 62,937               | 5,481                   | 3,470                     | 0.087       | 0.055                          |

### Table 2. Relative risk of an injury claim by head restraint rating.

| Variable                    | Risk ratio | 95% Confidence interval |
|-----------------------------|------------|-------------------------|
| Damage amount               |            |                         |
| $4,000–$8,000 vs. ≤ $4,000  | 2.451      | 2.413–2.490             |
| $8,000–$12,000 vs. ≤ $4,000  | 3.490      | 3.409–3.571             |
| $12,000–$16,000 vs. ≤ $4,000 | 4.292      | 4.132–4.452             |
| $16,000–≤ $4,000             | 5.027      | 4.769–5.278             |
| Vehicle age                 |            |                         |
| <1 year vs. 4 years         | 0.865      | 0.843–0.887             |
| 1 year vs. 4 years          | 0.903      | 0.881–0.924             |
| 2 years vs. 4 years         | 0.927      | 0.906–0.949             |
| 3 years vs. 4 years         | 0.965      | 0.941–0.988             |
| Rated driver age            |            |                         |
| 15–24 yrs vs. 75+           | 1.373      | 1.304–1.446             |
| 25–34 yrs vs. 75+           | 1.674      | 1.598–1.752             |
| 35–44 yrs vs. 75+           | 1.798      | 1.718–1.880             |
| 45–54 yrs vs. 75+           | 1.700      | 1.624–1.779             |
| 55–64 yrs vs. 75+           | 1.537      | 1.466–1.612             |
| 65–74 yrs vs. 75+           | 1.248      | 1.183–1.317             |
| Gender                      |            |                         |
| Female vs. unknown          | 1.179      | 1.127–1.233             |
| Male vs. unknown            | 0.910      | 0.867–0.955             |
| Married vs. unknown         | 0.799      | 0.763–0.837             |
| Single vs. unknown          | 0.845      | 0.807–0.886             |
| Vehicle type                |            |                         |
| Luxury SUV vs. regular car  | 0.702      | 0.667–0.738             |
| Luxury car vs. regular car  | 0.650      | 0.625–0.675             |
| Minivan vs. regular car     | 0.764      | 0.727–0.802             |
| Regular SUV vs. regular car | 0.941      | 0.920–0.964             |
| Sports car vs. regular car  | 0.713      | 0.609–0.833             |
| Curb weight (pounds)        |            |                         |
| ≤3,000 vs. >$4,500          | 1.058      | 1.073–1.103             |
| 3,001–3,500 vs. >$4,500     | 1.008      | 0.968–1.048             |
| 3,501–4,000 vs. >$4,500     | 1.017      | 0.975–1.059             |
| 4,001–4,500 vs. >$4,500     | 0.993      | 0.953–1.035             |
| Head restraint rating       |            |                         |
| Good vs. poor               | 0.888      | 0.866–0.911             |
| Acceptable vs. poor         | 0.956      | 0.930–0.983             |
| Marginal vs. poor           | 0.963      | 0.941–0.984             |

*aRisk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.

### Results

Table 2 gives the risk ratios and 95% confidence intervals for injury claim rates based on the vehicle seat/head restraint rating and covariates (vehicle and rated driver characteristics). Due to space limitations, the results for some covariates are not shown here but are listed in Table A2 (see online appendix). The amount of damage to the vehicle was a strong predictor of injury risk. Compared to PDL claims of $4,000 or less, injury rates were more than 2 times greater for damage amounts of $4,001–$8,000 and 5 times greater for damage amounts greater than $16,000 (P < .05). Injury rates tended to be higher for older model years, but most differences were not statistically significant. The effect of model year is diminished due to the seat rating variable accounting for head restraint improvements over time. Newer vehicles had lower injury rates than older vehicles. Rates for vehicles less than 1 year old were 14% lower than those for vehicles 4 years old (P < .05).

The oldest rated drivers (age 75 and older) had the lowest injury rates, with rates for ages 35–44 almost 80% higher (P < .05). Compared with unknown gender, females had significantly higher injury rates and males had significantly lower injury rates (P < .05). Some of the data-supplying insurance companies do not provide gender or marital status, resulting in
an “unknown” category. Drivers categorized by the insurer as nonstandard risk due to a bad driving record or other factors had higher injury rates than those categorized as standard risk ($P < .05$).

Regular cars (those not classified as luxury or sports) had the highest injury rate ($P < .05$) among the vehicle types (regular car, luxury car, sports car, minivan, regular SUV, and luxury SUV). Luxury cars had the lowest injury rate, 35% lower than regular cars. The vehicle group with the lightest curb weight ($\leq 3,000$ pounds) had the highest injury rate, about 5% more than vehicles $> 4,500$ pounds ($P < .05$). Lighter vehicles generally have higher injury rates than heavier vehicles, but the effect of curb weight in the model is mitigated by the vehicle type variable. Injury rates were lowest in Texas and highest in Oregon.

Both had rates statistically significant different from the comparison state of Maryland ($P < .05$). Related to state is the vehicle density variable measured in vehicles per square mile on the county level. Injury rates decreased as vehicle density decreased, with injury risk 16% less for low density and 9% less for moderate density compared with high density ($P < .05$). Because some states are mostly urban (New Jersey) and other are mostly rural (North Dakota), the effects of these 2 variables are intermingled.

Good-, acceptable-, and marginal-rated head restraints each had statistically significant lower injury rates than poor-rated head restraints ($P < .05$). Injury rates were 11.2% lower in good-rated seats than poor-rated seats. Acceptable- and marginal-rated seats were 4.4 and 3.7% lower than poor-rated seats, respectively.

Table 3 lists the relative risk of an injury claim for the seat ratings by gender. Better seats had a stronger effect for female rated drivers than male. For females, good-, acceptable-, and marginal-rated seats were associated with lower injury rates than poor-rated seats at the $P < .05$ level. In contrast, for males, only good-rated seats were associated with statistically significant lower injury rates. The percentage reduction for good- versus poor-rated seats was greater for females (12.7%) than males (8.9%).

Similar analyses were run on the risk of an injury claim $\geq$ $2,000 (Table 4). For all gender categories combined, good-rated seats had a 13.7% lower rate of injury claims $\geq$ $2,000 than poor-rated seats ($P < .05$). This decrease is more than the 11.2% seen for the all-injury amount in Table 2. Acceptable- and marginal-rated seats had rates 5.2 and 3.5% lower than poor-rated seats ($P < .05$). The risk of an injury claim $\geq$ $2,000 for female rated drivers was 16.2% lower in good-rated seats than poor-rated seats. For males, the risk was 10.0% lower. Both of these reductions were statistically significant at the 0.05 level, and both were greater than those seen for all-injury amounts in Table 3. Compared with poor-rated seats, acceptable- and marginal-rated seats had lower rates of injuries $\geq$ $2,000 for females ($P < .05$) but not for males.

Table 5 summarizes the relative risk of an injury claim by seat rating for logistic regressions run using rated drivers ages 15–24, 25–44, 45–64, and 65–99. Good-rated seats had statistically significant lower injury rates than poor-rated seats for drivers ages 15–24, 25–44, and 45–64. Drivers ages 15–24 had the largest reduction at 19.8%. Ages 25–44 and 45–64 had similar results of 10.4 and 10.7%, respectively.

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### Table 3. Relative risk of an injury claim by head restraint rating for models using only female or male rated drivers.

| Variable | Risk ratio | 95% Confidence interval |
|----------|------------|-------------------------|
| Females  |            |                         |
| Good vs. poor | 0.873       | 0.841 – 0.906           |
| Acceptable vs. poor | 0.940      | 0.902 – 0.978           |
| Marginal vs. poor | 0.947       | 0.915 – 0.978           |
| Males    |            |                         |
| Good vs. poor | 0.911       | 0.866 – 0.959           |
| Acceptable vs. poor | 0.976      | 0.922 – 1.033           |
| Marginal vs. poor | 0.996       | 0.951 – 1.043           |

*Risk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.

### Table 4. Relative risk of an injury claim $\geq$ $2,000 by head restraint rating.

| Variable | Risk ratio | 95% Confidence interval |
|----------|------------|-------------------------|
| All gender categories |            |                         |
| Good vs. poor | 0.863       | 0.836 – 0.891           |
| Acceptable vs. poor | 0.948      | 0.915 – 0.981           |
| Marginal vs. poor | 0.965       | 0.938 – 0.992           |
| Females |            |                         |
| Good vs. poor | 0.838       | 0.799 – 0.879           |
| Acceptable vs. poor | 0.944      | 0.896 – 0.995           |
| Marginal vs. poor | 0.958       | 0.918 – 0.999           |
| Males |            |                         |
| Good vs. poor | 0.900       | 0.844 – 0.960           |
| Acceptable vs. poor | 0.955      | 0.887 – 1.027           |
| Marginal vs. poor | 1.010       | 0.952 – 1.069           |

*Risk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.

### Table 5. Relative risk of an injury claim by head restraint rating for models using rated-driver age ranges.

| Variable | Risk ratio | 95% Confidence interval |
|----------|------------|-------------------------|
| Ages 15–24 |            |                         |
| Good vs. poor | 0.802       | 0.737 – 0.871           |
| Acceptable vs. poor | 0.882      | 0.809 – 0.959           |
| Marginal vs. poor | 0.879       | 0.817 – 0.946           |
| Ages 25–44 |            |                         |
| Good vs. poor | 0.896       | 0.864 – 0.930           |
| Acceptable vs. poor | 0.954      | 0.915 – 0.994           |
| Marginal vs. poor | 0.960       | 0.929 – 0.992           |
| Ages 45–64 |            |                         |
| Good vs. poor | 0.893       | 0.856 – 0.932           |
| Acceptable vs. poor | 0.970      | 0.924 – 1.018           |
| Marginal vs. poor | 0.969       | 0.933 – 1.007           |
| Ages 65–99 |            |                         |
| Good vs. poor | 0.954       | 0.872 – 1.043           |
| Acceptable vs. poor | 0.971      | 0.873 – 1.078           |
| Marginal vs. poor | 1.073       | 0.990 – 1.163           |

*Risk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.
The relative risk of an injury being at least $2,000 given an injury claim has occurred by head restraint rating for models using only female or male rated drivers is listed in Table 6 for results by rated-driver gender and in Table 7 for results by rated-driver age. Females had a 6% lower rate of a claim being at least $2,000 ($< .05) in good seats compared to poor-rated seats. There was almost no seat effect for males with good seats 0.5% lower than poor (not significant).

Among rated-driver age groups, only ages 25–44 and 45–64 had statistically significant lower rates of injury claims of at least $2,000 for good-rated seats compared to poor-rated seats (Table 7). Good seats had rates 4.5% lower for ages 45–64 and 3.4% lower for ages 25–44. Acceptable- and marginal-rated seats for these age groups had little effect on $2,000 claim rates, with risk ratios near 1 (0.986 to 1.010).

#### Table 6. Relative risk of an injury claim being at least $2,000 given that an injury claim has occurred by head restraint rating for models using only female or male rated drivers.

| Variable                  | Risk ratio | 95% Confidence interval |
|---------------------------|------------|-------------------------|
|                           |            | Lower limit             | Upper limit |
| Females                   |            |                         |             |
| Good rating vs. poor rating | 0.940      | 0.896                   | 0.985       |
| Acceptable rating vs. poor rating | 1.007    | 0.958                   | 1.058       |
| Marginal rating vs. poor rating | 1.011    | 0.970                   | 1.052       |
| Males                     |            |                         |             |
| Good rating vs. poor rating | 0.995      | 0.931                   | 1.060       |
| Acceptable rating vs. poor rating | 0.990    | 0.919                   | 1.064       |
| Marginal rating vs. poor rating | 1.025    | 0.965                   | 1.083       |

*aRisk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.

#### Table 7. Relative risk of an injury claim being at least $2,000 given that an injury claim has occurred by head restraint rating for models using rated-driver age ranges.

| Variable | Risk ratio | 95% Confidence interval |
|----------|------------|-------------------------|
|          |            | Lower limit             | Upper limit |
| Ages 15–24 |            |                         |             |
| Good rating vs. poor rating | 0.976      | 0.896                   | 1.055       |
| Acceptable rating vs. poor rating | 0.960    | 0.877                   | 1.042       |
| Marginal rating vs. poor rating | 0.952    | 0.880                   | 1.023       |
| Ages 25–44 |            |                         |             |
| Good rating vs. poor rating | 0.966      | 0.933                   | 0.998       |
| Acceptable rating vs. poor rating | 0.996    | 0.961                   | 1.032       |
| Marginal rating vs. poor rating | 1.010    | 0.981                   | 1.038       |
| Ages 45–64 |            |                         |             |
| Good rating vs. poor rating | 0.955      | 0.918                   | 0.990       |
| Acceptable rating vs. poor rating | 0.986    | 0.945                   | 1.025       |
| Marginal rating vs. poor rating | 1.001    | 0.969                   | 1.033       |
| Ages 65–99 |            |                         |             |
| Good rating vs. poor rating | 1.070      | 0.996                   | 1.139       |
| Acceptable rating vs. poor rating | 1.059    | 0.970                   | 1.141       |
| Marginal rating vs. poor rating | 1.026    | 0.957                   | 1.092       |

*aRisk ratio estimated from odds ratio using Zhang and Yu’s (1998) method.

#### Discussion

The results of this study show a strong correlation between better rated head restraints and lower injury claim rates in rear-end crashes. Occupants in vehicles with seats/head restraints rated good by IIHS had an 11.2% lower risk of injury than those in vehicles with poor-rated seats. Injury rates for acceptable-rated seats were 4.4% lower than poor-rated seats, and injury rates for marginal seats were 3.7% lower than poor seats.

The effect of better seats was greater for females than males. Vehicles with good, acceptable, and marginal seats all had lower injury rates than vehicles with poor seats for female rated drivers ($P < .05$). However, for males, only good seats had lower injury rates than poor seats ($P < .05$). Similar results were found when examining the rate of PDL claims with a PIP claim of at least $2,000. The analyses using the likelihood that an injury claim was greater than or equal to $2,000 given that an injury claim had occurred found a weaker correlation between seat ratings and injury risk, with only good-rated seats for females showing a significant reduction in injury risk compared to poor-rated seats. Note that the number of observations was much smaller for these analyses. Other studies have found larger reductions in neck injury risk for females than males with improved head restraints (Chapline et al. 2000; Farmer et al. 2003; O’Neill et al. 1972; States et al. 1972; Thomas et al. 1982). The opposite female–male relationship was seen in Kullgren and Kraft’s (2010) study looking at rates of permanent medical impairments. The studies differed in many ways (data sources, vehicle series included, and injury type measured), which may explain the inconsistencies. The higher initial injury rate for females may contribute to their larger reductions.

Differences exist between age groups in the effect of better rated seats on injury rates. Good-rated seats had lower injury rates than poor-rated seats for drivers ages 15–24, 25–44, and 45–64 but not for drivers ages 65–99 ($P < .05$). Other studies have observed a decreased risk of whiplash in older drivers (Farmer et al. 1999; Jakobsson et al. 2000; Temming and Zobel 1998). A 2014 HLDI study found that older drivers had lower injury claim rates than young or middle-age drivers in rear-end crashes.

Information on the severity of injuries was not available in the HLDI database and had to be approximated by the claim amount. A more severe injury was defined as a claim greater than or equal to $2,000. Analyses were run on both the likelihood of a severe injury given that a PDL claim had occurred and the likelihood of a severe injury given that an injury claim had occurred. The effect of good seats/head restraints compared to poor seats/head restraints on severe injury rates was strongest in females and among drivers ages 25–44 and 45–64, similar to the all-injury rate results. In females, good seats (versus poor seats) had a 16% lower rate of severe injuries compared to a 13% lower rate of all injuries. Farmer et al. (2008) found a 35% reduction in long-term neck injuries for good seats versus poor seats, compared to a 15% reduction in all neck injuries. The apparent reduced effectiveness of good seats/head restraints in the present study may be due to the presence of non-neck injuries in the PIP data. Seat design would not necessarily be expected to be influence injuries to other body regions.
The database used in this study contained information on more than 600,000 real-world crashes. Although its size provides greater statistical power than other studies, it lacked some driver and crash details. Though the specific nature of injuries in the PIP claims is unknown to HLID, more than 80% of injury claims in rear-impact crashes have been estimated to involve the neck (Watanabe and Ito 2007). Fraudulent injury claims also are a problem in the data but likely would not be biased by vehicle series or head restraint type. Information on the seating position of the injured occupant and the demographic characteristics of the driver at the time of the crash were not available in the HLID data. The low occupancy of vehicle rear seats in transit in the United States suggests that nearly all of the observations in the HLID database would be associated with front-seat passengers for whom the seats/head restraints ratings would be relevant (NHTSA 2015). Several studies have found higher whiplash rates among front-seat occupants compared to rear-seat occupants (Carlsson et al. 1985; Jakobsson et al. 2000; States et al. 1972).

The driver demographics used in the present study were based on the rated driver, not the actual driver. The exact effect of rated driver in lieu of actual driver is unknown, but comparisons to age and gender patterns seen in other studies suggest that using rated driver may reduce the sensitivity of some analyses but not produce contradicting effects. Furthermore, the rated-driver characteristics in the present study relate to injury risk in ways that are consistent with what has been reported in the literature about whiplash injury—female rated drivers had higher injury rates than males, and the oldest rated drivers were less likely to be injured than the younger rated drivers. Chapline et al. (2000) found that neck pain in females dropped from 69% for poor vertically positioned head restraints to less than 30% for adequately positioned head restraints ($P < .05$). Neck pain among males in the study decreased from 31% for poorly positioned head restraints to 22% (not significant) for adequately positioned head restraints. Farmer et al. (2003) found that active head restraints had a significant 55% lower driver neck injury risk for females and a nonsignificant 31% reduction for males compared to nonactive head restraints. When examining improvements in head restraint geometry, the study found that females had a significant 37% reduction in neck injury risk compared to a nonsignificant 8% increase for males. These findings parallel the current study’s finding that head restraints with good ratings have a stronger effect for females than males.

In summary, seats/head restraints with better rating results were found to have lower injury claim rates. The findings in this study should encourage automobile manufacturers to continue to improve head restraint designs as part of efforts to improve vehicle safety for all occupants.

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