IMPROVED SEAT AND HEAD RESTRAINT EVALUATIONS

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Paper Number 05-0374

ABSTRACT

Since 1995 the Insurance Institute for Highway Safety (IIHS) has measured and evaluated the static geometry of head restraints on vehicle seats. Geometry is important because a restraint positioned behind and close to the back of an occupant's head is a necessary first step toward reducing neck injury risk in rear crashes. In recent years head restraint geometry in new model passenger vehicles has improved steadily. However, a restraint that does not remain close to the head during a crash cannot effectively support the head and neck, so the effectiveness of a restraint with good static geometry may be reduced by poor dynamic response of a seatback or restraint cushion. In addition, the effectiveness of advanced seat and head restraints designed to move during a crash, either to improve geometry or reduce torso accelerations, can be evaluated only in dynamic tests. Thus, good geometry is necessary but, by itself, not sufficient for optimum protection. Dynamic evaluations using a test dummy also are needed to assess protection against neck injury in rear crashes.

Several insurance-sponsored organizations formed the International Insurance Whiplash Prevention Group to develop a seat/head restraint evaluation protocol, including a dynamic test. Tests using this protocol produce substantially different results among seat/head restraint combinations, even among those with active head restraints. IIHS published its first set of evaluations using the protocol in fall 2004. This paper describes the rationale behind the protocol and summarizes the results of IIHS testing so far.

INTRODUCTION

The Highway Loss Data Institute (HLDI) estimates that every year insurers pay approximately 1.7 million injury claims for which a neck sprain/strain (i.e. whiplash) is the most serious injury suffered by the claimant (HLDI, 2004). With an average cost of $4,798 for these claims (Insurance Research Council, 2003), the total cost for crashes that result in nothing more serious than whiplash is $8.2 billion, and this accounts for 25 percent of all crash injury claims dollars paid by insurers. This suggests a much larger whiplash problem than the federal government estimate of only 800,000 minor neck injuries occurring annually in the United States, of which 270,000 occur in rear crashes (National Highway Traffic Safety Administration (NHTSA), 2004). Bowie and Walz (1995) estimate that the total cost of U.S. whiplash injuries exceeds $19 billion. These injuries are similarly costly in other countries: CAN$ 409.7 million in British Columbia, Canada (Dayton, 1996); €2 billion in Germany (Langwieder and Hell, 2001); $43.5 million in Sweden (Holm, 1996); and £1.6 billion in the United Kingdom (Batchelor, 2001). These substantial economic costs are in addition to the emotional and social costs of the pain and suffering associated with minor neck injury.

Vehicle seats and head restraints have been recognized for more than 35 years as the primary countermeasures against whiplash injuries in rear crashes. In 1969 the U.S. government issued Federal Motor Vehicle Safety Standard (FMVSS) 202 as an initial effort to reduce the number of whiplash injuries (NHTSA, 2001). The standard required that all front outboard seating positions in cars be equipped with head restraints that could be adjusted to at least 700 mm above the seat reference point. In 1991 the standard was extended to cover pickup trucks, sport utility vehicles, and vans. This effort was partly successful, with various evaluations of the regulation estimating a 14-18 percent reduction in neck injuries in rear crashes in cars with head restraints compared with earlier models without them (Kahane, 1982; O'Neill et al., 1972; States et al., 1972). One weakness of the early standard was that it did not set a minimum height requirement for adjustable restraints. Not surprisingly, Kahane (1982) found that fixed restraints, which were no shorter than 700 mm above the seating reference point, were more effective than adjustable ones, which often are left in their lowest adjustment positions.

The current European head restraint standard (UN-ECE Regulation no. 17), which applies to passenger vehicles sold in Europe, addresses the shortcoming of the U.S. standard by specifying a minimum height for all head restraints. It also requires head restraints to be taller. Restraints must be at least 750 mm above the H-point and include at least one adjustment position 800 mm above the H-point (United Nations Economic Commission for Europe, 2002). Recognizing that the current U.S. standard leaves many taller vehicle occupants unprotected, NHTSA proposed to upgrade FMVSS 202 in January 2001. The proposal, which was issued as a new safety standard in December 2004, adopted the same height requirements as ECE regulation 17 and added a backset requirement specifying that a restraint could be no farther than 55 mm behind the head of a dummy representing a 50th percentile male seat occupant (NHTSA, 2004). The new backset requirement reflects the simple physical fact that a restraint must be near the head to help support it early in a crash and accelerate it along with the torso. FMVSS 202a will apply to passenger vehicles built after September 1, 2008.

In an effort to encourage manufacturers to equip their vehicles with seats and head restraints better able to provide rear crash protection to a wider range of vehicle occupants, the Insurance Institute for Highway Safety (IIHS) began rating static head restraint geometry for public information in 1995. The measurement protocol used the Head Restraint Measuring Device (HRMD) developed by the Insurance Corporation of British Columbia (ICBC) to measure the static geometry (height and backset) of vehicle head restraints relative to the head of an average-size male (Gane and Pedder, 1996). Ratings (good, acceptable, marginal, or poor) were based on static geometry (Figure 1) and whether the restraints had locking adjustments. The rating procedure was modified and adopted by the Research Council for Automotive Repairs (RCAR) in 2000 and was the basis for head restraint ratings in Australia, Canada, the Untied States, and the United Kingdom until it was replaced in 2004 by a procedure that includes dynamic tests.

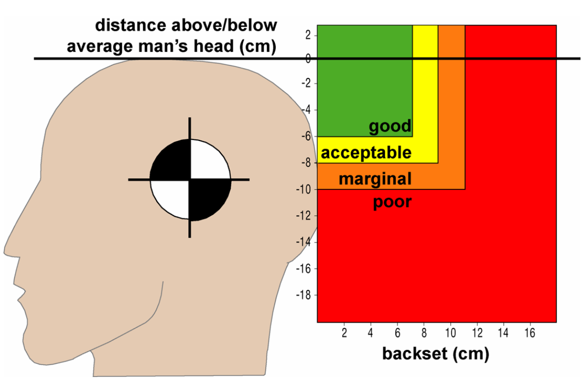

Figure 1. Head restraint geometry ratings

Ten years of IIHS static geometry ratings, combined with the more recent impending upgrade of the U.S. head restraint standard, effectively encouraged automakers to fit the U.S. vehicle fleet with seats and head restraints with better static geometry. As shown in Figure 2, the proportion of cars offering seats with good and acceptable head restraint geometry increased from 7 percent in 1995 to 78 percent in 2004.

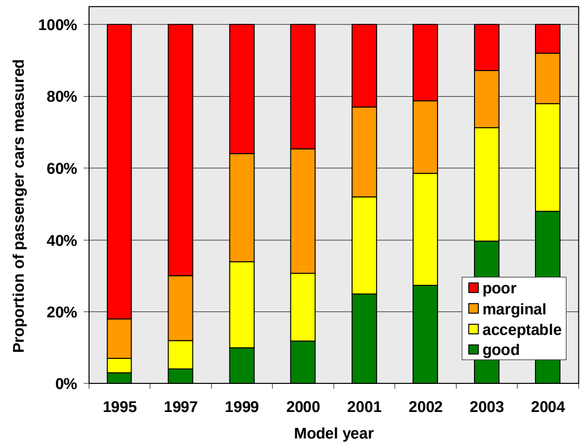

Figure 2. Evaluations of head restraint geometry, passenger cars, 1995-2004

In addition to improving static head restraint geometry, several automakers have developed seats and head restraints with other features intended to reduce whiplash injury risk in rear crashes. These features include yielding seatback cushions with strong perimeter frames (e.g., General Motors' Catcher's Mitt and Toyota's Whiplash Injury Lessening (WIL) system), energy-absorbing seats (e.g., Volvo's Whiplash Injury Prevention System (WHIPS)), and active head restraints. The yielding seatback cushion and energy-absorbing designs control the movement of an occupant's torso to reduce the stresses on the neck until the restraint can contact the head. Active head restraints include a mechanism to move the restraint closer to the head during a crash so it can help support the head earlier than a restraint that does not move. Studies have shown that several of these seat/head restraint designs are effective in reducing neck injury rates in rear crashes (Farmer et al, 2003; Jakobsson and Norin, 2004; Viano and Olsen, 2001).

Head restraints with better static geometry have been shown to reduce the risk and severity of neck injuries in rear crashes (Chapline et al., 2000; Farmer et al., 1999; Olsson et al., 1990). However, as the following example shows, not all restraints initially close to the head provide the same level of support for the head and neck in a rear crash.

Two seats from modern vehicles, the 2002 Ford Windstar and 2003 Pontiac Grand Am, were positioned so the static geometry of the restraints relative to a BioRID's head was similar (Figure 3). The seat/head restraints then were subjected to the same simulated rear crash; two tests were conducted with each design.

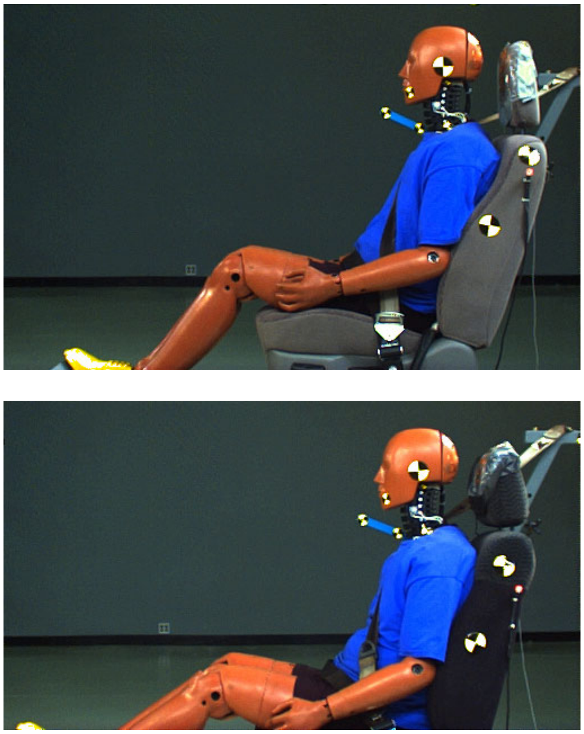

Figure 3. Photos (at T=0 ms) from tests of 2002 Ford Windstar (top) and 2003 Pontiac Grand Am (bottom)

Results indicated that the restraint in the Grand Am contacted the dummy's head earlier in the crash and provided better support than the restraint in the Windstar (Table 1). Figures 4 and 5 illustrate the two main reasons the Windstar seat and head restraint failed to provide the same level of support to the dummy's head and neck. First, although the restraints initially had the same backset, the head restraint in the Grand Am contacted the dummy's head at 60 ms into the crash, whereas the restraint in the Windstar did not contact the dummy's head until 40 ms later; rearward deflection of the Windstar's seatback kept the restraint from reaching the dummy's head sooner. Second, when the Windstar's restraint did contact the

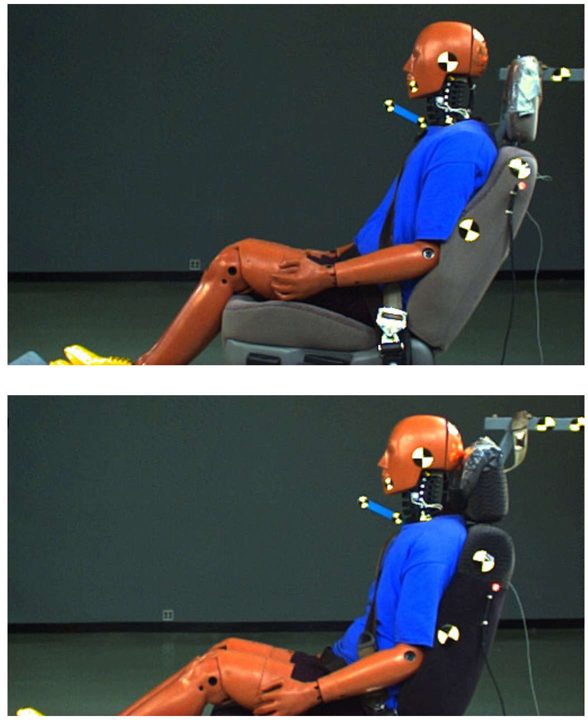

Figure 4. Photos (at T=60 ms) comparing seat movements in tests of 2002 Ford Windstar (top) and 2003 Pontiac Grand Am (bottom)

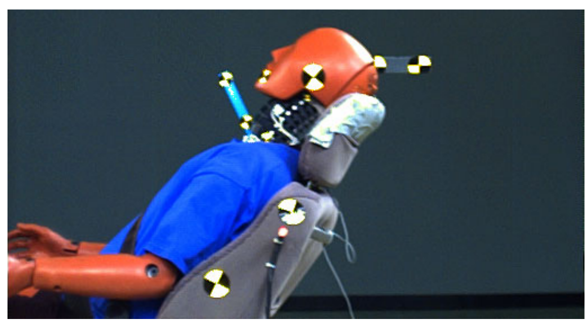

Figure 5. Photo (at T=168 ms) of head restraint contact showing compression of restraint from force of head, 2002 Ford Windstar

Table 1.
Comparison of 2002 Ford Windstar and 2003 Pontiac Grand Am seats tested with same dummy-to-head-restraint geometry

	2002 Ford Windstar		2003 Pontiac Grand Am	
	Test 1	**Test 2**	**Test 1**	**Test 2**
Time to head restraint contact (ms)	107	106	59	57
Upper neck shear force (N)	359	387	217	230
Upper neck tension force (N)	1084	1217	719	123
Neck injury criterion*	31	33	18	16

*Boström et al. (1996)

dummy's head, it offered little support because it was too soft. Thus, even if vehicle seats and restraints are required to meet more stringent geometric requirements, the level of whiplash protection will vary depending on other factors. The increasing proportion of new vehicle seats with good/acceptable static head restraint geometry and the advent of other whiplash protection features suggested a need for dynamic tests of seats to establish which designs are better able to provide beneficial support for occupants' heads and necks in rear crashes.

IIWPG SEAT/HEAD RESTRAINT EVALUATION

IIHS worked with the International Insurance Whiplash Prevention Group (IIWPG), formed in December 2000, to develop a vehicle seat and head restraint evaluation that included dynamic tests. IIWPG is comprised of research and testing organizations sponsored by automobile insurers, including Thatcham in the United Kingdom; Allianz Centre for Technology in Germany and the German Insurance Institute for Traffic Engineering; Folksam Insurance in Sweden; ICBC in Canada; Insurance Australia Group; and CESVIMap in Spain. The specific aims of the member groups vary, but their common objective is to use standardized testing of vehicle seats to encourage automakers to equip vehicles with seats that could help reduce whiplash injuries. The work of IIWPG included conducting many tests and considering all of the available research concerning whiplash injuries. The seat evaluation procedure adopted by IIHS reflects these efforts.

The IIWPG/IIHS evaluation procedure begins with an assessment of static geometry. The basic geometric requirements for seat and head restraint design, height and backset, are measured to produce a rating of good, acceptable, marginal, or poor, based solely on the adequacy of the restraint to accommodate large segments of the population. This rating procedure is detailed in the RCAR (2001) publication, "Procedure for Evaluating Motor Vehicle Head Restraints." Although the RCAR procedure assigns a good evaluation to all active head restraints, the IIWPG/IIHS static evaluation reflects the same measurement criteria as for nonactive restraints. The additional benefits of active head restraints, if any, are assessed through dynamic testing. Head restraints with geometric ratings of good or acceptable are tested in a simulated 16 km/h rear impact to determine a dynamic rating of how well they support the torso, neck, and head. The final overall rating of a seat is a combination of its geometric and dynamic ratings. Seat designs with geometric ratings of marginal or poor automatically receive an overall rating of poor. They are not subjected to dynamic testing because their geometry is inadequate to protect anyone taller than an average-size male.

The dynamic test consists of a rear impact using a crash-simulation sled and a BioRID IIg to represent an occupant. A sled test with standard crash pulse (Figure 6) is used rather than a full-vehicle test even though, in theory, full-vehicle test results could include the effect that a vehicle's rear structure might have on seat performance. However, in real-world rear crashes vehicles experience impacts with a wide range of vehicles at a variety of speeds such that seats in rear-struck vehicles will actually experience a wide range of crash pulses. The IIWPG procedure is designed specifically to assess the performance of seats and head restraints, not rear-end structures, the designs of which are driven by many factors other than neck injury prevention.

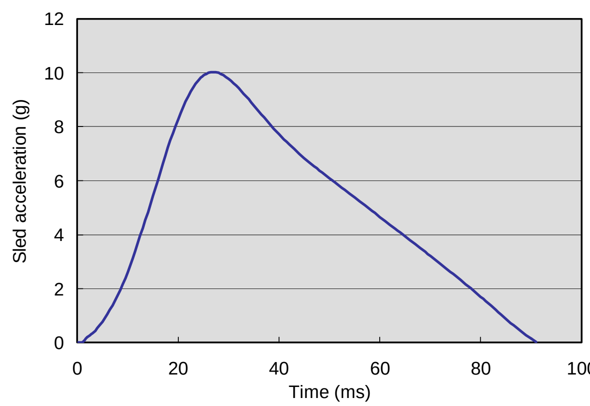

Figure 6. IIWPG sled pulse for dynamic tests of seats and head restraints

The performance criteria for the dynamic test are divided into two groups: two seat design parameters and two test dummy response parameters. The first seat design parameter, time to head restraint contact, requires that the head restraint or seatback contact the occupant's head early in the crash. This follows from the main reason for requiring a small static backset, which is to reduce the time during a rear crash until the head is supported by the restraint. Thus, the time-to-head-restraint-contact parameter ensures that initially good or acceptable static geometry is not made irrelevant by poor seat design. The second seat design parameter, forward acceleration of the seat occupant's torso (T1 acceleration), measures the extent to which the seat absorbs crash energy so that an occupant experiences lower forward acceleration. In some cases, seats designed to absorb crash energy may result in later head restraint contact times. Seats with features that reduce contact time or have effective energy-absorbing characteristics have been shown to reduce neck injury risk in rear crashes compared with seats with reasonably similar static geometry fitted to the same vehicle models (Farmer et al., 2003). The critical values of the seat design parameters have been set consistent with the performance of benchmark seats. The time-to-head-restraint-contact limit of 70 ms reflects head restraint contact times achieved by seats with active head restraint designs and good or acceptable static geometry. The T1 acceleration limit of 9.5 g is based on the maximum T1 accelerations recorded in tests of Volvo's WHIPS seats, which include energy-absorbing/force-limiting seatback hinges. Thus, these seat design parameters should encourage more automakers to adopt design principles that have been shown to be effective in the real world.

The two dummy response parameters, upper neck shear force and upper neck tension force, ensure that earlier head contact or lower torso acceleration actually results in less stress on the neck. The critical values of these neck forces are set according to the distribution of neck forces observed in current seats with good static geometry. The measured neck forces are classified low, moderate, or high depending on which region of Figure 7 the data points lie with respect to maximum neck shear and tension forces. The regions are bounded by curves representing the 30th and 75th percentiles of the joint probability distribution of neck shear and neck tension forces among seats with good geometry tested by IIHS or Thatcham in 2004. Thus the limits for low forces are achievable with current design knowledge.

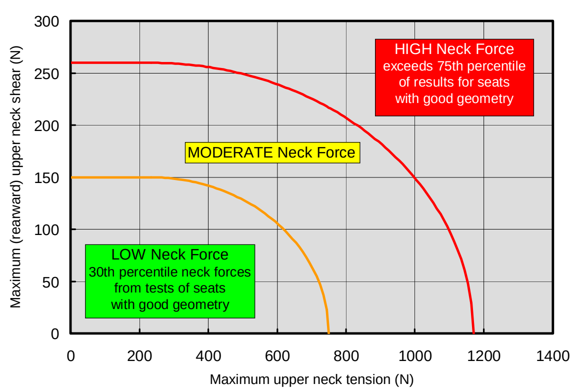

Figure 7. Rating for the joint distribution, maximum neck tension and maximum neck shear

To receive a good dynamic rating, a head restraint must pass at least one of the seat design parameters and also produce low neck forces. If neck forces are moderate or high, then the dynamic rating is only acceptable or marginal. If neck forces are high and neither seat design parameter is passed, then the dynamic rating falls to poor. Table 2 shows how the dynamic rating is determined, and Table 3 illustrates how the geometric and dynamic ratings are combined for an overall evaluation of seat design.

Table 2.
Dynamic rating requirements

Seat Design Criteria	Neck Force Classification	Dynamic Rating
T1 X-acceleration ≤9.5 g OR Time to head restraint contact ≤70 ms	Low	Good
	Moderate	Acceptable
	High	Marginal
T1 X-acceleration >9.5 g AND Time to head restraint contact >70 ms	Low	Acceptable
	Moderate	Marginal
	High	Poor

Table 3.
Formulation of overall rating

Geometric Rating	Dynamic Rating	Overall Rating
Good	Good	Good
	Acceptable	Acceptable
	Marginal	Marginal
	Poor	Poor
Acceptable	Good	Acceptable
	Acceptable	Acceptable
	Marginal	Marginal
	Poor	Poor
Marginal	No dynamic test	Poor
Poor	No dynamic test	Poor

RESULTS OF IIHS FIRST SEAT EVALUATION SERIES

IIHS's first evaluation series included only seats from 2004 and 2005 cars with current IIHS crashworthiness ratings for front or side impacts — a total of 97 seat/head restraint combinations from 79 different vehicle models. Forty-five seats had a static geometry rating of good, 28 were rated acceptable, 12 were marginal, and 12 were poor. Thus, 73 seats qualified for dynamic testing, and the remaining 24 seats received an overall rating of poor. A complete summary of the test results can be found in Appendix A.

Only 15 of the 73 seats tested passed the T1 acceleration criterion of 9.5 g. However, only 5 of these seats also had low neck forces, and they had either energy absorbing (WHIPS) or yielding seatback cushion (WIL) designs. Another 6 seats with low torso acceleration had high neck forces. Four of the seats with high neck forces also were among those with the largest seatback rotations: Ford Crown Victoria and Taurus, Lincoln Town Car, and Mercury Grand Marquis. The other two seats, Acura TL and Lexus GS, had relatively soft head restraint cushions that did not seem to offer enough support even after they contacted the dummy's head. Seats with good static head restraint geometry had lower T1 maximum accelerations on average than seats with acceptable geometry ($p<0.05$) (Table 4).

Table 4.
T1 maximum accelerations related to static geometry

Seat static rating	Good	Acceptable	All tests
Minimum T1 (g)	7.0	8.0	7.0
Maximum T1 (g)	16.2	17.0	17
Average T1 (g)	10.9	12.0	11.2

Eleven of the 73 seats tested passed the time-to-head-restraint-contact criterion of 70 ms. All but 2 of these seats were equipped with active head restraints. However, there also were 6 seats equipped with active head restraints that did not pass this criterion. None of the seats that passed produced high neck forces. Again, seats with good static head restraint geometry had significantly lower head restraint contact times on average than seats with acceptable geometry ($p<0.001$). The two nonactive seats that passed this criterion had good head restraint geometry (Table 5).

Table 5.
Head restraint contact times related to static geometry

Seat static rating	Good	Acceptable	All tests
Minimum time (ms)	53	64	53
Maximum time (ms)	126	133	133
Average time (ms)	84	100	92

The evaluation protocol takes into account that energy-absorbing seats are beneficial and that some designs may have delayed head restraint contact times. Results of this first series of seat evaluations indicate that seats meeting the T1 acceleration criterion had later head restraint contact times on average ($p<0.08$).

Thirteen of the seats tested produced low neck forces, 24 seats produced moderate neck forces, and the remaining 36 seats produced high forces. Of the 13 seats that produced low neck forces, 9 also passed either the T1 acceleration or head restraint contact time criteria. Three of the other 4 seats nearly passed one of the seat design criteria, with results just over the limit. Of the 13 seats with low neck forces, 12 had good static head restraint geometry. Both neck shear force and neck tension force were lower for seats with good static head restraint geometry ($p<0.001$) (Table 6).

Table 6.
Maximum upper neck forces related to static geometry

Seat static rating	Good	Acceptable	All tests
Minimum shear (N)	11	22	11
Maximum shear (N)	299	427	427
Average shear (N)	139	238	178
Minimum tension (N)	287	630	287
Maximum tension (N)	1365	1571	1571
Average tension (N)	750	1050	867

Of the 73 seats IIHS tested dynamically, only 8 earned an overall rating of good. Of the remaining 65 seats 16 were rated acceptable, 19 were marginal, and 30 were poor. Of the 8 seats with a good overall rating, 4 had active head restraints and 4 had energy-absorbing seats like Volvo's WHIPS. One seat with acceptable static head restraint geometry received a good dynamic rating, but its overall rating of acceptable reflects that it cannot be adjusted to protect the tallest seat occupants.

COMPARISON OF IIWPG/IIHS RATINGS WITH OTHER SYSTEMS

Since 2003, the Swedish Road Administration in conjunction with Folksam Insurance and Autoliv has published vehicle seat ratings based solely on dynamic tests. Ratings are derived from three tests at different speed/acceleration levels and from the scoring of three BioRID response parameters: NIC, Nkm, and head-rebound velocity (Krafft et al., 2004). Each of the three tests is assigned 5 points, so the maximum combined rating can be up to 15 points. Each of the three parameters evaluated in the tests is assigned points based on the magnitude of the value measured. The maximum point value assigned to NIC and Nkm for each test is 2, while head-rebound velocity is only assigned a maximum value of 1 point. When the points are combined from all three tests and all three rating parameters, a rating of Green+ (0-2.5 points), Green (2.6-5.0 points), Yellow (5.1-10.0 points) or Red (10.1-15.0 points) is assigned to the vehicle seat. Both the IIWPG/IIHS rating system and the SRA rating system have 4 rating categories; therefore, IIWPG/IIHS good can be compared with SRA Green+ and so on.

The mid-severity test that SRA conducts is similar to the IIWPG 16 km/h test. In order to compare the ratings systems for these tests, IIHS's first series of seat evaluations were scored according to the Swedish system. It was found that seat designs with the lowest point totals were those the IIWPG/IIHS system also rated good. In general, this partial application of the Swedish system to the IIHS test results showed good agreement with IIWPG/IIHS ratings. Seven seats had IIHS/IIWPG overall ratings that were two rating levels different from those suggested by the Swedish system for a single test. For fives models —Saab 9-2x and 9-3, Subaru Impreza, Nissan Altima, and Lincoln LS — the seat rating would have been two rating levels lower using the Swedish system compared with the IIWPG/IIHS procedure. For the other two models, Lexus LS 430 and Hyundai Elantra, seat ratings would have been two rating levels better using the Swedish system compared with the IIWPG/IIHS procedure. Among the 73 seats dynamically tested by IIHS, 6 also have been tested by SRA. All 6 of these seat designs received comparable ratings in both the SRA assessment and the IIWPG/ IIHS assessment (Table 7).

Table 7.
SRA vs. IIHS ratings

Make and series	SRA rating	IIHS rating
2003 BMW 3-Series	Red	Poor
2003 Saab 9-3	Green +	Good
2003 Saab 9-5	Green	Acceptable
2003-04 Toyota Corolla	Green	Acceptable
2004 Volvo S40	Green +	Good
2004 Volvo V70/S80	Green +	Good

SUMMARY

Vehicle head restraint geometry has improved in recent years, and forthcoming safety regulations will reinforce these improvements. In addition, some automakers have equipped their vehicles with seats having other features intended to help reduce the risk of whiplash injury in rear crashes, some of which have proven to be effective. Consequently, ratings of vehicle seats for consumer information need to incorporate dynamic testing to differentiate among current seat designs and encourage the greater adoption of designs with additional anti-whiplash benefits. IIWPG has developed a rating system that addresses this need, and IIHS and other IIWPG members have begun publishing vehicle seat ratings using the IIWPG system.

The IIWPG/IIHS system continues to emphasize the importance of static head restraint geometry by dynamically testing only those seats that meet certain geometric requirements. This decision recognizes that many current vehicles still are equipped with head restraints that are not high enough to help accelerate the heads of taller occupants in rear crashes and the fact that many head restraints with sufficient adjustment range cannot be locked into position or are too far behind the head to provide support early in a crash. In addition, government regulation requiring better geometry will not be in full effect for another 4 years. Adequate head restraint geometry and locks for adjustable restraints still are necessary first steps to provide protection against neck injuries in rear crashes.

Despite good or acceptable static geometry, two-thirds of the seats tested by IIHS failed to demonstrate adequate support for the head and neck in a simulated rear crash. These received dynamic ratings of marginal or poor. Thus improvement in dynamic performance is needed. In that regard, it is encouraging that 23 of the seats with good or acceptable dynamic ratings did not have special features such as active head restraints or energy-absorbing seatbacks. These results indicate that a good overall rating probably can be achieved without the addition of the more expensive special features if the static geometry is sufficiently good. However, the best rated seats in IIHS's initial series of tests were those equipped with some variation of the special features, which have been shown to be effective in real crashes.

As interest in minor neck injuries increases, other seat evaluation systems have appeared. A comparison of the IIWPG/IIHS system with that used in Sweden suggested that the two systems reward the same seat design strategies.

ACKNOWLEDGMENT

This work was supported by the Insurance Institute for Highway Safety.

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APPENDIX A. Ratings and technical data for vehicle seat/head restraints

			Geometry			Seat design parameters			Neck forces				
Make and model	**Model years**	**Seat type**	**Rating**	**Backset (mm)**	**Distance below top of head (mm)**	**Pass/Fail**	**Max. T1 accel. (g)**	**Head contact time (ms)**	**Force rating**	**Max. neck shear force (N)**	**Max. neck tension (N)**	**Dynamic rating**	**Overall rating**
Acura TL	2004-05	All Seats	Good	45	40	Pass	9.5	106	High	250	882		
Acura TSX	2004-05	All seats	Good	60	52	Fail	10.5	105	High	175	1253	Poor	Poor
Audi A4	2004-05	Seats that adjust manually	Good	42	60	Fail	12.9	88	High	247	905	Poor	Poor
Audi A4	2004-05	Seats with power adjustment	Acceptable	52	62	Fail	12.9	92	High	296	1075	Poor	Poor
Audi S4	2004-05	All seats	Good	62	50	Fail	11.2	91	High	248	911	Poor	Poor
Audi A6	2005	All seats AHR	Good	62	52	Pass	12.8	66	Moderate	183	674	Acceptable	Acceptable
BMW 3-Series	2002-05	All seats	Acceptable	68	80	Fail	11.3	102	High	309	988	Poor	Poor
BMW 5-Series	2004-05	Base seats	Acceptable	75	12	Fail	14.0	103	High	230	750	Poor	Poor
BMW 5-Series	2004-05	Sport/comfort seats with AHR	Good	60	15	Pass	9.9	64	Moderate	95	761	Acceptable	Acceptable
Cadillac CTS	2003-05	Seats without adjust-able lumbar	Acceptable	82	58	Fail	10.5	100	High	351	1148	Poor	Poor
Chevrolet Malibu	2004-05	All seats	Good	28	52	Fail	12.1	71	Low	14	732	Acceptable	Acceptable
Chrysler Sebring	2003-05	Seats with power recline	Good	45	52	Pass	8.6	116	Moderate	188	636	Acceptable	Acceptable
Chrysler 300	2005	All seats	Good	20	52	Pass	12.0	53	Moderate	79	787	Acceptable	Acceptable
Dodge Neon	2001-05	Seats with adjustable head restraints	Acceptable	65	68	Fail	12.6	118	High	256	1298	Poor	Poor
Dodge Stratus	2003-05	Without lumbar	Good	55	58	Fail	11.5	113	High	262	696	Poor	Poor
Dodge Stratus	2003-05	With lumbar	Acceptable	48	62	Pass	8.8	117	Moderate	173	630	Acceptable	Acceptable
Ford Focus	2001-05	All seats	Good	58	40	Fail	12.8	98	Moderate	97	923	Marginal	Marginal
Ford Taurus	2004-05	All seats	Acceptable	60	75	Pass	9.3	116	High	263	675	Marginal	Marginal
Ford Crown Victoria	2003-05	Seats with adjustable lumbar	Good	55	60	Pass	8.4	126	High	238	724	Marginal	Marginal
Honda Civic	2003-05	All seats	Good	62	45	Fail	12.5	99	High	299	1149	Poor	Poor
Honda Accord	2003-05	EX models standard seats	Good	55	45	Fail	11.3	88	High	45	1365	Poor	Poor
Honda Accord	2003-05	LX models standard seats	Acceptable	72	50	Fail	13.6	93	High	81	1168	Poor	Poor
Hyundai Elantra	2001-05	All seats	Acceptable	78	62	Fail	14.3	110	High	427	1490	Poor	Poor
Hyundai Sonata	2001-05	GL models	Acceptable	80	68	Fail	9.9	104	High	161	975	Poor	Poor
Hyundai XG350	2002-05	All seats	Acceptable	72	65	Fail	13.6	74	High	314	1235	Poor	Poor
Infiniti I35	2002-04	All seats AHR	Acceptable	85	70	Fail	16.5	77	High	399	1571	Poor	Poor

			Geometry			Seat design parameters			Neck forces				
Make and model	**Model years**	**Seat type**	**Rating**	**Backset (mm)**	**Distance below top of head (mm)**	**Pass/Fail**	**Max. T1 accel. (g)**	**Head contact time (ms)**	**Force rating**	**Max. neck shear force (N)**	**Max. neck tension (N)**	**Dynamic rating**	**Overall rating**
Infiniti G35	2005	All seats AHR	Acceptable	28	62	Fail	9.7	105	High	220	782	Poor	Poor
Infiniti Q45	2005	All seats AHR	Good	48	52	Fail	9.9	101	Moderate	191	864	Marginal	Marginal
Jaguar X-type	2004-05	All seats	Good	42	35	Fail	11.0	110	High	292	749	Poor	Poor
Jaguar S-type	2005	All seats	Good	38	48	Pass	8.5	75	Low	70	369	Good	Good
Kia Spectra	2005	All seats AHR	Good	68	40	Fail	10.1	87	Low	89	609	Acceptable	Acceptable
Kia Optima	2001-05	Seats that adjust manually	Acceptable	68	68	Fail	13.3	87	High	235	1394	Poor	Poor
Kia Amanti	2005	All seats AHR	Good	65	53	Fail	9.6	77	Low	105	588	Acceptable	Acceptable
Lexus IS	2001-05	All seats	Good	42	45	Fail	12.0	78	Moderate	79	934	Marginal	Marginal
Lexus ES	2004-05	All seats	Acceptable	75	68	Fail	10.9	102	High	179	1041	Poor	Poor
Lexus GS	2003-05	All seats	Good	52	52	Pass	9.5	96	High	237	1009	Marginal	Marginal
Lexus LS	2001-05	All seats	Good	40	25	Fail	11.1	94	Moderate	96	839	Marginal	Marginal
Lincoln LS	2003-05	All seats	Good	68	15	Pass	8.4	75	Moderate	184	636	Acceptable	Acceptable
Lincoln Town Car	2003-05	All seats	Acceptable	80	68	Pass	7.8	134	High	271	859	Marginal	Marginal
Mazda 3	2004-05	Base seats	Good	42	58	Fail	11.9	86	Moderate	116	984	Marginal	Marginal
Mazda 3	2004-05	Seats with adjustable lumbar support	Acceptable	48	65	Fail	10.4	104	Moderate	138	839	Marginal	Marginal
Mazda 6	2003-05	Seats without adjustable lumbar	Good	50	58	Fail	10.7	98	Moderate	151	966	Marginal	Marginal
Mazda 6	2003-05	Seats with adjustable lumbar	Acceptable	35	68	Fail	11.1	104	High	192	1178	Poor	Poor
Mercedes C class	2004-05	Seats with auto-adjust head restraints	Good	45	-15	Fail	12.1	74	Moderate	193	836	Marginal	Marginal
Mercedes E class	2004-05	Seats with auto-adjust head restraints	Good	30	5	Pass	11.8	63	Moderate	126	813	Acceptable	Acceptable
Mercury Sable	2004-05	All seats	Acceptable	52	65	Fail	10.7	118	High	377	1220	Poor	Poor
Mercury Grand Marquis	2003-05	All seats	Acceptable	72	65	Pass	8.7	125	High	228	735	Marginal	Marginal
Mini Cooper	2002-05	All seats	Good	32	32	Fail	11.0	88	Moderate	175	653	Marginal	Marginal
Mitsubishi Lancer	2002-05	All seats	Good	60	48	Fail	11.9	82	Moderate	186	773	Marginal	Marginal
Mitsubishi Galant	2004-05	Cloth seats	Acceptable	85	75	Fail	13.4	100	High	280	887	Poor	Poor
Nissan Altima	2005	All seats AHR	Acceptable	80	60	Pass	9.7	64	Moderate	221	660	Acceptable	Acceptable
Saab 9-2X	2005	All seats AHR	Good	38	48	Pass	10.2	62	Low	29	403	Good	Good
Saab 9-3	2005	All seats AHR	Good	60	33	Pass	16.2	64	Low	11	287	Good	Good
Saab 9-5	2005	All seats AHR	Good	45	50	Fail	11.0	72	Low	12	337	Acceptable	Acceptable
Saturn ION	2003-04	Cloth seats	Good	48	55	Fail	11.0	88	High	252	601	Poor	Poor
Saturn ION	2003-04	Leather seats	Acceptable	68	75	Fail	10.8	84	High	238	672	Poor	Poor
Subaru Impreza	2005	All seats AHR	Good	40	53	Pass	10.9	65	Low	43	462	Good	Good

			Geometry			Seat design parameters			Neck forces				
Make and model	Model years	Seat type	Rating	Backset (mm)	Distance below top of head (mm)	Pass/Fail	Max. T1 accel. (g)	Head contact time (ms)	Force rating	Max. neck shear force (N)	Max. neck tension (N)	Dynamic rating	Overall rating
Subaru Impreza WRX	2004-05	All seats	Acceptable	75	45	Fail	9.9	101	Moderate	137	678	Marginal	Marginal
Subaru Legacy	2005	All seats AHR	Good	50	58	Pass	10.4	67	Moderate	80	725	Acceptable	Acceptable
Subaru Outback	2005	All seats AHR	Good	50	58	Pass	10.4	67	Moderate	80	725	Acceptable	Acceptable
Suzuki Aerio	2002-04	All seats	Good	62	32	Fail	12.3	85	Moderate	164	745	Marginal	Marginal
Suzuki Forenza	2004	All seats	Acceptable	75	72	Fail	14.3	94	High	340	1168	Poor	Poor
Suzuki Verona	2004	All seats	Acceptable	60	75	Fail	12.4	102	High	268	1138	Poor	Poor
Toyota Corolla	2003-04	All seats	Acceptable	40	62	Pass	8.5	91	Low	22	686	Good	Acceptable
Toyota Corolla	2005	All seats	Acceptable	38	65	Fail	15.3	85	High	97	1333	Poor	Poor
Toyota Camry	2004?	Cloth seats	Good	60	60	Fail	13.4	96	Moderate	115	1073	Marginal	Marginal
Toyota Camry	2004?	Leather seats	Acceptable	42	65	Fail	11.8	106	High	178	1166	Poor	Poor
Toyota Avalon	2001-04	All seats	Acceptable	68	65	Fail	15.0	98	High	130	1408	Poor	Poor
Volkswagen New Beetle	2004-05	Seats without adjustable lumbar	Good	35	52	Pass	10.8	69	Moderate	128	579	Acceptable	Acceptable
Volkswagen New Beetle	2004-05	Seats with adjustable lumbar	Good	42	48	Pass	8.9	69	Low	88	530	Good	Good
Volvo S40	2004-05	All seats	Good	15	35	Pass	8.3	84	Low	46	583	Good	Good
Volvo S60	2004	All seats	Good	40	30	Pass	7.0	92	Low	56	663	Good	Good
Volvo S80	2005	All seats	Good	15	55	Pass	9.0	87	Low	37	550	Good	Good
Seats Not Tested													
Acura RL	2001-04	All seats	Poor	68	108							Not tested	Poor
BMW 5 series	2004-05	Seats with adjustable thigh support	Poor	108	18							Not tested	Poor
Buick Century	2001-05	Cloth seats	Marginal	60	100							Not tested	Poor
Buick Century	2001-05	Leather seats	Poor	90	130							Not tested	Poor
Buick Regal	2001-04	All seats	Poor	95	125							Not tested	Poor
Buick LeSabre	2003-05	All seats (AHR)	Poor	75	130							Not tested	Poor
Buick Park Avenue	2003-05	All seats	Poor	135	110							Not tested	Poor
Cadillac Seville	2001-04	All seats	Poor	110	105							Not tested	Poor
Chevrolet Cavalier	2001-05	All seats	Poor	125	135							Not tested	Poor
Chevrolet Classic	2003-05	Cloth seats	Marginal	60	90							Not tested	Poor
Chevrolet Classic	2003-05	Leather seats	Poor	65	105							Not tested	Poor
Chevrolet Impala	2001-05	Cloth bucket seats	Poor	90	130							Not tested	Poor
Chevrolet Impala	2001-05	Leather bucket seats	Marginal	60	90							Not tested	Poor
Chrysler Sebring	2003-05	Seats that recline manually	Marginal	98	58							Not tested	Poor
Honda Civic Hybrid	2003-05	Base seats	Marginal	92	75							Not tested	Poor

			Geometry			Seat design parameters			Neck forces				
Make and model	Model years	Seat type	Rating	Backset (mm)	Distance below top of head (mm)	Pass/Fail	Max. T1 accel. (g)	Head contact time (ms)	Force rating	Max. neck shear force (N)	Max. neck tension (N)	Dynamic rating	Overall rating
Mitsubishi Galant	2004-05	Leather seats	Marginal	70	85							Not tested	Poor
Nissan Sentra	2002-05	Base seats	Marginal	72	95							Not tested	Poor
Nissan Maxima	2004	Cloth seats (AHR)	Poor	130	75							Not tested	Poor
Nissan Maxima	2004	Leather seats (AHR)	Marginal	98	72							Not tested	Poor
Pontiac Grand Am	2001-05	Cloth seats	Marginal	70	83							Not tested	Poor
Pontiac Grand Prix	2004	All seats	Marginal	98	82							Not tested	Poor
Pontiac Bonneville	2003-05	Bench seats	Poor	135	115							Not tested	Poor
Pontaic Bonneville	2003-05	Leather seats	Marginal	105	100							Not tested	Poor
Saturn L series	2001-05	All seats	Poor	80	125							Not tested	Poor
Volkswagen Passat	2001-05	All seats	Marginal	100	58							Not tested	Poor