INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

March 5, 2008

The Honorable Nicole R. Nason
Administrator
National Highway Traffic Safety Administration
400 Seventh Street, SW
Washington, DC 20590

NHTSA's Activities Under the United Nations Economic Commission for Europe 1998 Global Agreement: Head Restraints; Request for Comments; Docket No. NHTSA-2008-0016, Notice 1

Dear Administrator Nason:

On February 14, 2008, the National Highway Traffic Safety Administration (NHTSA) announced the possible upcoming vote on the Global Technical Regulation (GTR) on Head Restraints at the March meeting of the World Forum for Harmonization of Vehicle Regulations (WP.29) and requested public comments about the proposed regulation. The Insurance Institute for Highway Safety (IIHS) welcomes this opportunity to comment on the GTR on Head Restraints and to share with the agency information from our recent research about how modern vehicle seat/head restraint designs are preventing neck injuries in rear crashes.

IIHS understands the GTR on Head Restraints is based on the recent upgrade to Federal Motor Vehicle Safety Standard (FMVSS) 202, Head Restraints. In our March 2001 comment on the proposed rule, we supported provisions in the standard requiring taller head restraints for front outboard seating positions and the addition of a minimum backset requirement (distance between the back of the head of a normally seated occupant and the front of a head restraint) because IIHS research had shown that the rate of driver neck injuries following rear crashes was lower for vehicles with seat/head restraints designed to be taller and fit closer to the backs of occupants' heads (Farmer et al., 1999; IIHS, 2001). We also applauded the adjustment retention provisions of the standard that reduce the chance a properly adjusted restraint will fall out of adjustment inadvertently. These provisions are part of the GTR on Head Restraints and represent improvements on existing standards regulating head restraints in the United States and other countries.

Although IIHS also supported the concept of a dynamic test compliance option, we raised concern about a test using the Hybrid III dummy and suggested postponing implementation of a dynamic test option until NHTSA could prescribe one using a more appropriate test dummy such as BioRID II. We understand our concern was shared by other commenters, but the agency chose to issue the final rule with a Hybrid III-based dynamic test option, citing lack of information about alternate dummies such as BioRID II and procedures for using them.

The GTR on Head Restraints permits a dynamic test compliance option using either Hybrid III or BioRID II, but the requirements for tests using BioRID II are not yet prescribed (United Nations Economic and Social Council, 2008). The informal group on head restraints again cites the lack of a recognized standard dynamic test procedure using BioRID II as the reason for not specifying these requirements further. In fact, a recognized standard BioRID II test does exist.

The Research Council for Automobile Repairs and the International Insurance Whiplash Prevention Group (RCAR-IIWPG), mentioned in our March 2001 comments to the agency, has developed a standard test using BioRID II to evaluate the ability of vehicle seat/head restraints to protect occupants' necks from injuries in rear crashes. IIHS and others have been using this test to publicly rate vehicle seat/head restraints since 2004. Vehicle manufacturers and their supplier companies are well aware of the test, and many are designing seats to earn good ratings. Between model years 2005 and 2007, the proportion of new model vehicles with seat/head restraints rated good or acceptable rose from 29 to 39 percent, whereas the proportion rated poor dropped from nearly half to 30 percent.

The most recent IIHS research shows that changes made to vehicle seat/head restraint designs to earn good ratings are effective at reducing neck injury risk in rear crashes (Farmer et al., 2008, attached). An analysis of more than 4,000 insurance claims involving rear crashes of vehicles with rated seat/head restraint designs showed that the risk of driver neck injury was 15 percent lower for vehicles with seats rated good than for vehicles with seats rated poor. More important is that the risk of long-term driver neck injury (requiring treatment for 3 months or more) was 35 percent lower for vehicles with seats rated good compared with vehicles with seats rated poor. Similar findings were reported by Folksam Insurance in Sweden (Kullgren et al., 2007). Thus the standardized dynamic test developed by RCAR-IIWPG is, in fact, promoting the kinds of seat/head restraint designs that the GTR on Head Restraints and FMVSS 202 also aim to promote. We suggest the agency and WP.29 amend FMVSS 202 and the proposed GTR on Head Restraints to adopt this proven dynamic test as a compliance option in place of the unproven one currently described in these regulations. A copy of the RCAR-IIWPG (2007) test protocol is included for your information.

Neck injuries, known as whiplash, are an expensive problem in the United States and around the world. US insurers pay more than $8.5 billion to treat these injuries every year, and the cost per injured person is even higher in other countries such as Switzerland, where the average cost per injured person is €35,000 (Soltermann, 2007). The upgraded FMVSS 202 and the proposed GTR on Head Restraints include provisions that should help address this problem by requiring better vehicle seat/head restraint designs than required by current regulations. However, the dynamic test compliance option prescribed in these standards fails to recognize the development of a standard test using BioRID II since the upgraded FMVSS 202 was first proposed and instead specifies an unproven test with Hybrid III. We urge the agency to consider our suggestion to adopt the RCAR-IIWPG test in place of a Hybrid III test because the latest research indicates it is promoting effective seat/head restraint designs.

Sincerely,

David Zuby

David S. Zuby
Senior Vice President, Vehicle Research

cc: Docket Clerk, Docket No. NHTSA-2008-0016, Notice 1

Attachments

Farmer, C.M.; Zuby, D.S.; Wells, J.K.; and Hellinga, L.A. 2008. Relationship of dynamic seat ratings to real-world neck injury rates. Presented at the World Congress on Neck Pain. Arlington, VA: Insurance Institute for Highway Safety.

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RELATIONSHIP OF DYNAMIC SEAT RATINGS TO REAL-WORLD NECK INJURY RATES

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ABSTRACT

Objectives: The Insurance Institute for Highway Safety assigns consumer safety ratings to passenger vehicle seats based on laboratory sled tests that simulate rear-end collisions. The purpose of this research was to determine how well these ratings correlate to driver neck injury risk in real-world crashes.

Methods: Insurance claims for cars and SUVs struck in the rear by the front of another passenger vehicle were examined for evidence of driver neck injury. Logistic regression was used to compare neck injury rates for vehicles with different seat ratings while controlling for other important variables.

Results: Driver neck injury rates were 15 percent lower for vehicles with seats rated good compared with vehicles with seats rated poor. Rates of driver neck injuries lasting 3 months or more were 35 percent lower for vehicles with seats rated good compared with vehicles with seats rated poor.

Conclusions: Seat/head restraints that perform better in dynamic sled tests have lower risk of neck injury than seats that rate poor, especially when considering long-term injuries. However, the relationship of dynamic seat ratings to neck injury rates is not linear. Further research is needed to determine whether the criteria for rating seats can be amended so as to be more uniformly predictive of real-world neck injury.

Keywords: Whiplash; Head Restraints; Insurance Claims

INTRODUCTION

In the United States there are approximately 1.8 million rear-end collisions of motor vehicles reported to police each year, 28 percent of which result in injury (National Highway Traffic Safety Administration (NHTSA), 2007). An estimated annual 2.1 million rear-end collisions are not reported to police, bringing the total to about 3.9 million collisions per year (Najm et al., 2006). Rear-end collisions are common in other countries as well. For example, 35 percent of reported crashes in Japan are rear-end collisions (Watanabe and Ito, 2007).

Whiplash and whiplash-associated disorders describe a range of neck injuries related to sudden distortions of the neck that often occur in rear-end crashes. The most common symptom reported by whiplash victims is pain due to mild muscle strain or minor tearing of soft tissue. Neck sprain or strain is the most serious injury reported in more than 33 percent of automobile injury insurance claims, with back sprain or strain accounting for another 20 percent (Insurance Research Council, 2003).

Factors influencing neck injury risk to occupants of rear-struck vehicles include gender, seating position, and seat design. Women are more likely to sustain neck injuries than men (Temming and Zobel, 1998; Watanabe and Ito, 2007). Front-seat occupants, especially drivers, are more likely to sustain neck injuries than rear-seat occupants (Krafft et al., 2003). Seats that allow an occupant's head to "whip" back and forth during a rear impact are more likely to see neck injuries than seats that support the head and torso simultaneously.

One way to limit the differential movement of an occupant's head and torso has been through extensions to seat backs known as head restraints. Effective head restraints must be high and close enough to support the head when the vehicle is pushed forward. Since 1995 the Insurance Institute for Highway Safety (IIHS) has published safety ratings of head restraints based on their height and the distance from the back of an average-size adult male occupant's head to the front of the head restraint (backset). Restraints are rated as good, acceptable, marginal, or poor based on these geometric measures.

Farmer et al. (1999) compared driver neck injury rates for rear-struck cars with varying IIHS head restraint ratings. More than 5,000 insurance claims were examined in detail. After accounting for differences in crash severity and driver demographics, the authors reported 24 percent fewer driver neck injuries in cars with seats rated good compared with cars with seats rated poor.

The design of head restraints has been regulated in the United States since 1969. Federal Motor Vehicle Safety Standard (FMVSS) No. 202 originally required all new passenger cars to include head restraints in the front outboard seats that could extend at least 700 mm (27.5 in) above the hip position. However, many drivers and passengers leave their head restraints in the lowest adjustable positions, which may be well below the optimal height (Cullen et al., 1996; IIHS, 2003; Viano and Gargan, 1996). Recent changes to FMVSS 202, fully effective on September 1, 2011, require head restraints to extend at least 750 mm (29.5 in) above the hip even when adjusted to the lowest positions (69 FR 74848; 72 FR 25484). In addition, backsets can be no greater than 55 mm (2.2 in).

The revised requirements of FMVSS 202 will put all head restraints in either the good or acceptable classes of the IIHS geometric ratings (NHTSA, 2004). However, there still may be significant differences in neck injury rates among seats with good/acceptable geometry. Geometric ratings do not take into account other seat design modifications that may reduce the risk of neck injury. Some seats are designed to reduce forward acceleration of the torso, thus keeping it more in line with the head (Lundell et al., 1998; Sekizuka, 1998). Also, some automakers have designed active head restraints that move closer to an occupant's head either during or in anticipation of a collision (Matsubayashi et al., 2007; Voo et al., 2007; Wiklund and Larsson, 1998).

Beginning in 2004, in cooperation with the International Insurance Whiplash Prevention Group (IIWPG), IIHS added a second component to the rating of seat/head restraints. Seats with geometry rated good or acceptable are attached to a steel flatbed sled running on fixed rails. The sled is accelerated and decelerated to simulate a stationary vehicle being rear-ended by another vehicle of the same weight going 32 km/h (20 mi/h). Dynamic seat ratings are assigned based on how well the seat supports the torso, neck, and head of an instrumented dummy (Edwards et al., 2005).

The Swedish Road Administration (SRA) and Folksam Insurance also assign dynamic seat ratings to new cars, using three different tests for each seat. The mid-severity test is similar to the IIHS/IIWPG test, but the measurements taken on the dummy differ. Kullgren et al. (2007) related long-term neck injury risk in Sweden to both the SRA and IIHS/IIWPG ratings. The risk of a neck injury with symptoms lasting more than 4 weeks was estimated to be 60 percent higher in the worst SRA group than in the best, and 43 percent higher in the worst IIHS/IIWPG group than in the best.

The dynamic ratings assigned by IIHS include results for more than 40 different vehicle makes and more than 175 different models. Ratings are given not only for cars but also for many SUVs. Thus the vehicles rated by IIHS should be representative of the fleet of recent model vehicles on the road. The objective of the present study was to determine whether dynamic seat ratings correlate well with real-world neck injury rates in the United States. In particular, the relationship of dynamic ratings to long-term neck injury risk was to be compared with that reported in Sweden.

METHOD

Two large automobile insurers provided claims data for the study. State Farm Mutual Insurance accounted for 18 percent of the personal auto insurance premiums paid in the United States in 2005, the largest of any auto insurer (Insurance Information Institute, 2007). Nationwide Insurance ranked sixth in market share, accounting for another 4.6 percent.

Study vehicles were 2005-06 model cars and SUVs for which IIHS had assigned a single dynamic seat rating (i.e., applying to all seat options) as of April 2007. There were 105 different vehicle models, some of which had different ratings for the 2005 and 2006 model years. Possibly relevant claims were defined as those for collisions occurring between January 1, 2005 and September 30, 2006 and involving rear damage to a study vehicle.

Claims also were restricted to those occurring in tort liability states, with the exception of Michigan. Tort liability states are those in which both injury and property damage claims in two-vehicle crashes are filed against the insurance carrier of the at-fault driver. In rear-end collisions the at-fault driver usually is the driver of the striking vehicle. Information on both property damage and occupant injury for the struck vehicle therefore would be in the records of the striking vehicle’s insurer, a key condition for the design of this study.

Most so-called “no-fault” states were excluded from the analysis because injury claims and property damage liability claims are not held by the same insurer; that is, both drivers first file their injury claims with their own insurers, whereas the property damage claims are filed with the insurer of the at-fault driver. Michigan differs from other no-fault states in that property damage claims also are treated as no-fault, so, again, the same insurer holds both injury and property damage claims.

Researchers identified 13,959 possibly relevant claims from tort states and 1,057 from Michigan. Of these, 3,562 claims were randomly sampled from tort states and 616 from Michigan, stratified by insurer, vehicle type of rear-struck vehicle, and IIHS seat rating assigned. These 4,178 claims were examined at the Nationwide offices in Columbus, Ohio, and the State Farm offices in Irving, Texas, during the last 2 weeks of June 2007.

Thirty percent of the claims examined were rejected as being not relevant. Some common reasons for rejection were that the struck vehicle was parked and unoccupied or that the vehicle experienced multiple impacts. The remaining 2,857 claims, when weighted by their sampling probabilities, were treated as being representative of 10,183 claims.

For each relevant claim, information was gathered on damage to the struck vehicle and weights of both the striking and struck vehicles. Damage was coded as severe if it involved the vehicle frame or trunk floorpan or if the vehicle was declared a total loss; moderate if it involved the quarter panels, deck lid, bumper energy absorber, or bumper reinforcement; and minor if it only involved the rear body panel, bumper, or bumper cover. Gender of the struck vehicle driver was determined, as well as any mention of neck pain or injury. For drivers who sought medical treatment, diagnostic codes (ICD-9) were reviewed to determine whether neck injuries were involved. Dates of treatment were copied from medical bills. Injuries were classified as long-term if medical treatment continued for at least 3 months after the collision.

Logistic regression was used to model the odds of struck vehicle driver neck injury as a function of state group, driver gender, vehicle type, vehicle damage severity, vehicle price, and dynamic seat rating. Odds ratios and 95 percent confidence limits were calculated using the SUDAAN software, a package of procedures for analyzing data from complex sampling designs (Research Triangle Institute, 2004). Risk ratios were derived from odds ratios using the method described by Zhang and Yu (1998).

Finally, SRA criteria also were used to categorize the head restraint performance in the IIHS laboratory sled tests. Point values were multiplied by three to account for the lack of low- and high-severity tests. Six of the 105 vehicle models in the study could not be assigned these approximate

Swedish ratings due to missing data. Driver neck injury rates then were compared for the four categories of SRA-type ratings (green+, green, yellow, and red).

RESULTS

Driver neck injury rates by state group and seat rating are summarized in Table 1. Michigan, the only no-fault state, tended to have lower neck injury claim rates than tort states (16.0 versus 18.8 percent), and neck injury rates tended to increase as seat ratings got worse. Driver neck injury rates were higher for vehicles with seats rated poor than for vehicles with seats rated good, and injury rates for vehicles with marginal seats fell in between.

(Table 1 inserted here)

However, driver neck injury rates for vehicles with seats rated acceptable did not behave as expected. In Michigan, vehicles with acceptable seats had very low driver neck injury rates, even lower than those for vehicles with good seats. In tort states, vehicles with acceptable seats had the highest driver neck injury rates. These anomalies could be due to unequal distributions of other factors affecting neck injury risk, such as driver gender and crash severity.

Driver neck injury rates by driver gender and seat rating are summarized in Table 2. Female drivers were much more likely to claim neck injuries than male drivers (21.7 versus 13.9 percent), and vehicles with good seats had lower driver neck injury rates than vehicles with poor seats for both genders. However, driver neck injury rates for vehicles with acceptable and marginal seats did not behave as expected.

(Table 2 inserted here)

Driver neck injury rates by vehicle damage severity and seat rating are summarized in Table 3. Drivers of vehicles with severe damage were more likely to claim neck injuries than drivers of vehicles with only moderate or minor damage (33.3 versus 21.8 and 13.1 percent). Within each damage severity category, driver neck injury rates tended to increase with lower seat ratings, but there were always exceptions.

(Table 3 inserted here)

Driver neck injury rates by struck vehicle type and seat rating are summarized in Table 4. Drivers of rear-struck cars were more likely to claim neck injuries than drivers of rear-struck SUVs (19.7 versus 17.0 percent). For both vehicle types, vehicles with seats rated good had lower driver neck injury rates than vehicles with seats rated poor, but injury rates for vehicles with acceptable and marginal seats did not behave as expected.

(Table 4 inserted here)

Driver neck injury rates by struck vehicle price and seat rating are summarized in Table 5. Drivers of more expensive vehicles were less likely to claim neck injuries than drivers of less expensive vehicles (12.9 versus 18.0 and 21.9 percent).

(Table 5 inserted here)

Driver neck injury rates by striking-to-struck-vehicle weight ratio and seat rating are summarized in Table 6. Drivers of vehicles struck by heavier vehicles were more likely to claim neck injuries than drivers of vehicles struck by vehicles of approximately equal or lesser weight (21.0 versus 18.7 and 16.4 percent).

(Table 6 inserted here)

Logistic regression was used to estimate the relative neck injury risks by seat rating after adjusting for the effects of insurer, state group, driver gender, vehicle type, vehicle damage severity, vehicle price, and striking-to-struck-vehicle weight ratio. The effect of weight ratio was not statistically significant in combination with the other variables, and was therefore dropped from the regression model. Results are summarized in Table 7. Drivers of vehicles with seats rated good were 15 percent less likely to claim neck injuries than drivers of vehicles with seats rated poor, and drivers of vehicles with marginal seats were 8 percent less likely to claim neck injuries than drivers of vehicles with poor seats. Neither of these differences was statistically significant at the $p < 0.05$ level, although the difference for good versus poor was very close. Also, after adjusting for the other factors, drivers of vehicles with acceptable seats were about as likely to claim neck injuries as drivers of vehicles with poor seats.

(Table 7 inserted here)

Next, the relationship of seat rating to the risk of long-term neck injury was examined. Overall 4.6 percent of claims involved long-term neck injury (Table 8), or about 1 in 4 of initial claims. Drivers of vehicles with seats rated good had lower rates of long-term neck injury than drivers of vehicles with seats rated poor (3.8 versus 5.8 percent), but, again, long-term driver neck injury rates for vehicles with acceptable and marginal seats were not quite in line.

(Table 8 inserted here)

The logistic regression was repeated to isolate the relative risk for long-term neck injuries attributable to the seat ratings (Table 9). Drivers of vehicles with seats rated good or marginal were each 35 percent less likely to claim long-term neck injuries than drivers of vehicles with seats rated poor. Both of these differences were statistically significant. Drivers of vehicles with acceptable seats were 24 percent less likely to claim long-term neck injuries than drivers of vehicles with poor seats, but this difference was not statistically significant.

(Table 9 inserted here)

Driver neck injury rates are summarized in Table 10 by the alternative seat ratings based on the SRA rating system variables. Only 102 struck vehicles (three vehicle models) had an analogue SRA rating of green, as opposed to more than 1,700 vehicles for each of the other categories. The vehicles rated green were combined with those rated yellow to ensure more reliable estimates of injury rates. Overall driver neck injury rates were lowest for vehicles with seats rated red, and long-term neck injury rates were lowest for vehicles with seats rated green+. Driver neck injury rates were highest for vehicles with seats rated green/yellow.

(Table 10 inserted here)

Logistic regression was used to estimate the relative neck injury risks attributable to the analogue SRA seat ratings after adjusting for the effects of insurer, state group, driver gender, vehicle type, vehicle damage severity, and vehicle price. Drivers of vehicles with seats rated green+ were equally likely to claim neck injuries as drivers of vehicles with seats rated red (Table 11), but 22 percent less likely to claim long-term neck injuries than drivers of vehicles with seats rated red (Table 12). Neither of these differences was statistically significant.

(Tables 11 and 12 inserted here)

DISCUSSION

Drivers of vehicles with good dynamic seat ratings tend to have a lower risk of neck injury than drivers of vehicles with poor seat ratings, especially when considering long-term injuries. However, the relationship is not clear for seats rated acceptable or marginal. When considering all neck injuries, seats with acceptable ratings had real-world experience just as bad as those with poor ratings. When considering only long-term neck injuries, seats with marginal ratings had real-world experience just as good as those with good ratings. Even though the differences were not statistically significant, the failure of acceptable and marginal seats to line up is puzzling.

It could be that a different evaluation of dynamic test results would produce a better correlation with neck injury rates than was observed for the IIHS/IIWPG ratings. However, one alternative tried here, an analogue to the SRA rating system based on the single IIHS crash pulse, did not improve the fit of the test results to real-world injuries. When the seats were rated using the test measures used in the SRA rating system, there was no difference between the injury rates of the best and worst rated seats.

This should not be surprising because the two systems are quite similar. Both ratings are derived from a number of individual components measured on the test dummy during dynamic sled tests. However, the two systems have two significant differences. First, the SRA ratings are based on results of three different dynamic tests, whereas the IIHS/IIWPG rating is based on a single test. Second, the two evaluations are based on different measurements from the tests. Despite these differences, the two systems assign ratings that are reasonably well correlated with one another. For example, Edwards et al. (2005) reported that six seat designs subjected to all three tests of the SRA evaluation had the same ratings as those assigned by the IIHS/IIWPG system. In addition, the authors scored 73 seats subjected to a single test by IIHS according to the SRA criteria. Most seats differed in their ratings by at most one level. The relationship between IIHS/IIWPG and SRA ratings was similar for the present study.

Seats with good IIHS/IIWPG ratings had lower initial driver neck injury rates than those with poor ratings, but the injury rates in seats rated acceptable or marginal were less clear. Good ratings appear to distinguish designs with lower injury rates, especially long-term injury rates, but establishing a one-to-one relationship between ratings and injury rates is a more vexing problem. It is possible that different test measurements or different combinations of test measurements than those used in the IIHS/IIWPG and

SRA rating systems will be better correlated with injury rates. Further research is needed to determine which of the test measurements are predictive of real-world neck injury and how best to combine these measures.

The majority of neck sprain symptoms clear up within a month, but some can last for years (Maag and Tao, 1993). Preventing these long-term injuries should be a high priority. Drivers of vehicles with seats that performed at least marginally well in the IIHS/IIWPG dynamic tests had a much lower rate of long-term neck injury than drivers of vehicles with seats rated poor. These results are consistent with a recent study conducted in Sweden (Kullgren et al., 2007). In conclusion, then, the dynamic safety ratings of automobile seat/head restraints give a useful indication of how they will protect occupants in real-world collisions. Encouraging automakers to design seats that earn good safety ratings should greatly lessen the problem of whiplash injuries.

ACKNOWLEDGMENT

The authors wish to acknowledge the efforts of all those who participated in gathering the data. In particular, they thank Laurette Stiles, Steve Roberson, Chad Miller, Dawn Quon, and Jackie Magee of State Farm and Bill Windsor, Andy Regera, and Jessica Sherman of Nationwide. This work was supported by the Insurance Institute for Highway Safety.

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Table 1. Driver neck injury rates (weighted) by state group and IIHS seat rating

State group	Seat rating	Claims	# with neck injury	% with neck injury
Michigan	Overall	603	96	16.0
	Good	123	18	15.0
	Acceptable	120	12	10.0
	Marginal	215	33	15.2
	Poor	146	33	22.9
Tort states*	Overall	9,580	1,804	18.8
	Good	1,221	199	16.3
	Acceptable	1,816	397	21.8
	Marginal	3,108	556	17.9
	Poor	3,435	653	19.0
Total	Overall	10,183	1,901	18.7
	Good	1,343	217	16.2
	Acceptable	1,936	409	21.1
	Marginal	3,323	589	17.7
	Poor	3,581	686	19.2

* AL, AK, AZ, AR, CA, CO, CT, GA, ID, IL, IN, IA, LA, ME, MS, MO, MT, NE, NV, NH, NM, NC, OH, OK, RI, SC, SD, TN, VT, VA, WV, WI, WY

Table 2. Driver neck injury rates (weighted) by driver gender and IIHS seat rating

Driver gender	Seat rating	Claims	# with neck injury	% with neck injury
Male	Overall	3,634	505	13.9
	Good	568	69	12.1
	Acceptable	629	98	15.6
	Marginal	1,203	141	11.8
	Poor	1,233	196	15.9
Female	Overall	6,441	1,396	21.7
	Good	764	148	19.4
	Acceptable	1,290	311	24.1
	Marginal	2,076	448	21.6
	Poor	2,311	489	21.2

Note: One percent of claims had missing values for driver gender

Table 3. Driver neck injury rates (weighted) by vehicle damage severity and IIHS seat rating

Damage severity*	Seat rating	Claims	# with neck injury	% with neck injury
Minor	Overall	5,862	766	13.1
	Good	771	85	11.1
	Acceptable	1,133	178	15.7
	Marginal	2,033	245	12.1
	Poor	1,924	258	13.4
Moderate	Overall	2,645	577	21.8
	Good	335	73	21.7
	Acceptable	451	123	27.2
	Marginal	808	168	20.8
	Poor	1,051	213	20.3
Severe	Overall	1,676	558	33.3
	Good	238	59	24.9
	Acceptable	351	108	30.9
	Marginal	481	175	36.4
	Poor	606	215	35.5

* Based on parts repaired/replaced on the struck vehicle

Table 4. Driver neck injury rates (weighted) by struck vehicle type and IIHS seat rating

Struck vehicle type	Seat rating	Claims	# with neck injury	% with neck injury
Car	Overall	6,315	1,245	19.7
	Good	710	142	19.9
	Acceptable	1,283	273	21.3
	Marginal	2,436	425	17.4
	Poor	1,885	406	21.5
SUV	Overall	3,868	656	17.0
	Good	633	75	11.9
	Acceptable	653	136	20.8
	Marginal	887	164	18.5
	Poor	1,695	280	16.5

Table 5. Driver neck injury rates (weighted) by struck vehicle price and IIHS seat rating

Price ($)	Seat rating	Claims	# with neck injury	% with neck injury
< 20,000	Overall	3,671	805	21.9
	Good	373	81	21.7
	Acceptable	472	104	22.0
	Marginal	1,432	300	20.9
	Poor	1,394	321	23.0
20,000 – 29,999	Overall	5,003	901	18.0
	Good	827	116	14.1
	Acceptable	1,399	294	21.0
	Marginal	1,473	249	16.9
	Poor	1,303	242	18.6
≥ 30,000	Overall	1,509	194	12.9
	Good	144	20	13.8
	Acceptable	65	11	17.2
	Marginal	418	40	9.7
	Poor	883	123	13.9

Table 6. Driver neck injury rates (weighted) by striking-to-struck-vehicle weight ratio and IIHS seat rating

Weight ratio	Seat rating	Claims	# with neck injury	% with neck injury
≤ 0.8	Overall	2,173	357	16.4
	Good	443	45	10.2
	Acceptable	303	65	21.6
	Marginal	552	68	12.3
	Poor	875	179	20.5
0.8 – 1.2	Overall	5,260	986	18.7
	Good	574	118	20.6
	Acceptable	1,097	214	19.5
	Marginal	1,921	368	19.2
	Poor	1,668	286	17.2
> 1.2	Overall	2,378	499	21.0
	Good	244	47	19.2
	Acceptable	456	109	23.9
	Marginal	722	137	19.0
	Poor	956	206	21.6

Note: Four percent of claims had missing values for striking vehicle weight

Table 7. Relative risk of driver neck injury by IIHS seat rating

		95% confidence interval	
Comparison	**Risk ratio**	**Lower limit**	**Upper limit**
Insurer 1 versus Insurer 2	0.94	0.77	1.13
Michigan versus tort states	0.78	0.61	0.98
Car versus SUV	1.12	0.96	1.28
Severe versus minor or moderate damage	1.85	1.63	2.08
Vehicle price $30,000+ versus lower	0.71	0.53	0.93
Female versus male	1.44	1.24	1.66
Good versus poor rating	0.85	0.70	1.01
Acceptable versus poor rating	1.00	0.82	1.20
Marginal versus poor rating	0.92	0.75	1.11

Note: Risk ratio derived from odds ratio using the formula of Zhang and Yu (1998)

Table 8. Driver long-term* neck injury rates (weighted) by IIHS seat rating

Seat rating	Claims	# with long-term neck injury	% with long-term neck injury
Overall	10,183	472	4.6
Good	1,343	51	3.8
Acceptable	1,936	91	4.7
Marginal	3,323	120	3.6
Poor	3,581	209	5.8

* Long-term injuries are those requiring at least 3 months of treatment

Table 9. Relative risk of long-term driver neck injury by IIHS seat rating

		95% confidence interval	
Comparison	**Risk ratio**	**Lower limit**	**Upper limit**
Insurer 1 versus Insurer 2	0.42	0.22	0.77
Michigan versus tort states	0.87	0.49	1.50
Car versus SUV	1.04	0.74	1.45
Severe versus minor or moderate damage	2.54	1.81	3.50
Vehicle price $30,000+ versus lower	0.91	0.52	1.53
Female versus male	1.44	1.00	2.03
Good versus poor rating	0.65	0.44	0.96
Acceptable versus poor rating	0.76	0.48	1.19
Marginal versus poor rating	0.65	0.41	1.00

Note: Risk ratio derived from odds ratio using the formula of Zhang and Yu (1998)

Table 10. Driver neck injury rates (weighted) by approximate SRA rating

Seat rating	Claims	# with neck injury	% with neck injury	% with long-term neck injury
Green+	1,747	321	18.4	3.7
Green/yellow	3,478	709	20.4	5.3
Green	102	17	16.8	0
Yellow	3,376	692	20.5	5.5
Red	4,933	870	17.6	4.5

Note: 25 claims had missing values for SRA rating.

Table 11. Relative risk of driver neck injury by approximate SRA rating

		95% confidence interval	
Comparison	Risk ratio	Lower limit	Upper limit
Insurer 1 versus Insurer 2	0.94	0.77	1.13
Michigan versus tort states	0.77	0.60	0.97
Car versus SUV	1.09	0.94	1.26
Severe versus minor or moderate damage	1.86	1.64	2.09
Vehicle price $30,000+ versus lower	0.74	0.55	0.96
Female versus male	1.45	1.25	1.66
Green+ versus red rating	1.00	0.84	1.19
Green/yellow versus red rating	1.12	0.94	1.30

Note: Risk ratio derived from odds ratio using the formula of Zhang and Yu (1998)

Table 12. Relative risk of long-term driver neck injury by approximate SRA rating

		95% confidence interval	
Comparison	Risk ratio	Lower limit	Upper limit
Insurer 1 versus Insurer 2	0.42	0.22	0.77
Michigan versus tort states	0.84	0.47	1.45
Car versus SUV	0.94	0.67	1.32
Severe versus minor or moderate damage	2.61	1.86	3.57
Vehicle price $30,000+ versus lower	0.99	0.58	1.63
Female versus male	1.44	1.01	2.04
Green+ versus red rating	0.78	0.52	1.15
Green/yellow versus red rating	1.20	0.83	1.73

Note: Risk ratio derived from odds ratio using the formula of Zhang and Yu (1998)

RCAR-IIWPG SEAT/HEAD RESTRAINT EVALUATION PROTOCOL

Version 3.0 – December 2007

1. Purpose

This document describes a Research Council for Automobile Repair (RCAR) standard for evaluating and rating the ability of seats and head restraints to prevent neck injury in moderate and low-speed rear-end crashes. The procedures and criteria were developed by the International Insurance Whiplash Prevention Group (IIWPG), which is comprised of various insurance industry supported research groups from around the world. These organizations are AZT, Centro Zaragoza, CESVIMap, Folksam, GDV, IAG, ICBC, IIHS, Thatcham, and Winterthur. In adopting this standard, RCAR recognizes that IIWPG continues research on the issue of whiplash injury prevention and RCAR will consider amending the standard in the future at the recommendation of the IIWPG.

The evaluation procedure is a two-stage process, starting with the measurement and rating of the static geometry of head restraints and followed by a dynamic evaluation in a simulated rear-end crash of those seats that meet certain geometric criteria. The procedures for conducting the geometric measurements are described in a separate document.

2. Overview of Evaluation Procedure

A head restraint prevents neck injury in a rear-end crash by supporting an occupant's neck and head so they can be accelerated together with the torso as the seat and head restraint are driven forward. To accomplish this, a vehicle's head restraint needs to be tall enough so that the top of the restraint is above the center of gravity of the tallest expected seat occupant's head. In addition, the top of the restraint should be close to the back of an occupant's head so that it can contact and support the head early. The farther the restraint is from the head, the less support it can provide and, consequently, the more the head and torso will tend to move separately, creating potentially injurious forces on the neck.

These basic geometric requirements for seat and head restraint design — height and backset — are measured to produce a geometric 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 Research Council for Automobile Repairs (RCAR, 2007) publication, *A Procedure for Evaluating Motor Vehicle Head Restraints*. However, although this RCAR procedure assigns a good evaluation to all active head restraints, the static geometric evaluation for this protocol will reflect the same measurement criteria as for nonactive head restraints. The additional benefits of active head restraints, if any, will be assessed through dynamic testing.

A head restraint design with a geometric rating of acceptable or good will be tested in a simulated 16 km/h rear impact to determine a dynamic rating of how well the restraint supports the torso, neck, and head. The final overall rating of the seat will be a combination of its geometric and dynamic ratings. A seat design with a geometric rating of marginal or poor automatically will receive an overall rating of poor. It will not be subjected to dynamic testing because its geometry is inadequate to protect anyone taller than an average-size adult male.

The performance criteria for the dynamic test are divided into two groups: seat design parameters (two) and test dummy response parameters (two). The first seat design parameter, time to head restraint contact, requires that the head restraint or seatback contact the seat occupant's head early in the crash. The main purpose of requiring a head restraint to have only a small distance behind the head is to reduce the time until the head is supported by the restraint. Thus, the time-to-head-restraint-contact parameter assures that initially good or acceptable static geometry is not made irrelevant by poor seat design.

Some seats are designed to absorb some of the crash energy so that occupants experience lower forward accelerations. This aspect of performance, the second seat design parameter, is measured by the forward acceleration of the seat occupant's torso (T1 acceleration). In some cases, these designs may result in later head contact times.

Seats with features that reduce head restraint contact times or have effective energy-absorbing characteristics have been shown to provide better protection from neck injuries in rear crashes than seats with reasonably similar geometry fitted to the same car models (Farmer et al., 2003). The critical values of the seat design parameters have been set consistent with the performance of these benchmark seats and thus are intended to encourage more automakers to adopt design principles that have been shown to work in the real world.

To assure that earlier head contact or lower T1 acceleration actually results in better support for the head, two dummy response parameters also are measured: neck shear force and neck tension force. The critical values of the neck forces are set according to the distribution of neck forces observed in current seats with good geometry.

To receive a good dynamic rating, a head restraint must pass at least one of the seat design parameters and also have 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.

The dynamic test consists of a simulated rear crash on a sled device using a BioRID IIg crash dummy to represent a human occupant. The RCAR-IIWPG procedures will use a sled test with standard crash pulse rather than a full-vehicle test. 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 vehicle types at a variety of speeds. Thus, the seats in rear-struck vehicles can experience a wide range of crash pulses. These RCAR-IIWPG procedures are 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.

3. Measurement and Rating of Static Head Restraint Geometry – The Initial Evaluation

The first step in evaluating the rear crash protection afforded by vehicle seats and head restraints is to measure the static head restraint geometry relative to an average-size adult male. Detailed instructions for conducting the static geometry evaluation are described in *A Procedure for Evaluating Motor Vehicle Head Restraints* (RCAR, 2007),[*] but note again that the geometric evaluation for this protocol makes no allowance for active head restraints, basing it solely on the static measurements as with all other head restraints. The following passage summarizes the principal concepts of the static geometry assessment.

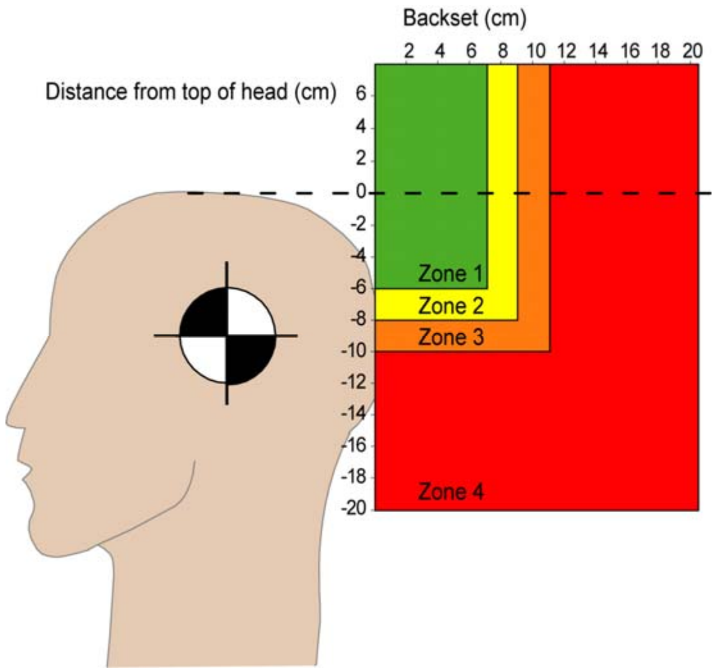
Static geometric evaluations are based on measurements of height and backset that are made with a manikin representing an average-size adult male. To be rated at least marginal, the top of a restraint should be no lower than the center of gravity of the head (no more than 10 cm below the top of the head) and no farther than 11 cm behind the head. Otherwise, the head restraint geometric evaluation is poor. Higher head restraints provide protection for even taller occupants, and closer head restraints can reduce the time the head is unsupported in a rear crash. An acceptable geometric rating implies a head restraint no farther than 8 cm below the top of the head and no farther than 9 cm behind it. Good geometry implies a head restraint no farther than 6 cm below the top of the head and no farther than 7 cm behind it (see Figure 1).

Seats with fixed geometry are rated using the measured height and backset when the seat is adjusted according to the RCAR procedure. Seats with adjustable head restraints that cannot be locked into the adjusted position are rated based on measurements from the unadjusted (lowest and rearmost) position of the head restraint. Seats with locking head restraint adjustments are rated using the midpoint between the lowest/rearmost adjustment and the highest/foremost adjustment.

[*] NOTE: The seat set-up for the static assessment of head restraint geometry is not the same as the seat set-up for the dynamic test. Consequently, both this document and *A Procedure for Evaluating Motor Vehicle Head Restraints* (RCAR, 2007) are required to conduct a complete seat evaluation.

For head restraints with marginal or poor geometry, the overall rating is poor. Head restraints with good or acceptable geometry undergo dynamic testing, as described below.

Figure 1
Diagram of Geometric Head Restraint Ratings



Normally, the static evaluation of seat/head restraint geometry should be conducted with the seat and head restraint installed in the vehicle for which they are designed. When this is not possible (e.g., a new or prototype seat design), the static evaluation can be conducted with the seat and head restraint mounted on a crash simulator (sled) or other test fixture. The seat should be attached to the sled or test fixture so that its orientation relative to horizontal is the same as in the vehicle for which it is intended. Also, a representation of the vehicle floor immediately in front of the seat should be attached to the sled or test fixture at the same relative height so that the H-point machine's feet can be positioned as described in the RCAR procedure. All seat adjustments should be set as described in the RCAR procedure before installing the H-point machine and head restraint measuring device (HRMD). A static evaluation conducted in this way can be used to qualify/disqualify a seat/head restraint design for dynamic testing until the static measurement can be conducted in the vehicle.

4. Dynamic Test Requirements

The dynamic test consists of a rear crash simulation in which a BioRID IIg dummy is positioned in the seat to be tested. The seat is attached to a crash simulation sled and accelerated/decelerated to represent a rear crash with a velocity change (delta V) of 16 km/h. The acceleration profile is roughly triangular, with a peak of 10 g and a total duration of 91 ms. Seats with adjustable head restraints will be tested with the restraints adjusted as in section 5.7.

5. Dynamic Test Procedure

5.1 Acceleration or Deceleration Sled

The dynamic test is intended to simulate a typical rear crash in which the rear-struck vehicle is initially stationary or moving forward very slowly. Consequently, an acceleration sled is recommended for these tests. A deceleration sled, on which the dummy is initially moving rearward at 16 km/h and then stopped, may be used if careful attention is paid to dummy positioning (see step 5.9.5 BioRID positioning requirements). In either case, some sled motion is allowed at the initiation of the test (T = 0). To accommodate different sled types and different relationships between sled motion and the recording of test data, test time will be indexed from the peak sled acceleration as described in section 7 Data Acquisition and Processing.

5.2 Laboratory Environment

The temperature in the test laboratory should be 22.5 ± 3 degrees Celsius (67-78 degrees Fahrenheit) with a relative humidity of 10-70 percent. The BioRID test dummy and seat being tested shall be maintained at this temperature at least 3 hours prior to the test.

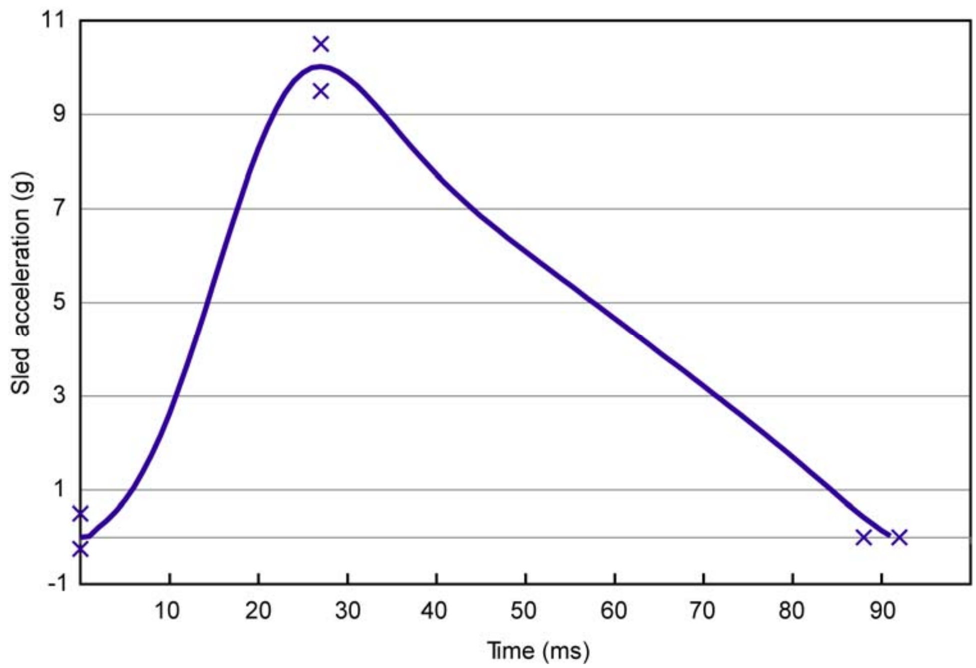
5.3 Coordinate System

The coordinate reference frame for measurements is as follows: +X forward (i.e., direction of sled motion), +Y right, +Z down

5.4 Acceleration Pulse

The target sled acceleration and pulse specifications are given in Figure 2 and Table 1, respectively. Sled accelerations should be measured by an appropriate accelerometer attached to the sled platform and recorded according to the Society of Automotive Engineers (SAE, 2003) Standard J211-1. Prior to establishing conformance with the acceleration pulse specification, any quiescent signal bias should be removed* from the acceleration measurement. Conformance with pulse duration, peak acceleration and its timing are done with the signal filtered to channel frequency class (CFC) 60. Velocity change (delta V) is judged using velocity calculated from a CFC 180 signal. For delta V calculation, integrate the sled acceleration data from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace. Figure 3 shows the typical variation in accelerations from 50 tests conducted on a particular sled.

Figure 2
Target Sled Acceleration and Specification Corridors

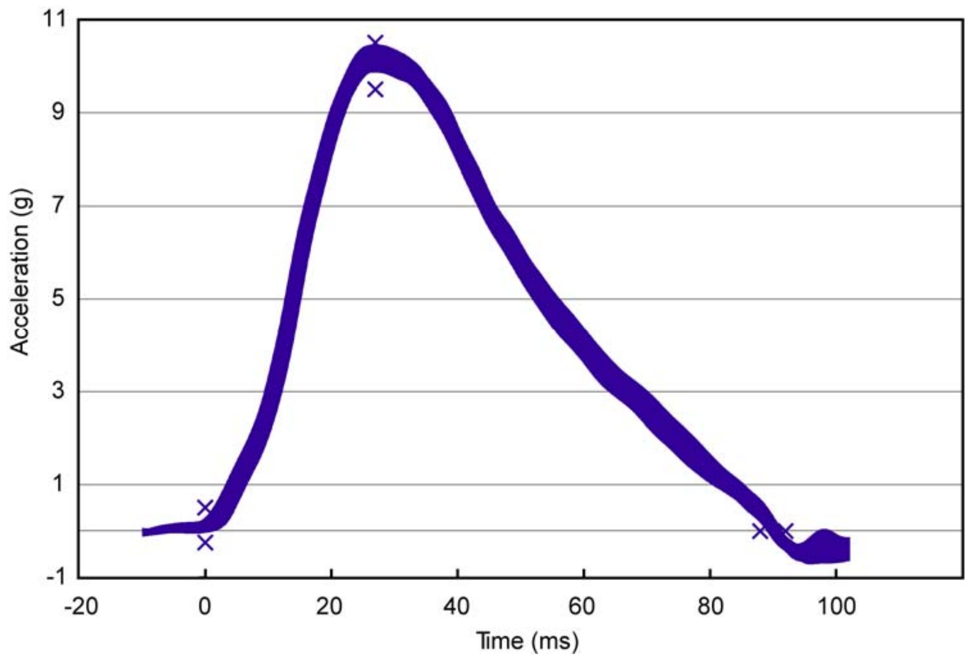


* This typically is done by subtracting the average value of approximately 100 preimpact data points from each acceleration measurement during the test.

Table 1
Sled Acceleration Pulse Specifications

Acceleration Pulse Characteristic	Minimum	Maximum
Acceleration at time = 0 ms	-0.25 g	0.50 g
Acceleration at time = 27 ms	9.5 g	10.5 g
Time that sled acceleration returns to 0 g	88 ms	94 ms
Velocity change (delta V)	14.8 km/h	16.2 km/h

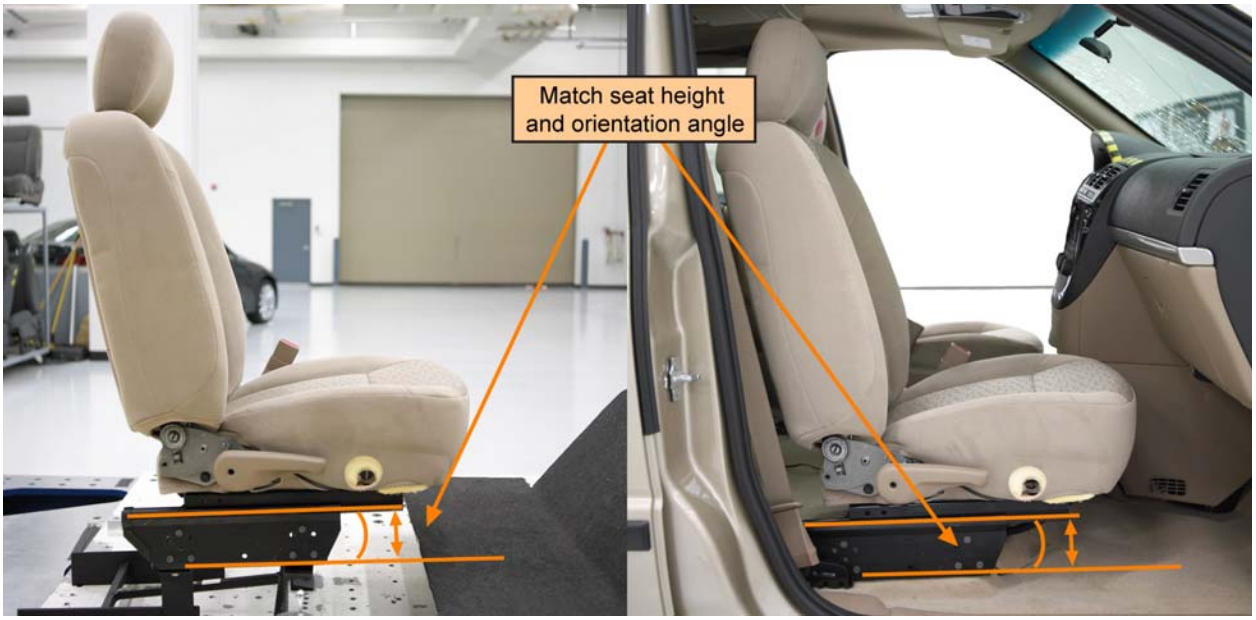
Figure 3
Typical Variation in Accelerations from 50 Sled Tests



5.5 Attachment of Seat/Head Restraint to Sled

The seat, including all of its adjustment mechanisms and hardware that normally connect it to the vehicle floor (e.g., longitudinal adjustment rails), should be securely fastened to the test sled platform. The attachment should be made so that the seat's orientation relative to horizontal is the same as it would be in its intended vehicle. The actual height of the seat from the sled platform may be different from its height above the vehicle floor. A simulated floor and toepan, consisting of a horizontal section sufficiently large to rest the dummy's feet and connected to a section oriented 45 degrees from horizontal and at least 30 cm long, also is attached to the sled platform. Both surfaces should be covered with short-piled carpet. The horizontal floor portion should be mounted at the same height relative to the seat bolts/rails as the heel rest point (section 5.5.1). The fore/aft position of the toepan should be adjustable. Figure 4 shows an example seat both in the vehicle and mounted on the sled platform.

Figure 4
Attachment of Seat to Test Sled Compared with Vehicle Installation



5.5.1 Determine heel rest point location

The heel rest point is defined in the vehicle (with removable floor mats removed) by using the accelerator pedal as follows.

5.5.1.1 Find the geometric center point of the accelerator pedal contact surface (laterally and vertically). Place a straight edge between the accelerator pedal and the fixed carpeting on the vehicle floor so that the straight edge is tangential to the accelerator pedal surface at the center point. The heel rest point location is then the contact point of the straight edge on the vehicle floor (Figure 5).

Figure 5
Heel Rest Point Location

5.5.2 Seat belt geometry

A three-point lap/shoulder belt should be used during the test. The belt should be placed across the dummy's torso, clavicle, and pelvis and be routed above the pelvic angle gauge (if equipped). When testing seats equipped with integrated belts, secure the dummy with the hardware as fitted to the seat.

5.5.3 Trigger active elements

For each seat, it should be ascertained from the manufacturer whether active elements (e.g., active head restraint) are fitted. For each element that requires a trigger, time to fire (TTF) should be specified by the vehicle manufacturer. Supporting data will be requested.

5.6 Set Seat Adjustments

The various seat adjustments possible on many modern vehicle seats should be set according to the following instructions. Because the settings of some adjustments may affect the ranges of other adjustments, the seat should be set according to the order of the procedural steps outlined here. The seatback angle will be set in section 5.9; the initial setting is not important as long as it does not interfere with other adjustments. Seats with automatically adjusting head restraints (i.e., those for which head restraint height adjusts automatically when other seat adjustments are made) should be set according to the instructions in section 5.8.

5.6.1 Initial seat adjustments

All seat adjustments should be set initially as follows. Appendix A provides more detailed descriptions and illustrations of these adjustments.

- **Seat track** should be in its most rearward position.
- **Seat height** should be set to its lowest position.
- **Seat tilt** should be set to the extreme of its range that puts the cushion angle closest to zero (horizontal). Section 5.6.2 describes the method for measuring the cushion angle.
- **Cushion height** should be set to its lowest position.
- **Cushion tilt** should be set to the extreme of its range that puts the cushion angle closest to zero (horizontal). Section 5.6.2 describes the method for measuring the cushion angle.
- **Lumbar support** should be set to its most rearward or least prominent position.
- **Upper seatback**, if separately adjustable from the lower portion, should be rotated fully rearward.
- **Cushion extension** should be set to its most rearward or least extended position.
- **Side bolsters** should be set to the widest position.

5.6.2 Measure seat cushion angle

Method 1: Locate and mark a point on the forward edge of the top surface of the seat cushion and midway between the right and left edges of the cushion. Locate, mark, and record a second point that is 400 mm rearward along a line parallel to the direction of the sled movement (Figure 6). The cushion angle is the reading from a digital protractor sitting on the surface of the seat with the rearmost end on the rear seat mark.

Method 2: If a coordinate measurement machine (CMM) is used to record the locations of the seat marks, then the sine of the cushion angle is the difference in the Z-coordinates (in mm) of these two points (first minus the second) divided by 400 mm.

Figure 6
Seat Cushion Angle (400 mm measurement)

5.6.3 Set seat track adjustment to midrange

Method 1: Mark the seat track and the adjacent portion of the seat support structure. Move the seat to its most forward adjustment position and mark the seat track adjacent to the corresponding mark on the seat support structure. Measure the distance between the two seat track marks and mark the track midway between the two marks. Move the seat rearward until the mark on the seat support structure aligns with center seat track (midtrack) mark. The final position will depend on whether the seat track adjusts continuously or incrementally.

Method 2: Mark a hard point on the seat and record its location with a CMM. Move the seat to its most forward adjustment position and record the position of the seat hard point. Move the seat rearward until the marked hard point is midway between the two previously recorded hard point locations. The final position will depend on whether the seat track adjusts continuously or incrementally.

5.6.3.1 Continuously adjusting seat track – The mark on the seat support structure should align (± 2 mm) with the midtrack mark. Alternatively, the hard point should have an X-coordinate that is midway (± 2 mm) between the X-coordinates of the most forward and most rearward adjustment positions.

5.6.3.2 Incrementally adjusting seat track – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat should be set to the first indexed position rearward of the calculated midpoint.

5.6.4 Set seat height adjustment to midrange

Mark two hard points on the side of the seat that are attached to and move with the cushion frame — one near the front of the cushion and one near the rear. Record the locations of both points with a CMM or measure the vertical heights of the points relative to a fixed reference with a measuring tape. Use the seat height adjustment control(s) to move the seat to its highest position. If front and rear seat heights are adjusted separately (dual control), then make sure that both the front and rear of the seat are raised to their highest positions. Record the locations of the two hard points with the CMM or measure the vertical heights of the points relative to a fixed reference with a measuring tape. Then lower the seat until both hard points are midway between their highest and lowest positions. The final position will depend on the type of seat height adjustment control.

5.6.4.1 Single control seat height adjustment – The final position of the seat will depend on whether seat height adjusts continuously or incrementally.

5.6.4.1.1 Continuously adjusting seat height – The rear hard point should be ± 2 mm of the calculated midpoint.

5.6.4.1.2 Incrementally adjusting seat height – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat height should be set to the first indexed position below the calculated midpoint.

5.6.4.2 Dual control seat height adjustment – If front and rear seat heights are adjusted separately, then lower the front hard point using the front adjustment control and lower the rear hard point using the rear adjustment control. The final position will depend on whether seat height adjusts continuously or incrementally. Note that the front and rear seat height adjustments may need to be iterated to achieve the calculated midpoints.

5.6.4.2.1 Continuously adjusting seat height – Both front and rear hard points should be ± 2 mm of the calculated midpoints. If this is not possible, then the rear hard point should be ± 2 mm of the calculated midpoint and the front hard point as close as possible to the calculated midpoint.

5.6.4.2.2 Incrementally adjusting seat height – If either the front or rear midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat height should be set to the first indexed position below the calculated midpoint for the corresponding seat hard point.

5.6.5 Set seat cushion height adjustment

The cushion height adjustment uses the points marked on the top surface of the cushion in step 5.6.2.

5.6.5.1 Single control seat cushion height adjustment – Raise the cushion to its highest position and record the location of the rear cushion point (400 mm behind the front edge point). Lower the seat cushion to its midrange position. The final position of the seat will depend on whether seat cushion height adjusts continuously or incrementally.

5.6.5.1.1 Continuously adjusting seat cushion height – The rear cushion point should have a Z-coordinate midway (± 2 mm) between the lowest (initial) and highest positions.

5.6.5.1.2 Incrementally adjusting seat cushion height – If the midrange adjustment does not correspond to an indexed adjustment position (± 2 mm), then the seat cushion height should be set to the first indexed position below the calculated midpoint.

5.6.5.2 Dual control seat cushion height adjustment – Raise the rear of the cushion to its highest position using the rear adjustment control and record the location of the rear cushion point (400 mm behind the front edge point). Lower the rear of the cushion using the rear adjustment control so that the rear cushion point is midway between the lowest (initial) and highest positions. Raise the front of the cushion using the front adjustment control until the cushion angle matches the angle recorded in step 5.6.2. The final position will depend on whether seat cushion height adjusts continuously or incrementally.

5.6.5.2.1 Continuously adjusting seat cushion height – The rear cushion point Z-coordinate should be ± 2 mm of the calculated midpoint, and the cushion angle should match (± 0.5 degrees) the angle recorded in step 5.6.2.

5.6.5.2.2 Incrementally adjusting seat cushion height – If the rear midrange adjustment does not correspond to an indexed adjustment position, then the rear cushion height should be set to the first indexed position below the calculated midpoint. Likewise, if the cushion angle in step 5.6.2 cannot be matched (± 0.5 degrees) with the front midrange adjustment at an indexed position, then the front cushion height should be set to the next lowest indexed position.

5.6.6 Adjust upper seatback angle

Measure the angle relative to vertical of the head restraint support post or some flat part of the seatback frame. Without changing the adjustment of the lower seatback, move the upper seatback to its most forward position and measure the angle at the same location as the initial measurement. Adjust the upper seatback rearward until the angle is midway (± 0.5 degrees) between the most rearward and most forward angles.

5.6.7 Other seat adjustments

Any seat adjustments not specified in steps 5.6.3 through 5.6.6 should remain in their initial adjustment positions as described in step 5.6.1.

5.7 Head Restraint Test Position

The head restraint should be set in a position closest to that on which the static (RCAR) rating is based. Thus, the test position for the restraint depends on whether it is fixed or adjustable and, if adjustable, whether the adjustments lock. Automatically adjusting head restraints are tested as if they are fixed restraints, and the seat adjustments are set according to section 5.8.

5.7.1 Fixed head restraint

No adjustment of the restraint is possible.

5.7.2 Nonlocking adjustable head restraint

Restraint is adjusted to its lowest vertical adjustment position and/or most rearward horizontal adjustment position.

5.7.3 Locking adjustable head restraint

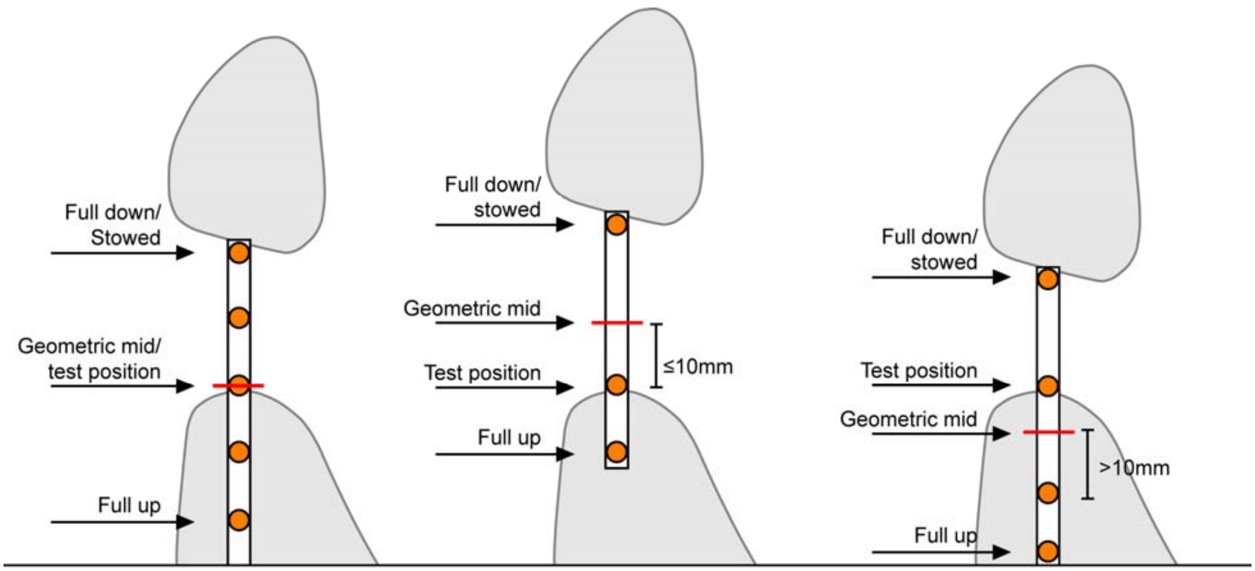
Restraint is adjusted to the midrange of its vertical and/or horizontal adjustment positions. Only locking adjustments are set to the midrange positions. For example, a restraint with locking height adjustment and nonlocking horizontal adjustment would be set to its midrange vertical position and most rearward horizontal position.

Midrange height position is determined by calculating the geometric mid point between the lowest (locking or nonlocking) and highest locking vertical adjustments, considering only the vertical component of measurement. Similarly, midrange tilt position is determined by calculating the geometric mid point between the most rearward locking and most forward locking horizontal adjustments, considering only the horizontal component of measurement. (Figure 7). The test position will then be selected based on the following conditions:

- Place the head restraint at the geometric mid point if a locking position exists there (Figure 7A).
- If there is no locking position at the geometric mid point, raise the head restraint by up to 10 mm (Figure 7B). If a locking position exists within this 10mm of travel, that position will be the test position.
- If there is no locking position within 10 mm above the geometric mid point, lower the head restraint to the next lowest locking position (Figure 7C), that position will be the test position.

Once the vertical test position has been determined, the procedure should be repeated for locking horizontal adjustments moving the restraint forward instead of upward and rearward instead of downward.

Figures 7
Examples of Adjustment Positions for Head Restraints with Locking Height
(Locking positions indicated in orange)



Example A
(Locking position at geometric mid point)

Example B
(Locking position up to 10 mm above geometric mid point)

Example C
(Locking position more than 10 mm above geometric mid point)

5.8 Seating Adjustments: Seats with Automatically Adjusting Head Restraints

The BioRID used in these dynamic tests represents an average-size adult male driver or vehicle occupant. Consequently, seats equipped with head restraints that automatically adjust depending on other seat adjustments (e.g., seat track or height) should be set to a position that most likely would accommodate a seat occupant of the same size. The procedure described in *Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version V)* (Insurance Institute for Highway Safety, 2004) should be followed for seat positioning only. The UMTRI ATD positioning procedure must be conducted with the seat installed in a vehicle, then the seat adjustments recorded are transferred to the test seat on the sled. If it is not possible to employ the UMTRI procedure to determine the appropriate seat position for an average-size male seat occupant, then the seat should be set to the middle of its fore/aft adjustment range (see step 5.6.3). Regardless of which method is used to determine the head restraint test position, the seat should be moved rearward from the most forward position to the test position because the starting position can affect the final position of the head restraint.

5.9 BioRID Positioning

The BioRID test position is based on reference measurements made with the H-point machine and HRMD. Installation of the H-point machine and HRMD follows the procedure described in *A Procedure for Evaluating Motor Vehicle Head Restraints* (RCAR, 2007) sections 5.2 and 5.3 without changing the seat adjustment obtained in section 5.6.

5.9.1 Install H-point machine and HRMD

Follow the instructions described in sections 5.2 and 5.3 of *A Procedure for Evaluating Motor Vehicle Head Restraints* (RCAR, 2007). It is important to ensure that the feet of the H-point machine do not contact the angled surface of the simulated toepan during this step. If more than three installations of the H-point machine and HRMD are required to obtain a seatback angle that supports a torso angle of 24-26 degrees, then the seat should be allowed to recover for 15 minutes with nothing in it between each third and fourth installation.

Some indexed seatback adjustments may have more than 2 degrees between adjustments, with none giving a torso angle between 24 and 26 degrees. In such cases, adjust the seatback to the most reclined position that supports a torso angle less than 24 degrees.

5.9.2 Record location of H-point machine's H-point marker

Use a CMM or other means to record the location of the H-point machine's H-point marker relative to the seat or sled.

5.9.3 Measure and record reference backset

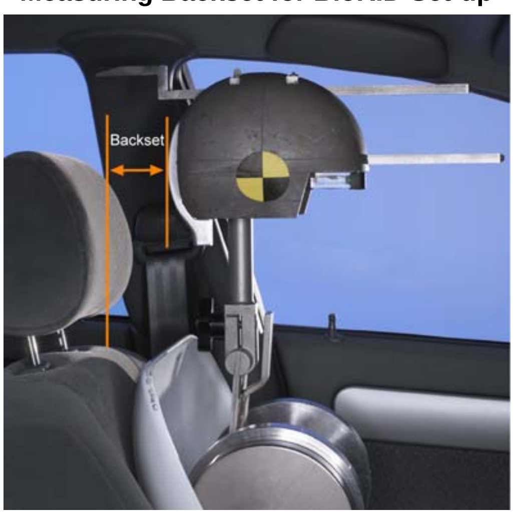
5.9.3.1 Set the head restraint to the test position described in section 5.7.

5.9.3.2 Locate the screw on the center of the rear surface of the HRMD backset probe.

5.9.3.3 Mark an identifiable point on the head restraint along its vertical centerline.

5.9.3.4 Measure and record the reference backset as shown in Figure 9. This is the horizontal distance between the most rearward point on the HRMD skull (i.e., the screw on the backset probe) and the same identifiable point on the head restraint.

Figure 9
Measuring Backset for BioRID Set-up



5.9.4 Remove HRMD and H-point machine and install BioRID

5.9.4.1 Allow the seat to recover for 15 minutes with nothing in it before installing the BioRID.

5.9.4.2 Align the BioRID's midsagittal plane with the centerline of the seat.

5.9.4.3 Adjust the BioRID's midsagittal plane to be vertical; the instrumentation platform in the head should be laterally level.

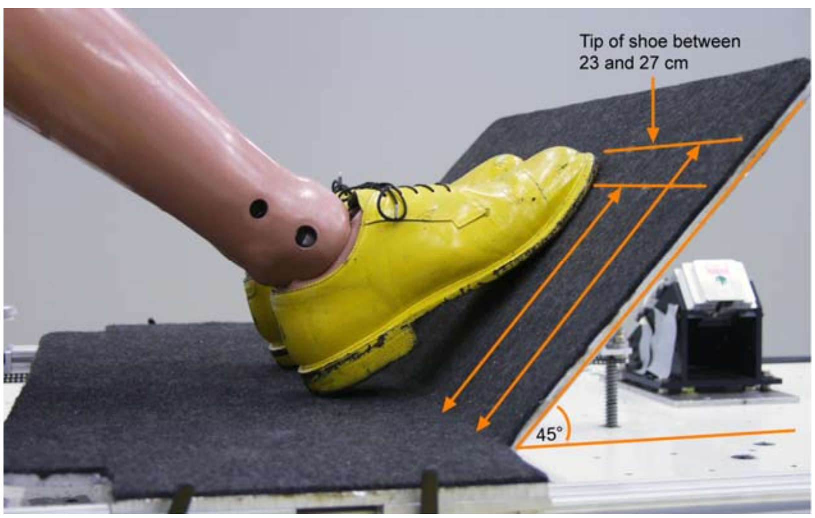
5.9.4.4 Adjust the BioRID's pelvis angle to 26.5 ± 2.5 degrees from horizontal.

5.9.4.5 Position the H-Point 20 ± 10 mm forward of the location recorded in step 5.9.2. Position the H-Point the same vertically ± 10 mm as the location recorded in step 5.9.2, while keeping the pelvis angle at 26.5 ± 2.5 degrees. NOTE: It is recommended that the dummy be positioned as close as possible to the nominal target values; the tolerance window should be used only if there is difficulty achieving the required H-point target or backset value.

5.9.4.6 Adjust the spacing of the BioRID's legs so that the centerlines of the knees and ankles are 200 ± 10 mm apart.

5.9.4.7 Adjust the BioRID's feet and/or the adjustable toeboard so that the heels of the dummy's shoes are resting on the simulated vehicle floor and the tips of the shoes are resting on the toeboard 23-27 cm from the intersection of the heel surface and toe board, as measured along the surface of the toe board (Figure 10). Note if it is not possible to achieve the toe position as specified above, the feet should be positioned with the heels of the dummy's shoes resting on the simulated vehicle floor and the tips of the shoes resting on the toeboard keeping the following in mind. The foot position should be set so that no joint of the BioRID leg or foot is at its endstop, the heel of the BioRID is not positioned in the intersection of the heel surface and toe board, and the pelvis location found in step 5.9.4.5 is not altered by the position of the leg and foot.

Figure 10
Proper BioRID Feet Positioning



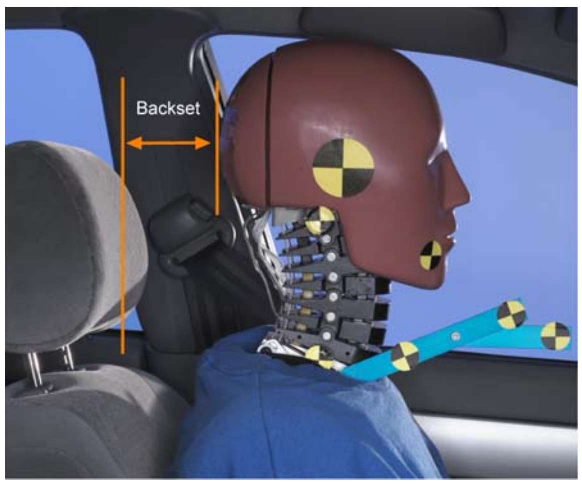
5.9.4.8 Position the BioRID's arms so that the upper arms contact the seatback and the elbows are bent so that the small fingers of both hands contact the top of the vehicle seat cushion with the palms facing the dummy's thighs.

5.9.4.9 Level the instrumentation plane of the head (front/rear and left/right directions) to within ± 1 degree.

5.9.4.10 Measure the BioRID's backset (distance between the front of the head restraint and the back of the dummy's head) as follows:

A) Mark the most rearward point on the centerline of the dummy's skullcap. (NOTE: If using a measuring tape that contours to the shape of the skullcap, then this point is 9.5 cm from the top edge of the skullcap along the midsagittal plane of the skull.)
B) Measure the backset using the same identifiable location on the head restraint that was determined when measuring the HRMD (step 5.9.3.3).
C) The BioRID backset is the horizontal distance between the rearmost point on the dummy's head and the point on the head restraint marked in step 5.9.3.3 (Figure 11).

Figure 11
Measuring BioRID Backset



5.9.4.11 If the BioRID backset is different from the reference backset (step 5.9.3.4) plus 15 ± 5 mm, then do the following:

A) Tip the head fore/aft no more than ± 1 degree from level to meet the backset requirement.
B) If the BioRID backset still cannot be brought closer to the reference backset plus 15 mm, adjust the pelvis angle and H-point position within their respective tolerance bands, then begin with step 5.9.4.4 and adjust the BioRID position accordingly.
C) If the above iterations still do not allow the backset to come within the specified tolerance for backset target and the H-point position is as far forward as the tolerance allows, then move the H-point forward of the allowed position the smallest distance that allows the backset requirement to be met.

5.9.5 BioRID positioning requirements for tests using decelerating sled

The dummy's head, T1 vertebra, and the sled should have the same velocity ± 0.1 m/s at T = 0. The back of the dummy's head and T1 vertebra should be in the same position (± 5 mm) relative to the head restraint at T = 0 as the initial test set-up.

6. BioRID

These tests should be conducted with a BioRID IIg or later revision dummy. The dummy should comply with both spine stature and dynamic response specifications before the test.

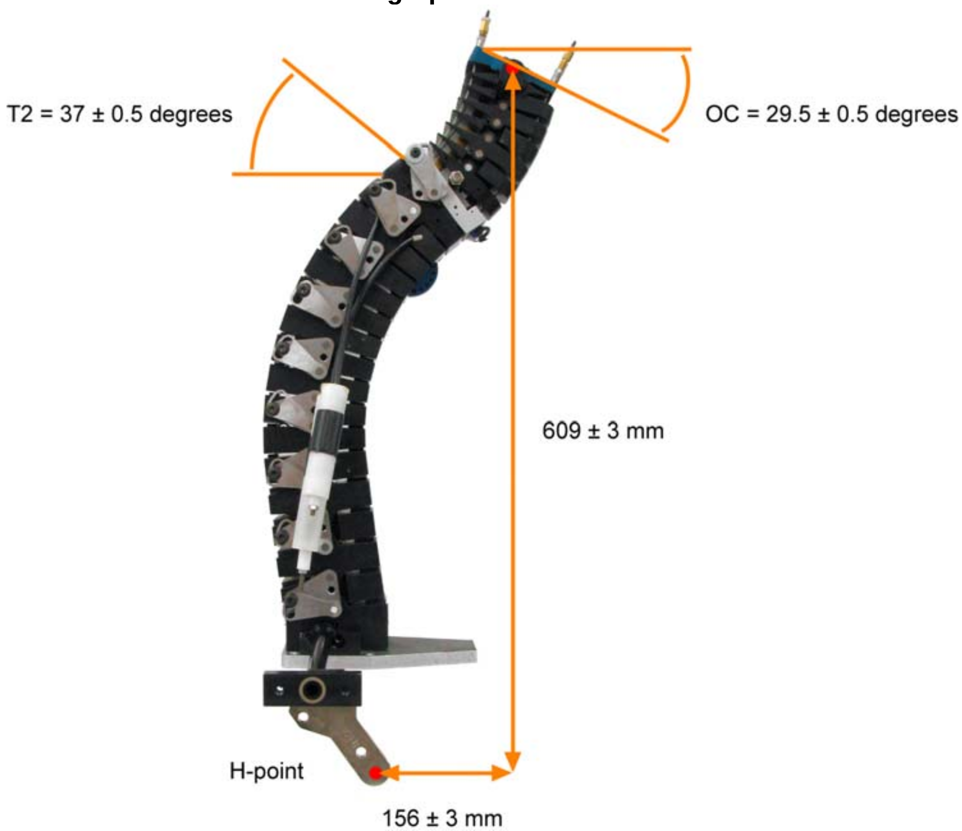
6.1 Spine Curvature Check

With the pelvis adapter plate placed on a level surface with the occipital condyle (OC) angle at 29.5 ± 0.5 degrees, the T2 angle at 37 ± 0.5 degrees, and the neck plate laterally level ± 0.5 degrees, the distance (X) between the H-point and OC pin should be 156 ± 3 mm, and the distance (Z) between the H-point and OC pin should be 609 ± 3 mm (Table 2 and Figure 12).

Table 2
BioRID IIg Spine Curvature Specifications

Measurement	Specification
Angle of occipital interface plate relative to horizontal	29.5 ± 0.5 degrees
Angle of T2 vertebra relative to horizontal	37.0 ± 0.5 degrees
Angle of neck plate (lateral)	0 ± 0.5 degrees
H-point indicator to occipital condyle pin (horizontal)	156 ± 3 mm
H-point indicator to occipital condyle pin (vertical)	609 ± 3 mm

Figure 12
BioRID IIg Spine Curvature Check



6.2 Calibration

The dynamic response of BioRID is checked by attaching the spine, torso, and head to a mini sled that is impacted through foam by a 33.4 kg probe at a velocity of 4.76 ± 0.1 m/s. The specified response of the dummy and detailed test specifications are described in *Test Procedure: Calibration of BioRID II*, available from DentonATD, Inc. Generally, if the dummy's spine curvature changes so that it does not meet the dimensional specifications described in section 6.1, then likely it will no longer meet the dynamic response specifications.

6.3 Clothing

The dummy should be dressed with two pairs of close-fitting, knee-length, spandex (e.g., lycra) pants and two close-fitting, short-sleeved spandex shirts. The under layer of clothes should be worn with the shiny/smooth side of the fabric facing out and the over-clothes with the shiny/smooth side against the underclothes (i.e., dull side facing out). The dummies feet should be shod with size 11 (45 European or 27.9 cm) Oxford-style, hard-soled work shoes (e.g., MIL-S-13192P).

6.4 Instrumentation

The instrumentation required to conduct an RCAR-IIWPG evaluation are listed in Table 3. BioRID IIg includes a loadcell (or structural replacement) at the T1 vertebra; output of this sensor may be recorded at the tester's discretion. In addition, accelerometers may be used in the head, at the C4 vertebra, T8 vertebra, L1 vertebra, and pelvis.

Table 3
BioRID Instrumentation – Required for RCAR-IIWPG Evaluation

Measurement Location	Sensor Type
Back of head	Switch to indicate contact with head restraint
Upper neck	Loadcell (R.A. Denton model 4985J)
T1 vertebra – left side	Acceleration X-direction (e.g., Endevco 7264B-500)
T1 vertebra – right side	Acceleration X-direction (e.g., Endevco 7264B-500)
Sled acceleration	Acceleration X-direction (e.g., Endevco 7264B-500)

7. Data Acquisition and Processing

The measurement data shall be recorded according to ISO 6487 or SAE J211-1. Table 4 specifies the channel frequency classes for each necessary measurement. Measurement data shall be considered for evaluation until the point in time at which the head rebounds from the head restraint or at 300 ms after T = 0, whichever occurs first.

Table 4
Channel Filter Classes for Evaluation Measurements

Evaluation Measurement	Channel Frequency Class (CFC)
Head-to-head restraint contact	None
T1 (vertebra) X-acceleration (left and right)	Class 60
Neck X-force (shear)	Class 1000
Neck Z-force (tension/compression)	Class 1000
Sled acceleration (X)	Class 60
Sled acceleration (X) delta V	Class 180

7.1.1 RCAR-IIWPG test time indexing

To normalize the time index among sled laboratory protocols with different T = 0 trigger levels, the time of the occurrence of the maximum acceleration is used as the reference for indexing time. The procedure is described as follows:

7.1.1.1 Record the X-acceleration of the sled in accordance with SAE J211-1.

7.1.1.2 If necessary, remove any data channel DC bias. Typically, the value of the average measurement over 100 samples of the quiescent data channel signal is subtracted from every test measurement.

7.1.1.3 Filter the sled acceleration to CFC 60 as defined by SAE J211-1.

7.1.1.4 Find the measurement that corresponds to the maximum sled acceleration and note the time it occurs.

7.1.1.5 Subtract 27 ms from the time noted in step 7.1.1.4 and use the resulting difference to re-index the time for all test measurements. If the difference is positive (>0), then measurements recorded at the original T = 0 will now occur before T = 0. If the difference is negative (<0), then measurements recorded at the original T = 0 will now occur after T = 0. The peak sled acceleration (filtered data) should occur at exactly 27 ms.

7.1.2 RCAR-IIWPG variable head contact adjustment

Sled accelerations meeting the specified corridors may have different timing that can lead to differences in head contact times recorded on identical seats tested at different labs. To eliminate variation in head restraint contact times between labs, the recorded head contact time must be adjusted to reflect the contact time that would be expected if the exact target pulse was achieved. The procedure for adjusting recorded head contact time is described as follows:

Note: All data referred to in this section must already be time indexed as described in section 7.1.1. See Appendix B for an example of how to adjust the head contact time.

7.1.2.1 Using the sled filtered acceleration (CFC 180), integrate the data from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace. Convert to m/s by multiplying by 9.81.

7.1.2.2 Find the time in milliseconds at which the recorded sled velocity change reaches 4 m/s and round the value to the next highest number. For example 61.3 ms should round to 62 ms and 61.8 ms should round to 62 ms. An exact value recorded (i.e. 60.0 ms) will not be rounded.

7.1.2.3 Subtract the time recorded in step 7.1.2.2 from 70 ms. Add the difference to the time indexed head contact time from step 7.1.1.5. The resulting value will be the official head contact time used for evaluation.

7.1.3 RCAR-IIWPG calculations and rounding

Round neck forces and head restraint contact time to the nearest whole Newton and millisecond, respectively, and T1 acceleration to the nearest tenth g. Calculations are listed in section 8.3.

8. Evaluation Procedure

8.1 Seat Design Parameters

There are two seat design parameters: time to head restraint contact and maximum T1 acceleration.

8.1.1 Time to head restraint contact

Time to head restraint contact must be less than 70 ms to pass this requirement. This limit reflects head restraint contact times achieved by seats with active head restraint designs and acceptable or better static geometry. Time to head restraint contact is the time after the beginning of the sled test (T = 0) that the dummy's head contacts the head restraint and maintains that contact for at least 40 ms. Contact is indicated by an electrical contact switch attached to either the dummy's head or the head restraint.

Note: Minor breaks in time to head restraint contact (up to 1 ms) are permissible if it can be proven that these are due to poor electrical contacts, however these must be investigated with reference to the film to ascertain whether the breaks in contact are not due to biomechanical phenomena such as ATD ramping, head restraint or seatback collapse, or "bounce" of the head during non-structural contact with the head restraint.

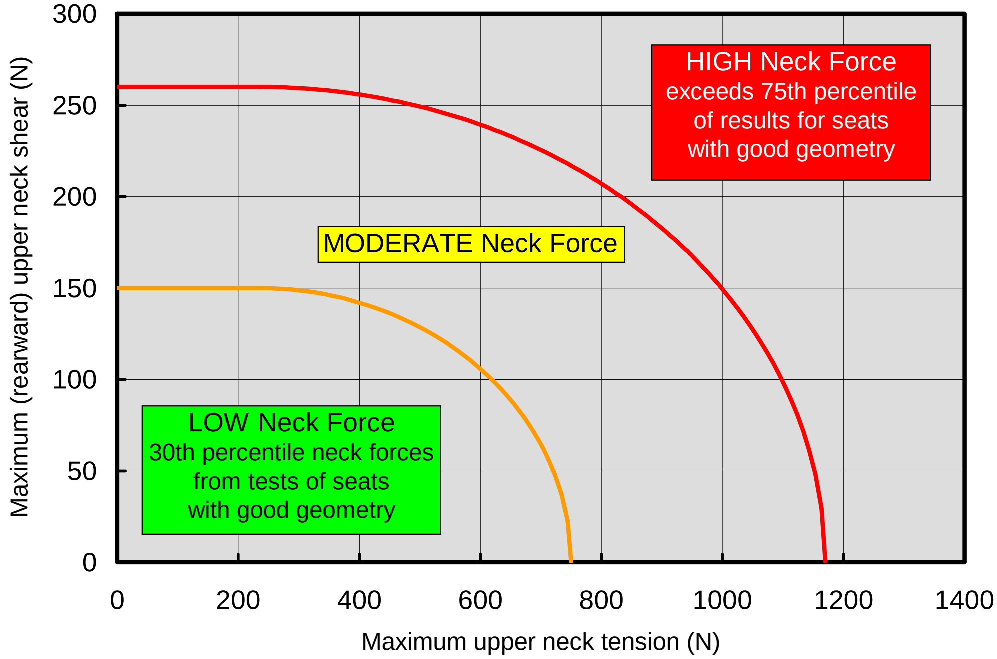
8.1.2 T1 acceleration

The maximum T1 forward acceleration must be less than 9.5 g to pass this requirement. This limit is based on the maximum T1 accelerations recorded in tests of Volvo Whiplash Injury Prevention System (WHIPS) seats, which include energy-absorbing/force-limiting seatback hinges. Maximum T1 forward acceleration is the average of the highest acceleration recorded by an SAE J211-1-compliant (CFC 60 Hz) and horizontally oriented accelerometer attached to BioRID's T1 vertebral unit on both left and right sides anytime between the beginning of the test and the time the dummy's head first leaves contact with the head restraint at the beginning of the rebound phase of the simulated crash.

8.2 Test Dummy Response Parameters

Neck shear and tension forces are measured at the connection between the dummy's cervical spine and head using an SAE J211-1-compliant (CFC 1000) load cell. The measured neck forces will be classified as low, moderate, or high depending on which region of Figure 13 the data point representing the maximum neck tension and maximum rearward neck shear force lies. These regions are bounded by curves representing the 30th and 75th percentiles of the joint probability distribution of neck shear and neck tension forces among tested seats with good geometry. Thus, low neck forces mean that measured forces are as low or lower than 30 percent of seats with good geometry, when shear and tension are considered jointly; high neck forces mean that measured forces are higher than 75 percent of seats with good geometry. Although these criteria are based on 2004 model year seats, they will be maintained for the foreseeable future. The goal was to establish force limits that were achievable with current design knowledge.

Figure 13
Rating for the Joint Distribution, Maximum Neck Tension and Maximum Neck Shear



8.3 Procedure for Evaluating Neck Shear and Tension

The critical values for neck shear and tension were based on 102 seats with good static geometry ratings. In dynamic tests of these seats, peak neck shear (F_X) ranged from 0 to 315 N and peak neck tension (F_Z) ranged from 234 to 1365 N. For each test, neck tension values were standardized by subtracting 234 (the minimum) and dividing by 1131 (the range). Neck shear values were similarly standardized by dividing by 315. Thus, the standardized values for both neck shear and tension were between 0 and 1.

Vector sums of the standardized shear and tension values were calculated. Note that the vector sum has no intended biomechanical interpretation. Rather it has a statistical interpretation, indicating how extreme the forces were for a particular seat when shear and tension were considered jointly. In this joint statistical distribution, deviations in the standardized scores for tension and shear are weighted equally in the absence of clear, scientific evidence that one is more important than the other for neck whiplash injury.

Low neck forces are defined as those with vector sums less than or equal to the 30th percentile vector sum for seats with good geometry ($\leq$0.45); high neck forces were defined as those with vector sums exceeding the 75th percentile sum for seats with good geometry (>0.825). The remaining vectors were termed moderate forces.

These vector sums form quarter-circle boundaries on the bivariate distribution of standardized shear and tension forces, which can be written as follows:

$$\{F_X / 315\}^2 + \{(F_Z - 234) / 1131\}^2 < \{0.450\}^2 \text{ for low forces}$$

and

$$\{F_X / 315\}^2 + \{(F_Z - 234) / 1131\}^2 > \{0.825\}^2 \text{ for high forces.}$$

Alternatively, the boundaries can also be defined on the unstandardized bivariate distribution of neck shear and tension forces (see Figure 13), as follows:

$F_X = 142$ for $F_Z \leq 234$
$= 142\ \mathrm{SQRT}\{1 - (F_Z - 234)^2 / (509)^2\}$ for $234 < F_Z < 743$
$= 0$ for $F_Z \geq 743$

and

$F_X = 260$ for $F_Z \leq 234$
$= 260\ \mathrm{SQRT}\{1 - (F_Z - 234)^2 / (933)^2\}$ for $234 < F_Z < 1167$
$= 0$ for $F_Z \geq 1167$.

For computational ease, intercept values of these curves were rounded up, yielding:

$F_X = 150$ for $F_Z \leq 234$
$= 150\ \mathrm{SQRT}\{1 - (F_Z - 234)^2 / (516)^2\}$ for $234 < F_Z < 750$
$= 0$ for $F_Z \geq 750$

and

$F_X = 260$ for $F_Z \leq 234$
$= 260\ \mathrm{SQRT}\{1 - (F_Z - 234)^2 / (936)^2\}$ for $234 < F_Z < 1170$
$= 0$ for $F_Z \geq 1170$.

8.4 Dynamic Rating

The dynamic rating for dynamically tested seats will be good, acceptable or marginal for those seats registering low, moderate, or high neck forces, respectively, and also meeting one of the two seat design parameter requirements: T1 X-acceleration ≤9.5 g or time to head restraint contact ≤70 ms. Seats failing to meet one of the seat design parameters will be rated good, acceptable, or marginal depending on whether the neck forces were classified as low, moderate, or high. Similarly, seats failing to meet both seat design requirements will be rated acceptable, marginal, or poor. Table 5 summarizes the requirements for dynamic ratings at each level.

Table 5
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

8.5 Overall Rating

The static geometry rating and the dynamic rating are combined as shown in Table 6 to establish the overall rating for the seat. A seat with a static rating of Acceptable due to backset and not height will earn a Good overall rating if the dynamic rating is Good. This exception was made to give credit to seats with geometry that is tall enough to support an averaged size male and when dynamically tested, can compensate for a larger backset.

Table 6
Formulation of Overall Rating

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

9. References

Farmer, C.M.; Wells, J.K.; and Lund, A.K. 2003. Effects of head restraint and seat redesign on neck injury risk in rear-end crashes. *Traffic Injury Prevention* 4:83-90.

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10. Additional References

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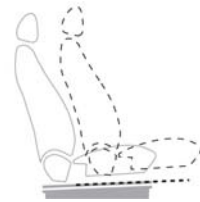
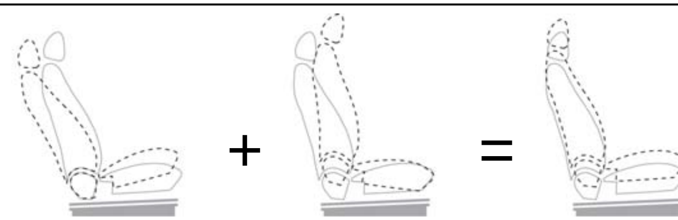
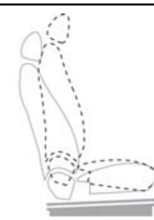
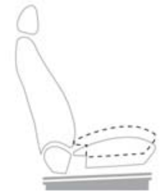
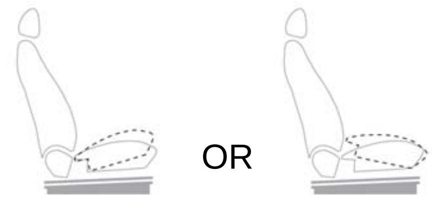
Appendix A – Seat Adjustment Definitions

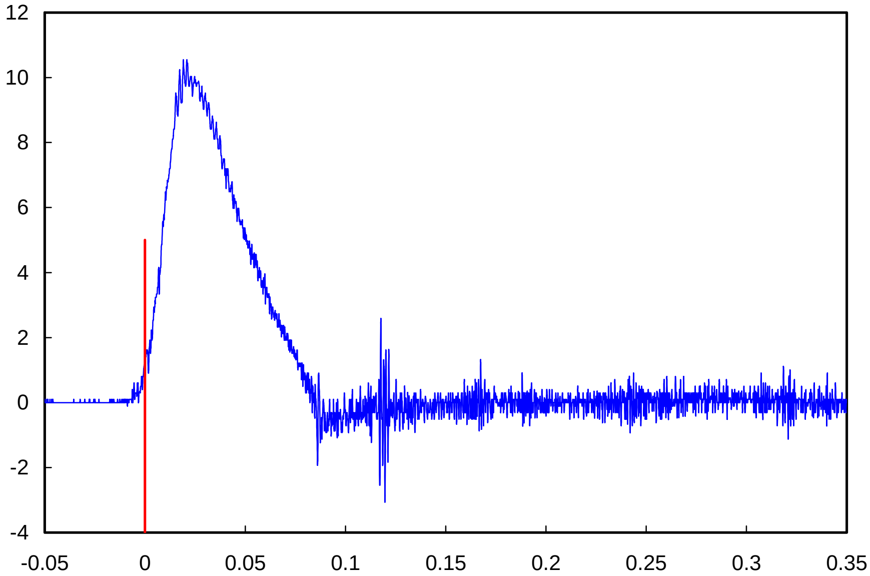
Definition	Image	Additional Images
Seat Track – An adjustment that moves the entire seat (seat cushion and seatback) in the fore and aft directions.		
Seatback – An adjustment that rotates the entire seatback, independently of the seat cushion, about a pivot at the seatback/seat cushion joint, therefore, changing the angle of the seatback relative to the seat cushion.		
Seat Height – An adjustment that moves the entire seat vertically (seat cushion and seatback in unison). This adjustment must keep the angle of the seat cushion the nearly the same relative to the ground. This can be one control (two-way) that moves the whole seat in unison or a combination of controls (four-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion nearly the same relative to the ground.	 Two-way (one control)	 Four-way (toggle or multiple knobs) NOTE: It is not possible to have four-way seat height AND seat tilt
Seat Tilt – An adjustment that rotates the entire seat (seat cushion and seatback in unison). This adjustment rotates a seat in such a way to significantly change the angle of the seat cushion, relative to ground, from its full-down position. This adjustment can move either the front or rear of the seat in order to change the angle.		 OR 

Definition	Image	Additional Images
Seat Cushion Height – An adjustment that moves the seat cushion vertically, independent of the seatback, while keeping angle of the seat cushion nearly the same relative to the ground. This can be one control (two-way) that moves the whole seat cushion in unison or a combination of controls (four-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion nearly the same relative to the ground.	 Two-way (one control)	 Four-way (toggle or multiple knobs) NOTE: It is not possible to have four-way seat cushion height AND seat cushion tilt
Seat Cushion Tilt – An adjustment that moves the seat cushion, independent of the seatback, in such a way to significantly change the angle of the seat cushion, relative to ground, from its full-down position. This adjustment can move either the front or rear of the seat cushion in order to change the angle.		
Lumbar Support – An adjustment that causes the lower center portion of the seatback to protrude in order to provide support to the lumbar section of an occupant's spine.		
Upper Seatback – An adjustment that rotates only the upper portion of the seatback about a pivot point in the seatback. This adjustment will change the angle of the upper seatback relative to the lower portion of the seatback.		

Definition	Image	Additional Images
Cushion Extension – An adjustment that moves or extends a portion of the seat cushion forward so that the overall length of the cushion can be increased.		
Side Bolsters – An adjustment the moves the sides of the seatback or seat cushion so that the contour of the seat can be changed.		
Head Restraint Height – An adjustment that moves the head restraint vertically.		
Head Restraint Tilt – An adjustment that moves the head restraint horizontally.		 OR  OR 

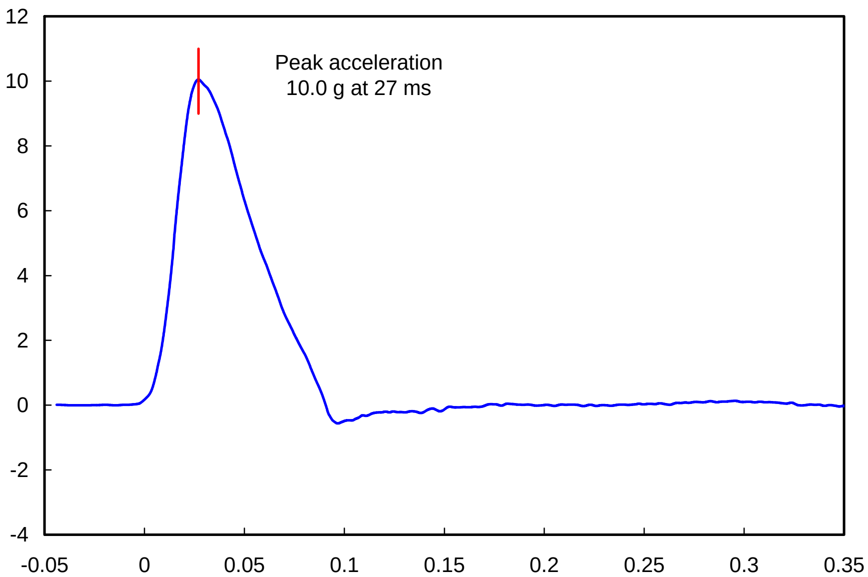
Appendix B – Example Head Contact Adjustment

Step 1. Record sled acceleration.

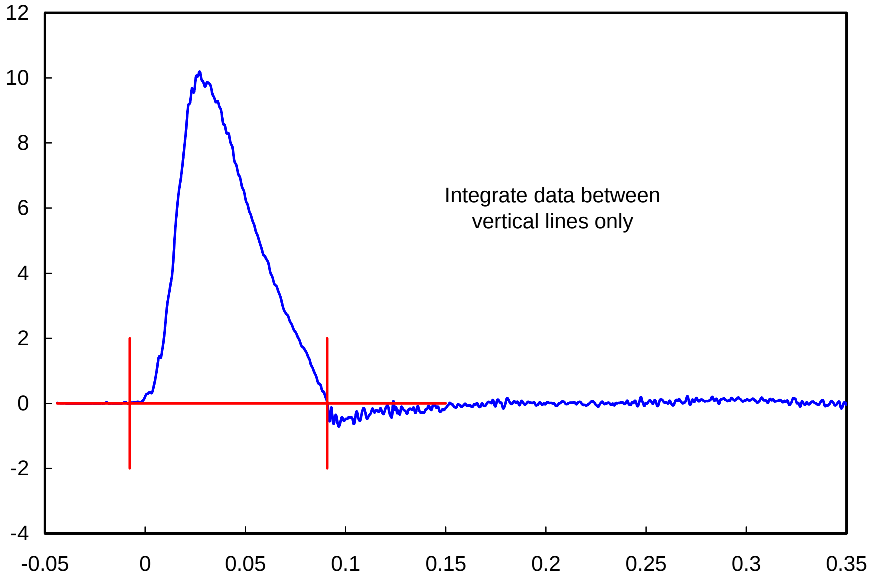


Step 2. Remove signal bias.

Step 3. Filter sled acceleration to CFC 60 to determine time shift and time shift all data (including head contact time).

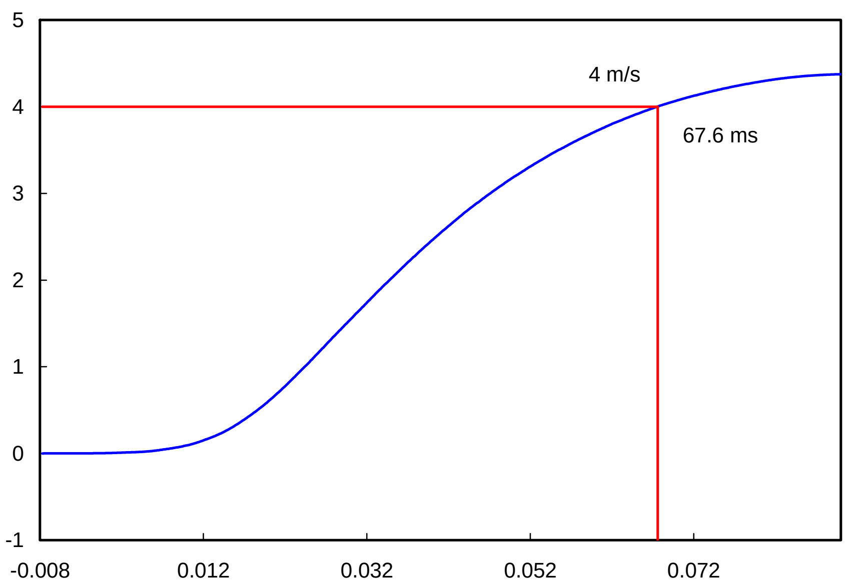


Step 4. Filter sled acceleration data to CFC 180. Integrate from the last time the acceleration passes through zero at the beginning of the trace until the first time the acceleration passes through zero at the end of the trace.



Step 5. Convert from g to m/s by multiplying by 9.81.

Step 6. Find the time at which the velocity change reaches 4 m/s and round the value to the next highest number. For example, 61.3 ms should round to 62 ms and 61.8 ms should round to 62 ms. An exact value recorded (e.g., 60.0 ms) will not be rounded.



Step 7. Subtract the time recorded in step 6 from 70 ms. Add the difference to the time indexed head contact time from step 3. The resulting value will be the official head contact time (HCT) used for evaluation.