Special issue: head restraints

STATUS REPORT

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

Vol. 32, No. 4, April 12, 1997

This is a head rest. This isn't.

Napping on a sofa makes good use of a head rest, but the padded thing behind you in your car is *not* a head rest. It has been a safety requirement since 1969.

It's a head restraint, but motorists generally don't think of it as a safety essential like a lap/shoulder belt. The head restraints in most cars are adjustable, but even people who buckle up every time they get in a car seldom, if ever, adjust the gizmos behind their heads.

Part of the problem is confusion about whether head restraints are for comfort or for safety. Another problem is that the head restraints in most cars are poorly designed. They cannot be positioned high enough and close enough to the backs of many people's heads, which is where they need to be to provide protection in rear-end crashes. Come to think of it, they might as well be head rests.

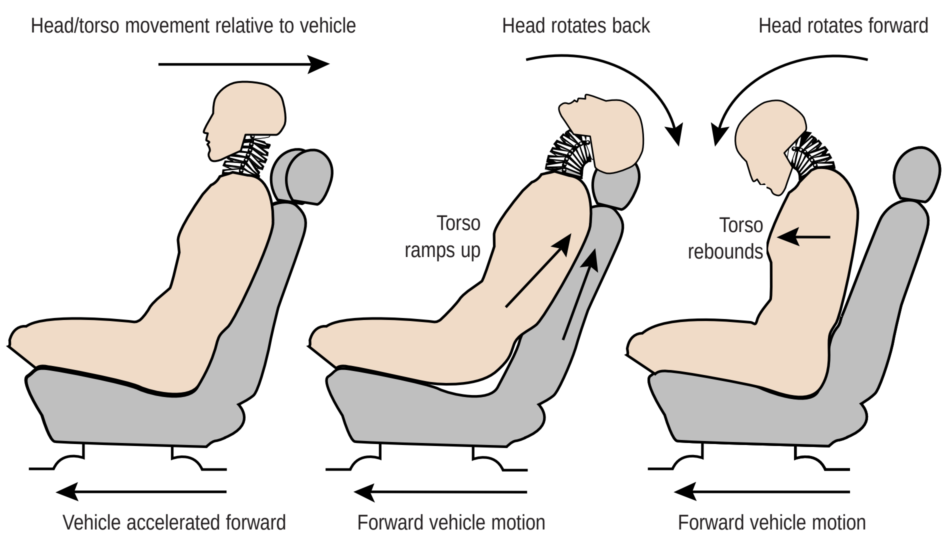
In the most comprehensive evaluation of head restraint designs in 1997 models, Institute researchers found that more than half of the models measured have poor head restraints (see page 4). Fewer than 3 percent have head restraint designs with good geometry. There hasn't been much improvement since the last time Institute researchers evaluated head restraint geometry in 1995 models (see *Status Report*, Vol. 30, No. 8, Sept. 16, 1995).

But the status quo may be changing. New designs and tougher standards could mean the end of head restraints that don't protect people because they cannot be positioned behind and/or close enough to many occupants' heads.

"This issue finally is making it onto the radar screens of auto and equipment manufacturers," says Institute President Brian O'Neill. "We're hopeful this new attention will translate into better designs so head restraints will have the potential to prevent many neck injuries in rear-end crashes."

From a geometric perspective, a good head restraint is one that's behind and close to the backs of the heads of seated occupants of varying heights. And the occupants shouldn't have to remember to adjust their head restraints, because any feature that requires manual adjustment often is misused. The best head restraints in cars today are of two kinds. They're either fixed in a position that puts them behind and close to most people's heads, or they adjust automatically to such positions.

Especially poor designs are adjustable restraints that, in their lowest positions, couldn't protect most people and, at maximum height, still aren't high enough for many people. Some of these poorly designed restraints don't even lock in the full vertical, or "up," position so even when they're adjusted, they can be pushed down in a crash.



The head/neck motion of whiplash begins when a vehicle is accelerated forward by an impact. The torso moves forward after compressing the seat back, but the head lags behind. Then the head rotates rearward, bending or extending the neck back in an extension-rotation motion while the torso ramps up the seat back. Next the head and torso rebound forward. During this rebound, the head rotates forward, causing a flexed (forward-bent) neck posture before the body settles back in the seat.

What will it take? Researchers around the world point to several essential elements. The first is geometry. A head restraint must be in a position so it can limit differential motion between the head and torso in a rear-end collision. Second is the vehicle seat, because its stiffness characteristics also influence relative head/torso motion. Ultimately, the mechanisms that cause neck injuries need to be better understood. This will enable researchers to develop test procedures and injury measures to help optimize designs.

Good head restraint geometry is important, but it isn't the only thing. It doesn't guarantee good dynamic performance. For good performance in a crash, restraints and vehicle seats must work together. In particular, if the top part of a seat is too stiff or too elastic, the relative motion between the head and torso can increase.

Injury mechanisms: Because the mechanisms of whiplash aren't fully understood — and because the necks of current test dummies aren't adequate to evaluate head/torso movement in rear-end crashes at slow speeds — it isn't feasible yet to reliably evaluate the dynamic performance of seat backs and head restraints together. It's known that differential head and torso motion is harmful, but it isn't known just how much, or what type, of motion is most likely to injure people. And researchers still must develop a dummy neck to accurately represent human head/torso movement. (Hybrid III dummy necks are too stiff.)

Whiplash is defined as an "acceleration-deceleration mechanism of energy transfer to the neck" by experts known as the Quebec task force in their extensive review of neck injury research. The biomechanics of head/neck/torso motion that produce whiplash can be described in stages. But precisely how this motion causes injury still is the subject of debate.

The injury mechanism originally was thought to be neck hyperextension alone. But some researchers describe neck injury mechanisms independent of hyperextension. One theory suggests a compression-tension cycle during which an occupant's neck shortens as the torso ramps up the seat back and then lengthens during rebound. Other researchers have theorized that rapidly changing fluid pressure in the spinal canal very early in a crash, when an occupant's head movement lags behind the body, may be causing injuries.

So far, progress toward understanding whiplash has relied heavily on tests in which volunteers are subjected to forces similar to those experienced in rear-end crashes at slow speeds. Drivers instrumented to measure head and torso accelerations are asked about subjective pain experienced during the tests. Head and neck motion is studied from high-speed film of the tests.

Work of this type by the German insurer, Allianz, shows that a wider backset — the horizontal distance between the back of an occupant's head and the front of a restraint — allows more rearward movement of the head relative to the body even before the neck starts to extend. Swedish research with animals shows that such movement can cause nerve tissue damage that's not detectable through the usual diagnostic procedures applied to humans.

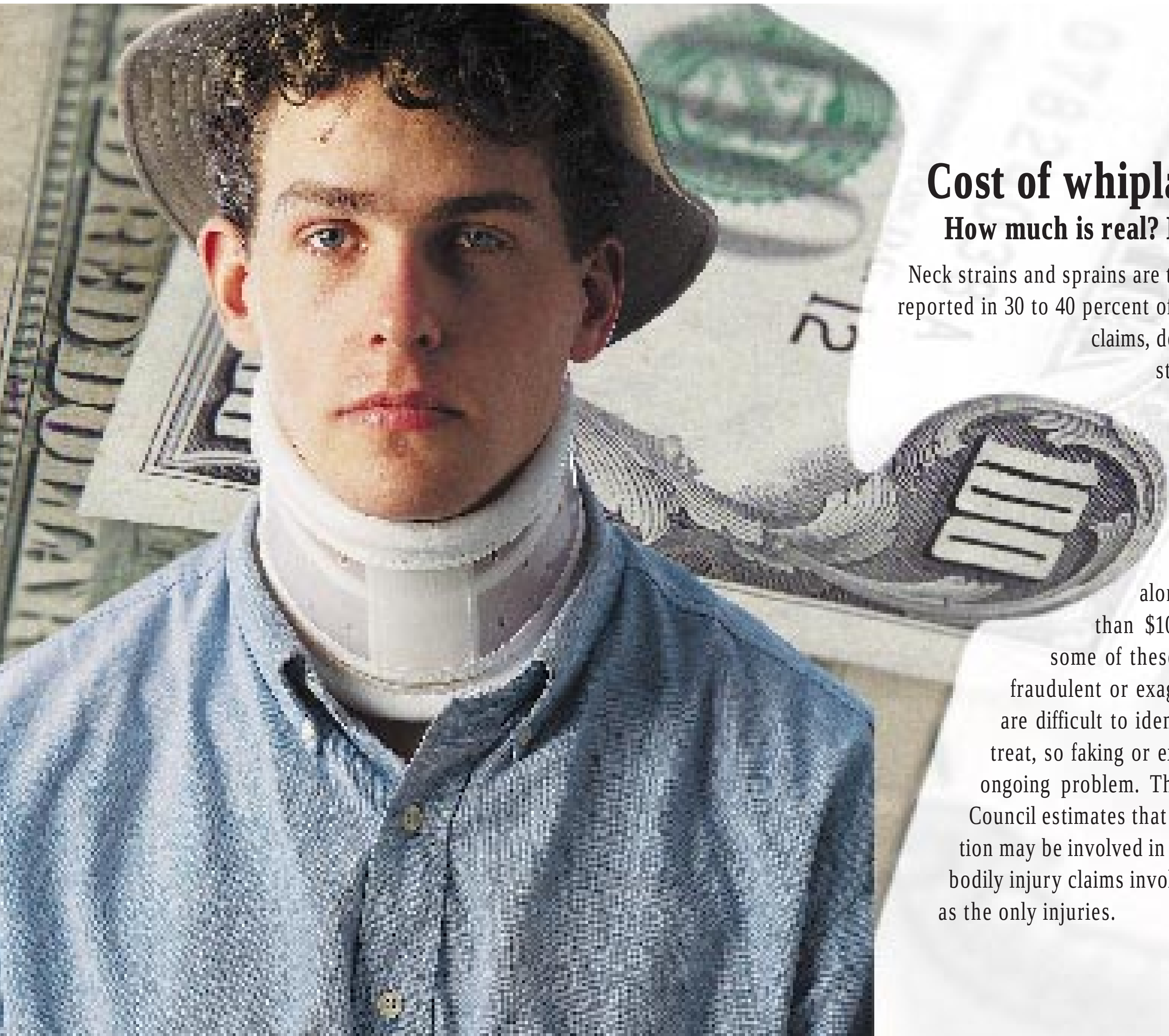
Although none of the volunteers in the Allianz tests were injured, another German study of volunteers reports complaints of pain associated with backsets of 8 centimeters or more. One person with a backset of 13 centimeters complained of "symptoms of cervical distortion" for about two weeks.

Allianz tests also confirm the importance of locks on adjustable head restraints. One restraint without a lock repeatedly was pushed down by volunteers' heads in tests at very slow speeds, precluding tests at somewhat higher speeds.

To study the influence of vehicle structure, Swedish researchers swapped the seats and head restraints in same-size cars with widely differing on-the-road neck injury rates and then measured the forces in rear-end collisions. This work indicates that differences in the forces on front-seat occupants were due primarily to differences among seats and restraints, not structural differences.

General Motors researchers estimated overall neck injury potential by conducting sled tests simulating rear-end impacts using a Hybrid III dummy to assess injury risk. The head restraint was adjusted to different positions, and neck injury risk was assumed proportional to the neck extension angle change. The lowest (best) angle occurred with a high, close head restraint. Increasing the gap or reducing the height resulted in worse extension angles.

U.S. standard: A 1996 report from the National Highway Traffic Safety Administration (NHTSA) poses questions about current head restraint requirements including whether they should be changed, integrated with seating system requirements, and/or harmonized with the rules in Europe. These issues are a long time coming. The U.S. standard, in effect since 1969, is basically a geometric requirement that restraints at full extension be at least 27.5 inches above the seating reference point, *(cont'd on p.6)*



Cost of whiplash injuries

How much is real? How much fraud?

Neck strains and sprains are the most serious injury reported in 30 to 40 percent of automobile insurance claims, depending on the type of state insurance system. This is the finding of the Insurance Research Council. Projections from State Farm Insurance indicate that such claims alone translate into more than $10 billion annually. But some of these insurance claims are fraudulent or exaggerated. Neck injuries are difficult to identify objectively and to treat, so faking or exaggerating them is an ongoing problem. The Insurance Research Council estimates that fraud and/or exaggeration may be involved in nearly 40 percent of all bodily injury claims involving sprains or strains as the only injuries.

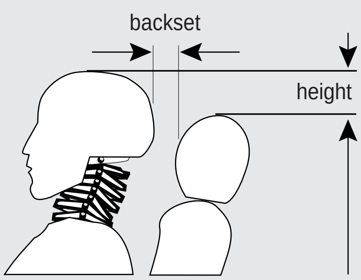
How bad are they?

Only five passenger vehicles have head restraints with good geometry. More than half of the restraints are poor.

Institute researchers evaluated head restraint geometry in more than 200 passenger vehicles, all 1997 models. Measuring the geometry of all seat options in each vehicle model they could find in dealer showrooms, the researchers found fewer than 3 percent with good geometry (see table). "A sad showing," says Institute President Brian O'Neill. "This issue hasn't been a priority among automakers. It's a situation that needs to change because good geometry is the fundamental first step without which you simply cannot design a good head restraint."

In reading the table of head restraint ratings, it's important to note that different seat options in the same model can result in more than one rating for the same vehicle. If the ratings for all seat options are the same, only one rating is shown.

The Institute's head restraint evaluations are based on two criteria. The first is the distance down from the top of an average-size male's head to the top of a restraint. A head restraint should be at least as high as the head's center of gravity, or about 9 centimeters (3.5 inches) below the top. The second criterion is the distance from the back of an average-size male's head to the front of the restraint. This distance, called backset, should be small — the smaller the better. Backsets of more than 10 centimeters (about 4 inches) have been associated with increased symptoms of neck injury in crashes.

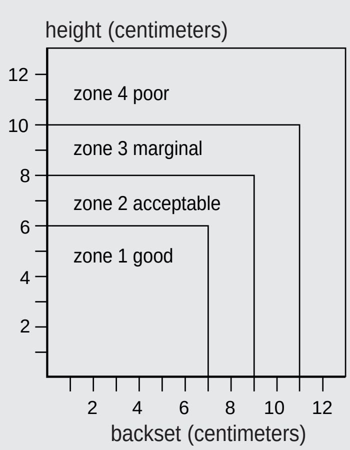


Two criteria determine good head restraint geometry.

Height: ideally, as high as the top of the head

Backset: as little distance as possible between the back of the head and the front of the restraint

Each restraint is classified into one of four geometric zones according to height and backset.



Each head restraint is classified into one of four geometric zones defined by its height and backset measures. The rating for a fixed restraint is straightforward — the zone into which its height and backset place it also defines its rating.

The rating for a head restraint that adjusts in height and/or backset depends on whether it locks in the adjusted position. If it doesn't, its rating is defined by the zone for height and backset in the "down" and/or rear position. If an adjustable restraint does lock, its height and backset are measured in two positions — the "down" one and the most favorable locked position. The final rating is the better of these except that if the adjusted rating is used, it's downgraded a category because so few motorists adjust their restraints.

Some car models from BMW and Mercedes have restraints that adjust automatically. These are evaluated in the position to which they adjust for an average-size male, and the ratings aren't downgraded.

Passenger cars

Model	Rating
Acura CL	poor
Acura Integra	acceptable
Acura RL	marginal
Acura TL	poor
Audi A4, comfort seat	poor
Audi A4, sport seat	not measured
Audi A6	poor
Audi A8	poor
Audi Cabriolet, comfort seat	poor
Audi Cabriolet, GIS sport seat	not measured
BMW 3 series	poor
BMW 5 series	marginal
BMW 5 series, midback adjustment	acceptable
BMW 7 series, midback adjustment	acceptable
BMW 8 series, auto adjust	marginal
BMW Z3	poor
Buick Century	poor
Buick LeSabre	poor
Buick Park Avenue, 55/45 split bench	poor
Buick Park Avenue, bucket seat	not measured
Buick Riviera, bucket seat	poor
Buick Riviera, 55/45 split bench seat	not measured
Buick Skylark, 55/45 split bench seat	poor
Buick Skylark, bucket seat	not measured

Legend

- good
- acceptable
- marginal
- poor
- not measured

Height and backset were measured with the angle of the torso at about 25 degrees, a typical seat back angle. Many vehicles have more than one seat option, and if seat differences affect the head restraint ratings, more than one rating is shown. But if ratings for all seat options in a model are the same, then only one rating is shown. As indicated, some seat options couldn't be found in showrooms to measure.

- Cadillac Catera
- Cadillac Deville
- Cadillac Eldorado
- Cadillac Seville

- Chevrolet Astro (fixed)
- Chevrolet Astro (adjustable)
- Chevrolet Camaro
- Chevrolet Cavalier
- Chevrolet Lumina sedan
- Chevrolet Malibu
- Chevrolet Monte Carlo
- Chevrolet Venture

- Chrysler Cirrus
- Chrysler Concorde
- Chrysler LHS, bucket seat
- Chrysler LHS, 50/50 split bench
- Chrysler Sebring coupe
- Chrysler Sebring convertible
- Chrysler Town & Country

- Dodge Avenger
- Dodge Caravan/Grand Caravan
- Dodge Intrepid
- Dodge Neon
- Dodge Stratus

- Eagle Talon
- Eagle Vision

- Ford Aerostar
- Ford Aspire
- Ford Contour, bucket seat
- Ford Contour, sport bucket seat
- Ford Crown Victoria
- Ford Escort
- Ford Mustang
- Ford Probe
- Ford Taurus
- Ford Thunderbird
- Ford Windstar

- Geo Metro
- Geo Prizm

- GMC Safari

- Honda Accord, cloth seat
- Honda Accord, leather seat
- Honda Civic
- Honda Civic Del Sol
- Honda Odyssey
- Honda Prelude

- Hyundai Accent
- Hyundai Elantra
- Hyundai Sonata
- Hyundai Tiburon

- Infiniti I30
- Infiniti J30
- Infiniti Q45

- Jaguar VDP
- Jaguar XJ6
- Jaguar XJR
- Jaguar XK8

- Kia Sephia

- Lexus ES 300
- Lexus LS 400
- Lexus SC 300

- Lincoln Continental
- Lincoln Mark VIII
- Lincoln Town Car

- Mazda 626
- Mazda Millenia, manual seat
- Mazda Millenia, power seat
- Mazda MPV
- Mazda MX-5 Miata
- Mazda Protege

- Mercedes C class
- Mercedes C class, multicontour seat
- Mercedes E class, auto adjust
- Mercedes E class, multicontour seat
- Mercedes S class
- Mercedes S class, multicontour seat
- Mercedes SL class

- Mercury Cougar XR7
- Mercury Grand Marquis
- Mercury Mystique
- Mercury Sable
- Mercury Tracer
- Mercury Villager

- Mitsubishi 3000 GT
- Mitsubishi Diamante
- Mitsubishi Eclipse
- Mitsubishi Eclipse, spyder seat
- Mitsubishi Galant
- Mitsubishi Mirage (adjustable)
- Mitsubishi Mirage (fixed)

- Nissan 200 SX
- Nissan 240 SX
- Nissan Altima
- Nissan Maxima
- Nissan Quest
- Nissan Sentra

- Oldsmobile Achieva
- Oldsmobile Aurora
- Oldsmobile Cutlass
- Oldsmobile Cutlass Supreme
- Oldsmobile Eighty-Eight
- Oldsmobile LSS
- Oldsmobile Regency
- Oldsmobile Silhouette

- Plymouth Breeze
- Plymouth Neon
- Plymouth Voyager/Grand Voyager

- Pontiac Bonneville
- Pontiac Firebird
- Pontiac Grand Am, bucket seat
- Pontiac Grand Am, other seat types
- Pontiac Grand Prix, sport bucket seat
- Pontiac Grand Prix, 45/55 split bench
- Pontiac Sunfire
- Pontiac Trans Sport

- Porsche 911 Carrera
- Porsche 911, sport bucket seat
- Porsche Boxster

- Saab 900
- Saab 9000

- Saturn SC1
- Saturn SC2
- Saturn SL1
- Saturn SL2
- Saturn SW1
- Saturn SW2

- Subaru Impreza coupe
- Subaru Impreza Outback
- Subaru Legacy

- Toyota Avalon
- Toyota Camry
- Toyota Celica
- Toyota Corolla
- Toyota Paseo
- Toyota Previa, bucket seat
- Toyota Previa, captain chair
- Toyota Supra
- Toyota Tercel

- Volkswagen Cabrio
- Volkswagen Golf
- Volkswagen Jetta
- Volkswagen Passat

- Volvo 850
- Volvo 960

Pickup trucks

- Chevrolet C/K series
- Chevrolet S/T series

- Dodge Dakota
- Dodge Ram pickup

- Ford F series
- Ford Ranger, straight bench seat
- Ford Ranger, other seat types

- GMC Sierra
- GMC Sierra, bucket seat
- GMC Sonoma

- Mazda B-series, straight bench seat
- Mazda B-series, 60/40 split bench
- Mazda B-series, sport bucket seat

- Nissan pickup, straight bench seat
- Nissan pickup SE, bucket seat
- Nissan pickup SE, sport bucket seat
- Nissan pickup XE, bucket seat

- Toyota T100, sport seat
- Toyota T100, 60/40 split bench
- Toyota T100, straight bench seat
- Toyota Tacoma, bucket seat
- Toyota Tacoma, sport bucket seat
- Toyota Tacoma, straight bench seat
- Toyota Tacoma, 60/40 split bench

Utility vehicles

- Chevrolet Blazer
- Chevrolet Suburban, bucket seat
- Chevrolet Suburban, other seat types
- Chevrolet Tahoe, high-back bucket seat
- Chevrolet Tahoe, low-back bucket seat
- Chevrolet Tahoe, 60/40 split bench

- Ford Expedition
- Ford Explorer

- GMC Jimmy, bucket seat
- GMC Jimmy, 60/40 split bench
- GMC Suburban
- GMC Suburban, straight bench seat
- GMC Yukon, bucket seat
- GMC Yukon, other seat types

- Geo Tracker

- Honda CR-V
- Honda Passport

- Infiniti QX4

- Isuzu Rodeo
- Isuzu Trooper

- Jeep Cherokee
- Jeep Grand Cherokee
- Jeep Wrangler

- Kia Sportage

- Land Rover Discovery, adjustable
- Land Rover Discovery, fixed
- Land Rover Range Rover

- Lexus LX 450

- Mercury Mountaineer

- Mitsubishi Montero
- Mitsubishi Montero Sport

- Nissan Pathfinder

- Oldsmobile Bravada

- Suzuki Sidekick, bucket seat
- Suzuki Sidekick, sport bucket seat
- Suzuki X-90

- Toyota 4Runner, sport bucket seat
- Toyota 4Runner, other seat types
- Toyota Land Cruiser
- Toyota RAV4

Large vans

- Chevrolet Express
- Chevrolet van

- Dodge Ram van

- Ford Econoline

- GMC Savana

Measuring Device: The head-form device Institute researchers use to evaluate head restraint designs attaches to an H-point machine representing an occupant to provide accurate and repeatable measurements of restraint height and backset. The growing customer list for this device, marketed by the Insurance Corporation of British Columbia, indicates increasing interest in head restraint geometry. Customers besides the Institute include not only government entities like Transport Canada, England's Transport Research Laboratory, and Australia's Roads and Traffic Authority but also BMW of North America, Toyota, First Technology Safety Systems, and Lear Corporation.

(cont'd from p.3) which is just in front of, and above, where the seat and seat back meet.

The first problem with this is that most motorists leave adjustable restraints in the "down" position. Even if they did adjust their restraints, nothing requires the devices to lock in position. And even if they did lock, the required minimum height in the "up" position isn't as high as an average male head's center of gravity. Finally, the standard doesn't address the horizontal distance between a head restraint and the back of the head.

A 1974 NHTSA proposal to impose a 31-inch minimum height for driver head restraints wasn't adopted. The agency also proposed consolidating standards for seats and head restraints to improve overall crashworthiness, but this idea was dropped.

NHTSA's new report revisits these proposals and covers some new ground including recent research on whiplash injury mechanisms, the Institute's critical evaluation of head restraints in 1995 vehicles, and the range of innovative head restraint designs in development (see page 7). And the agency is taking another look at seating system requirements, which could affect the head restraint standard. For example, NHTSA studies by University of Virginia researchers focus on how seat design can influence dummy kinematics. One goal would be to decrease ramping, or occupant movement up the seat back in a crash, which worsens head position in relation to the restraint.

Worldwide harmonization: Under the present European standard, fixed head restraints have to be at least 29.5 inches high. Adjustable ones have to be at least this high in the middle of the adjustment range, and they may be no lower than 27.5 inches.

These requirements are scheduled for an upgrade. Front-seat head restraints will have to be at least 31.5 inches high if they're fixed, and adjustable restraints will have to be at least this high at mid-range. Minimum heights at all front and rear seating positions will be 29.5 inches. Both present and proposed requirements are more demanding than the U.S. standard, but neither European nor U.S. rules include any backset or locking requirements.

"NHTSA is focusing on harmonization issues," says James Hackney, director of the agency's Office of Crashworthiness Standards, but automakers speak of this only broadly. Association of International Automobile Manufacturers safety spokesman, George Parker, says "generally speaking, we are for harmonization and no lowering of safety," but he has no other comment now.

Resting your head isn't the same as restraining it

The American Automobile Manufacturers Association's director of safety and international harmonization, Vann Wilber, says the head restraint standard presents "an opportunity for harmonization." He notes general agreement on front-seat restraint requirements but says his members are less sure about the mounting heights for rear-seat restraints specified by the European standard. Such heights, he says, could cause "visibility problems."

Asked about the absence of a backset requirement in Europe, Wilber says it makes sense to agree on current rules first and then seek consensus on further refinements. His group is working on a head restraint proposal that could be ready in about a month, but it could be delayed waiting for NHTSA's promised release of procedures for fast-track harmonization.

Head restraint design: what's new now and what's just around the corner

Head restraint designs may be about to change for the better. The Institute has surveyed what's new and what may be in cars of the future.

The improvements needn't be complicated. They could be as simple as, for example, adding locks to adjustable head restraints so they won't be pushed down in crashes.

Or improvements may be more sophisticated. Both Mercedes and BMW offer head restraints that position themselves automatically based on up-and-down or forward-and-back seat adjustments. As someone who's taller positions the Mercedes seat rearward, the head restraint rises. It lowers as the seat moves forward for a shorter driver. In the BMW, the restraint adjusts according to whether the seat is raised or lowered, based on the assumption that taller people lower the seat and shorter people raise it.

Saab's "active head restraint" is set to debut in the 9-5 model available in 1998. This system pivots forward and up when a pressure plate in the seat back is activated by the force of the upper torso. The idea is to reduce relative movement between the head and the body in a rear-end crash and close the gap between the head and the restraint.

Marketed as Pro-tech by Delphi Interior and Lighting Systems, the restraint scheduled for the Saab 9-5 is part of a total seating system called the "catcher's mitt" that includes a "high retention seat," according to Delphi's engineering manager of seat systems development, Dick Neely. The seat back has deformable crossbars and padding designed to absorb crash energy and pocket an occupant's pelvis and lower back to minimize differential movement between the head and torso.

Volvo and Autoliv are collaborating on a new seat/head restraint design that's not yet scheduled for production. When a rear impact occurs, an occupant loads the seat and head restraint, which move slightly rearward to reduce relative movement between the body and the head and help maintain a narrow backset. The seat back then rotates slightly to help reduce forward rebound. Volvo says this new seat back also will distribute crash forces more evenly along occupants' backs and necks.

The National Highway Traffic Safety Administration is working on a generic safety seat the agency says will exceed current requirements. A report on this seat, being developed by EASi Engineering and Johnson Controls, was due last fall but hasn't been released.

These are all mechanical designs. On the electronic front, Lear Corporation and Cervigard are at work on a system that has two sensors at the top of the head restraint to determine occupant height and position the restraint automatically. The contoured shape of the restraint itself is promoted as a way to lessen the force of impact by spreading it over the entire head/neck structure.

Pro-tech will be in new Saab model

Both mechanical and electronic improvements are welcome, and they're long overdue. More than 25 years have passed since University of Michigan researchers concluded that "deployable head restraints are technically feasible and can provide a general level of performance better than conventional fixed head restraints."

STATUS REPORT

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

1005 N. Glebe Rd., Arlington, VA 22201 703/247-1500 FAX 247-1678 Internet: www.hwysafety.org

Vol. 32, No. 4, April 12, 1997

This special issue focuses on whiplash injuries in crashes. Other special issues have focused on the following subjects:

This part of the vehicle is for resting. This isn't.

Editor: Kim Stewart
Writers: Mike Davis, Maria Kaufmann
Art Director: Joyce Thompson

Contents may be republished with attribution.
This publication is printed on recycled paper.

ISSN 0018-988X

The Insurance Institute for Highway Safety is an independent, nonprofit, scientific and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's highways. The Institute is wholly supported by automobile insurers: