



Log H-516

National Transportation Safety Board

Washington, D.C. 20594
Safety Recommendation

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In reply refer to: H-88-7 through -10

Honorable Diane K. Steed
Administrator
National Highway Traffic
Safety Administration
Washington, D.C. 20590

That lap/shoulder belts are of value to reduce death and injury is undisputed, but just how valuable they are is a matter of debate. Manual seatbelt systems in motor vehicles (unlike passive restraints, such as air bags and automatic seatbelts) have never been required to be tested for crash protection performance; complete and accurate data on their performance in real-world crashes have been extremely limited, and basic changes in vehicle design over the years could have affected belt performance. In addition, seatbelt performance is a timely topic since States are enacting mandatory seatbelt-use laws requiring front seat occupants (and rear seat occupants, in some cases) to wear their seatbelts.

With these factors in mind, the Safety Board conducted a study on the performance of seatbelts in real-world crashes during 1984-86. This case study emphasized the collection of accurate, complete data on a number of specific points relevant to the question of belt performance. Specifically, the Board wished to explore how well the belts protected occupants from injury during the crashes and what injuries, if any, occurred despite (or perhaps because of) the belt.

This letter addresses the recommendations contained in the second and final publication to come out of the Board's investigations of seatbelt performance. This report presents the bulk of the cases (167 accidents) investigated for the study and discusses the crash performance of lap/shoulder belts for front seat occupants in the Safety Board's cases. 1/

The first report addressed the crash performance of another type of seatbelt--lapbelts--and discussed their performance primarily in terms of outcome for rear seat occupants involved in frontal crashes. The results of the lapbelt investigations, along with analysis of the accident databases used in the past to derive lapbelt effectiveness, a review of medical literature on lapbelt-induced injuries, and other research on lapbelt performance, were published in 1986. 2/

1/ For more information, read Safety Study--"Performance of Lap/Shoulder Belts in 167 Motor Vehicle Crashes" (NTSB/SS-88/02).

2/ Safety Study--"Performance of Lap Belts in 26 Frontal Crashes," July 28, 1986, (NTSB/SS-86/03). The report is available through the National Technical Information Service, Springfield, Virginia 22161. Some of the cases described in the lapbelt report had lap/shoulder-belted occupants in the vehicle. These cases were also included in the second report.

In the 1986 lapbelt report, the Safety Board recommended to auto manufacturers that they provide lap/shoulder belts in place of lap-only belts. Domestic manufacturers were urged to provide voluntarily lap/shoulder belts in rear outboard seating positions in new vehicles, and to provide retrofit kits for existing models. Foreign manufacturers were asked to undertake similar efforts for any models not already equipped with rear seat lap/shoulder belts. The Board also recommended that manufacturers and the National Highway Traffic Safety Administration (NHTSA) work together to explore the possibility of providing lap/shoulder belts at the rear center seating position. The Safety Board also issued several recommendations to the NHTSA--most importantly, that it "immediately initiate rulemaking action" to require lap/shoulder belts at all outboard seating positions in new vehicles.

Lap/shoulder belts clearly offer occupants of motor vehicles substantial protection in a wide variety of crashes. In the Safety Board's cases described in the lap/shoulder belt report, which were all tow-away crashes, 80 percent of the 214 front seat occupants wearing properly routed lap/shoulder belts sustained only minor or moderate injuries or no injuries at all; 34 percent of these crashes exceeded Delta V 20 mph. ^{3/} In the Safety Board's cases, the injury-reducing effectiveness of lap/shoulder belt use during rollover accidents was particularly striking: in overturns of more than 360 degrees, many lap/shoulder-belted occupants sustained minor injuries only.

Furthermore, properly worn lap/shoulder belts provided crash protection without the introduction of serious or fatal belt-induced injuries of the type seen in the Safety Board's lapbelt study--that is, injuries induced by a properly worn belt that were more serious than the injuries to be expected if the occupant had been unrestrained at the time of the crash. This further supports the Safety Board's previous recommendations that lap/shoulder belts replace lapbelts in the rear seats of passenger cars.

However, if the occupant is to receive the full benefit of the lap/shoulder belt, the belt must be worn properly. Improper use can degrade the belt's ability to prevent serious injury and, given certain accident circumstances, may introduce the possibility of serious belt-induced injuries. The protection offered by a lap/shoulder belt can be compromised, for example, if its user has the seatback reclined while the vehicle is in motion. The three-point belt cannot provide proper protection to an occupant in this position. Other forms of lap/shoulder belt misuse include deliberately or unwittingly introducing slack into the belt system, misrouting the shoulder portion, or sharing the belt with another occupant. The Board's cases included examples of all of these forms of misuse. Fortunately, accident circumstances in many cases were such that occupants who were wearing their belts improperly suffered few consequences. In a few cases, however, the misuse caused serious injuries.

As more and more people buckle up, the safety community is becoming aware that motorists need to be taught that correct use of a seatbelt is critical if they are to obtain optimum protection. Some studies suggest that as more people who formerly were nonbelt users are required to buckle up, misuse will grow. As a result of this study, the Safety Board has issued four recommendations to the NHTSA to combat misuse of lap/shoulder belts that can degrade the fine protection offered by the belt.

^{3/} Delta V, as defined in the Safety Board's report, is the instantaneous speed change undergone by a vehicle at impact.

Children and Lap/Shoulder Belts

Parents who have a child who has "graduated" from a child safety seat or booster seat may wonder if lap/shoulder belts are effective and safe for children to wear. The Safety Board's cases, along with the results of other studies (many conducted in foreign countries where rear seat lap/shoulder belts are routinely available) suggest they are. Nevertheless, the Safety Board strongly recommends use of a child safety seat or booster for as long as possible in preference to a seatbelt. A restraint especially designed for a child's body is always to be preferred over a seatbelt that is designed for an adult's body.

When a lap/shoulder belt is used in lieu of a child safety seat or booster seat, it must be properly worn to provide crash protection without the drawbacks of lapbelt use. These include causing head injury through the lapbelt's jackknife effect in frontal crashes or lapbelt-induced abdominal or spinal injuries, as documented in the Safety Board's study in 1986 and in numerous other studies. In the Safety Board's cases, the injury consequences to the child depended on the dynamics and severity of the particular crash and the mode of misuse. Such misuse included belt sharing, improperly routing the belt, wearing the belt with slack, and reclining the seat while using the belt.

Belt Sharing.--The Safety Board does not know how often belt-sharing occurs. Whether it is advisable to secure two children in one belt is a question parents often ask child safety advocates. As recently as 1984, the NHTSA stated, "If an emergency situation arises where there are more children than seat belts, two children can be secured within one belt." ^{4/}

The Safety Board does not agree. No child or adult should ever share a seatbelt. If a child shares a belt with an adult, the child's body is likely to be crushed as the larger mass of the adult's body moves forward or sideways in a frontal angle or side impact. If the child shares a belt with another child, abdominal and head injuries that normally would not have occurred can result.

Crash tests have demonstrated the hazards associated with more than one child using the same seatbelt. ^{5/} The result can be a tremendous increase in the injury severity to both occupants as they collide violently with one another. The heads and shoulders of the children can strike one another, and unusual loading of the pelvis can occur as one child impacts another. Proper fit, a crucial requirement of a lapbelt, which is what such a misrouted lap/shoulder belt becomes, is impossible; there is no way the lap portion can be properly positioned over the pelvic girdle of two children if they differ in size.

Misrouting.--The most common belt routing error--indeed the most common form of misuse by children in the Safety Board's study--was placement of the shoulder harness behind the child's back. Such misuse essentially reduces the lap/shoulder belt to a lapbelt. This form of misuse may well be more prevalent among children than adults. Parents may route the shoulder strap behind a child's back in an effort to "protect" the child from the shoulder strap. This misuse mode reduces the lap/shoulder belt to a lap-only belt. A lapbelt can cause serious spinal, head, or abdominal injuries to a child, as discussed in the Board's lapbelt report. In the Safety Board's cases, no child occupants sustained more than minor injuries attributable to this misrouting because most of these crashes were of low severity. Parents who restrained their children in lap/shoulder belts in this fashion cited fears that the shoulder strap was too close to the child's face or neck.

^{4/} "Child Safety Seats for Your Automobile," NHTSA, DOT HS 805 174, 1983.

^{5/} Weber, K. and Melvin, J.W., "Injury Potential With Misused Child Restraining Systems," SAE/NHTSA Child Restraint and Injury Conference Proceedings, San Diego, October 17-18, 1983.

Many safety advocates have advised parents to misroute the lap/shoulder belts in this manner if the child is small. The Safety Board does not agree for several reasons. First, as demonstrated in a variety of studies from Europe where lap/shoulder belts are more commonly used by children, there is little evidence that small children (or short adults) are likely to be harmed by the shoulder portion of a lap/shoulder belt. 6/ 7/ 8/ (For further discussion, see the Safety Board's lapbelt report cited earlier.)

Second, misrouting the shoulder strap behind the back reduces the belt to a lap-only belt. A child in the front seat restrained in this manner can make violent contact with frontal and side interior components. (The Safety Board investigated cases involving 2-year-olds who struck the dashboard while lapbelted.) In addition, children have larger heads than adults do in proportion to the rest of their bodies; this makes them "top heavy" and more apt to jackknife than an adult. 9/ During a jackknife, the head gains momentum and strikes the dashboard or seat with increased force.

Third, rerouting the shoulder portion behind the back introduces the possibility of other serious lapbelt-induced injuries (intra-abdominal, spinal, etc.), as were documented in the Safety Board's lapbelt study.

A lap/shoulder belt should be used correctly, just as a child safety seat must be used correctly to impart full crash protection. 10/ Indeed, most of the children in misrouted belts should have been in properly used child restraints, and not in seatbelts at all. For example, in the Safety Board's cases, most of the children with the shoulder strap routed behind the back were younger than 4 years of age. These children belonged in child safety seats or toddler seats. Some researchers in the United States have suggested that children's bodies need specially designed restraint systems, not adult belt systems, up to age 10. 11/ 12/

6/ Lowne, R., et al. "The Effect of the UK Seat Belt Legislation on Restraint Use by Children," in *Advances in Belt Restraint Systems: Design, Performance and Usage*, Detroit (1984).

7/ Dejeammes, M., et al. "Exploration of Biomechanical Data Towards a Better Evaluation of Tolerance for Children Involved in Automotive Accidents" (SAE 840530), in *Advances in Belt Restraint Systems: Design, Performance and Usage* (Detroit 1984).

8/ Norin, H. and Andersson, B., "The Adult Belt--A Hazard to the Child," *Proceedings, 6th International Association for Automotive and Traffic Medicine Conference*, Melbourne, 1977.

9/ Herbert, D.C., and Cutting, D. "Crash Protection for Children After Their Third Birthday," *Traffic Accident Research Unit*, New South Wales, July 1978.

10/ The Safety Board has issued recommendations to States to collect data on the incidence of child restraint misuse in traffic accidents and to initiate programs to educate parents about the need for proper use and installation of child restraints. Some States have fulfilled the Board's requests; others are considering action. More gratifying has been the child safety seat industry response to the Board's recommendation that child safety seats be clearly labeled as to how the seatbelt should be routed through the restraint. See also Safety Study--"Child Passenger Safety Symposium: Ways to Increase Use and Decrease Misuse of Child Restraints," September 4, 1985 (NTSB/SS-85/03). Available through the National Technical Information Service, Springfield, Virginia 22161.

11/ Agran, P., Dunkle, D., and Winn, D. "Injuries to a Sample of Seat-Belted Children Evaluated and Treated in a Hospital Emergency Room," in press, *Journal of Trauma*.

12/ Burdi, A.R., and Huelke, D.F. "Infants and Children in the Adult World of Automobile Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints," *American Society of Mechanical Engineers Third Biomechanical and Human Factors Division Conference*, University of Michigan, June 12-13, 1969.

If parents are concerned about lap/shoulder belt fit for the child, they may be able to move the seat on its track to try to position the shoulder strap correctly. In some models of cars, primarily imports, the angle of the shoulder strap can also be adjusted at the roof line so that the belt can cross closer to the sternum. The child may also be placed in a booster seat to ensure correct positioning of the shoulder portion of the three-point belt.

Adjustable Upper Anchors

Great Britain has a solution to the problem of poor shoulder harness fit for both children and adults. When that country passed a mandatory seatbelt-use law effective January 31, 1983, short people, particularly small females, complained of the uncomfortable position and seatbelt tension of the shoulder portion of their lap/shoulder belts in certain cars. Indeed, certain models of cars manufactured in the mid and late 70s, particularly those with the upper mounting points located in the roof rather than on the B-pillar, posed difficulties to good belt fit. The solution was:

. . . to produce an accessory drop link which lowers the effective position of the upper mounting point to take the lie of the diagonal section away from the neck and down onto the clavicle. The requirements have been changed for new cars to allow adjustable upper anchorages to be built into the car, and these are appearing in some 1984/85 model year vehicles. 13/

Currently, a large number of new model vehicles sold in Great Britain have adjustable upper mounting points, but this is not a legislative requirement. Most new vehicles in Great Britain have at least one of the lower anchorages mounted on the seat.

Few domestic manufacturers have offered adjustable upper anchors. GM currently provides adjustable upper anchorages in its 1988 four-door Pontiac LeMans, and Chrysler as well as others plans to offer this feature in the future. Fords marketed in Europe, but not in the United States, have adjustable upper anchors. (Many countries, Austria for example, require adjustable upper anchors.) In contrast, many foreign manufacturers have routinely offered adjustable upper anchorages. For example, all models except two marketed by Mercedes Benz have adjustable anchorages. Saab, in its 9000 Series, and Volvo, in all its models, plan to provide such anchorages in the future; in the meantime, Volvo offers dealer-installed adjustable anchors for certain models. BMW also offers a dealer-assisted adjustment feature and a feature that automatically adjusts the shoulder harness according to seat track location.

The absence of such adjustable upper anchorages in most American cars has meant parents continue to be concerned about the placement of the shoulder portion of a three-point belt relative to the child's face or neck; such concern can lead them to misroute the belt. Short adults also share the fear of neck injury from an ill-fitting shoulder harness and also may be tempted to misroute the belt. Such misrouting not only degrades the crash protection a lap/shoulder belt can offer, it introduces the possibility of belt-induced injuries where there need be none. Underarm routing, a particularly dangerous form of misrouting, may decrease as a practice among short adults, particularly women, if adjustable anchorages are provided. Underarm routing directly led to one case vehicle occupant's death in the study; additional cases have been described.

13/ Mackay, M., "Two Years' Experience with the Seat Belt Law in Britain," SAE Technical Paper Series, No. 851234, Washington, D.C., May 20-23, 1985.

The Safety Board believes that lap/shoulder belts in passenger vehicles should provide the occupants with the opportunity to adjust the shoulder strap to an angle compatible with their body size. The NHTSA should work with manufacturers to explore the possibility of providing adjustable upper anchorages for lap/shoulder belts in new cars.

Slack

Another area of concern in this study is slack in the shoulder portion of the three-point belt; the Safety Board has made recommendations regarding the testing of windowshade devices on lap/shoulder belts and the inclusion of a pretensioner as part of the belt design. Since the 1970s, most cars designed and manufactured in the United States have used windowshade devices to introduce slack into the shoulder portion of the belt. Owner's manuals warn that no more than 1 inch of slack, or the equivalent of a clenched fist, should be introduced between the body and belt. But far more slack is possible in windowshade-equipped belts--more than 16 inches in many cases. An occupant can introduce slack by deliberately extending the belt or through voluntary or involuntary body movement; the slack remains in the system until the occupant deliberately reactivates the windowshade and resets the belt more snugly. Contrary to the belief held by many occupants in the Safety Board's study, the slack existing at the beginning of the crash will not be taken out of the belt as the crash progresses--i.e., the belt will not tighten up as the crash takes place. 14/

Rulemaking.--In 1979, the NHTSA issued rulemaking calling for the elimination of slack in the shoulder portion of the three-point belt (44 FR 77215, December 31, 1979), but the proposal was not enacted. Instead, in 1981, a "final" comfort and convenience rule was issued, permitting tension-relief devices such as windowshades, but requiring that the eventual testing of these systems be conducted with the shoulder belt at its maximum extension (46 FR 2064, January 8, 1981). This, of course, would have effectively eliminated windowshade devices, since the belts could not meet the crash injury protection criteria if they were tested when fully extended.

The effective date of the "final" rule was delayed several times. Furthermore, in early 1985, the NHTSA proposed that testing of windowshade belts be conducted, not with the shoulder position set at its fully extended position, but with only "the maximum amount of slack that is recommended... in the owner's manual..." (50 FR 14580, April 12, 1985). In comments to the docket, the Safety Board objected to this change in the proposed testing procedure, noting that many owners and passengers of "windowshade-equipped vehicles are not familiar with the proper adjustment of these belts," and questioning whether many owners and passengers are likely to read and follow the manual's instructions. Moreover, the Board pointed out, "Research has shown that it is possible inadvertently to introduce excessive slack... through normal movements involved in operating a vehicle." The Board urged that "Dynamic tests of belts equipped with windowshade devices be performed with the windowshade adjusted for the maximum slack permitted by the system."

14/ Unless, of course, the belt has a "pretensioner," which causes the belt to take up the additional slack and become snug if sensors sense a crash impulse. Pretensioners (more accurately called emergency tensioning retractors) have been standard equipment on all models of Mercedes Benz since 1986, and are standard in certain models of Saab, Volvo, and other imported cars. (BMW lap/shoulder belts come equipped with a "snubber," a mechanical device, not sensor-activated, which clamps on the belt webbing during a crash and reduces "spool-out.")

Later that year, however, the NHTSA announced its decision to require that the dynamic testing to be eventually required of manual lap/shoulder belts be conducted (in the case of windowshade-equipped belts) with only the amount of slack "recommended" by the manufacturer, even if a great deal more slack was possible in the system (50 FR 46056, November 6, 1985).

Reclining Seats.--Proper use of a lap/shoulder belt also includes sitting upright so that crash forces can be spread over the body by the three-point belt. A person reclined in a seat while wearing a lap/shoulder belt is not "centered" in the belt. Some owner's manuals warn of the dangers of reclining seatbacks while the vehicle is in motion or that seatbelts are designed to be worn by upright occupants. However, despite such warnings, some advertisements for cars equipped with reclining seats show a right front passenger reclined in a seat while wearing a lap/shoulder belt with the vehicle obviously in motion. Such advertisements undermine the already limited effectiveness of owner's manual warnings (especially if the warnings are unclear, as in advising not to recline the seat "any more than needed for comfort"). If car manufacturers had limited the angle to which seats could be safely reclined, the death of the 7-year-old boy in one of the Safety Board's cases could have been prevented, as well as other injuries. The Safety Board believes the NHTSA should determine to what degree a seatback can be reclined and still allow the occupant to be properly and safely restrained by a lap/shoulder belt.

NHTSA Crash Test Data on Slack.--Crash test data support the view that slack increases the chances of head injury. In 1982, the NHTSA conducted four "informal" sled crash tests. Dummies wearing lap/shoulder belts equipped with windowshade devices were placed in the right front passenger position in a sled containing the front section of a car. The lap portion of the three-point belt was snug in all tests, but researchers varied the tests by introducing different amounts of slack in the shoulder portion ranging from 0 (no slack), 1 inch, 2 inches, and 16 3/4 inches (the maximum amount of slack possible). Instrumentation on the dummies during the 30-mph frontal crash tests recorded the following head impacts in terms of Head Injury Criterion (HIC):

<u>Slack</u> <u>(inches)</u>	<u>HIC</u>
0	439
1	641
2	796
16 3/4	1,802

The higher the HIC, the greater the likelihood of serious or fatal injuries; 1,000 is the threshold above which serious or fatal head injuries are thought to be likely. As the figures above show, slack increased the likelihood of head injuries in NHTSA's crash tests. The Safety Board notes the data were for right front passengers only; the consequences of slack for a driver may well be more severe in terms of head injury.

Examples of the Injurious Effect of Slack in Safety Board Cases.--The Safety Board's cases include examples of lap/shoulder-belted occupants who sustained more serious injuries due to slack than the injuries that would have been expected with a snug belt. In one case, the slack introduced into a windowshade-equipped belt system directly lead to the passenger's death from massive chest trauma. In some of the cases, slack in the shoulder portion allowed the lap/shoulder-belted driver or right front passenger to strike the windshield or rear-view mirror and sustain head and face injuries that otherwise could

have been avoided. In other cases, slack in the shoulder portion allowed the driver to contact the steering assembly with increased force. The steering assembly was identified in the Safety Board's cases as the most common probable source of facial or head injury, AIS 2 or greater, for lap/shoulder belted drivers.

Great Britain, alarmed at the increase in major head injuries among lap/shoulder belted drivers (a 44-percent increase the year following effective date of the law) is considering changes to the belt system and steering assembly including air bags, pretensioners, web locking devices, etc.

Prevalence of Slack.--In 1987, Insurance Institute of Highway Safety (IIHS) researchers analyzing films of Maryland drivers found that, although they had routed their lap/shoulder belts across their bodies correctly, close to 1/4 of all drivers were still using the belts improperly--excess slack was present in the shoulder harness. Of the restrained drivers of domestic cars, 27 percent had 1 to 2 inches of slack in the shoulder portions of their belts, and 8 percent had 3 or more inches. In contrast, only 5 percent of the restrained drivers of imported cars had 1 to 2 inches of slack, and none had 3 or more inches. The windowshade slack device, found only in domestic vehicles, was most often associated with slack.

In the Safety Board's cases, slack was present for 23 percent of the case vehicle drivers restrained by lap/shoulder belts, and it was more often found in the shoulder than in the lap portion. (Only eight drivers had slack in the lap portion).

Shoulder belt slack was more common in windowshade-equipped belts than in those without windowshade. If slack was present, nonwindowshade-equipped belts had slack more often in both the lap and shoulder portions (compared to shoulder only), but this reflects the fact that many nonwindowshade belts have free-sliding latchplates, which automatically apportion slack between the lap and shoulder portions.

Therefore, the National Transportation Safety Board recommends that the National Highway Traffic Safety Administration:

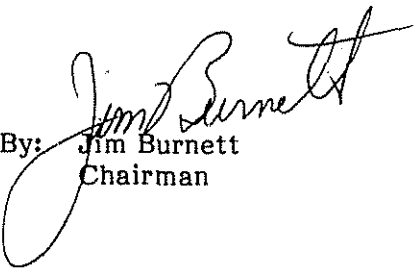
Revise publications on child passenger protection to eliminate the suggestion that parents, concerned about the relationship of the shoulder harness to the child's body, misroute the child's lap/shoulder belt, or that parents allow children to share a seatbelt. (Class II, Priority Action) (H-88-7)

Amend Federal Motor Vehicle Safety Standard 208 to require that windowshade-equipped lap/shoulder belts either be tested with the maximum amount of slack that can be introduced or that they be equipped with a pretensioner as part of the belt system to ensure, during a crash, the elimination of any slack introduced into the system prior to the accident. (Class II, Priority Action) (H-88-8)

Limit the angle of inclination allowable in reclining seats in passenger vehicles to no greater than the maximum angle that can safely be used with a lap/shoulder belt. (Class II, Priority Action) (H-88-9)

Evaluate the possibility of requiring an adjustable upper anchorage point for the shoulder portion of lap/shoulder belts in newly manufactured motor vehicles. (Class II, Priority Action) (H-88-10)

BURNETT, Chairman, KOLSTAD, Vice Chairman, and LAUBER and NALL, Members, concurred in these recommendations.

By: 
Jim Burnett
Chairman

