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16. Abstract

Pretensioners and load limiters are technologies designed to make seat belts more effective. Pretensioners retract the seat belt to remove excess slack almost instantly upon sensing the vehicle has crashed. Load limiters allow the belt to "give" or yield when forces on the belt rise above a predetermined level. NHTSA has long encouraged -- but never required -- installation of these technologies in the front seats of vehicles. By model year 2008, all new cars and LTVs sold in the United States were equipped with pretensioners and load limiters at the driver's and right-front passenger's seats. Double-pair comparison analyses of FARS data for 1986 to 2011 compare the fatality-reducing effectiveness of seat belts with and without pretensioners and load limiters at those seats. In passenger cars, CUVs, and minivans, a belted driver or right-front passenger has an estimated 12.8 percent lower fatality risk if the belt is equipped with a pretensioner and a load limiter than if it is not equipped with either (95% confidence bounds: 2.6% to 23.0%). By contrast, the analyses of the currently available data do not yet show a significant effect for pretensioners and load limiters in truck-based LTVs (pickup trucks, SUVs with body-and-frame construction, and full-sized vans); it may be advisable to rerun the analyses in about 4 or 5 years when more data will be available.

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LIST OF ABBREVIATIONS

CDS	Crashworthiness Data System of NASS
CUV	crossover utility vehicle
CY	calendar year
df	degrees of freedom
DOT	United States Department of Transportation
ESC	electronic stability control
FARS	Fatality Analysis Reporting System, a census of fatal crashes in the United States since 1975
HIC	Head Injury Criterion
IIHS	Insurance Institute for Highway Safety
LTV	light trucks and vans, includes pickup trucks, SUVs, minivans, and full-size vans
MY	model year
NASS	National Automotive Sampling System, a probability sample of police-reported crashes in the United States since 1979, investigated in detail
NCAP	New Car Assessment Program: Ratings of new vehicles since 1979 based on performance in frontal impact tests
NHTSA	National Highway Traffic Safety Administration
RF	right-front seat
SAS	statistical and database management software produced by SAS Institute, Inc.
SUV	sport utility vehicle
UEF	universal exaggeration factor for belt effectiveness estimates after buckle-up laws
VIN	Vehicle Identification Number

EXECUTIVE SUMMARY

Pretensioners and load limiters are technologies designed to make seat belts more effective. Pretensioners retract the seat belt to remove excess slack almost instantly upon sensing the vehicle has crashed, typically by firing a pyrotechnic device. When forces on the shoulder belt rise above a predetermined level, load limiters allow the belt to give or yield while controlling the tension in the belt, typically by spooling it out of the retractor, to avoid concentrating too much force on the occupant's chest. NHTSA has never required installation of these technologies, but encouraged it by listing the makes and models of vehicles that offer them in its *Buying a Safer Car* brochures from 1997 to 2004 and, subsequently, on the Internet at www.safercar.gov. Furthermore, NHTSA's NCAP tests demonstrated that pretensioners and load limiters improve belt performance. While pretensioners were offered on some cars as early as 1981 and load limiters in 1995, a move to industry-wide application began around 1998. By model year 2008, all new cars and LTVs sold in the United States were equipped with pretensioners and load limiters at the driver's and right-front passenger's seats.

NHTSA's Fatality Analysis Reporting System for 1986 to 2011 now has enough crash data to evaluate whether pretensioners and load limiters enhance the fatality-reducing effectiveness of seat belts for drivers and right-front passengers. This report presents double-pair comparison analyses, the agency's preferred method for estimating belt effectiveness, of 16,642 FARS cases of vehicles equipped with both technologies and 27,389 comparison vehicles equipped with dual frontal air bags, but neither pretensioners nor load limiters.

The analyses show that the combination of pretensioners and load limiters (and perhaps other belt or belt-related improvements introduced at about the same time) has significantly enhanced belt effectiveness in passenger cars, CUVs and minivans. A belted driver or right-front passenger has an estimated 12.8 percent lower fatality risk if the belt is equipped with a pretensioner and a load limiter than if it is not equipped with either (95% confidence bounds: 2.6% to 23.0%). In other words, the analyses typically show a fatality-reducing effectiveness of belts about 5 to 7 percentage points higher with pretensioners and load limiters than without them. By contrast, the analyses of the currently available data do not yet show a significant effect for pretensioners and load limiters in truck-based LTVs (pickup trucks, SUVs with body-and-frame construction, and full-sized vans). Although there is enough data for statistically significant results for cars, CUVs, and minivans, the relatively wide confidence bounds demonstrate that effectiveness of pretensioners and load limiters cannot yet be estimated precisely; it may be advisable to rerun the analyses in about 4 or 5 years when more data will be available.

Pretensioners and load limiters are effective in frontal impacts of cars, CUVs, and minivans, but it is also possible that they have some benefits in side impacts and rollovers. Researchers have expressed concern that load limiters might allow excessive occupant motion in oblique-frontal or front-corner impacts, but in the FARS analyses, the combination of pretensioners and load limiters was clearly beneficial in those crashes. It might be surmised that load limiters would especially benefit older occupants (who are more vulnerable to high belt loads), but not tall or heavy occupants (who might spool out the belt too far and contact interior components); the analysis results lean slightly, but not yet convincingly, in those directions. The analyses show the technologies are about equally effective for male and female occupants.

1. Description, history, and previous studies of pretensioners and load limiters

Seat belt pretensioners retract the safety belt almost instantly in a crash to remove excess slack. Load limiters control the tension in the seat belts, allowing them to yield in a crash, preventing the shoulder belt from exerting too much force on the chest of an occupant.

In a crash, a seat belt needs to firmly engage the occupant's pelvis, clavicle, and rib cage to restrict occupant motion within the vehicle such that injurious contacts with other interior components are minimized. This process needs to occur early in the crash in order to couple the occupant to the decelerating vehicle and provide the most controlled ride-down. Any slack in the seat belt works against this process. Seat belt pretensioners are used to eliminate small amounts of slack in the lap and/or torso portion of the belt almost immediately when a crash occurs. Mercedes-Benz introduced pretensioners in the front seats of their S-class cars in 1981. Pretensioners are typically pyrotechnic devices but some are electro-mechanical. They are triggered by the same crash sensors that are used to determine the need to deploy the vehicle's air bags. In minor collisions, the seat belt pretensioners may be fired without the air bags being deployed. In more serious crashes, both the pretensioners and the air bags will be deployed.

Where pretensioning is applied to the lap belt, the pyrotechnic device usually forms part of the buckle assembly. A steel cable links the seat belt's buckle to a piston that can move along a steel tube. When the pyrotechnic charge is ignited, gas is produced very rapidly and this propels the piston down the tube. The steel cable attached to the piston pulls down on the seat belt buckle and eliminates any slack in the belt system. Shoulder belt pretensioners generally feature a turbine device connected to the seat belt retractor spool. The gas generated by the pyrotechnic charge drives the turbine so as to rewind the retractor, thus removing slack in the seat belt. Some vehicles employ a pretensioner at the outboard anchor location.

A load limiter is designed to allow the seat belt force applied to the chest to rise to a pre-determined point where the injury risk is still relatively low. The seat belt is then allowed to spool out of the retractor in a controlled manner, maintaining a constant restraining force as it absorbs energy. In a severe impact where the extension of the belt could be substantial, a frontal, side, or curtain air bag would in many cases work in conjunction with the belt and arrest the occupant's motion before it results in potentially injurious contact with the vehicle interior. Volvo introduced load limiters on its 850 series in 1995.[1]

A simple form of load limiter is a fold sewn into the seat belt webbing. The stitching holding the fold in place is designed to pull apart when a certain amount of force is applied to the belt. If this force is exceeded, the stitches are ripped out. The webbing unfolds, allowing the occupant greater forward motion. A mechanical device that uses the same principle takes the form of a "ladder" with a set of open, metal teeth. The seat belt retractor is held in place at the bottom end of the ladder and its motion restricted by the presence of the teeth. As the seat belt force increases, the teeth begin to deform, allowing the seat belt anchor to move along the length of the ladder device. An alternative type of load limiter uses a torsion bar built into the seat belt

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[1] Brumbelow, M. L., Baker, B. C., & Nolan, J. M. (2007). Effects of Seat Belt Load Limiters on Driver Fatalities in Frontal Crashes of Passenger Cars,. Proceedings, 20th International Technical Conference on the Enhanced Safety of Vehicles. Washington, DC: National Highway Traffic Safety Administration.
Available at www-nrd.nhtsa.dot.gov/pdf/esv/esv20/07-0067-W.pdf.

retractor. The torsion bar is a metal rod that will twist when sufficient torque is applied. In minor collisions, the torsion bar will hold its shape, and the seat belt retractor will lock normally. But, when the force applied by the webbing reaches the design limit, the torsion bar twists and allows the webbing to spool out of the retractor.[2]

NHTSA has not mandated pretensioners or load limiters for seat belts in vehicles, but has long encouraged their installation. The agency began publishing *Buying a Safer Car* brochures in 1996. From 1997 to 2004, these annual brochures described pretensioners and load limiters as "additional features that **improve seat belt performance**" [emphasis added] and have listed what new cars and LTVs offer them as standard or optional equipment; subsequently, information was available on the Internet at http://www.safercar.gov/.[3]

Furthermore, the agency may have indirectly encouraged their installation through its frontal New Car Assessment Program test, a 35 mph impact into a rigid barrier with belted dummies. It soon became apparent that vehicles could improve their test results by adding pretensioners and load limiters to their belt systems. In 2003, NHTSA published a statistical analysis tracking the improvements in NCAP results for various makes and models over the preceding five model years. In the models that added pretensioners and load limiters, the Head Injury Criterion was reduced (i.e., improved) by an average of 232 units, chest acceleration by 6.6 g's, and chest deflection by 10.6 mm, for drivers and right front passengers. Each of these reductions was statistically significant. This is a promising indication that pretensioners and load limiters make belts more effective in at least one type of crash: collinear full frontal impacts. Moreover, the analysis attributed 154 units of the HIC reduction to pretensioners and 78 to load limiters; a reduction of 2.9 chest g's to pretensioners and 3.7 to load limiters; and a reduction of 5.6 mm chest deflection to pretensioners and 5.0 mm due to load limiters. In other words, both technologies are individually beneficial and their combination even more so.[4]

Appendix A of this report lists all makes and models of passenger cars and LTVs that have been equipped with dual frontal air bags, indicating the first MY when pretensioners were standard equipment at both front-outboard seats and the first MY for load limiters. LTVs include pickup trucks, SUVs, and vans.[5] SUVs comprise truck-based SUVs, typically of body-on-frame construction and often sharing platforms with pickup trucks and CUVs, typically of unibody construction and often sharing platforms with passenger cars. Appendix B lists the make-models

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[2] Canadian Association of Road Safety Professionals, available at www.carsp.ca/hitech/hitech_pretensioners.htm and www.carsp.ca/hitech/hitech_load_limiters.htm.

[3] Load limiters are called "energy management features" in the brochures. *Buying a Safer Car, 1998* describes the features as follows: **Seat belt pretensioner.** Pretensioners retract the seat belt to remove excess slack almost instantly in a crash. Like air bags, pretensioners are usually "one-use" devices and need to be replaced after a crash. Pretensioners are not powerful enough to pull you back into your seat. For this reason, seat belts should be adjusted as snugly as possible. **Energy management features.** In very severe crashes, forces in the seat belt may rise above levels considered safe. If forces on the shoulder belt rise to a predetermined maximum level, some seat belts are designed to "give" or yield to avoid concentrating too much force on your chest. Energy management features can include load limiters built into the seat belt retractor and/or "tear stitching" in the webbing.

[4] Walz, M. C. (2003). *NCAP Test Improvements with Pretensioners and Load Limiters*. (Report No. DOT HS 809 562). Washington, DC: National Highway Traffic Safety Administration Available at www-nrd.nhtsa.dot.gov/Pubs/809562.PDF

[5] The analyses of this report include pickup trucks and vans exceeding 10,000 pounds GVWR if they are built on the 3500 chassis, but exclude any pickup trucks or vans built on a 4500 or larger chassis.

of SUVs that are considered CUVs in this report. Vans include minivans and full-sized vans.[6] Although CUVs and minivans are classified as LTVs for regulatory purposes, they resemble passenger cars in some respects. Many of the analyses of this report consider passenger cars, CUVs, and minivans as one group of vehicles, as opposed to the other, truck-based LTVs (while other analyses compare cars versus all LTVs).

The introduction of pretensioners was spread over many years, although most models received them sometime between 1998 and 2006. Load limiters started later but entered the new-vehicle fleet quickly, mostly between 1997 and 2002. By MY 2002, approximately 63 percent of new cars and LTVs were already being equipped with pretensioners and 84 percent with load limiters.[7] All new cars were equipped with pretensioners by MY 2006 and load limiters by MY 2007 at front-outboard seats. All new LTVs were equipped with pretensioners and load limiters by MY 2008 at the front-outboard positions. Before 2007, a moderate number of vehicles were equipped with load limiters but not pretensioners or vice-versa. No such vehicles were produced in MY 2007 or later (and all vehicles of MY 2008 or later were equipped with both). As stated above, these installations were always voluntary on the part of the manufacturers; no regulation specifically required pretensioners or load limiters.

During the 1997-to-2006 timeframe when pretensioners and load limiters were introduced in most new vehicles, some makes and models also received other improvements to their belts, such as adjustable anchors or integrated belt systems, both of which help belts fit right for occupants of various sizes or who position the seat far back or forward. *Buying a Safer Car* also discussed these features and listed the makes and models equipped with them. Engineers also became more proficient at tuning belts' performance to work in tandem with the air bag, tailoring the energy-absorption of the vehicle structure to optimize ride-down for a belted occupant, and redesigning vehicle seats to promote better belt-hip interaction during a crash.

In 2007, Brumbelow, Baker, and Nolan of the Insurance Institute for Highway Safety questioned the overall effectiveness of load limiters in frontal impacts with long crash pulses and high intrusion, such as some types of oblique-frontal or front-corner impacts, while acknowledging that load limiters mitigated belt-induced thoracic injury and were effective overall in impacts with severe crash pulses of short duration, such as full-width frontal impacts resembling the NCAP tests. The issue is that the spooling or stretching of the load limiter allows the occupant to move forward, resulting in especially large head excursions. When the occupant's motion is directly forward, the deployed air bag is usually sufficient to arrest it without severe injury. But if oblique forces or vehicle rotation due to a corner impact diminish the occupant's interaction with the air bag, head excursion could result in injurious contacts with the vehicle interior, especially if intrusion has reduced the available ride-down space. A statistical analysis of CY 1996 to 2003 FARS data by the IIHS authors suggested that load limiters had not reduced and were possibly increasing fatality rates per million vehicle registration years for belted occupants in frontal impacts.[8]

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[6] Full-sized vans include Dodge Ram Van, Sprinter, Ford Econoline, and GM Express/Savana; Astro and Safari, although somewhat smaller, are also included, as their designs are closer to full-sized vans than to minivans.

[7] Ibid.

[8] Brumbelow, Baker, & Nolan, (2007).

NHTSA announced in its evaluation plans of 1998, 2004, and 2008 that the agency would perform its own statistical analyses of FARS data to estimate the effects of pretensioners and load limiters on fatality risk.[9] This evaluation has been a long time coming because, until now, there was not enough FARS data for statistically meaningful results based on double-pair comparison analysis, the agency's preferred method for estimating belt effectiveness.

This evaluation will compare the fatality-reducing effectiveness of seat belts with and without pretensioners or load limiters in vehicles with dual frontal air bags and check if belts have become significantly more effective after installation of these technologies. The analyses will consider drivers and right-front passengers of several types of light vehicles: cars, truck-based LTVs, and CUVs/minivans. Given the issues raised by Brumbelow, Baker, and Nolan, the report will compare effects in different types of frontal crashes, to the extent they can be differentiated in FARS data and also, for that matter, in other types of crashes such as side impacts or rollovers. The report will also consider groups of occupants who might be especially vulnerable to injury from belt forces, such as older occupants or females, or who might experience substantial head excursion when load limiters spool out, such as tall or heavy drivers.

2. Analysis method and database

2.1 Double-pair comparison

Since the mid-1980s, fatality-reducing effectiveness estimates for occupant protection requiring activation (namely, buckling up), such as seat belts or child safety seats, have usually been based on **double-pair comparison** analyses of FARS data.[10] NHTSA started FARS, a census of the fatal traffic crashes in the United States, in 1975. Double-pair comparison is valuable because it allows the direct use of FARS data, which have a much higher N of fatalities than any other crash files. A second major advantage is that double-pair comparison implicitly "adjusts" or "controls" for the differences in the severity of crashes involving belted and unrestrained occupants. It separates belt effectiveness from other factors that influence fatality risk, such as an occupant's age, the type and severity of the crash, or the overall crashworthiness of the vehicle.

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[9] NHTSA (1998). *Evaluation Program Plan, 1998-2002*. (Report No. DOT HS 808 709). Washington, DC: National Highway Traffic Safety Administration Available at www-nrd.nhtsa.dot.gov/Pubs/808709.PDF; NHTSA (2004). *National Highway Traffic Safety Administration Evaluation Program Plan, Calendar Years 2004-2007*. (Report No. DOT HS 809 699). Washington, DC: National Highway Traffic Safety Administration Available at www-nrd.nhtsa.dot.gov/Pubs/809699.PDF; NHTSA (2008). *Evaluation Program Plan, 2008-2012*. (Report No. DOT HS 810 983). Washington, DC: National Highway Traffic Safety Administration Available at www-nrd.nhtsa.dot.gov/Pubs/810983.PDF.

[10] Partyka, S. C. (1984). *Restraint Use and Fatality Risk for Infants and Toddlers*. Washington, DC: National Highway Traffic Safety Administration; Evans, L. (1986a). Double Pair Comparison – A New Method to Determine How Occupant Characteristics Affect Fatality Risk in Traffic Crashes. *Accident Analysis and Prevention*, *18*, pp. 217-227; Evans, L. (1986b). The Effectiveness of Safety Belts in Preventing Fatalities. *Accident Analysis and Prevention*, *18*, pp. 229-241; Kahane, C. J. (1986). *An Evaluation of Child Passenger Safety: The Effectiveness and Benefits of Safety Seats*. (Report No. DOT HS 806 890, Chapter 4). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/806890.PDF ; Partyka, S. C. (1988). "Belt Effectiveness in Pickup Trucks and Passenger Cars by Crash Direction and Accident Year," *Papers on Adult Seat Belts – Effectiveness and Use*. (Report No. DOT HS 807 285). Washington, DC: National Highway Traffic Safety Administration; Kahane, C. J. (2000). *Fatality Reduction by Safety Belts for Front-Seat Occupants of Cars and Light Trucks: Updated and Expanded Estimates Based on 1986-99 FARS Data*. (Report No. DOT HS 809 199).

In this analysis, the fatality-reducing effectiveness of seat belts for drivers and right front (RF) passengers of cars and LTVs equipped with pretensioners and load-limiters at those seats will be compared to the effectiveness of belts in corresponding baseline vehicles not equipped with either technology. If possible, vehicles equipped with just one or the other technology may also be considered. The database needed to drive the analysis comprises FARS cases of vehicles occupied by a driver and a RF passenger (and perhaps other occupants), where at least one and possibly both the driver and the RF passenger were fatalities. Because almost all vehicles with pretensioners and load limiters are also equipped with dual frontal air bags, the analysis will be limited to vehicles with dual air bags. Specifically, the "corresponding baseline vehicles" are those with dual frontal air bags but without pretensioners or load limiters.

Dual frontal air bags that can be identified from the first 12 characters of the VIN began to appear in passenger cars in MY 1987 (Porsche 944) and in LTVs in 1994 (Chrysler Corp. minivans, Toyota Previa).[11] FARS data for CY 1986 to 2011 includes 57,882 cases of vehicles with dual air bags, occupied by a driver and a RF passenger, at least one or possibly both fatalities, also meeting the following conditions:

- The make, model, and MY must be decodable from the first 12 characters of the VIN, using the VIN-decode programs developed by NHTSA's Evaluation Division;
- The driver's and RF passenger's age and gender are known in FARS and both of these occupants must be at least 13 years old;
- Cases with unknown belt use for the driver, RF passenger or both are excluded. The driver's and RF passenger's restraint-use code, REST_USE has to be 0 (in CY 1986 to 2009 only), 1, 2, 3, 7 (in CY 2010 or 2011 only), 8, or 13; 0 or 7 mean unbelted, the other codes mean belted;
- The study excludes those pickup trucks and other vehicles without a back seat that are equipped with a manual on-off switch for the passenger air bag (because an impact might deploy only the driver air bag if the passenger bag is switched off); and
- The belts must be the manual 3-point type; vehicles with automatic 2-point belts and dual air bags are excluded.

Appendix A lists the makes and models of cars and LTVs with dual air bags, indicating the MY when pretensioners first became standard equipment for the driver and RF passenger seats and the MY when load limiters became standard equipment. The primary source of information on pretensioners and load limiters is material compiled at www.safercar.gov from data furnished to NHTSA by the manufacturers. Information was also gleaned from www.cars.com, www.motortrend.com, and the Walz and Brumbelow reports.[12] The determinations in Appendix A are judgments of the most likely status of the vehicles, based on the various sources and taking into account the findings for similar vehicles; the status of pretensioners and/or load limiters was marked unknown if the information was inconsistent or ambiguous. The 57,882 vehicle cases have the following distribution of pretensioners and load limiters:

Washington, DC: National Highway Traffic Safety Administration.
Available at www-nrd.nhtsa.dot.gov/Pubs/809199.PDF.

[11] There are earlier cars with dual frontal air bags, but the 1987 Porsche were the first ones that could be identified from the first 12 characters of the VIN.

[12] Walz (2003); Brumbelow et al. (2007).

27,389	No pretensioners or load limiters at the driver and RF passenger seats,
1,705	Pretensioners at both seats but no load limiters at either seat,
11,040	Load limiters at both seats but no pretensioners,
16,642	Pretensioners and load limiters at both seats, and
1,106	Cases that cannot be used because pretensioner and/or load-limiter availability is unknown for one or both seats, or because availability is different for the driver and passenger seats

The analysis will focus on the two conditions with the most data: no pretensioners or load limiters versus both. There are also enough cases with load limiters but not pretensioners to pursue at least a preliminary analysis – but not enough with pretensioners in the absence of load limiters.

Here are examples of the analysis techniques of this report, applied to the full database of 57,882 FARS cases of crash-involved vehicles occupied by a driver and an RF passenger, at least one of them a fatality, in cars and LTVs with dual frontal air bags. Actually, NHTSA has estimated effectiveness separately for cars and LTVs in the past and will do so again in this report, but in these initial examples cars and LTVs are combined for relative simplicity and to maximize the database.

This is how double-pair comparison estimates the overall fatality reduction by seat belts for drivers and RF passengers in the subset of 27,389 vehicles without pretensioners or load limiters. Table 1 counts the 27,389 vehicle cases, based on each occupant's belt use (as reported in FARS) and survival:

Table 1: Vehicles by Front-Outboard Belt Use and Survival Status
(Cars and LTVs with dual air bags, with a driver and an RF passenger,
at least one a fatality, FARS 1986 to 2011)

Vehicles	Driver Died RF Survived	Driver Survived RF Died	Both Died
Both unrestrained	3,539	3,317	1,810
Driver unrestrained, RF belted	1,972	428	377
Driver belted, RF unrestrained	482	2,133	419
Both belted	5,186	5,585	2,141

Table 2 tallies fatality counts rather than vehicle cases by adding the "both died" column to each of the preceding columns. There are 32,136 fatalities (15,926 drivers and 16,210 RF passengers) in the 27,389 vehicles, classified as follows:

Table 2: Fatalities by Belt Use and Seat Position
(Cars and LTVs with dual air bags, with a driver and RF passenger, FARS 1986 to 2011)

Fatalities	Driver Fatalities	RF Fatalities	Driver/RF Risk Ratio
Both unrestrained	5,349	5,127	1.043
Driver unrestrained, RF belted	2,349	805	2.918
Driver belted, RF unrestrained	901	2,552	0.353
Both belted	7,327	7,726	0.948

In these vehicles with dual air bags, it is clear that (1) unrestrained drivers and RF passengers are at approximately equal risk in the same crash; (2) belted drivers and RF passengers are also at approximately equal risk; and (3) whoever buckled up substantially reduced their risk.

The four rows of data in Table 2 allow a total of four double-pair comparisons, two for computing the effectiveness of belts for drivers, and two for RF passengers. The first comparison for the driver is based on the first and third rows of data in Table 2:

		Driver Fatalities	RF Fatalities	Driver/RF Risk Ratio
Driver unrestrained	RF unrestrained	5,349	5,127	1.043
Driver belted	RF unrestrained	901	2,552	0.353

In both pairs, the driver's fatality risk is compared to the same control group: the unrestrained RF passenger. The unrestrained driver has essentially the same fatality risk as the unrestrained RF passenger in the same crash; the belted driver has about one-third the fatality risk as the unrestrained RF passenger (if FARS reporting of belt use is accepted at face value). The observed fatality reduction for belts is

$$1 - (0.353/1.043) = 66.2 \text{ percent.}$$

The other comparison for the driver is based on the second and fourth rows of data in Table 2:

		Driver Fatalities	RF Fatalities	Driver/RF Risk Ratio
Driver unrestrained	RF belted	2,349	805	2.918
Driver belted	RF belted	7,327	7,726	0.948

Here, the control group is the belted RF passenger. The unrestrained driver has higher fatality risk than the belted RF passenger in the same crash, the belted driver, lower. The fatality reduction is:

1 - (0.948/2.918) = 67.5 percent.

It is important that the effectiveness estimates are quite similar with the two control groups: it suggests the estimates are robust and not affected by the choice of control group.

The first double-pair comparison for estimating belt effectiveness for the RF passenger is obtained by using the first two rows of data in Table 2, reversing the order of the columns and computing the RF/Driver rather than the Driver/RF risk ratio:

		RF Fatalities	Driver Fatalities	RF/Driver Risk Ratio
RF unrestrained	Driver unrestrained	5,127	5,349	0.958
RF belted	Driver unrestrained	805	2,349	0.343

The control group is the unrestrained driver. The fatality reduction for the belted RF passenger is:

1 - (0.343/0.958) = 64.2 percent.

The second estimate uses the last two rows of data in Table 2:

		RF Fatalities	Driver Fatalities	RF/Driver Risk Ratio
RF unrestrained	Driver belted	2,552	901	2.832
RF belted	Driver belted	7,726	7,327	1.054

The control group is the belted driver. The fatality reduction for the belted RF passenger is:

1 - (1.054/2.832) = 62.8 percent.

Again, the two control groups produce similar estimates. Also, as in earlier studies, belt effectiveness is slightly lower for the RF passenger than for the driver.

The next task is to develop a weighting procedure that combines the two driver estimates into a single number, and likewise for the two RF passenger estimates. In Table 2, the actual number of driver fatalities is:

Actual driver fatalities = 5,349 + 2,349 + 901 + 7,327 = 15,926

The first two numbers in that sum are unrestrained drivers, the last two, belted. However, if every driver had been unrestrained, that sum would have increased to:

All-unrestrained driver fatalities = 5,349 + 2,349 + (1.043 x 2,552) + (2.918 x 7,726) = 32,904

(Here, 2,552 was the number of unrestrained RF passenger fatalities that accompanied the 901 belted drivers and 1.043 is the risk ratio of unrestrained driver to unrestrained RF passenger fatalities; 7,726 is the number of belted RF passenger fatalities that accompanied the 7,327 belted drivers and 2.918 is the risk ratio of unrestrained drivers to belted RF passenger fatalities.) On the other hand, if every driver had buckled up, the sum would have dropped to:

All-belted driver fatalities = (0.353 x 5,127) + (0.948 x 805) + 901 + 7,327 = 10,801.

The overall effectiveness of 3-point belts for drivers (if FARS reporting of belt use is accepted at face value) is:

(32,904 – 10,801) / 32,904 = 67.2 percent,

which is between the results of the two separate double-pair comparisons for drivers (66.2 and 67.5 percent).

Similarly, the actual number of RF passenger fatalities in Table 2is

Actual RF fatalities = 5,127 + 805 + 2,552 + 7,726 = 16,210

If every RF passenger had been unrestrained, that sum would have increased to

All-unrestrained RF fatalities = 5,127 + (0.958 x 2,349) + 2,552 + (2.832 x 7,327) = 30,679

(Here, 2,349 was the number of unrestrained driver fatalities that accompanied the 805 belted RF passengers and 0.958 is the risk ratio of unrestrained RF to unrestrained driver fatalities; 7,327 is the number of belted driver fatalities that accompanied the 7,726 belted RF and 2.832 is the risk ratio of unrestrained RF to belted driver fatalities.)

But if every RF passenger had buckled up, the sum would have dropped to

All-belted RF fatalities = (0.343 x 5,349) + 805 + (1.054 x 901) + 7,726 = 11,315

The overall effectiveness of belts for RF passengers (if FARS reporting of belt use is accepted at face value) is

(30,679 - 11,315) / 30,679 = 63.1 percent,

which is between the results of the two separate double-pair comparisons for RF passengers (64.2 and 62.8 percent).

FARS data from CY 1986 and later adds a complication when it is used for double-pair comparison analyses of belt effectiveness for drivers and RF passengers with the reported belt use taken at face value. The observed effectiveness of belts is higher than in analyses of earlier calendar years of FARS data, even for vehicles of the same model years. During the mid-1980s, large numbers of States began to pass buckle-up laws for drivers and RF passengers.

> "Specifically, New York was the first [S]tate to enact a belt use law, effective December 1, 1984. After a brief 'wait and see,' 21 [S]tates, including 9 of the 10 most populous [S]tates had belt laws effective by August 1986 for front-seat occupants of passenger cars. For the first time, unbelted people had a tangible incentive - avoidance of a fine - to report that they were belted. NHTSA hypothesized that uninjured or slightly injured occupants are often up and about before police arrive at the crash scene. Since the investigating officer is not an eye-witness to their belt use, they have an opportunity – and now also a motive – to say they wore belts, even if they hadn't. Mortally injured occupants may be in their original post-crash location when police arrive, often allowing direct observation of belt use. Thus, NHTSA believes belt use of fatalities is reported without net biases on FARS before and after belt laws. However, after the laws, belt use of survivors is over-reported. A bias has apparently been introduced in the reporting of this one data element, for survivors, as a consequence of belt use laws."[13]

NHTSA empirically derived a universal exaggeration factor to adjust estimates based on FARS data after 1985 and make them comparable to estimates from earlier data.[14] The UEF is 1.369 and it is applied as follows to the observed effectiveness (percentage fatality reduction) E* to estimate the actual effectiveness E:

$$E = 100 - [1.369 \times (100 - E^*)]$$

For example, if the observed effectiveness is 60 percent, the actual effectiveness is 45.24 percent. The analyses of this report are based entirely on FARS data from CY 1986 and later. Every point estimate based directly on FARS data needs to be corrected downward with the UEF. Tables of point estimates will indicate if they have been corrected or are based on the actual FARS data.

Table 3 compares belt effectiveness with and without pretensioners and/or load limiters, for the complete database of all cars and LTVs equipped with dual air bags, showing both the uncorrected and the corrected estimates. The uncorrected estimates for vehicles without pretensioners or load limiters were derived above. Corresponding estimates for vehicles equipped with pretensioners and/or load limiters are derived by the same techniques. The few cases (1,705) with pretensioners but no load limiters are excluded from the analysis and so are the 1,106 cases with unknowns or where the driver and RF seat belts are differently equipped.

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[13] Kahane (2000), pp. 2-3.
[14] Ibid., pp. 10-19.

Table 3: Fatality Reduction (%) by Seat Belts, Cars Plus LTVs
(Cars and LTVs with dual air bags, with a driver and RF passenger, FARS 1986 to 2011)

	Uncorrected		Corrected with UEF	
	Driver	RF	Driver	RF
No pretensioner, no load limiter	67.17	63.13	55.06	49.52
Load limiter but no pretensioner	68.02	65.78	56.21	53.15
Pretensioner and load limiter	70.36	66.76	59.42	54.49

In the aggregate analysis combining cars and LTVs, Table 3 shows that the corrected fatality reduction for belts with pretensioners and load limiters is about 4 to 5 percentage points higher than belt effectiveness with neither: 59.42 versus 55.06 percent for drivers and 54.49 versus 49.52 percent for RF passengers. Effectiveness with load limiters but without pretensioners is higher than with neither but lower than with both.

2.2 Significance testing with CATMOD

The SAS procedure CATMOD statistically tests whether the observed belt-effectiveness estimates with pretensioners and load limiters are "approximately the same" as the estimates for belts equipped with neither or whether 3-point belts are significantly more effective when they are equipped with pretensioners and load limiters. In this example, as well as elsewhere in the report, the effectiveness estimate for the intermediate scenarios of load limiters without pretensioners or pretensioners without load limiters are not tested. Furthermore, the CATMOD analyses are based on the actual, observed FARS data and do not involve the UEF correction factor. When effectiveness is expressed as a log-odds ratio, as it is in logistic-regression models such as CATMOD, the UEF is merely a constant added to this ratio for any subgroup of cases. The differences between subgroups for these log-odds ratios will be the same, regardless of whether the UEF is added to all of them or to none.

CATMOD is a form of logistic regression that allows all the variables to be categorical rather than continuous. The first CATMOD analysis tests whether the combination of pretensioners and load limiters significantly enhances belt effectiveness for the driver. Here, the 32,136 driver and RF passenger fatality cases without pretensioners or load limiters in Table 2 and the corresponding 19,564 fatalities with pretensioners and load limiters, a total of 51,700 fatality cases, each have known values for the following four variables:

- DRIVER is treated as the dependent variable (= 1 if this specific fatality case is a driver, = 2 if it is an RF passenger);
- The three independent variables are:

- BELT1[15] (= 1 if the driver of the vehicle in which the fatality occurred is belted, = 2 if unrestrained);
- BELT3 (= 1 if the RF passenger of the vehicle in which the fatality occurred is belted, = 2 if unrestrained); and
- PRETENLL (= 1 if the vehicle in which the fatality occurred is equipped with pretensioners and load limiters at the driver and RF seats, = 2 if not equipped with either).

The logistic regression model for the dependent variable DRIVER includes not only the three independent variables BELT1, BELT3, and PRETENLL but also the two-way interaction terms BELT1 * PRETENLL and BELT3 * PRETENLL. However, the two-way interaction term BELT1 * BELT3 and the three-way interaction term BELT1 * BELT3 * PRETENLL are omitted. The regression coefficients and their statistics are:

```
                    Analysis of Maximum Likelihood Estimates

                                                 Standard        Chi-
Parameter       Value                Estimate       Error      Square    Pr > ChiSq
Intercept                             -0.0118     0.00993        1.40        0.2360
BELT3           BELTED                 0.5287      0.0127     1724.16        <.0001
BELT1           BELTED                -0.5779      0.0128     2031.08        <.0001
PRETENLL        PRETEN+LL            -0.00988     0.00993        0.99        0.3197
BELT3*PRETENLL  BELTED PRETEN+LL       0.0253      0.0127        3.94        0.0471
BELT1*PRETENLL  BELTED PRETEN+LL      -0.0262      0.0128        4.16        0.0414
```

As stated above, the dependent variable is DRIVER: given a fatally-injured occupant in these vehicles where drivers and RF passengers sit together, is this occupant a driver or an RF passenger? The results for the intercept and the first two main terms (BELT1 and BELT3) are straightforward: the negative intercept indicates that, all else being equal, fatality risk is slightly lower for the driver than for the RF passenger. The statistically significant, strongly negative (- 0.5779) coefficient for BELT1 (χ^2 = 2031.08; χ^2 needs to be 3.84 or larger for statistical significance at the two-sided .05 level) says that belt use by the driver reduces the odds that the fatality will be the driver – i.e., belts save drivers' lives. The significant positive (0.5287) coefficient for BELT3 (χ^2 = 1724.16) says that belt use by the RF passenger increases the odds that, in this particular database, the fatality will be the driver – i.e., belts save passengers' lives; in this database where either the driver or the passenger (but only occasionally both) is a fatality, the survival of the passenger in this crash means that the driver must have been a fatality (because the only vehicles included in the analysis are those where at least one of these two people died). The coefficient for PRETENLL is close to zero, not statistically significant (χ^2 = .99), and, frankly, not particularly meaningful; PRETENLL was included as a main term only because the model also includes interaction terms with PRETENLL.

That leaves the two interaction terms. The crucial statistics are on the last line, BELT1 * PRETENLL. The negative coefficient -0.0262 when BELT1 = 1 and PRETENLL = 1 indicates that a pretensioner plus load limiter further reduces the odds that the fatality will be the driver

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[15] In diagrams of passenger cars, the driver's seat is traditionally labeled no. 1, [the center-front seat, no. 2,] and the RF passenger seat no. 3 – thus, the variables for driver and RF passenger belt use are called BELT1 and BELT3, respectively.

when the belt is in use, but of course has no effect when the belt is not in use. With a chi-square of 4.16, the effect is **statistically significant**. In other words, pretensioners and load limiters make belts more effective for the driver. BELT3 * PRETENLL has a statistically significant positive coefficient (0.0253, $\chi^2 = 3.94$). Because pretensioners and load limiters make belts more effective for the RF passenger, the better chance of survival for the passenger implies a higher fatality risk for the driver in this database, where at least one of the two occupants is a fatality.

Actually, none of the regression coefficients themselves are particularly important; they do not translate directly into effectiveness estimates. Their chi-square values are what matters. It is sufficient to look at the simpler table of just the chi-squares and, as a matter of fact, even there, only the chi-square of BELT1 * PRETENLL really matters:

```
     Maximum Likelihood Analysis of Variance

Source              DF   Chi-Square    Pr > ChiSq
Intercept            1         1.40        0.2360
BELT3                1      1724.16        <.0001
BELT1                1      2031.08        <.0001
PRETENLL             1         0.99        0.3197
BELT3*PRETENLL       1         3.94        0.0471
BELT1*PRETENLL       1         4.16        0.0414

Likelihood Ratio     2         0.52        0.7729
```

This table, however, introduces a new term: a “likelihood ratio,” which is found to be non-significant ($\chi^2 = 0.52$ with 2 df). It measures the combined, residual effect of the two interaction terms omitted from the model, namely BELT1 * BELT3 and BELT1 * BELT3 * PRETENLL. The initial model only includes the interaction terms that have a clear intuitive meaning and/or are essential to the research question, such as BELT1 * PRETENLL. If the likelihood ratio has $p > .05$ (and certainly if $p > .50$, as in this case), the initial model limited to these terms adequately fits the data and may be accepted as is. But if $p < .05$, it may be necessary to add other interaction terms that are statistically significant, even if they have no obvious intuitive explanation. BELT1 * BELT3 was omitted from the initial model because it has no obvious meaning. BELT1 * BELT3 * PRETENLL, also omitted, is actually counterintuitive: it would suggest that the benefit of pretensioners and load limiters for the belted driver depends on whether or not the passenger is belted. Thus, it is reassuring that the likelihood ratio for the two omitted terms has such low chi-square. It is further good news, because in the absence of BELT1 * BELT3 * PRETENLL, the two-way term BELT1 * PRETENLL directly measures the difference in the driver’s belt effectiveness with and without pretensioners and load limiters; its chi-square tells us if the difference is significant or not. But if the three-way term had been included, the two-way term BELT1 * PRETENLL would have lost its straightforward interpretation.

The second CATMOD analysis tests whether the combination of pretensioners and load limiters significantly enhances belt effectiveness <u>for the RF passenger</u>. It uses the same 51,700 fatality cases as the preceding analysis, but now the dependent variable is RF (= 1 if this specific fatality case is an RF passenger, = 2 if it is a driver). The three independent variables, BELT1, BELT3, and PRETENLL are identical to the preceding analysis. The model is identical to the preceding analysis, except the values of the dependent variable are flipped. Thus, all regression coefficients have the identical magnitude and the opposite sign of the preceding analysis. Chi-square values are identical.

```
                   Analysis of Maximum Likelihood Estimates

                                                     Standard        Chi-
Parameter       Value                 Estimate       Error         Square    Pr > ChiSq
Intercept                               0.0118     0.00993           1.40        0.2360
BELT1           BELTED                  0.5779      0.0128        2031.08        <.0001
BELT3           BELTED                 -0.5287      0.0127        1724.16        <.0001
PRETENLL        PRETEN+LL              0.00988     0.00993           0.99        0.3197
BELT1*PRETENLL  BELTED PRETEN+LL        0.0262      0.0128           4.16        0.0414
BELT3*PRETENLL  BELTED PRETEN+LL       -0.0253      0.0127           3.94        0.0471
```

```
     Maximum Likelihood Analysis of Variance

Source               DF   Chi-Square    Pr > ChiSq
Intercept             1         1.40        0.2360
BELT1                 1      2031.08        <.0001
BELT3                 1      1724.16        <.0001
PRETENLL              1         0.99        0.3197
BELT1*PRETENLL        1         4.16        0.0414
BELT3*PRETENLL        1         3.94        0.0471

Likelihood Ratio      2         0.52        0.7729
```

Now, BELT3 * PRETENLL has a statistically significant negative coefficient (-0.0253, $\chi^2 = 3.94$). In other words, the odds of a RF passenger fatality are reduced: pretensioners and load limiters make belts more effective for the RF passenger, when and if that passenger buckles up (when BELT3 = 1 and PRETENLL = 1). Because the CATMOD analyses for the driver and the RF passenger generate identical results (except for the sign of the regression coefficients), it is not strictly necessary to run both analyses; it would be sufficient just to examine the chi-squares for BELT1 * PRETENLL and BELT3 * PRETENLL coefficients in the analysis for the driver.

The other analyses in this report repeat the double-pair comparisons and CATMOD-based testing of the preceding examples for various subsets of the database. A further complexity is that some analyses will estimate the effectiveness-enhancing effect of pretensioners and load limiters while **controlling** for some additional parameter such as the vehicle type or the crash type. That parameter becomes the fourth independent variable in CATMOD, generating a slew of potential interactions with the first three variables that can be included or omitted from the model. The report will describe the procedure in detail the first time it appears.

3. Results

3.1 Effectiveness by vehicle type

The preceding examples used the entire database and computed effectiveness for cars and LTVs combined. But NHTSA has estimated belt effectiveness separately for cars and LTVs since 1984.[16] Furthermore, pooling the cars and LTVs creates a bias in favor of pretensioners and load limiters, because of the market shift from cars to LTVs. The more recent vehicles equipped with pretensioners and load limiters include a higher proportion of LTVs, where effectiveness is intrinsically about 15 percentage points higher for reasons not necessarily related to these safety technologies. The first order of business is to estimate the effect of pretensioners and load limiters separately by type of vehicle and then, perhaps, to control for the market shift in any test of the overall, average effect of these technologies across vehicle types.

But before that, it is necessary to define "vehicle types." The distinction between cars and LTVs was once fairly clear. In recent years, LTVs have included a growing share of CUVs such as the Dodge Magnum or Subaru Forester that resemble cars in some respects (unibody design, extensive use in urban areas) but not in others (built higher off the ground). Appendix B is a list of CUVs through MY 2011. Some minivans also seem closer to CUVs than to pickup trucks and pickup-based SUVs. In 2011, NHTSA statistically analyzed crash data separately for three classes of vehicles: passenger cars, truck-based LTVs, and CUVs plus minivans.[17] The same classification may be of additional value here, because of the differing proportions of vehicles equipped with pretensioners and load limiters. Table 4 shows how the 55,071 FARS cases of vehicles equipped with dual air bags (excluding the 1,705 vehicles with pretensioners but no load limiters and the 1,106 cases with unknowns) are distributed by vehicle type and availability of pretensioners and load limiters:

Table 4: Pretensioner/Load Limiter Availability in 5 Vehicle Types
(Cars and LTVs with dual air bags, with a driver and an RF passenger,
at least one a fatality, FARS 1986 to 2011)

Row Percentage	No Pretensioners No Load Limiters	Load Limiters No Pretensioners	Pretensioners & Load Limiters	
Passenger cars	51.3	21.2	27.5	100
Pickup trucks	35.1	3.4	61.5	100
Truck-based SUVs	54.9	24.9	20.2	100
Vans	51.7	11.9	36.4	100
CUVs	2.6	6.9	90.5	100

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[16] NHTSA. (1984). *Final Regulatory Impact Analysis, Amendment to Federal Motor Vehicle Safety Standard 208, Passenger Car Front Seat Occupant Protection.* (Report No. DOT HS 806 572, pp. IV-1 - IV-16). Washington, DC: National Highway Traffic Safety Administration; Kahane (2000).

[17] Kahane, C. J. (2012, August). *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Final Report*. (Report No. DOT HS 811 665). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/811665.PDF.

It would be futile to analyze CUVs separately in this report because so few of these relatively late-model vehicles were not equipped with pretensioners and load limiters. Pickup trucks in the database mostly have pretensioners and load limiters, because so many of the earlier models were excluded from the database due to having manual on-off switches for the passenger air bag. However, Table 4a shows that combining CUVs with minivans[18] and combining pickups, truck-based SUVs and full-sized vans make it possible to obtain three fairly distinct groups of vehicles that each have substantial numbers of cases with and without pretensioners and load limiters. Furthermore, cars and truck-based LTVs have nearly identical distributions; only CUVs and minivans have a substantially higher proportion of vehicles with pretensioners and load limiters.

Table 4a: Pretensioner/Load Limiter Availability in 3 Vehicle Types
(Cars and LTVs with dual air bags, with a driver and an RF passenger,
at least one a fatality, FARS 1986 to 2011)

Row Percent	No Pretensioners No Load Limiters	Load Limiters No Pretensioners	Pretensioners & Load Limiters	
Passenger cars	51.3	21.2	27.5	100
Truck-based LTVs	51.6	19.6	28.7	100
CUVs and minivans	29.8	10.6	59.6	100

Table 5 separately compares belt effectiveness with and without pretensioners and/or load limiters for each of those three vehicle types and also for cars, CUVs, and minivans combined. In passenger cars, pretensioners and load limiters enhance the effectiveness of seat belts. The UEF-corrected baseline fatality reduction is 44 percent for drivers and 38 percent for RF passengers in cars with dual air bags. With pretensioners and load limiters, effectiveness increases by about 6 percentage points for drivers, to 50 percent and by nearly 10 percentage points for RF passengers, to 48 percent. With load limiters but no pretensioners, belt effectiveness is 47 percent for both drivers and passengers: higher than baseline, but not as high as with both pretensioners and load limiters (although it comes close for RF passengers).

The baseline effectiveness of seat belts is much higher in truck-based LTVs (75% for drivers and 71% for RF passengers) than in passenger cars (44% and 38%). That is primarily because such a large percentage of fatalities in LTVs, at least in the past, were in rollover crashes, where belts are highly effective. Another reason is that the high sills, mass, and rigidity of truck-based LTVs make them less vulnerable to structural collapse in side impacts, allowing seat belts to better protect the occupants. Pretensioners and load limiters, however, at first glance have not enhanced belt effectiveness: fatality reduction is unchanged for drivers and drops by 4 percentage points for passengers.

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[18] Chevrolet Astro van and GMC Safari are sometimes called minivans but are here included with full-sized vans, which they more closely resemble in structure.

Table 5: Fatality Reduction (%) by Seat Belts, by Vehicle Type
(Cars and LTVs with dual air bags, with a driver and RF passenger, FARS 1986 to 2011)

	Uncorrected		Corrected with UEF	
	Driver	RF	Driver	RF
PASSENGER CARS				
No pretensioner, no load limiter	59.18	54.87	44.12	38.22
Load limiter but no pretensioner	61.33	61.30	47.07	47.02
Pretensioner and load limiter	63.70	62.08	50.31	48.08
TRUCK-BASED LTVs				
No pretensioner, no load limiter	81.59	79.15	74.79	71.46
Load limiter but no pretensioner	83.64	75.66	77.61	66.68
Pretensioner and load limiter	81.42	75.68	74.57	66.71
CUVs and MINIVANS				
No pretensioner, no load limiter	71.60	66.69	61.12	54.40
Load limiter but no pretensioner	65.08	70.82	52.20	60.06
Pretensioner and load limiter	75.14	70.52	65.97	59.64
PASSENGER CARS, CUVs, and MINIVANS				
No pretensioner, no load limiter	59.77	55.73	44.92	39.39
Load limiter but no pretensioner	61.44	61.90	47.22	47.84
Pretensioner and load limiter	65.49	63.85	52.75	50.51

Baseline effectiveness of seat belts in CUVs and minivans is approximately midway between passenger cars and truck-based LTVs, consistent with their design incorporating both car-like and truck-like features. But pretensioners and load limiters seem to have similar benefits as in passenger cars, increasing the already-high baseline effectiveness by about 5 percentage points for both drivers and passengers.

Although the added benefit in CUVs and minivans is lower than in cars as a percentage-point increase, it is in fact almost identical when expressed as an odds ratio. For car drivers, the baseline effectiveness of belts is 44.12 percent, but with pretensioners and load limiters it is 50.31 percent. In other words, in a baseline car, the fatality risk for a belted driver relative to an unbelted driver is 1-.4412, but with pretensioners and load limiters that drops to 1-.5031; the odds ratio is (1-.5031)/(1-.4412) = .889. The corresponding odds ratio for car passengers is (1-.4808)/(1-.3822) = .840; for CUV and minivan drivers, (1-.6597)/(1-.6112) = .875; and for CUV and minivan passengers, (1-.5964)/(1-.5440) = .885. The harmonic average of these four odds ratios is .872. This would appear to be the **best estimate** of the effectiveness of pretensioners and load limiters in cars, CUVs, and minivans: the addition of pretensioners and load limiters reduces fatality risk by 1 - .872 = **12.8 percent** relative to a belted occupant in a vehicle without pretensioners and load limiters. Note that this effectiveness of 12.8 **percent** translates into considerably smaller **percentage-point** increases in belt effectiveness, depending on the baseline effectiveness. Also, the estimate may to some extent reflect the effects of other belt or belt-related improvements introduced in some makes and models at about the same time as pretensioners and load limiters, such as adjustable anchorages; integrated belt systems; or tuning the air bag, vehicle structure, or seats especially to improve protection for a belted occupant.

For load limiters without pretensioners, the available data is fairly limited in truck-based LTVs and in CUVs/minivans and results are ambiguous: in truck-based LTVs, effectiveness is relatively highest for drivers and lowest for RF passengers, whereas in CUVs/minivans it is the other way around. In other words, none of the three vehicle types show a large risk increase (or reduction, for that matter) with load limiters but no pretensioners.

The last section of Table 5 simply pools the data for cars, CUVs, and minivans. Effectiveness increases by almost 8 percentage points for drivers and more than 11 for passengers. These numbers appear to be unrealistically high, because they exceed the percentage point increases for cars alone (6 and 10) or CUVs/minivans alone (5 and 5). The effect is biased upward because so many of the CUVs and minivans (where baseline belt effectiveness is higher than in cars) have pretensioners and load limiters. It is not a reliable estimate.

The CATMOD analysis for car drivers generates a coefficient of -0.0338 for BELT1 * PRETENLL when BELT1 = 1 and PRETENLL = 1. It is statistically significant (χ^2 = 4.75). Similarly, the CATMOD analysis for car passengers generates a coefficient of -0.0392 for BELT3 * PRETENLL when BELT3 = 1 and PRETENLL = 1. It is also statistically significant (χ^2 = 6.43). In other words, the combination of pretensioners and load limiters significantly enhances belt effectiveness in passenger cars, for both drivers and RF passengers.

The CATMOD analyses for truck-based LTVs generate coefficients of +0.0202 for BELT1 * PRETENLL and +0.0270 for BELT3 * PRETENLL, neither of which is statistically significant (χ^2 = .53 and .95, respectively). Note, however, that the coefficients have positive signs, indicating (for the time being) point estimates that fatality risk is higher with pretensioners and load limiters than without them.

The CATMOD analyses for CUVs and minivans generate coefficients of -0.0524 for BELT1 * PRETENLL and -0.0227 for BELT3 * PRETENLL, neither of which is statistically significant (χ^2 = 1.21 and .22, respectively). Although the coefficients are in the same direction and of similar magnitude as for cars, the quantity of data is lower for CUVs and minivans, not enough to achieve statistical significance.

CATMOD analyses for the pooled data in the last section of Table 5 (cars + CUVs + minivans) generate coefficients of -0.0427 for BELT1 * PRETENLL and -0.0467 for BELT3 * PRETENLL, both of which are statistically significant (χ^2 = 8.61 and 10.44, respectively). As stated above, these analyses are biased and the coefficients and their chi-square values likely exaggerate the true benefits of pretensioners and load limiters.

3.2 Estimating overall effectiveness while controlling for vehicle type

The bias in the pooled data for cars, CUVs, and minivans (the last section of Table 5) can be addressed in CATMOD analyses by adding one more independent variable, NEWVTYP (= 1 if the vehicle is a car, = 3 if it is a CUV or minivan) and, initially, the two interaction terms BELT1 * NEWVTYP and BELT3 * NEWVTYP. Adding the main effect NEWVTYP will control for the fact that a higher proportion of the CUVs and minivans are equipped with pretensioners, while adding the two interaction terms will control for baseline belt effectiveness being higher in CUVs and minivans than in passenger cars. At first glance, no other potential interaction terms seem to have a clear intuitive meaning – and no others are included in the model. The CATMOD analysis for drivers generates the following statistics:

```
                     Analysis of Maximum Likelihood Estimates

                                                     Standard        Chi-
Parameter        Value                    Estimate      Error      Square    Pr > ChiSq
Intercept                                  -0.0403     0.0197        4.19        0.0407
BELT3            BELTED                     0.5199     0.0241      464.80        <.0001
BELT1            BELTED                    -0.5496     0.0251      478.98        <.0001
PRETENLL         PRETEN+LL                 -0.0174     0.0115        2.29        0.1303
NEWVTYP          PASSENGER CAR            -0.00981     0.0199        0.24        0.6223
BELT3*NEWVTYP    BELTED PASSENGER CAR      -0.0807     0.0245       10.87        0.0010
BELT1*NEWVTYP    BELTED PASSENGER CAR       0.0701     0.0255        7.57        0.0059
BELT3*PRETENLL   BELTED PRETEN+LL           0.0375     0.0147        6.51        0.0107
BELT1*PRETENLL   BELTED PRETEN+LL          -0.0354     0.0148        5.73        0.0167
```

```
     Maximum Likelihood Analysis of Variance

Source                DF    Chi-Square    Pr > ChiSq
Intercept              1          4.19        0.0407
BELT3                  1        464.80        <.0001
BELT1                  1        478.98        <.0001
PRETENLL               1          2.29        0.1303
NEWVTYP                1          0.24        0.6223
BELT3*NEWVTYP          1         10.87        0.0010
BELT1*NEWVTYP          1          7.57        0.0059
BELT3*PRETENLL         1          6.51        0.0107
BELT1*PRETENLL         1          5.73        0.0167

Likelihood Ratio       7          2.20        0.9480
```

The "likelihood ratio" is not statistically significant (χ^2 = 2.20 with 7 df), indicating that the model limited to these terms adequately fits the data. The coefficient for BELT1 * PRETENLL, -0.0354 is negative (indicating a benefit for pretensioners and load limiters) and it is statistically significant (χ^2 = 5.73). Nevertheless, the coefficient and its chi-square are both of lower magnitude than in the immediately preceding analysis, based on the same data, but without controlling for NEWVTYP (-.0427 and 8.61, respectively). NHTSA believes the new analysis controls for the bias due to the market shift from cars to CUVs, yet it continues to show a significant benefit for pretensioners and load limiters in the combined population of cars, CUVs, and minivans. Similarly, the CATMOD analysis for RF passengers generates a coefficient of -0.0375 for BELT3 * PRETENLL, which is also statistically significant (χ^2 = 6.51), although of smaller magnitude than in the preceding, biased analysis.

The regression coefficients and their standard errors for BELT1 * PRETENLL and BELT3 * PRETENLL (and the resultant chi-squares) indicate how strong the results are, statistically speaking. They also allow estimation of a heuristic 95-percent confidence interval for the earlier best estimate that pretensioners plus load limiters in cars, CUVs, and minivans reduce fatality risk by 12.8 percent relative to a belted occupant in a vehicle without pretensioners and load limiters.[19] The two coefficients are -0.0354 and -0.0375, averaging to -0.03645. Their standard errors (shown in the second column of numbers in the preceding "Analysis of Maximum Likelihood Estimates") are 0.0148 and 0.0147, respectively, averaging to 0.01475. The average of 1.96 standard errors[20] relative to the average magnitude of the coefficients is

$$(1.96 \times 0.01475) / 0.03645 = .793$$

The same ratio may be applied to the best effectiveness estimate (12.8%) to obtain 95-percent confidence bounds of $12.8 \pm (.793 \times 12.8)$: an interval of approximately 2.6 to 23.0 percent.

These confidence bounds demonstrate that the effectiveness of pretensioners and load limiters, although statistically significant, cannot yet be estimated precisely from the currently available data. The best estimate can serve as a working number for the time being, but it would be advisable to rerun the analyses in about four or five years when somewhat more data will be available, especially for vehicles equipped with pretensioners and load limiters.

These CATMOD analyses controlling for vehicle type can also be applied to the full database in Table 2 – i.e., also including truck-based LTVs. NEWVTYP now has 3 categories (= 1 if the vehicle is a car, = 2 if it is a truck-based LTV, = 3 if it is a CUV or minivan); otherwise the models are unchanged. These models generate coefficients of -0.0239 for BELT1 * PRETENLL and -0.0227 for BELT3 * PRETENLL, neither of which is statistically significant ($\chi^2 = 3.35$ and 3.04, respectively). Whereas the simpler but biased CATMOD analyses on Table 2, without controlling for NEWVTYP showed significant benefits for pretensioners and load limiters, these drop out of the significant range, when truck-based LTVs are included in the data, after controlling for NEWVTYP.

3.3 Car-CUV-minivan models produced with/without pretensioners/load limiters

Recent NHTSA evaluations of safety technologies often compare absolute fatality rates or they compare fatalities in crashes affected by the technology relative to control group crashes – before and after the technology is introduced. To avoid potential bias in the analyses, the database was usually limited to (1) makes and models that were produced both with and without the safety feature; (2) a limited number of model years before and after the transition to the new technology, say 2 to 4 MY; (3) further limiting the range of model years, if necessary, to avoid a major redesign of that model or the introduction of another important safety technology during the timespan included.[21]

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[19] This "best estimate" was an average of four partially correlated results; it would be difficult to calculate confidence bounds for it directly.

[20] The 95% confidence bounds of a normally distributed statistic are the point estimate ±1.96 standard errors.

[21] Greenwell, N. K. (2013, July). *Evaluation of the Certified-Advanced Air Bags*. (Report No. DOT HS 811 834). Washington, DC: National Highway Traffic Safety Administration. Available at

This report, however, is based on double-pair comparison analyses and compares **belt effectiveness** – i.e., the difference in fatality risk between a belted and an unbelted occupant – before and after the introduction of pretensioners and load limiters. A drawback is that double-pair comparison needs a lot of crash cases: to begin with, the database is restricted to vehicles that had a RF passenger as well as a driver. Further limiting the analysis to selected models for a narrow range of years could shrink the database and preclude statistically significant findings. But a compensatory advantage is a lower risk of bias. Broadly speaking, a safety improvement or change in the crash environment that benefits unbelted occupants would tend to also help belted occupants, and vice-versa; belt effectiveness (the difference between belted and unbelted risk) should stay about the same. The obvious exceptions are technologies that by definition work only for belted occupants – such as pretensioners or load limiters. That permits consideration of a wider range of models, including even those that were never, or always equipped with pretensioners and load limiters.

Nevertheless, there are some trends that conceivably, over a long time span, might have slightly increased the gap between belted and unbelted risk. For example, if vehicle structures have been modified over the years to better resist intrusion, it might have helped the belted occupant somewhat more than the unbelted occupant. The same could have happened if air bags had been gradually redesigned for optimal performance when the occupant is belted. As a check on the preceding results, it would be appropriate to limit the analyses to a narrower range of models, at least to the extent that the results remain statistically meaningful.

The first step is to limit the database of cars, CUVs, and minivans to make-models that were produced at one time without pretensioners and load limiters and subsequently with both. Only 72 of the 369 make-models equipped with dual air bags meet that criterion; the first step nearly cuts the database in half, from 40,453 to 21,188 fatality cases.

The second step is to further limit the database to a range of 8 or at most 9 model years for each individual make-model. If a make-model transitioned directly from no pretensioners or load limiters to being equipped with both, the range comprises the last 4 MY without and the first 4 MY with the two technologies. If there was one intervening MY with only one of the two technologies, or with unknown equipment, this MY is excluded from the analysis, but the last 4 MY without and the first 4 MY with pretensioners and load limiters are still included. However, if there were two intervening years, both are excluded and only the last 3 MY without and the first 3 MY with pretensioners and load limiters are included. There are 60 make-models still left in the analysis after this step, which again cuts the database approximately in half, to 11,794 fatality cases. Make-models, however, are not excluded, nor are the ranges of MY reduced if the models were redesigned at some point during those years.

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www-nrd.nhtsa.dot.gov/Pubs/811834.PDF; Kahane, C. J. (2011, November). *Evaluation of the 1999-2003 Head Impact Upgrade of FMVSS No. 201 – Upper-Interior Components: Effectiveness of Energy-Absorbing Materials Without Head-Protection Air Bags*. (Report No. DOT HS 811 538, pp. 39-41). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/811538.PDF; Kahane, C. J. (2009, August). *The Long-Term Effect of ABS in Passenger Cars and LTVs*. (Report No. DOT HS 811 182, pp. 19-22). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/811182.PDF; Allen, K. C. (2009, April). *The Effectiveness of Amber Rear Turn Signals for Reducing Rear Impacts*. (Report No. DOT HS 811 115). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/811115.PDF.

Table 6 shows that the effectiveness estimates for the two limited analyses are quite similar to the analysis of all cars, CUVs, and minivans. The left column of Table 6 analyzes the full database. The point estimates of belt effectiveness (corrected with the UEF) are copied from the last section of Table 5. Belts reduce fatality risk for drivers by 44.9 percent without pretensioners and load limiters and by 52.8 percent with both technologies, an improvement of 7.9 percentage points. For RF passengers, the improvement is 11.1 percentage points. When the analysis is initially limited to the models produced at one time without pretensioners or load limiters but later with both, the point estimates of effectiveness are little changed. However, the improvements with pretensioners and load limiters diminish slightly, to 6.2 percentage points for drivers and 8.4 percentage points for RF passengers. When the analysis is further limited to at most 4 MY without pretensioners or load limiters and at most 4 MY with both, the improvements are a bit larger: 7.2 percentage points for drivers and 13.0 percentage points for RF passengers, which are similar to the results for the full database.

Table 6: Fatality Reduction (%) by Seat Belts in 3 Analyses of Cars, Cuvs, and Minivans
(Vehicles with dual air bags, with a driver and RF passenger, FARS 1986 to 2011; all estimates corrected with the UEF)

	All Make-Models of Cars, CUVs, and Minivans N = 40,453 cases		Make-Models Produced With & Without Preten & Load Lim N = 21,188 cases		Make-Models Produced W & W/O Preten & Load Lim Limited to ± 4 MY Before/ After Transition N = 11,794 cases	
	Driver	RF	Driver	RF	Driver	RF
Fatality Reduction (%)						
No pretensioner, no load limiter	44.9	39.4	46.1	39.7	44.4	36.8
Pretensioner and load limiter	52.8	50.5	52.3	48.1	51.6	49.8
Percentage point improvement with pretensioner/load limiter	7.9	11.1	6.2	8.4	7.2	13.0
Coefficient for BELT_ * PRETENLL	- .0354	- .0375	- .0301	- .0329	- .0397	- .0534
Chi-square	5.73	6.51	2.14	2.65	2.08	3.84

The last section of Table 6 provides statistics from the CATMOD analyses controlling for vehicle type. For the full database, this analysis is discussed in Section 3.2: the coefficient for BELT1 * PRETENLL was -0.0354 and for BELT3 * PRETENLL, -0.0374. Both were statistically significant (χ^2 = 5.73 and 6.51, respectively). If the more limited analyses produce consistent results, the coefficients should stay about the same as in the full database, but the chi-square values will be smaller, because, given similar coefficients, the chi-square statistic is approximately proportional to the N of cases. Table 6 shows that the coefficients were -0.0301 and -0.0329 in the first-step limited analysis and -0.0397 and -0.0534 on the second step, all quite similar to the full database. The chi-squares, as expected, are smaller in the analyses with less data; only the coefficient for RF passengers in the ± 4 MY analysis is significant (3.84 or greater). The chi-squares demonstrate that it would be futile to even further limit the database to a smaller range of model years or by excluding years when a model was redesigned, because results would likely not be statistically meaningful.

The results for the limited databases instill some confidence that the observed increases in belt effectiveness in the full database are due primarily to pretensioners and load limiters rather than reflecting a diffuse **long-term** trend in vehicle design that has gradually improved safety for belted occupants more than for unbelted occupants. However, these results do not preclude that at least some of the observed effect could be due to other belt or belt-related improvements if they were introduced in some makes and models at **nearly the same time** as pretensioners and load limiters – such as adjustable anchorages; integrated belt systems; or tuning the air bag, vehicle structure, or seats especially to improve protection for a belted occupant.

3.4 Truck-based LTVs: estimating effectiveness while controlling for crash type

The basic CATMOD analyses of truck-based LTVs in Section 3.1 generated coefficients of +0.0202 for BELT1 * PRETENLL and +0.0270 for BELT3 * PRETENLL – i.e., estimated fatality increases. Although neither was statistically significant (χ^2 = .53 and .95, respectively), point estimates that large in the unfavorable direction warrant a further look. Here, unlike the preceding situation, there may be a bias working against pretensioners and load limiters, namely, that rollovers, especially first-event rollovers have decreased in late-model truck-based LTVs (because of ESC and improved static stability, reasons unrelated to pretensioners or load limiters).[22] (Cars, CUVs, and minivans do not show similar reduction in rollovers in the timeframe of the database.) Belt effectiveness is higher in rollovers than in other crash types; thus, belt effectiveness is lowered in the late-model vehicles (the ones with pretensioners and load limiters) because they have relatively fewer rollovers. Table 7 demonstrates that the proportion of fatal crash involvements in which a rollover is the first harmful event has declined substantially in truck-based LTVs. There has also been a slight decline in rollovers that are subsequent but most harmful events.

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[22] Walz, M. C. (2005, June). *Trends in the Static Stability Factor of Passenger Cars, Light Trucks, and Vans*. (Report No. DOT HS 809 868). Washington, DC: National Highway Traffic Safety Administration. Available at www-nrd.nhtsa.dot.gov/Pubs/809868.PDF; Sivinski, R. (2011, June). *Crash Prevention Effectiveness of Light-Vehicle Electronic Stability Control: An Update of the 2007 NHTSA Evaluation*. (Report No. DOT HS 811 486). Washington, DC: National Highway Traffic Safety Administration.
Available at www-nrd.nhtsa.dot.gov/Pubs/811486.PDF.

Table 7: Distribution of Fatal Crash Involvements by Type of Crash
(Truck-based LTVs with dual air bags, FARS 1994 to 2011)

Truck-Based LTVs Column Percent	No Pretensioners No Load Limiters	Load Limiters No Pretensioners	Pretensioners & Load Limiters
Frontal impacts	23.7	23.1	29.9
Side impacts	12.7	13.5	15.1
Rollover first harmful event	40.1	39.4	31.6
Rollover subsequent but most harmful event	19.6	20.2	18.3
Rear impact, other, unknown	3.9	3.8	5.2
	100	100	100

The bias can be addressed in CATMOD analyses by adding one more categorical independent variable CRSH (= 1.1 for 12:00 frontal impacts, = 1.2 for 11:00 or 1:00 frontal impacts, = 2 for left-side impacts, = 3 for right-side impacts, = 4.1 if a rollover is the first harmful event , = 4.2 if a rollover is a subsequent but most harmful event, and = 5 for rear, other, and unknown impacts[23]) and the two interaction terms BELT1 * CRSH and BELT3 * CRSH. Adding the main effect CRSH will control for the fact that later-model LTVs equipped with pretensioners/load limiters are less rollover-prone (for reasons unrelated to the pretensioners or load limiters), while adding the two interaction terms will control for baseline belt effectiveness being higher in rollovers than in planar impacts. The CATMOD analysis for drivers generates the following chi-squares for the main terms, the selected interactions, and the likelihood ratio:

```
     Maximum Likelihood Analysis of Variance

Source               DF   Chi-Square    Pr > ChiSq
Intercept             1         2.01        0.1560
BELT3                 1       403.03        <.0001
BELT1                 1       385.20        <.0001
PRETENLL              1         0.47        0.4926
CRSH                  6       270.40        <.0001
BELT3*CRSH            6        52.65        <.0001
BELT1*CRSH            6        94.18        <.0001
BELT3*PRETENLL        1         0.15        0.7010
BELT1*PRETENLL        1         0.00        0.9485

Likelihood Ratio     32        45.50        0.0574
```

The coefficient for BELT1 * PRETENLL is only +0.0019, one-tenth as large as it was in the simpler model without control for CRSH. The CATMOD analysis for RF passengers generates exactly the same chi-square statistics. Its coefficient for BELT3 * PRETENLL is just +0.0109, about one-third as large as in the simpler model. Controlling for CRSH has reduced the effects of pretensioners and load limiters in truck-based LTVs to near-zero, and with very low chi-squares (χ^2 = .00 and .15, respectively).

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[23] Because CATMOD treats CRSH as a categorical (not linear) variable, the specific numeric codes assigned to the various crash types are irrelevant to the computations.

Statistically, the most defensible conclusion at this time is simply to accept the null hypothesis that pretensioners and load limiters have no measurable net effect in truck-based LTVs – in contrast to the 12.8 percent reduction of fatality risk, relative to baseline 3-point belts, in cars, CUVs, and minivans. Intuitively, there is no clear reason why the benefit in truck-based LTVs should be zero, but it is easy to explain why the benefit would likely be lower than in cars, CUVs, and minivans: (1) a smaller proportion of the fatalities in truck-based LTVs are frontal impacts, where pretensioners and load limiters are apparently most effective, as will be discussed in the next section; and (2) because LTVs tend to be heavy and conserve momentum in collisions with lighter vehicles, a higher proportion of the frontal impacts are probably of relatively low severity where even a standard belt would be satisfactory. However, the data is currently insufficient to quantify **how much** lower the likely benefits in LTVs would be than the benefits in cars, CUVs, and minivans; as will be shown in the next section, for example, there is not enough data to estimate effectiveness separately by crash type. It is better to be conservative for now and accept the null hypothesis of zero effectiveness in LTVs until more data become available to demonstrate otherwise.

By contrast, a corresponding CATMOD analysis of cars, CUVs, and minivans, controlling for crash type (and also vehicle type) produces similar coefficients as the analysis in Section 3.2, not controlling for crash type (but controlling for vehicle type). The coefficients for BELT1 * PRETENLL and BELT3 * PRETENLL, controlling for crash type and vehicle type, are -0.0347 and -0.0313, respectively, both statistically significant (χ^2 = 4.99 and 4.13) and both similar to the -0.0354 and -0.0375 coefficients in Section 3.2, not controlling only for vehicle type. Unlike the truck-based LTVs, controlling for crash type is not so influential here, because there was no major shift in the distribution of crashes during the timeframe of the database. Specifically, the proportion of fatal crashes that are rollovers was 12.4 percent in cars, CUVs, and minivans without pretensioners and load limiters, 13.7 percent in vehicles with pretensioners and load limiters (as compared to a reduction from 40.1% to 31.6% for truck-based SUVs).

3.5 Effectiveness by crash type

The remainder of this chapter compares the effectiveness of pretensioners/load limiters for various subgroups of the data: by crash type or by occupants' age, gender, height, or weight. The analyses in most cases will just hint at rather than definitively identify the subgroups where pretensioners and load limiters are most effective, because of the limited quantity of data. Even though the overall effectiveness in cars, CUVs, and minivans was statistically significant, the chi-square values (5.73 for drivers and 6.51 for RF passengers, where 3.84 or greater is needed for significance) suggest that significance may be lost if the data is divided into subgroups.

There are several hypotheses why the effectiveness of pretensioners and load limiters could vary by the type of crash:

- Frontal-impact crash pulses are more likely to command pretensioner actuation from the restraint-control module and have a greater tendency to build up occupant load on the belts to spool out the load limiter; belt loads are typically lower in side impacts and rear impacts;

- Some pretensioner actuation algorithms may be designed for actuation only in frontal impacts; and
- Even among frontal impacts, there could be a difference between purely longitudinal impacts with full structural engagement and oblique or corner impacts: increased occupant excursion due to the load limiter might have a different effect in the oblique or corner impact where the frontal air bag might not intercept the occupant's forward motion.[24]

Crash data collected for NHTSA in the Crashworthiness Data System of NASS during CY 2005 to 2009 provides statistics on how often pretensioners activate. In crash involvements that resulted in a fatality to at least one occupant of the vehicle and where the driver was belted, the pretensioners activated in 84 percent of the frontal impacts (including 93 percent of the frontal impacts involving vehicles of MY 2007 or later), 61 percent of the side impacts, and 48 percent of the most-harmful-event rollovers. In other words, while it is true that activation is most likely in frontal impacts, it is by no means uncommon in side impacts and rollovers.

Table 8 separately compares belt effectiveness with and without pretensioners and/or load limiters, by type of crash, for each of the three vehicle types. Table 8 and all subsequent tables only show the belt-effectiveness estimates that have been corrected with the UEF. It is evident from the large variations in observed effectiveness that some of the estimates are based on limited data, especially those for the less frequent crash types and for vehicles other than passenger cars; in some cases, there is no estimate at all because at least one of the eight cells (as shown in the example of Table 2) needed to run a double-pair comparison has zero cases. The objective here is to look for directional trends. Specifically, is effectiveness in, say, frontal crashes consistently higher, across vehicle types and at both seat positions, with pretensioners and load limiters? CATMOD is useful for testing significance of effectiveness differences across vehicle types.

The first section of Table 8 analyzes all frontal impacts except those where FARS judged a subsequent rollover to be the most harmful event. For cars, CUVs, and minivans, point estimates of belt effectiveness are consistently higher with pretensioners and load limiters than without them: 53 versus 34 percent (car drivers), 49 versus 43 percent (car passengers), 52 versus 50 percent (CUV/minivan drivers) and 52 versus 45 percent (CUV/minivan passengers). Nevertheless, in the CATMOD analysis combining cars, CUVs, and minivans and controlling for vehicle type, the effectiveness enhancement is statistically significant only for drivers ($\chi^2 = 9.43$), not for passengers ($\chi^2 = 2.38$). For truck-based LTVs, there is no consistent trend even in the point estimates: a small improvement for drivers, but a change in the opposite direction for passengers.

In frontal impacts of cars, CUVs, and minivans, the effect of load limiters without pretensioners is inconsistent: effectiveness is sometimes higher, sometimes lower, and sometimes between the estimates with both technologies and with neither.

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[24] Brumbelow et al. (2007).

Table 8: Fatality Reduction (%) by Seat Belts, by Crash Type and Vehicle Type
(Vehicles with dual air bags, with a driver and RF passenger, FARS 1986 to 2011; all estimates corrected with the UEF)

	Passenger Cars		Truck-Based LTVs		CUVs and Minivans	
	Driver	RF	Driver	RF	Driver	RF
ALL FRONTAL IMPACTS[25]						
No pretensioner, no load limiter	34.0	42.6	52.5	52.6	49.5	44.8
Load limiter but no pretensioner	40.2	50.1	52.4	40.8	34.0	53.4
Pretensioner and load limiter	52.9	48.8	55.9	48.8	52.0	52.1
12:00 FRONTAL IMPACTS[26]						
No pretensioner, no load limiter	32.7	41.5	48.5	48.1	62.8	51.8
Load limiter but no pretensioner	43.1	51.9	51.4	32.8	44.0	48.3
Pretensioner and load limiter	50.4	43.2	61.4	50.9	50.7	50.9
OTHER FRONTAL IMPACTS						
No pretensioner, no load limiter	37.6	45.8	64.3	65.5	- 31.7	12.8
Load limiter but no pretensioner	30.8	44.1	55.5	60.4	-[27]	70.5
Pretensioner and load limiter	59.6	63.8	31.7	46.5	56.8	56.1
NEARSIDE IMPACTS[28]						
No pretensioner, no load limiter	- 2.3	- 25.6	6.5	83.4	7.1	.5
Load limiter but no pretensioner	- 27.8	- 26.1	71.2	- 18.1	14.5	- 7.9
Pretensioner and load limiter	- 20.8	- 1.3	63.1	35.0	4.5	13.2
FAR-SIDE IMPACTS[29]						
No pretensioner, no load limiter	39.9	30.0	69.1	37.5	51.6	67.8
Load limiter but no pretensioner	35.8	30.0	64.7	66.8	48.5	56.1
Pretensioner and load limiter	40.3	37.2	60.9	56.9	76.2	51.5

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[25] The frontal-, side-, and rear-impact groups all exclude any crash where a subsequent rollover was the most harmful event.
[26] IMPACT1 = IMPACT2 = 12.
[27] Insufficient data to perform double-pair comparison analysis; specifically, at least one of the eight cells (as shown in the example of Table 2) has zero cases.
[28] Left side for the driver, right side for the RF passenger.
[29] Right side for the driver, left side for the RF passenger.

Table 8 (Continued): Fatality Reduction (%) by Seat Belts, by Crash Type and Vehicle Type
(Cars and LTVs with dual air bags, with a driver and RF passenger, FARS 1986 to 2011; all estimates corrected with the UEF)

	Passenger Cars		Truck-Based LTVs		CUVs and Minivans	
	Driver	RF	Driver	RF	Driver	RF
ALL MOST-HARMFUL-EVENT ROLLOVERS						
No pretensioner, no load limiter	70.6	69.4	85.3	79.2	85.8	72.9
Load limiter but no pretensioner	74.7	70.0	85.7	79.0	84.7	73.1
Pretensioner and load limiter	74.8	72.4	82.1	78.1	77.7	76.0
FIRST-HARMFUL-EVENT ROLLOVERS[30]						
No pretensioner, no load limiter	74.3	73.3	85.3	80.3	85.9	78.8
Load limiter but no pretensioner	73.6	74.7	88.0	80.6	-	87.7
Pretensioner and load limiter	75.6	77.3	80.5	73.9	82.9	73.4
SUBSEQUENT MOST-HARMFUL-EVENT ROLLOVERS						
No pretensioner, no load limiter	66.7	65.0	85.0	77.3	85.9	66.8
Load limiter but no pretensioner	75.5	64.4	79.9	75.6	89.7	14.0
Pretensioner and load limiter	73.8	66.5	84.7	86.7	82.9	73.4
REAR-IMPACT, OTHER, & UNKNOWN CRASHES						
No pretensioner, no load limiter	45.2	44.4	45.1	72.6	- 4.1	-
Load limiter but no pretensioner	54.7	68.3	56.0	56.4	-	-
Pretensioner and load limiter	36.9	41.1	89.1	67.1	84.3	57.8

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[30] Includes most-harmful-event rollovers (M_HARM = 1) where the first “harmful” event (HARM_EV) was basically a tripping mechanism such as contacting a curb or ditch.

The next section of Table 8 addresses the subset of frontal impacts where IMPACT1 = IMPACT2 = 12.[31] Although these crashes by no means coincide exactly with the subgroup of impacts with primarily longitudinal force and full-frontal damage or only a slight offset, they are the closest approach to that subgroup, given the information available in FARS (which does not report direction of force or extent of offset, only the general location of damage).

With pretensioners and load limiters, observed belt effectiveness increases substantially for car drivers, slightly for car passengers, but decreases for CUV/minivan drivers and passengers. The CATMOD analysis combining cars, CUVs, and minivans and controlling for vehicle type, shows a significant improvement for drivers (χ^2 = 3.86), but not for passengers (χ^2 = .34).

Truck-based LTVs show higher belt effectiveness with pretensioners and load limiters for both the driver (61% versus 49%) and the passenger (51% versus 48%) in 12:00 frontals. But the differences are not statistically significant for either the driver or the passenger in the CATMOD analyses (χ^2 = .81 and .28, respectively).

The next subgroup in Table 8, "other frontal impacts," comprises the FARS cases where IMPACT2 = 11 or 1, plus the cases where IMPACT2 = 12 but the initial damage location is somewhere else, possibly not even frontal. It may include many of the oblique, corner, and small-overlap impacts discussed by Brumbelow, who conjectures that load limiters might allow excessive head excursion, resulting in contacts with interior components such as the A-pillar. Nevertheless, in cars, CUVs, and minivans, the data shows large benefits for pretensioners plus load limiters relative to baseline belts – the only subgroup of crashes where the CATMOD analysis finds statistically significant gains for both drivers and passengers (χ^2 = 7.88 and 4.51, respectively; however, the estimates of baseline belt effectiveness in CUVs and minivans, based on limited data are unrealistically low, -31.7 percent and 12.8 percent, and may be a factor in making the gain for pretensioners and load limiters significant). By contrast, truck-based SUVs show diminutions in belt effectiveness with pretensioners and load limiters (from 64% to 32% for drivers and from 66% to 47% for passengers), consistent with Brumbelow's conjectures; the diminution is statistically significant for drivers (χ^2 = 4.97) but not for passengers (χ^2 = .30). However, with load limiters only (no pretensioners), belt effectiveness in the truck-based LTVs is only slightly lower than baseline. There does not appear to be any obvious explanation why pretensioners and load limiters are especially beneficial in these 11:00 and 1:00 impacts of cars,

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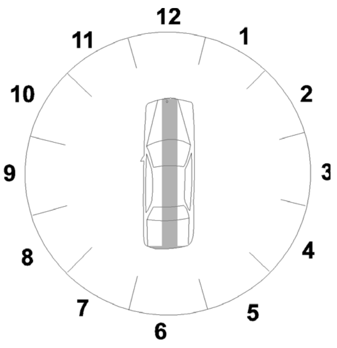
[31] IMPACT1 is the initial impact and IMPACT2 is the principal impact. FARS uses a clock schematic to indicate the damage location, with 12:00 corresponding to the front of the vehicle.



CUVs, and minivans, but not for truck-based LTVs. Although several of the observed differences are statistically significant, data on this type of crash is limited, making it difficult to reach firm conclusions.

Data is also relatively limited for side impacts. Table 8 shows that belt effectiveness is consistently higher in far-side impacts (where belts may readily prevent occupant contacts with interior components) than in nearside impacts (where belts may be unable to mitigate contact with the intruding side structure immediately adjacent to the occupant) and that belts are generally more effective in LTVs, CUVs, and minivans than in passenger cars (whose lower sills make them structurally more vulnerable in side impact).[32] But the effect of pretensioners and load limiters relative to baseline belts shows no strong, consistent pattern across vehicle types or seat positions in either nearside or far-side impacts, although observed effectiveness does increase in far-side impacts at both seat positions for cars and one position for CUVs and minivans. However, none of the CATMOD tests shows a statistically significant difference.

In rollover crashes, pretensioners might potentially be helpful by reducing occupant excursion while load limiters might conceivably have the opposite effect. It is unknown to what extent first-event rollovers produce acceleration pulses interpreted by the restraint controller as warranting pretensioner triggering or build up belt loads to spool out load limiters. Subsequent-event rollovers, on the other hand, might follow an impact that does both. The second page of Table 8 analyzes rollover crashes: all most-harmful-event rollovers combined, then separately for first-harmful-event and subsequent-most-harmful-event rollovers. Passenger cars show a slight tendency toward higher belt effectiveness with pretensioners and load limiters: observed effectiveness is always higher at both seat positions; however, the CATMOD tests do not show significant differences (χ^2 ranges from .13 to 1.25 in the various tests). In the truck-based LTVs, CUVs, and minivans there are no clear trends in the observed results and CATMOD tests do not show significant differences.

In rear impacts and other crash types, the limited data does not show significant effects for pretensioners and load limiters.

The overall impression from Table 8 is that the beneficial effect of pretensioners and load limiters for cars, CUVs, and minivans may be most noticeable in frontal impacts, but it is not necessarily limited to those impacts. There might be comparable benefits in far-side impacts and rollovers in passenger cars, for example.

3.6 Effectiveness by occupant age groups

Table 9 compares the effectiveness of pretensioners/load limiters for occupants 55 and older to drivers less than 55 years old and RF passengers 13 to 54 years old. A working hypothesis here is that load limiters would especially help older people, because they are more vulnerable to injury (particularly in the chest area) from belt forces. Pretensioners might also be effective for

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[32] Nevertheless, the observed negatives for some of the side impact categories may reflect not only limited data but also the UEF correction. The UEF is a single factor applied across all crash types, when in fact it might vary to some extent across crash types. Without the UEF correction, all observed effectiveness estimates, even in nearside impacts, are positive.

older people if they reduce peak forces by starting the occupant's ride-down sooner and spreading it over a longer time.

For passenger cars, Table 9 shows a small additional improvement in the benefits of pretensioners/load limiters for older drivers, compared to younger drivers. Belt effectiveness increases with pretensioners and load limiters by 5 percentage points for drivers less than 55 (i.e., from 45.0% to 49.9%) and by 9 percentage points for drivers 55 or older. But effectiveness increases are similar for RF passengers, increasing by 11 percentage points for younger RF passengers and by 9 percentage points for older passengers.

For truck-based LTVs, however, the observed effectiveness of seat belts declines by about 5 percentage points for younger occupants at both seat positions, while it increases by 5 to 10 percentage points for older people. For CUVs, and minivans, observed effectiveness of seat belts declines by 3 to 5 percentage points for younger occupants at both seat positions and increases by 20 percentage points at both positions for older people. In fact, with pretensioners and load limiters, belts have become about equally effective for the two age groups in LTVs, CUVs, and minivans.

A CATMOD analysis of drivers 55 and older in all vehicles, controlling for vehicle type, indicates that belt effectiveness is significantly higher with pretensioners and load limiters (χ^2 = 4.02). CATMOD analyses of RF passengers in cars, CUVs, and minivans, controlling for vehicle type, estimate the same regression coefficient for PRETENLL, -.042, for younger and older passengers, indicating a similar relative benefit for pretensioners and load limiters in the two age groups; however, this coefficient is statistically significant only for the younger passengers, where there are more crash cases. No other CATMOD analysis produced statistically significant coefficients. In other words, the results lean in the direction of showing relatively greater benefits for older occupants, although they do not yet establish a firm conclusion to that effect.

3.7 Effectiveness by occupant's gender

Table 10 compares the effectiveness of pretensioners/load limiters for male and female occupants. The working hypothesis from the preceding section might also apply here – namely, that load limiters and pretensioners would especially help females, because they are somewhat more vulnerable to chest or abdominal injury from belt forces than males. Load limiters could have a disadvantage for males who are tall or large, if they contribute to head excursion.

Table 9: Fatality Reduction (%) by Seat Belts, by Occupant Age Groups and Vehicle Type
(Vehicles with dual air bags, with a driver and RF passenger, FARS 1986 to 2011; all estimates corrected with the UEF)

	Passenger Cars		Truck-Based LTVs		CUVs and Minivans	
	Driver	RF	Driver	RF	Driver	RF
13 TO 54 YEARS OLD						
No pretensioner, no load limiter	45.0	43.8	76.5	74.2	68.4	69.1
Load limiter but no pretensioner	47.5	50.3	79.3	68.1	61.8	77.8
Pretensioner and load limiter	49.9	54.9	74.9	69.1	63.8	66.1
55 AND OLDER						
No pretensioner, no load limiter	38.3	34.8	63.7	67.3	47.2	31.8
Load limiter but no pretensioner	39.3	49.8	76.1	66.9	34.9	27.3
Pretensioner and load limiter	46.8	43.4	73.3	72.3	70.0	56.1

Table 10: Fatality Reduction (%) by Seat Belts, by Occupant's Gender and Vehicle Type
(Vehicles with dual air bags, with a driver and RF passenger, FARS 1986 to 2011; all estimates corrected with the UEF)

	Passenger Cars		Truck-Based LTVs		CUVs and Minivans	
	Driver	RF	Driver	RF	Driver	RF
MALES						
No pretensioner, no load limiter	40.6	40.5	72.8	74.7	53.5	63.2
Load limiter but no pretensioner	46.6	44.6	75.2	64.3	41.0	61.2
Pretensioner and load limiter	48.6	44.8	70.9	70.7	56.7	65.2
FEMALES						
No pretensioner, no load limiter	56.1	39.6	79.9	68.1	76.0	48.9
Load limiter but no pretensioner	49.0	51.2	82.5	68.8	73.1	60.5
Pretensioner and load limiter	52.0	54.4	84.8	62.1	80.0	55.3

The results in Table 10 do not strongly support these hypotheses. In fact, for passenger cars, the results are not easy to interpret. For car drivers, belt effectiveness increased with pretensioners and load limiters by 8 percentage points above baseline for males while it decreased by 4 percentage points from baseline for females. However, the baseline effectiveness estimates are a surprisingly low 41 percent for male drivers, but a high 56 percent for female drivers. Even though effectiveness increases for males and decreases for females, it still remains higher for females (52%) than males (49%) after cars were equipped with pretensioners and load limiters. Thus, it is not clear if the observed changes in effectiveness are really due to pretensioners and load limiters or are merely a sort of "regression to the mean" from the baseline. For car passengers, baseline effectiveness was almost equal for males and females. With pretensioners and load limiters, effectiveness increased by 15 percentage points for females and only 4 percentage points for males. With pretensioners and load limiters, belt effectiveness is higher for females than males at both seat positions.

In CUVs and minivans, belt effectiveness increased for both males and females at both seat positions, all by similar increments. For truck-based LTVs, effectiveness declined with pretensioners and load limiters in three of the four comparisons, improving only for female drivers.

A CATMOD analysis of male drivers in cars, CUVs, and minivans, controlling for vehicle type, showed significantly higher belt effectiveness with pretensioners and load limiters ($\chi^2 = 4.05$). A CATMOD analysis of female passengers in cars, CUVs, and minivans, controlling for vehicle type, likewise showed significantly higher belt effectiveness with pretensioners and load limiters ($\chi^2 = 8.21$). These were the only CATMOD analyses that produced significant coefficients. In all, the data do not strongly support a conclusion that pretensioners and load limiters are more beneficial for females than males, or vice-versa.

3.8 Effectiveness by driver height groups

FARS began recording the height and weight of drivers, if they were available from driver-license files or other State record systems, in CY 1998. It has never reported passengers' height or weight. The driver's height is reported in 86 percent of the FARS cases considered in this report and the weight is reported in 66 percent of the cases. Table 11 compares the effects of pretensioners/load limiters for drivers 70 inches or taller to drivers less than 70 inches tall (where 70 inches is the height of the 50th percentile male in this fairly recent FARS data). The working hypothesis, as already discussed in the preceding section, is that load limiters might be relatively less advantageous for taller drivers because they would be even more likely to contact interior components of the vehicle if the load limiters spool out extensively.

Table 11: Drivers – Fatality Reduction (%) by Seat Belts
By Driver Height Groups and Vehicle Type
(Vehicles with dual air bags, FARS 1998 to 2011; all estimates corrected with the UEF)

	Passenger Cars	Truck-Based LTVs	CUVs & Minivans
LESS THAN 70 INCHES TALL			
No pretensioner, no load limiter	46.6	75.9	69.3
Load limiter but no pretensioner	48.1	82.4	50.3
Pretensioner and load limiter	52.9	74.6	72.4
70 INCHES OR TALLER			
No pretensioner, no load limiter	38.4	72.3	60.7
Load limiter but no pretensioner	44.5	75.1	42.5
Pretensioner and load limiter	46.5	74.0	57.6

Table 11 does not show any obvious differences in belt performance between shorter and taller drivers. Among the drivers less than 70 inches tall, observed belt effectiveness increases slightly with pretensioners and load limiters in two of three vehicle groups and decreases slightly in the other group. The same is true for drivers over 70 inches tall. There is nothing in Table 11 to suggest a drastic loss of belt effectiveness for taller occupants when belts are equipped with load limiters (with or without pretensioners). A CATMOD analysis of drivers less than 70 inches tall in cars, CUVs, and minivans, controlling for vehicle type generated a coefficient of -.045 for BELT1 * PRETENLL, indicating higher belt effectiveness with pretensioners and load limiters – and the effect is statistically significant ($\chi^2 = 4.98$). The corresponding analysis for drivers 70 inches or taller produced a coefficient in the same direction but of slightly less magnitude, -.029, which was not statistically significant ($\chi^2 = 1.35$). In other words, the data lean just slightly in the direction of higher effectiveness for the shorter drivers.

3.9 Effectiveness by driver weight groups

Table 12 compares belt effectiveness with and without pretensioners/load limiters for drivers 175 pounds or heavier to drivers weighing less than 175 pounds (where 175 pounds is the weight of the 50th percentile male in this fairly recent FARS data). The hypothesis is that load limiters might be relatively less advantageous for heavier drivers because they would spool out more and allow more head excursion (and that could be even more likely if the heavy drivers are also tall, as is often the case).

Table 12 does not show any clear-cut differences between lighter and heavier drivers. In both weight groups, belt effectiveness increases with pretensioners and load limiters in two of the three vehicle types. In cars, effectiveness increases more for the heavier drivers, but in CUVs and minivans it increases only for the lighter drivers. CATMOD analyses controlling for vehicle type do not produce statistically significant BELT1 * PRETENLL coefficients for either weight group.

Table 12: Drivers – Fatality Reduction (%) by Seat Belts
By Driver Weight Groups and Vehicle Type
(Vehicles with dual air bags, FARS 1998 to 2011; all estimates corrected with the UEF)

	Passenger Cars	Truck-Based LTVs	CUVs & Minivans
LIGHTER THAN 175 POUNDS			
No pretensioner, no load limiter	48.8	76.7	58.6
Load limiter but no pretensioner	49.7	82.9	43.3
Pretensioner and load limiter	49.7	70.9	71.1
175 POUNDS OR HEAVIER			
No pretensioner, no load limiter	41.1	72.2	63.9
Load limiter but no pretensioner	44.2	81.1	32.3
Pretensioner and load limiter	49.7	76.3	54.7

Appendix A

Pretensioners and Load Limiters at the Front-Outboard Seat Belts of Cars and LTVs Equipped With Dual Frontal Air Bags (No On-Off Switches), MY 1987 to 2011

Sources: www.safercar.gov, www.cars.com, www.motortrend.com, Walz (2003), Brumbelow et al. (2007). The numeric codes shown before the make-model names are the ones assigned by the VIN-decode programs developed by NHTSA's Evaluation Division; for passenger cars, they are usually the same as the make-model codes in FARS. These programs are updated periodically and are available to the public.

Make and Model(s)	MY with Dual Air Bags[33]	First MY with Pretensioners	First MY with Load Limiters
2001 Jeep Compass	2007-	always	always
2300-2303 Jeep Cherokee	1997-2001	never	never
2312-2313 Jeep Grand Cherokee	1996-	2004	2000[34]
2316-2317 Jeep Commander	2006-2010	always	always
2320-2323 Jeep Wrangler	1997-	2007	2002
2342-2343 Jeep Liberty	2002-	always	always
2352-2353 Jeep Patriot	2007-	always	always
3301-3303 Hummer H1	1997-2006	never	never
3307 Hummer H3	2006-2010	always	always
3313-3317 Hummer H2	2003-2009	2008	2008
6016 Chrysler LeBaron	1994-1995	never	never
6018 Chrysler 200	2011-	always	always
6030 Chrysler unknown LH car	1995	never	never
6041 Chrysler Concorde	1993-2004	never	1999
6042 Chrysler LHS	1994-2001	never	1999
6043 Chrysler Sebring Convertible	1996-2010	2001	2008
6043 Chrysler Sebring Coupe	1995-2005	never	1999
6043 Chrysler Sebring Sedan	2001-2010	always	always
6044 Chrysler Cirrus	1995-2001	2001	1998
6051 Chrysler 300	1999-	2005	always
6052 Chrysler PT Cruiser	2001-2010	always	2002
6053 Chrysler Prowler	2001-2002	unknown	never
6054 Chrysler Pacifica	2004-2008	always	always
6055 Chrysler Crossfire	2004-2008	always	always
6312-6317 Chrysler Aspen	2007-2009	always	always
6402-6409 Chrysler T&C, Voyager	1994-	2001	1999
7013 Dodge Viper	1997-2010	2003	2003
7020 Dodge Neon	1995-2005	never	2000
7021 Dodge Magnum	2005-2008	always	always

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[33] For pickup trucks, model years are excluded if all vehicles equipped with dual air bags were also equipped with a manual on-off switch for the passenger bag.

[34] Unknown if Jeep Grand Cherokee had load limiters in 1999.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
7024 Dodge Charger	2006-	always	always
7025 Dodge Caliber	2007-	always	always
7026 Dodge Avenger	2008-	always	always
7027 Dodge Journey CUV	2009-	always	always
7028 Dodge Challenger	2008-	always	always
7039 Dodge Stealth	1994-1996	never	never
7041 Dodge Intrepid	1993-2004	never	1999
7042 Dodge Avenger	1995-2000	never	1999
7043 Dodge Stratus Coupe	2001-2005	never	always
7043 Dodge Stratus Sedan	1995-2006	2001	1998
7200-7209 Dodge Dakota	1997-	2005	1998
7210-7219 Dodge Ram Pickup 1500	2002-	2002	2002
7220-7239 Ram Pickup 2500/3500	2003-	2003	2003
7312-7313 Dodge Durango	1998-	2001	1999
7342-7343 Dodge Nitro	2007-	always	always
7400-7409 Dodge Caravan	1994-	2001	1999
7410-7431 Dodge Ram Van	1998-2003	2001	2001
9020 Plymouth Neon	1995-2001	never	2000
9038 Plymouth Breeze	1996-2000	never	1998
9039 Plymouth Prowler	1997-2000	never	never
9402-9407 Plymouth Voyager	1994-2000	never	1999
10034 Eagle Summit coupe, sedan	1995-1996	never	never
10037 Eagle Talon	1995-1998	never	1997
10041 Eagle Vision	1993-1997	never	never
10044 Eagle Summit SW	1995-1996	never	never
11… All Sprinter	2002-	always	always
12003 Ford Mustang	1994-	2005	2001
12004 Ford Thunderbird	1994-2005	2002	2002
12013 Ford Escort	1997-2003[35]	never	1999
12016 Ford Crown Victoria	1992-	2001	2001
12017 Ford Taurus, Taurus X	1992-	2000	1999
12018 Ford Probe	1994-1997	never	never
12021 Ford 500	2005-2007	always	always
12022 Ford Freestyle	2005-2007	always	always
12023 Ford Fusion	2006-	always	always
12024 Ford Edge	2007-	always	always
12025 Ford Flex	2009-	always	always
12032 Ford Fiesta	2011-	always	always
12035 Ford Contour	1995-2000	never	1999[36]

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[35] Excludes MY 1995-1996 (equipped with 2-point automatic belts and dual air bags).

[36] Unknown if Ford Contour had load limiters in 1998.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
12036 Ford Aspire	1994-1997	never	never
12037 Ford Focus	2000-	always	always
12038 Ford GT	2004-2006	always	always
12200-12205 Ford Ranger	2007-	always	always
12210-12215 Ford F-150	2001-	always	always
12220-12235 Ford Super-Duty Pk	1999-	2002	2002
12300-12301 Ford Explorer 2-door	1995-2003	2003	2002
12302,03,08 Ford Explorer 4-door	1995-	2002	2002
12306-12307 Explorer Sport-Trac	2001-2010	2003	2002
12312-12317 Ford Expedition	1997-	2001	2001
12332-12333 Ford Excursion	2000-2005	2002	2002
12342-12347 Ford Escape	2001-	always	always
12402 Ford Wind/Freestar	1995-2007	2000	2001
12410-12436 Ford E Van	1997-	1998	2004
12460-12462 Ford Transit Connect	2010-	always	always
13001 Lincoln Town Car	1990-	2001	2001
13002 Lincoln Mark8	1993-1998	never	never
13005 Lincoln Continental	1989-2002	never	never
13012 Lincoln LS	2000-2006	always	always
13013 Lincoln MKZ	2007-	always	always
13014 Lincoln MKX	2007-	always	always
13015 Lincoln MKS	2009-	always	always
13016 Lincoln MKT	2010-	always	always
13214-15 Lincoln Blackwood/Mark LT	2002-2008	always	always
13302-13308 Lincoln Aviator	2003-2005	always	always
13312-13317 Lincoln Navigator	1998-	2001	always
14004 Mercury Cougar	1994-1997	never	never
14016 Mercury Grand Marquis	1992-2011	2001	2001
14017 Mercury Sable	1992-2009	2000	1999
14020 Mercury Montego	2005-2007	2006[37]	always
14021 Mercury Milan	2006-2010	always	always
14036 Mercury Tracer	1997-1999[38]	never	1999
14037 Mercury Mystique	1995-2000	never	1999[39]
14038 Mercury Cougar	1999-2002	2002	always
14039 Mercury Marauder	2003-2004	2004[40]	always
14302-14308 Mercury Mountaineer	1997-2010	2002	2002
14342-14347 Mercury Mariner	2005-2011	always	always
14402 Mercury Monterey	2004-2007	always	always
14450-14452 Mercury Villager	1996-2002	2001	1999

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[37] Unknown if Mercury Montego had pretensioners in 2005.

[38] Excludes MY 1995-1996 (equipped with 2-point automatic belts and dual air bags).

[39] Unknown if Mercury Mystique had load limiters in 1998.

[40] Unknown if Mercury Marauder had pretensioners in 2003.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
18002 Buick LeSabre	1994-2005	never	never
18003 Buick Park Avenue	1994-2005	never	never
18004 Buick Roadmaster	1994-1996	never	never
18005 Buick Riviera	1995-1999	never	never
18017 Buick Century	1997-2005	never	1999
18018 Buick Skylark	1996-1998	never	never
18019 Buick Regal	2011-	always	always
18020 Buick Regal	1995-2004	never	1999
18022 Buick LaCrosse	2005-	always	always
18023 Buick Lucerne	2006-	always	always
18024 Buick Enclave	2008-	always	always
18302-18303 Buick Rainier	2004-2007	2005	always
18356-18357 Buick Rendezvous	2002-2007	2004	always
18454-18457 Buick Teraza	2005-2007	always	always
19003 Cadillac DeVille	1993-2005	2000	2001
19005 Cadillac Eldorado	1993-2002	never	never
19014 Cadillac Seville	1993-2004	1998	2001
19017 Cadillac Catera	1997-2001	always	always
19018 Cadillac CTS	2003-	always	always
19019 Cadillac XLR	2004-	always	always
19020 Cadillac SRX	2004-	always	always
19021 Cadillac STS	2005-	always	always
19022 Cadillac DTS	2006-	always	always
19312-19343 Cadillac Escalade	1999-	2007	2007
20002 Chevrolet Caprice	1994-1995	never	never
20002 Chevrolet Impala	2000-	2006	2000
20004 Chevrolet Corvette	1994-	2005	2005
20009 Chevrolet Camaro	1993-2002, 2010-	2010	2010
20016 Chevrolet Cavalier	1995-2005	never	1997[41]
20020 Chevrolet Lumina	1995-2001	never	2000
20022 Chevrolet Cobalt	2005-2010	2006	always
20023 Chevrolet HHR	2006-	always	always
20024 Chevrolet Traverse	2009-	always	always
20025 Chevrolet Cruze	2011-	always	always
20026 Chevrolet Volt	2011-	always	always
20027 Chevrolet Caprice Police	2011-	always	always
20032 Chevrolet Prizm	1994-2002	1998	1998
20034 Chevrolet Metro	1995-2001	never	never
20036 Chevrolet Monte Carlo	1995-2007	2006	2000
20037 Chevrolet Malibu	1997-	2004[42]	always

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[41] Unknown if Chevrolet Cavalier had load limiters in 1996.

[42] 2004-2005 Chevrolet Classic (MM2=20037, CG=18068) did not have pretensioners.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
20038 Chevrolet SSR	2003-2006	always	always
20039 Chevrolet Aveo	2004-	always	always
20200-20205 Chevrolet S/T/Colorado	2001-	2004[43]	always
20210-20235 Chevrolet Silverado	2001-	2007[44]	2007[45]
20300-20301 Chevrolet Blazer 2-door	1998-2005	never	1998
20302-20307 Trailblazer/Blazer 4-door	1998-2009	2005[46]	1998
20310-20311 Chevrolet Tahoe 2-door	1997-1999	never	never
20312-20313 Chevrolet Tahoe 4-door	1997-	2007	2007
20322-20327 Chevrolet Suburban	1997-	2007	2007
20330-20333 Chevrolet/Geo Tracker	1996-2004	never	1999
20338-20339 Chevrolet Equinox	2005-	always	always
20342-20347 Chevrolet Avalanche	2002-	2007	2007
20404-20407 Chevrolet Astro Van	1996-2005	never	2004
20410-20436 Chevrolet Express	1996-	2006	2004
20452-20457 Venture/Uplander vans	1997-2008	1998	2002
21002 Oldsmobile Delta 88	1994-1999	never	never
21003 Oldsmobile 98	1994-1996	never	never
21020 Oldsmobile Cutlass/Supreme	1995-1999	never	1997[47]
21021 Oldsmobile Achieva/Alero	1996-2004	never	1999
21022 Oldsmobile Aurora	1995-2003	never	never
21023 Oldsmobile Intrigue	1998-2002	never	2000[48]
21302-21303 Oldsmobile Bravada	1998-2004	never	1998
21452-21457 Oldsmobile Silhouette	1997-2004	1998	2002
22002 Pontiac Bonneville	1992-2005	never	never
22008 Pontiac GTO	2004-2006	always	always
22009 Pontiac Firebird	1993-2002	never	never
22016 Pontiac Sunfire	1995-2005	never	1997[49]
22018 Pontiac Grand Am	1996-2005	never	1999
22019 Pontiac G5	2007-2009	always	always
22020 Pontiac Grand Prix	1994-2008	2004	1999
22022 Pontiac G6	2005-2010	always	always
22023 Pontiac Solstice	2006-2009	always	always
22024 Pontiac G8	2008-2009	always	always
22025 Pontiac G3	2009	always	always
22032 Pontiac Vibe	2003-2010	always	always
22338-22339 Pontiac Torrent	2006-2009	always	always

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[43] 2004 Chevrolet S/T pickup (CG=18205, 18206) did not have pretensioners; only Colorado had them.

[44] 2007 Chevrolet Silverado Classic (CG=18213-18218, 18223) did not have pretensioners.

[45] 2007 Chevrolet Silverado Classic (CG=18213-18218, 18223) did not have load limiters.

[46] 2005 Chevrolet Blazer did not have pretensioners; only Trailblazers had them.

[47] 1997 Oldsmobile Cutlass Supreme (W-body, CG=18059) did not have load limiters; only Cutlass (N-body, CG=18068) had them.

[48] Unknown if Oldsmobile Intrigue had load limiters in 1999.

[49] Unknown if Pontiac Sunfire had load limiters in 1996.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
22352-22353 Pontiac Aztek	2001-2005	always	2002
22442-22446 Pontiac Trans Sport	1997-1998	1998	never
22452-22457 Pontiac Montana/SV6	1999-2006	always	2002
23008 GMC Acadia	2007-	always	always
23200 GMC Sonoma/Canyon	2001-	2004[50]	always
23210-23235 GMC Sierra	2001-	2007[51]	2007[52]
23300-23303 GMC Jimmy	1998-2001	never	1998
23302-23307 GMC Envoy	2002-2009	2005	always
23310-23311 GMC Yukon 2-door	1997	never	never
23312-23313 GMC Yukon 4-door	1997-	2007	2007
23322-23327 GMC Yukon XL	1997-	2007	2007
23338-23339 GMC Terrain	2010-	always	always
23404-23407 GMC Safari	1996-2005	never	2004
23410-23436 GMC Savana	1996-	2006	2004
24001-24003 Saturn S	1995-2002	never	1999
24004 GM EV1 (electric)	1997-1999	never	never
24005 Saturn L	2000-2005	never	always
24007 Saturn Ion	2003-2007	always	always
24008 Saturn Sky	2007-2009	always	always
24009 Saturn Aura	2007-2009	always	always
24010 Saturn Outlook	2007-2010	always	always
24011 Saturn Astra	2008-2009	always	always
24362-24366 Saturn Vue	2002-2010	2004	always
24454-24457 Saturn Relay	2005-2007	always	always
30036 VW Rabbit	2006-2009	always	always
30040 VW Jetta	1993-	1995[53]	2000[54]
30042 VW Golf/GTI	1994-	1995[55]	2000[56]
30043 VW Cabrio	1995-2002	always	2000[57]
30046 VW Passat	1995-	always	1998
30047 VW Beetle	1998-2010	always	always
30048 VW Phaeton	2004-2006	always	always
30051 VW Eos	2007-	always	always
30302-30303 VW Tiguan	2009-	always	always
30313 VW Touareg	2004-	always	always
30406 VW Routan	2009-	always	always

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[50] 2004 GMC Sonoma pickup (CG=18205, 18206) did not have pretensioners; only Canyon had them.
[51] 2007 GMC Sierra Classic (CG=18213-18218, 18223) did not have pretensioners.
[52] 2007 GMC Sierra Classic (CG=18213-18218, 18223) did not have load limiters.
[53] Unknown if VW Jetta had pretensioners in 1994.
[54] Redesigned 1999 VW Jetta (CG=30010) had load limiters; carryover Jetta III design (CG=30006) did not.
[55] Unknown if VW Golf had pretensioners in 1994.
[56] Redesigned 1999 VW Golf (CG=30010) had load limiters; carryover design (CG=30006) did not.
[57] Unknown if VW Cabrio had load limiters in 1999.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
30412 VW Eurovan	1997-2004	1999	2000
32030 Audi A6 or S6	2002	always	always
32036 Audi 90	1993-1995	always	never
32037 Audi 100 or 200	1992-1994	always	never
32040 Audi S4 or S6	1995-	always	1999
32041 Audi Cabriolet	1994-1998	always	never
32042 Audi A6	1995-	always	1999[58]
32043 Audi A4	1996-	always	1999
32044 Audi A8	1997-	always	1999
32045 Audi TT	2000-	always	always
32046 Audi S8	2001-2009	always	always
32047 Audi Allroad	2001-2005	always	always
32048 Audi A3	2006-	always	always
32049 Audi A5	2008-	always	always
32050 Audi R8	2008-	always	always
32052 Audi S5	2008-	always	always
32303 Audi Q5	2009-	always	always
32313 Audi Q7	2007-	always	always
33035 Mini-Cooper	2002-	always	always
34034 BMW 300	1994-	1998 (≤ 97 unk)	1998 (97 unk)
34035 BMW 500	1994-	1998 (≤ 97 unk)	1998 (97 unk)
34036 BMW 600	2004-2010	always	always
34037 BMW 700	1993-	1998 (≤ 97 unk)	1998 (97 unk)
34038 BMW 850	1993-1997	unknown	never
34039 BMW Z3	1996-2002	1998 (≤ 97 unk)	1998 (97 unk)
34040 BMW Z8	2000-2003	always	always
34042 BMW Z4	2003-	always	always
34043 BMW 100	2008-	always	always
34044 BMW X6	2008-	always	always
34303 BMW X3	2004-	always	always
34313 BMW X5	2000-	always	always
35034 Nissan 300ZX	1994-1996	unknown	never
35039 Nissan Maxima	1995-	1999	2000
35043 Nissan Sentra	1995-	2000	2000
35047 Nissan Altima	1994-	2000	2000
35048 Nissan 350/370Z	2003-	always	always
35049 Nissan Murano	2003-	always	always
35050 Nissan Versa	2007-	always	always
35051 Nissan Rogue CUV	2008-	always	always

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[58] Unknown if Audi A6 had load limiters in 1998.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
35052 Nissan Cube CUV	2009-	always	always
35053 Nissan GT-R	2009-	always	always
35055 Nissan Leaf	2011-	always	always
35200-35205 Nissan Frontier	1999-	2000	1999
35212-35215 Nissan Titan	2004-	always	always
35302-35303 Nissan Pathfinder	1996-	2000	2000
35312-35313 Nissan Armada	2004-	always	always
35322-35323 Nissan Xterra	2000-	always	always
35332-35333 Nissan Juke	2011-	always	always
35452 Nissan Quest	1996-	2001	1999
37030 Honda Civic Del Sol	1993-1997	never	never
37031 Honda Civic	1994-	2001	1999
37032 Honda Accord	1993-	2001	2001[59]
37033 Honda Prelude	1992-2001	never	1999
37035 Honda S2000	2000-2009	always	always
37036 Honda EV Plus	1997-1999	never	1999
37037 Honda Insight	2000-	always	always
37039 Honda Fit	2007-	always	always
37041 Honda CR-Z	2011-	always	always
37205 Honda Ridgeline	2006-	always	always
37302-37303 Honda CR-V	1997-	1998	1997
37322-37323 Honda Passport	1995-2002	never	1998
37322-37323 Honda Pilot	2003-	always	always
37332-37333 Honda Element	2003-	always	always
37402 Honda Odyssey	1996-	1999	1999
38202-38205 Isuzu Pickups	2006-2008	always	always
38300-38301 Isuzu Amigo/Rodeo Sport	1998-2003	never	1998
38302-38307 Isuzu Ascender	2003-2008	2005	always
38311-38313 Isuzu Trooper	1995-2002	never	2000[60]
38322-38323 Isuzu Rodeo	1996-2004	never	1998
38326-38327 Isuzu Axiom	2002-2004	never	always
38331 Isuzu Vehicross	1999-2002	never	always
38402 Isuzu Oasis	1996-1999	never	never
39031 Jaguar XJ-S, XK coupes	1994-2006	1998[61]	2002[62]
39032 Jaguar XJ sedans	1994-	1998	2002[63]
39034 Jaguar S-Type	2000-2008	always	always
39035 Jaguar XK coupes	2007-	always	always

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[59] Unknown if Honda Accord had load limiters in 2000.

[60] Unknown if Isuzu Trooper had load limiters in 1998-1999.

[61] Unknown if Jaguar XK Coupes had pretensioners in 1997.

[62] Unknown if Jaguar XK Coupes had load limiters in 1999-2001.

[63] Unknown if Jaguar XJ Sedans had load limiters in 1999-2001.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
39036 Jaguar X-Type	2002-2008	always	always
39037 Jaguar XF	2009-	always	always
41035 Mazda Protégé	1995-2003	2001	1997
41037 Mazda 626	1994-2002	never	1997
41043 Mazda 929	1992-1995	never	never
41044 Mazda MX-6	1994-1997	never	1997
41045 Mazda Miata/MX-5	1994-	2001	1997
41046 Mazda MX-3	1994-1995	never	never
41047 Mazda Millenia	1995-2002	never	1997
41049 Mazda RX-8	2004-	always	always
41050 Mazda 6	2003-	always	always
41051 Mazda 3	2004-	always	always
41052 Mazda 5	2006-2010	always	always
41053 Mazda CX-7	2007-	always	always
41054 Mazda CX-9	2007-	always	always
41055 Mazda 2	2011-	always	always
41200-41205 Mazda B pickup	2007-2009	always	always
41342-41347 Mazda Tribute	2001-	always	always
41402-41403 Mazda MPV wagon	1996-2006	2002	2000
42031 Mercedes E (thru 1995)	1989-1995	always	never
42033 Mercedes SL (thru 1989)	1989	always	never
42036 Mercedes SEL/SEC	1989-1993	always	never
42037 Mercedes S (thru 1991)	1989-1991	always	never
42039 Mercedes 190	1990-1993	always	never
42042 Mercedes C	1994-	always	2000
42043 Mercedes S	1992-	always	2000
42044 Mercedes SL	1990-	always	2003
42045 Mercedes SLK	1998-	always	always
42046 Mercedes CL	1998-	always	2000
42047 Mercedes CLK	1998-2009	always	2000
42048 Mercedes E	1996-	always	always
42049 Mercedes SLR	2005-2009	always	always
42051 Mercedes CLS	2006-	always	always
42052 Mercedes SLS	2011-	always	always
42302-42307 Mercedes ML	1998-	always	always
42313 Mercedes G	2002-	always	always
42323 Mercedes R	2006-	always	always
42333 Mercedes GL	2007-	always	always
42336-42337 Mercedes GLK	2010-	always	always
45030 Porsche unknown model	1992-1994	never	never

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
45031 Porsche 911	1990-	2002	2002[64]
45035 Porsche 928	1990-1995	never	never
45037 Porsche 944	1987-1991	never	never
45040 Porsche Boxster	1997-	2002	2002[65]
45041 Porsche Cayman	2006-	always	always
45042 Porsche Panamera	2010-	always	always
45313 Porsche Cayenne	2004-	always	always
47031 Saab 900	1994-1998	1998 (≤ 97 unk)	never
47034 Saab 9000	1994-1998	1998 (≤ 97 unk)	never
47035 Saab 9-3	1999-	always	2004[66]
47036 Saab 9-5	1999-	always	always
47037 Saab 9-2X	2005-2006	always	always
47038 Saab 9-4X	2011-	always	always
47308 Saab 9-7X	2005-2009	always	always
48034 Subaru Legacy	1995-	2000	2000
48037 Subaru SVX	1994-1997	unknown	never
48038 Subaru Impreza	1994-	2001	2002
48044 Subaru Baja	2003-2006	always	always
48045 Subaru Outback	2003-	always	always
48303 Subaru Forester	1998-	2003	1999
48313 Subaru Tribeca	2006-	always	always
49032 Toyota Corolla	1994-	1998	1998
49033 Toyota Celica	1994-2005	2000	2000
49034 Toyota Supra	1994-1998	never	never (98 unk)
49038 Toyota Tercel	1995-1998	1998	never (98 unk)
49040 Toyota Camry	1994-	1998	1998
49041 Toyota MR2	1994-2005	2000	2000
49042 Toyota Paseo	1996-1997	never	never
49043 Toyota Avalon	1995-	1999	1998
49044 Toyota Camry Solara	1999-2009	always	always
49045 Toyota Echo	2000-2006	always	always
49046 Toyota Prius	2001-	always	always
49047 Toyota Matrix	2003-	always	always
49048 Scion xA	2004-2006	always	always
49049 Scion xB	2004-	always	always
49050 Scion tC	2005-	always	always
49051 Toyota Yaris	2007-	always	always
49052 Scion xD	2008-	always	always
49053 Toyota Venza CUV	2009-	always	always

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[64] Unknown if Porsche 911 had load limiters in 2000-2001.

[65] Unknown if Porsche Boxster had load limiters in 2000-2001.

[66] Redesigned 2003 Saab 9-3 4-door sedan (CG=47008) had load limiters.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
49200-49205 Toyota Tacoma Pk	2001-	always	always
49210-49215 Toyota Tundra Pk	2000-	always	always
49302-49303 Toyota 4Runner	1996-	1999	1998
49313 Toyota Land Cruiser	1995-	1998	1998
49320-49323 Toyota RAV4	1996-	1998	1998
49342-49347 Toyota Highlander	2001-	always	always
49352 Toyota Sequoia	2001-	always	always
49362 Toyota FJ Cruiser	2007-	always	always
49400-49403 Toyota Sienna Van	1998-	always	always
49422 Toyota Previa Van	1994-1997	never	never[67]
51040 Volvo 940	1994-1995	always	never (95 unk)
51041 Volvo 960	1993-1997	always	never[68]
51042 Volvo 850	1993-1997	always	1995
51043 Volvo S70, V70, C70, XC70	1998-	always	always
51044 Volvo 90-Series	1998	always	always
51045 Volvo S80	1999-	always	always
51046 Volvo 40	2000-	always	always
51047 Volvo S60, XC60	2001-	always	always
51048 Volvo V50	2005-	always	always
51049 Volvo C30	2008-	always	always
51312-51313 Volvo XC90	2003-	always	always
52034 Mitsubishi Galant	1994-	2004	1999[69]
52035 Mitsubishi Mirage	1995-2002	never[70]	1997
52037 Mitsubishi Eclipse	1995-	2006	1997
52039 Mitsubishi 3000GT	1994-1997	never	1997
52040 Mitsubishi Diamante	1994-2004	1999[71]	1997
52046 Mitsubishi Lancer	2002-	always	always
52047 Mitsubishi Outlander	2003-	always	always
52202-52205 Mitsubishi Raider	2006-2009	always	always
52312-52313 Mitsubishi Endeavor	2004-	always	always
52333 Mitsubishi Montero	1996-2006	2002	1997
52336-52337 Mitsubishi Montero Sport	1997-2004	2003[72]	1997
53031 Suzuki Swift	1995-2001	never	never
53032 Suzuki Esteem	1995-2002	never	never
53033 Suzuki Aerio	2002-2007	always	always
53034 Suzuki Forenza	2004-2008	always	always

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[67] Toyota Previa never had load limiters for RF passengers; unknown for drivers.

[68] Unknown if Volvo 960 had load limiters in 1995-1997.

[69] Unknown if Mitsubishi Galant had load limiters in 1997-1998.

[70] Unknown if Mitsubishi Mirage had pretensioners in 2000-2002.

[71] Unknown if Mitsubishi Diamante had pretensioners in 1994-1998.

[72] In 2001-2002, Mitsubishi Montero Sport had pretensioners for drivers but not RF passengers (exclude from analysis).

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
53035 Suzuki Verona	2004-2006	always	always
53036 Suzuki Reno	2005-2008	always	always
53040 Suzuki SX4	2007-	always	always
53041 Suzuki Kizashi	2010-	always	always
53202-53205 Suzuki Equator	2009-	always	always
53310-53313 Suzuki Sidekick	1996-1998	never	never
53320-53321 Suzuki X-90	1996-1998	never	never
53332-53333 Suzuki Vitara	1999-2004	never	always
53336-53337 Suzuki Grand Vitara	1999-	2006	always
53338-53339 Suzuki XL-7	2001-	always	always
54031 Acura Integra	1994-2001	never	1999
54032 Acura Legend	1991-1995	1992[73]	never
54033 Acura NSX	1993-2005	1993	never
54034 Acura Vigor	1993-1994	never	never
54035 Acura TL	1995-	2002	2000
54036 Acura RL	1996-	always	1999
54037 Acura CL	1997-2003	2001	1999
54038 Acura RSX	2002-2006	always	always
54039 Acura TSX	2004-	always	always
54040 Acura ZDX	2010-	always	always
54302-54303 Acura RDX	2007-	always	always
54313 Acura SLX	1996-1999	never	never
54323 Acura MDX	2001-	always	always
55033 Hyundai Sonata	1994-	1999	2003
55035 Hyundai Elantra	1996-	1999	2004
55036 Hyundai Accent	1995-	2000	2004
55037 Hyundai Tiburon	1997-2008	2000	2004
55038 Hyundai XG300	2001-2005	always	2003
55039 Hyundai Azera	2006-	always	always
55040 Hyundai Equus	2011-	always	always
55041 Hyundai Genesis	2009-	always	always
55302-55309 Hyundai Santa Fe	2001-	always	always
55322-55323 Hyundai Tucson	2005-	always	always
55332-55323 Hyundai Veracruz	2007-	always	always
55402 Hyundai Entourage	2007-2009	always	always
58032 Infiniti Q45	1994-2006	1994	1999
58033 Infiniti G20	1993-2002	1993	1999
58034 Infiniti J30	1993-1997	1994	never
58035 Infiniti I30	1996-2001	1999	2000
58036 Infiniti I35	2002-2004	always	always

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[73] Unknown if Acura Legend had pretensioners in 1991.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
58037 Infiniti G35	2003-	always	always
58038 Infiniti M45	2003-	always	always
58039 Infiniti FX35	2003-	always	always
58040 Infiniti EX35	2008-	always	always
58302-58303 Infiniti QX4	1997-2003	2000 (99 unk)	2000
58312-58313 Infiniti QX56	2004-	always	always
59031 Lexus ES	1994-	1997	1998
59032 Lexus LS	1993-	1993	1998
59033 Lexus SC-300/400	1993-2000	1996	never
59034 Lexus GS	1993-	always	1998
59035 Lexus IS	2001-	always	always
59036 Lexus SC-430	2002-2010	always	always
59037 Lexus HS	2010-	always	always
59038 Lexus CT	2011-	always	always
59303 Lexus GX	2003-	always	always
59313 Lexus LX	1996-	1998	1998
59332-59333 Lexus RX300	1999-2003	always	always
59342-59343 Lexus RX330	2004-	always	always
62303 Land Rover Discovery	1996-1999	never	never
62307 Land Rover Discovery II	1999-2004	always	2000 (99 unk)
62313 Land Rover Range Rover	1996-	2000 (99 unk)	2000
62317 L. R. Range Rover Sport	2006-	always	always
62325 Land Rover Defender	1997	never	never
62341-62343 Land Rover Freelander	2002-2005	always	always
62353 Land Rover LR3/LR4	2005-	always	always
62357 Land Rover LR2	2008-	always	always
63031 Kia Sephia	1996-2001	2001	2001
63032 Kia Rio	2001-	always	always
63033 Kia Spectra	2000-2009	2001	2001[74]
63034 Kia Optima	2001-	always	always
63035 Kia Amanti	2004-2009	always	always
63036 Kia Rondo	2007-	always	always
63037 Kia Soul	2010-	always	always
63038 Kia Forte	2010-	always	always
63300-63303 Kia Sportage	1998-	2005	2005
63312-63313 Kia Sorento	2003-	always	always
63316-63317 Kia Borrego	2009	always	always
63402 Kia Sedona	2002-	always	always
64031 Daewoo Lanos	1998-2002	2000	never

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[74] Unknown if Kia Spectra had load limiters in 2000.

Make and Model(s)	MY with Dual Air Bags	First MY with Pretensioners	First MY with Load Limiters
64032 Daewoo Nubira	1998-2002	always	never
64033 Daewoo Leganza	1998-2002	always	never
65031 Smart Fortwo	2008-	always	always

Appendix B

MY 1996 to 2011 SUVs Considered CUVs in This Report

Ward's Automotive Yearbooks began to list certain makes and models as "CUVs" in MY 2002 in its "Light-Duty Truck Specifications" and its narrative descriptions of the new vehicles.[75] In general, the list of vehicles considered CUVs in this report includes all those called CUVs by Ward's but also some other vehicles (among them, any CUVs of designs discontinued before 2002, since Ward's was not yet using the term), based on sources or criteria documented in the footnotes.[76] Typically, SUVs of unibody construction are considered CUVs, while SUVs of body-and-frame construction are called truck-based SUVs, but there are a few exceptions (see footnotes). The "LTV groups" are the 5-digit codes assigned by the VIN-decode programs developed by NHTSA's Evaluation Division; an LTV group includes all of a manufacturer's vehicles of the same type and wheelbase, and runs for several years, until those vehicles are redesigned – e.g., Ford Escape, Mercury Mariner, and Mazda Tribute belong to the same LTV group. These programs are updated periodically and are available to the public.

	First MY	Last MY[77]	LTV Groups Included (NHTSA 5-Digit Codes)
Chrysler PT Cruiser	2001	2010	6304
Chrysler Pacifica	2004	2008	6307
Dodge Magnum	2005	2008	6310
Jeep Compass/Patriot	2007	2011	6312
Dodge Journey	2009	2011	6316
Ford Escape/Merc Mariner/Mazda Tribute	2001	2009	12309
Ford Freestyle	2005	2007	12312
Ford Edge/Lincoln MKX	2007	2011	12314
Ford Flex/Lincoln MKT	2009	2011	12318
Pontiac Aztec	2001	2005	18313
Buick Rendezvous	2002	2007	18315
Saturn Vue	2002	2010	18317
Cadillac SRX/Saab 9-4X	2004	2011	18319, 18327
Chevrolet HHR	2006	2011	18321
Buick Enclave/Chevrolet Traverse/ GMC Acadia/Saturn Outlook	2007	2011	18323
VW Touareg/Porsche Cayenne	2004	2011	30301, 30303

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[75] Southfield, MI: Penton Media, Inc.

[76] Ward's does not call the Jeep Liberty a CUV, nor the Dodge Nitro (a related design with a longer wheelbase, according to cars.com). Although these vehicles are of unibody design, they have additional structure for the front and rear suspension to provide better off-road and towing capabilities and for that reason it is probably more appropriate to consider them truck-based SUVs.

[77] 2011 is the last model year in the VIN decoder used for this report; however, most of these vehicles continued as CUVs beyond MY 2011.

	First MY	Last MY[78]	LTV Groups Included (NHTSA 5-Digit Codes)
VW Tiguan	2009	2011	30302
Audi Allroad	2001	2005	32301
Audi Q7	2007	2011	32302
Audi Q5	2009	2011	32303
BMW X5/BMW X6	2000	2011	34301, 34303
BMW X3	2004	2011	34302, 34304
Mini-Cooper Countryman	2011	2011	34305
Nissan Murano	2003	2011	35304
Infiniti FX	2003	2011	35305, 35311
Nissan Rogue	2008	2011	35309
Infiniti EX	2008	2011	35310
Nissan Cube/Nissan Juke	2009	2011	35312
Honda CR-V	1997	2011	37301, 37303, 37307
Acura MDX/Acura ZDX	2001	2011	37302, 37305
Honda Pilot	2003	2011	37302, 37308
Honda Element	2003	2011	37304
Acura RDX	2007	2011	37306
Honda Accord Crosstour	2010	2011	37309
Mazda CX-7	2007	2011	41301
Mazda CX-9	2007	2011	41302
Mercedes ML[79]	2006	2011	42303
Mercedes R[80]	2006	2011	42304
Mercedes GL	2007	2011	42305
Mercedes GLK	2010	2011	42306
Subaru Forester	1998	2011	48301, 48304
Subaru Outback[81]	2005	2011	48302, 48303
Subaru Tribeca	2006	2011	48303
Subaru Baja	2003	2006	48702
Toyota RAV4[82]	1996	2011	49306, 49309, 49313
Lexus RX300	1999	2003	49308
Toyota Highlander	2001	2011	49310, 49315
Lexus RX330/350	2004	2011	49310, 49317

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[78] 2011 is the last model year in the VIN decoder used for this report; however, most of these vehicles continued as CUVs beyond MY 2011.

[79] But not the 1998-2005 Mercedes ML (LTV group 42301). Mercedes ML was redesigned in 2006 as a unibody according to www.motortrend.com/roadtests/suvs/112_0506_2006_mercedes_benz_m_class/viewall.html, (even though Ward's does not call it a CUV).

[80] Mercedes R was built on the same platform as ML starting in 2006 and it is a crossover according to msn.auto, http://editorial.autos.msn.com/article.aspx?cp-documentid=435375, (even though Ward's does not call it a CUV).

[81] But not the 2003-2004 Subaru Outback (car group 48013), which is a passenger car by NHTSA's definitions for FMVSS and CAFE purposes. In 2005, Subaru Outback was reclassified an LTV and it became a CUV (even though Ward's still calls it a car).

[82] http://auto.howstuffworks.com/car-models/crossover-cars/first-crossover-vehicle.htm says RAV4 was the first crossover SUV.

	First MY	Last MY[83]	LTV Groups Included (NHTSA 5-Digit Codes)
Toyota Venza	2009	2011	49315
Volvo XC70	2001	2011	51301, 51303
Volvo XC90	2003	2011	51302
Volvo XC60	2010	2011	51304
Mitsubishi Outlander[84]	2003	2011	52305, 52307
Mitsubishi Endeavor[85]	2004	2011	52306, 52308
Chevrolet Equinox/Pontiac Torrent/ GMC Terrain	2005	2011	53307
Suzuki XL-7[86]	2007	2009	53307
Hyundai Santa Fe	2001	2011	55301, 55304
Hyundai Tucson/Kia Sportage[87]	2005	2011	55302, 55305
Hyundai Veracruz	2007	2011	55303
Land Rover Freelander	2002	2005	62307
Kia Sorento[88]	2011	2011	5530

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[83] 2011 is the last model year in the VIN decoder used for this report; however, most of these vehicles continued as CUVs beyond MY 2011.

[84] Ward's does not call it a CUV until 2007, but www.motortrend.com/roadtests/suvs/112_0306_2003_subaru_mitsubishi_suv_comparison/viewall.html calls it a CUV from the start.

[85] Ward's does not call it a CUV until 2007, but www.cars.com calls it a CUV from the start.

[86] Ward's states that the 2007 XL-7 (LTV group 53307) was redesigned as a CUV, whereas the 2001-2006 XL-7 (LTV group 53306) was truck-based.

[87] Ward's does not call them CUVs, but www.edmunds.com/kia/sportage calls them CUVs, whereas it calls the 1995-2002 Kia Sportage a body-on-frame SUV.

[88] Kia Sorento was redesigned in MY 2011 as a CUV on the Hyundai Santa Fe platform.

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