SAFETY CHANGES IN THE US VEHICLE FLEET BY VEHICLE MODEL YEAR

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ABSTRACT

NASS/CDS 1995-2009 was the basis for evaluating safety changes in the vehicle fleet with model year. The analysis shows that the mean AIS 3+ HARM for belted drivers in 1996-2009 model year vehicles had decreased injuries in side and frontal crashes. Head injuries were the most reduced body region in frontal crashes, decreased by 40%; however, there was an increase in lower extremity injuries. Chest injuries were most reduced in side crashes, decreased by 25%. For rollovers, reduction in injuries for all body regions were observed in 2000 to 2009 model years compared to models up to five years earlier. For the most recent model years, a larger fraction of the AIS 3+ HARM occurred in severe rollover (more than 7 quarter-turns).

INTRODUCTION

Recent models of passenger vehicles have incorporated numerous safety features. The objective of this research was to determine how the injury environment has changed in recent vehicles compared to older vehicle models. More specifically, for recent model vehicles, how has the distribution of crashes and injuries changed for belted drivers by crash mode and injured body region.

There are a variety of ways to examine the frequency and rate of injuries in the available databases. Frequently, Maximum Abbreviated Injury Scale (MAIS) 3 and above injuries are combined. Alternatively, the HARM weighting scheme is applied to injuries of different severity. The latter has the advantage of weighting injuries in proportion to their cost (Malliaris 1982). The HARM method will be the primary focus of this paper. The change in Mean HARM for different vehicle model years is used as a surrogate for changes in injury rates.

The model year period from 1985 through 2009 is of principal interest. During the past 25 years there have been a number of changes in safety testing to encourage safety improvements in passenger vehicles. Although the first commercial airbags were introduced in limited numbers during the 1970's, it was not until1984 that Federal Motor Vehicle Safety Standard (FMVSS) 208 mandated a phased introduction of the driver airbags for passenger cars produced after 1989, with light trucks phased-in by 1997. It was not until the early 1990 model years that air bags penetrated the fleet in large numbers. In 1998, FMVSS 208 mandated the second generation airbag, also with phased enforcement. In addition, the evolution of New Car Assessment Program (NCAP) to add a star rating system in 1992, and the 1995 entrance of the Insurance Institute for Highway Safety (IIHS) crash testing for consumer information increased the incentives to improve frontal crash safety. In 1997 NCAP initiated a side impact test program, followed by IIHS and in 2004 a Motor Vehicle Safety Standard was strengthened to require a side crash test.

Electronic stability control (ESC) entered the market in 1995 and became standard on approximately 38% of the cars and SUV's by model year 2005. By model year 2009, the ESC was standard equipment on 100% of SUV's, 74% of cars and 38% of pickups (IIHS 2013).

METHODS

The source for exposure and injury data was the NASS/CDS (National Automotive Sampling System/Crashworthiness Data System) years 1995 to 2009. NASS/CDS is a weighted estimate of tow-away crashes occurring in the United States. The NASS/CDS weighted data contains approximately 23 million drivers of passenger cars, SUV's, passenger vans or light trucks (pickups) who were exposed to crashes. NASS/CDS data were disaggregated by vehicle model year and crash mode. Since this study focused on the safety changes for belted drivers, only vehicles with belted drivers were included. The resulting population of vehicles was 22,541,582.

The resulting data permitted the assessment of changes in injury distributions and rates by model year, crash mode and body region for belted drivers. The front, side and rear crash mode categories

excluded all rollovers. The rollover crash mode contains all rollovers including those with planar impacts as an earlier event.

The HARM calculations for the body regions were based on the approach introduced by Fildes and Digges [Fildes 1992]. This methodology applies a weighting factor to each AIS 3+ injury in the database. The weighting factor is proportional to the cost of the occupant's most serious injury. In general, minor and moderate injuries (AIS 1 and 2) are high frequency, events that tend to cloud the analysis of serious injury reduction by safety systems. For this reason, AIS 1 and 2 injuries were excluded from the HARM calculations. The AIS 3+ HARM, measured in equivalent fatalities, was based on NHTSA's data on average cost of injuries. The equivalent fatality measurement is obtained by normalizing the average cost of a given injury by the cost of a fatality. The average cost of each injury severity was obtained from a Table E-1 in the 1995-1997 NASS/CDS Summary (NHTSA 2001). The injury cost values are: MAIS 3, 98,011; MAIS 4, 221,494; MAIS 5, 697,533; and MAIS 6, 822,328. The Mean HARM for each category was calculated by dividing the HARM suffered by drivers by the number of drivers exposed to that category. The Mean HARM results were multiplied by 100 to simplify the presentation. The HARM values were applied to the maximum injury per body region.

RESULTS

The distributions of belted drivers by crash mode and AIS 3+ HARM from NASS/CDS 1995-2009 are displayed in Table 1. Since the principal interest was in the newer vehicles, the model years 2000 to 2009 were aggregated. This group contained 5,339,833 belted

TABLE 1.
Distribution of Exposed Vehicles and Driver 3+ HARM by Crash Mode for Vehicle Model Years 2000 to 2009

CRASH MODE	FRONT	NEAR SIDE	ROLL	FAR SIDE	REAR
EXPOSURE	55%	14%	12%	11%	8%
3+ HARM	38%	28%	22%	10%	2%

Figure 2 separates the model years into three groups – 1985-1989; 1990-1995 and 1996-2009. Figure 1 suggests that the model years 1985 to 1989 have fewer vehicles, but the number in each model year are fairly constant. However, the 1990-1995 group is biased by larger numbers of vehicles in the later years. The 1996 - 2009 group is biased by a larger number of vehicles in the earlier years. Consequently a comparison of the two latter groups is closer to a comparison of vehicles in the late 1990's to those in the early 2000's.

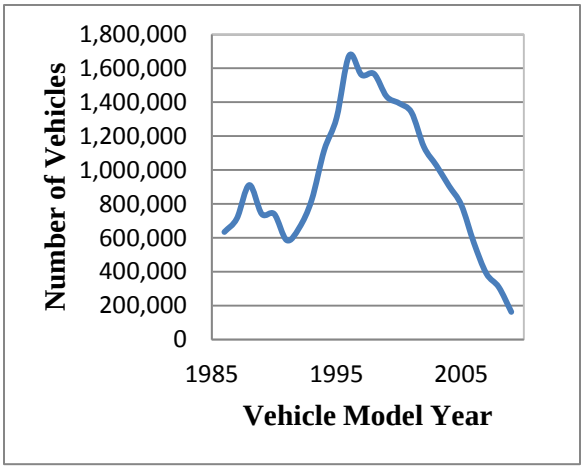

Figure 1. Distribution of light vehicles with belted drivers in 1995-2009 NASS/CDS by model years.

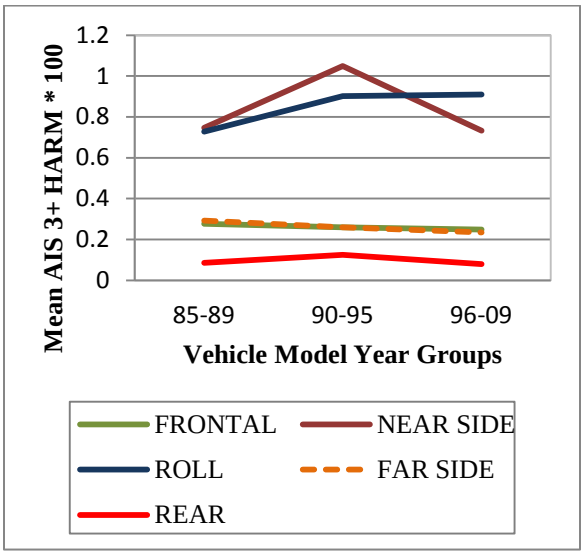

Figure 2. Mean AIS 3+ HARM for belted drivers in 1995-2009 NASS/CDS by crash mode for three model year groupings.

Frontal Crash Mode Results

The frontal crash mode was disaggregated to determine the exposure of belted drivers and the injuries received by belted drivers. Injuries were determined for each body region, with the restriction that only the most serious injury per body region was included. AIS 3+ HARM for each model year

grouping was calculated for each body region and the distribution of HARM was determined. The resulting distributions are plotted in Figure 3.

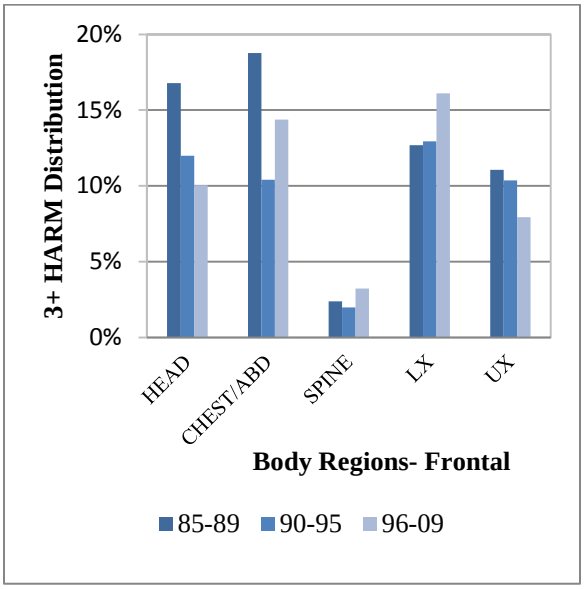

Figure 3. Body region distribution of AIS 3+ HARM for 1995-2009 NASS/CDS belted drivers involved in frontal crashes for three model year groups.

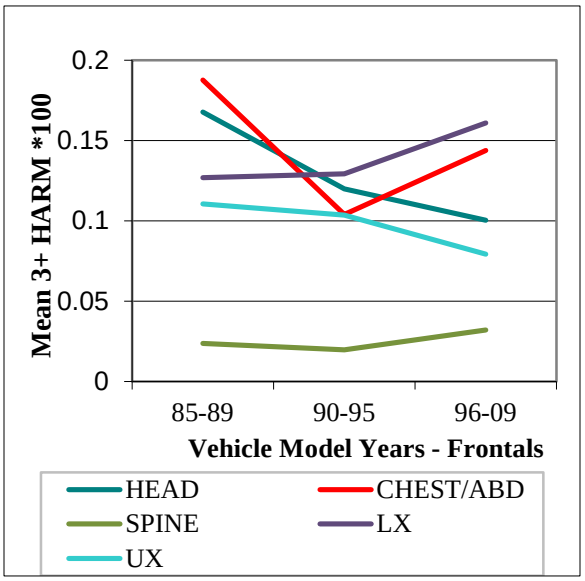

Figure 4. Body region distribution of AIS 3+ Mean HARM for 1995-2009 NASS/CDS belted drivers involved in frontal crashes for three model year groups.

Figure 4 displays the trends in frontal crashes by model year groupings for mean AIS 3+ HARM by body region.

Near-side Crash Mode Results

The near-side crash mode was treated in a manner similar to that described for the frontal mode. The resulting distribution of AIS 3+ HARM by body region for three model year groupings is displayed in Figure 5.

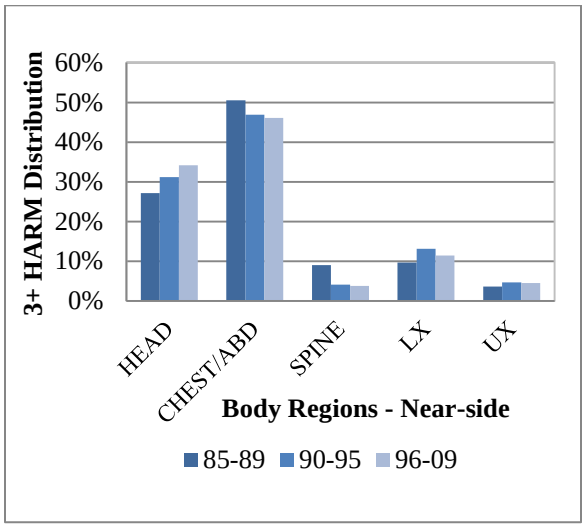

Figure 5. Body region distribution of AIS 3+ HARM for 1995-2009 NASS/CDS belted drivers involved in near-side crashes for three model year groups.

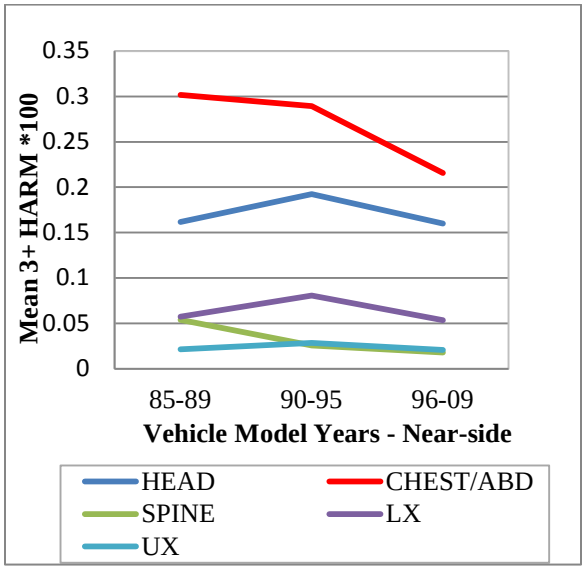

Figure 6. Body region distribution of AIS 3+ Mean HARM for 1995-2009 NASS/CDS belted drivers involved in near-side crashes for three model year groups.

Figure 6 shows the trends by model year groupings for mean AIS 3+ HARM by body region applied to the near-side crash mode.

Rollover Crash Mode Results

Data analysis similar to that described for the frontal crash mode was applied to rollovers. Figure 7 shows the AIS 3+ HARM distribution for rollovers. This figure displays the distributions for three model year groupings and five body regions.

Figure 8 shows four model year groupings for the mean rollover AIS 3+ HARM by body regions. For the rollover, the 1996-2009 model year grouping was split into two. The early group included the years 1996-1999 and the later group 2000-2009. This grouping was done because ESC did not arrive in the fleet in significant numbers until after model year 1999. The split was intended to investigate changes in rollovers as ESC penetrated the fleet. The latest model year grouping exhibited a downturn in the mean AIS 3+ HARM for all body regions.

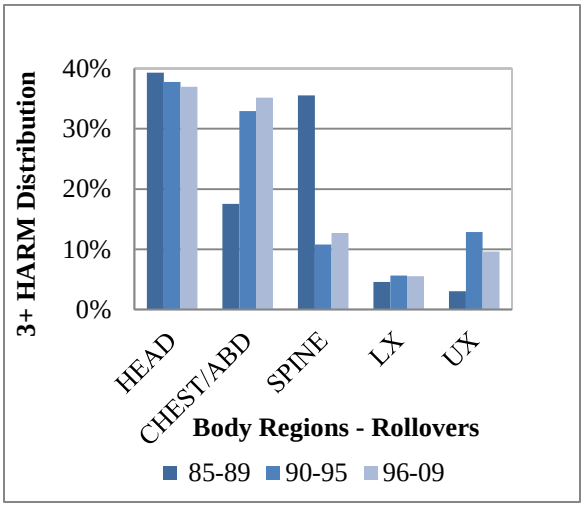

Figure 7. Body region distribution of AIS 3+ HARM for 1995-2009 NASS/CDS belted drivers involved in rollover crashes for three model year groups.

Figure 9 shows the distribution of belted drivers exposed to rollovers and the distribution of their AIS 3+ HARM by number of quarter-turns. Because the quarter-turns further divides the data, the entire range of model years was included in the plots. It is evident that quarter-turns 1, 2, 4, 6 and 8 are most frequently represented in both exposure and AIS 3+ HARM. Subsequent plots will apply quarter-turn groupings that cluster the data around these numbers.

In view of the benefit of ESC to reduce rollovers, it is of interest to examine how the HARM distribution has changed with rollover severity for the recent models of vehicles. The number of quarter-turns is a generally accepted measure of the initial rollover energy and it was used as a measure of severity.

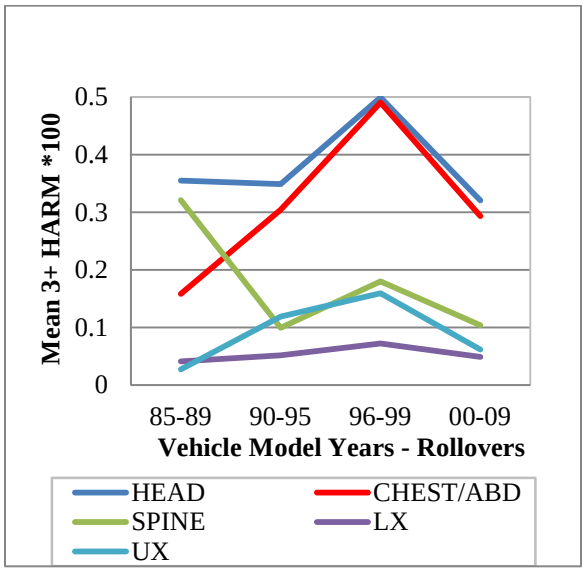

Figure 8. Body region distribution of AIS 3+ Mean HARM for 1995-2009 NASS/CDS belted drivers involved in rollover crashes for three model year groups.

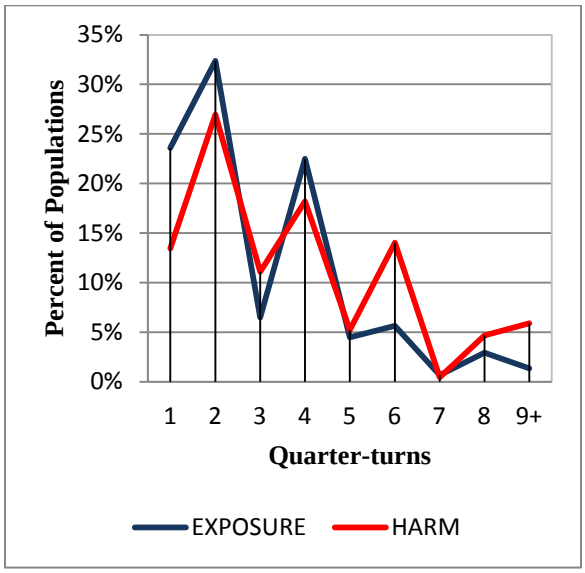

Figure 9. Distribution of model year 1985 to 2009 vehicles in rollover crashes and AIS 3+ Mean HARM for their belted drivers in NASS/CDS 1995-2009 by number of quarter-turns.

However, when the data was separated by number of quarter-turns it became necessary to group larger numbers of model years. For the data to follow, two groups of ten model years were used. The model year groups are: 1990-1999 and 2000-2009.

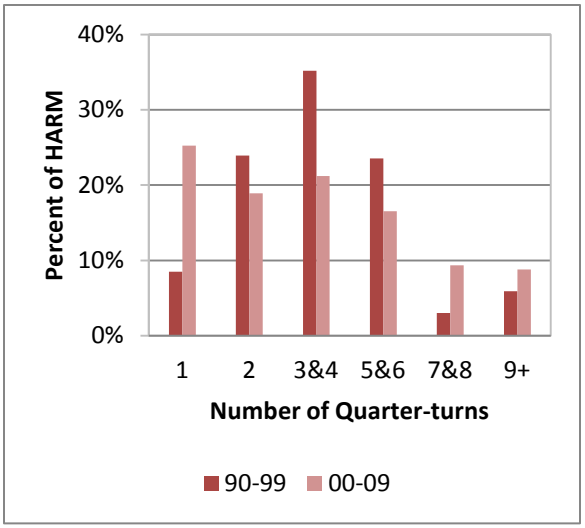

Figure 10. Distribution of AIS 3+ HARM for belted drivers in NASS/CDS 1995-2009 for Model Years 1990-1999 and 2000-2009 by number of quarter-turns.

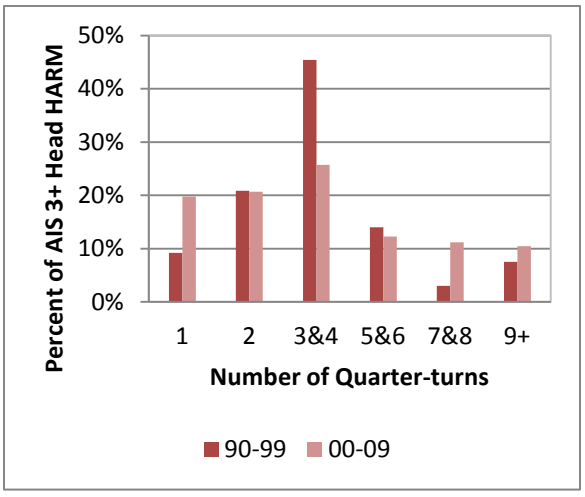

Figure 11. Distribution of AIS 3+ Head HARM for belted drivers in NASS/CDS 1995-2009 for Model Years 1990-1999 and 2000-2009 by number of quarter-turns.

Figure 10 displays the AIS 3+ HARM distribution for belted drivers in the two model year groupings by rollover severity. Figure 11 is a further disaggregation of the data that shows the distribution of AIS 3+ head HARM. Figure 12 is similar to Figure 11, but shows the AIS 3+ chest HARM distribution.

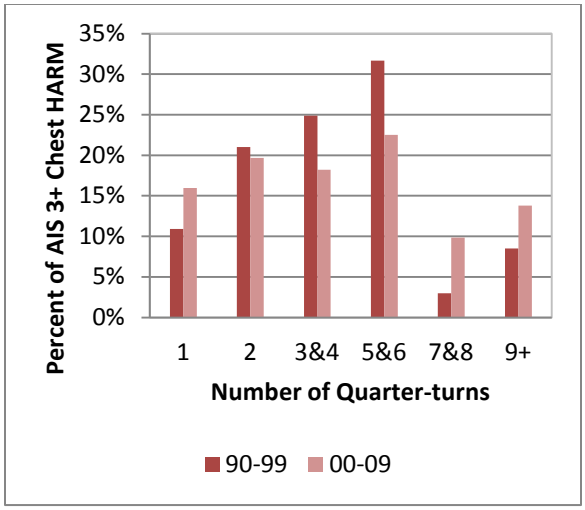

Figure 12. Distribution of AIS 3+ Chest HARM for belted drivers in NASS/CDS 1995-2009 for Model Years 1990-1999 and 2000-2009 by number of quarter-turns.

DISCUSSION

The purpose of the analysis presented was to examine how the population of NASS vehicles has changed with particular emphasis on changes in the protection of different body regions. This study was not an attempt to examine the effectiveness of the countermeasures that have been introduced. Consequently (except for rollovers,) there was no attempt to control for crash severity, vehicle age at the time of the crash, and driver factors. However, the study shows how the populations of belted drivers in vehicles of different model years are being injured, according to NASS/CDS.

Table 1 shows that for belted drivers in the NASS model year grouping 2000-2009, frontal crashes retained the largest fraction of AIS 3+ HARM at 38%. Near-side accounted for 28% and rollovers accounted for 22%. It should be noted that unbelted occupants were not included in these calculations.

Figure 2 shows that the most recent model year grouping has reduced mean HARM in all modes except rollover. However, when the 1996-2009 grouping is further divided, as in Figure 8, a reduction of rollover mean HARM in the latest model years is evident. The near-side experienced an increase in mean HARM for the mid years (1990-1995). This period was before the most recent side protection standards and consumer information tests

were advanced. In addition, the passenger cars of this period may have been subjected to more severe crashes from an increasing population of light trucks and SUV's.

Figures 3, 5 and 7 show the distributions of AIS 3+ HARM for three model year groupings. The bars for each model year grouping add to 100%. Consequently, reductions in one body region may lead to increases in other regions. The mean HARM calculation shown in Figures 2, 4 and 6 divides the HARM by the exposure and consequently reductions in all categories may be possible.

Figures 3 and 4 show a dramatic reduction in head injury HARM for the most recent grouping of model years. The mean HARM is down 40% from the early model years and 16% from the mid-model years. However, offsetting this gain is an increase in chest/abdominal and lower extremity injury - up 36% and 25% from the mid-years. As shown in Figure 2, the overall mean HARM for frontal crashes decreased for the recent model years.

Figure 6 shows that the most recent vehicles exhibit a reduction in the near-side mean HARM for all body regions. The reduction of chest HARM is most apparent – down 25% from the mid-model years.

The rollover results in Figure 8 show increases in head and chest mean HARM for the 1996-1999 model year groupings. However, dramatic reduction for all body regions occurred for the latest model years. The penetration of ESC into the fleet is a possible explanation for this effect.

To further investigate changes in AIS 3+ HARM with rollover severity, the rollover data was disaggregated by quarter-turns. Figure 9 suggests clustering the quarter-turn data as follows: 1, 2. 3&4, 5&6, 7&8 and 9+. In order to achieve sufficient cell sizes, ten model years were grouped. The results of the HARM distribution with quarter-turns are shown in Figures 10, 11 and 12. These Figures indicate that the later models of vehicles have lower AIS 3+ HARM in the mid quarter-turn ranges from 2 through 6. Their HARM is higher at 1 and 7+ quarter-turns. The higher HARM at 1 quarter turn may be caused by a planar crash with another vehicle prior to the rollover. The fraction of HARM at the higher quarter-turns is 8.9% for the early model years and 18.2% for the later model years. This higher HARM fraction at high severities is present in both head and chest injuries.

CONCLUSION

The NASS/CDS analysis shows that the mean HARM for belted drivers in 1996-2009 model year vehicles had decreased in side and frontal crashes. Head injuries were the most reduced body region in frontal impacts and chest injuries were most reduced in side impacts.

Consumer information testing and regulatory initiatives in the early and mid 1990's may have contributed to encouraging the improvements in the frontal and side crash mode.

For rollovers, there was an increase in the mean HARM for the model years 1996 -1999. However, for the model year grouping 2000-2009 the mean HARM of all body regions decreased dramatically. The penetration of ESC into the vehicle fleet may have contributed to this decrease in HARM.

ACKNOWLEDGMENTS

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