U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
www.nhtsa.gov

DOT HS 811 101 **March 2009**

Evaluation of Thoracic Injuries Among Older Motor Vehicle Occupants

Technical Report

DISCLAIMER

This publication is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade names, manufacturers' names, or specific products are mentioned, it is because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

Technical Report Documentation Page

1. Report No. **DOT HS 811 101**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle **Evaluation of Thoracic Injuries Among Older Motor Vehicle Occupants**		**5. Report Date:** March 2009 **6. Performing Organization Code:** NVS-421
7. Author(s) Refaat Hanna and Lawrence Hershman		**8. Performing Organization Report No**.
9. Performing Organization Name and Address Mathematical Analysis Division, National Center for Statistics and Analysis, NHTSA.		**10. Work Unit No. (TRAIS)n code** **11. Contract of Grant No.**
12. Sponsoring Agency Name and Address Mathematical Analysis Division, National Center for Statistics and Analysis National Highway Traffic Safety Administration U.S. Department of Transportation 1200 New Jersey Avenue SE., Washington, DC 20590		**13. Type of Report and Period Covered** **Technical Report (1998-2007)** **14. Sponsoring Agency Code**

15.Supplementary Notes

16. Abstract

Objective - According to the National Center for Health Statistics, the total resident population of the United States increased from 151 million in 1950 to 296 million in 2005, representing an average annual growth rate of 1.2 percent. As the population ages, there is a growing need for vehicle safety to suit older occupants. This study examines the relationship between age and the incidence of thoracic injuries in different motor vehicle crashes.

Method - The National Automotive Sampling System/Crashworthiness Data System (NASS-CDS) for the years 1998 to 2007 was used to measure the relationship between occupant's age and the incidence of thoracic injuries. NASS-CDS only includes crashes involving at least one passenger vehicle towed due to damage.

Results – The age group 75 and older (75+) had a higher percentage of Abbreviated Injury Scale (AIS) moderate or more severe (2+) thoracic injuries when driving or riding in any passenger vehicle type compared to three other age groups in a tow-away crash. Age groups 25 to 44, 45 to 64 and 65 to 74 had a lower percent of thoracic injuries when driving or riding in utility vehicles, pickup trucks, and vans, referred to collectively as LTVs, compared to passenger cars. However, age group 75+ had a higher percentage of thoracic injuries when driving or riding in LTVs compared to cars. Data analysis showed that seat belt use has a positive impact in reducing the incidence of a moderate or more severe thoracic injury among all age groups in towaway crashes. However, even when controlling for restraint use, the incidence of thoracic injuries among the four age groups shows a steady increase for both belted and unbelted occupants as age increases. The analysis results by occupants' seating position showed that people 75+ had a higher incidence of AIS 2+ thoracic injuries than other age groups in the same seating position. Furthermore, people 75 and older had an exceptionally higher incidence of AIS 2+ thoracic injuries when riding in the rear seats at an estimate of 18.7 percent compared to drivers and front-seat passengers of the same age group. Data analysis of the incidence of AIS 2+ thoracic injuries by vehicle model year showed that young and middle-age groups had lower incidence of thoracic injuries when driving or riding in vehicles of model year 1996 or later compared to model years before 1996. However, for occupants 75+ the incidence of thoracic injuries was slightly higher in vehicle model years 1996 and later. The incidence of thoracic injury remains in a steady increasing pattern in relation to occupants' age in both single- and two-vehicle crashes. Both age groups 65 to 74 and 75+ had higher bony structures injuries as indicated by an estimate of 79 percent and 23 percent of the occupants sustaining rib cage and sternal fractures. Lung contusions and lacerations were sustained by an estimated 20 percent of occupants 75+. The steering wheel was the most common source of injury among young and middle-age group occupants, while seat belt was reported as the source of thoracic injuries among occupants 75+.

17. Key Words : Thorax, Elderly, Vehicle Crash, Seat Belt, Abbreviated Injury Scale, General Area of Damage, Vehicle Model Year		**18. Distribution Statement**	
19. Security Classification. (of this report) **Unclassified**	**20. Security Classification (of this page)** **Unclassified**	**21. No of Pages** **39**	**22. Price**

Form DOT F1700.7 (8-72) **Reproduction of completed page authorize**

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Objective - According to the National Center for Health Statistics, the total resident population of the United States increased from 151 million in 1950 to 296 million in 2005, representing an average annual growth rate of 1.2 percent. During the same period, the population group 65 and older grew on average 2.0 percent per year, increasing from 12 to 37 million people. As the population ages, there is a growing need for vehicle safety to suit older occupants. The fragility associated with the aging process is thought to reduce tolerance to crash forces, making this group more vulnerable to injury in a crash. This study examines the relationship between age and the incidence of thoracic injuries in different motor vehicle crashes.

Method - The National Automotive Sampling System/Crashworthiness Data System (NASS-CDS) for the years 1998 to 2007 was used to measure the relationship between occupant age and the incidence of thoracic injuries. NASS-CDS only includes crashes involving at least one passenger vehicle towed due to damage.

Results – The age group 75 and older (75+) had a higher percentage of Abbreviated Injury Scale (AIS) moderate or more severe (2+) thoracic injuries when driving or riding in any passenger vehicle type compared to three other age groups in a tow-away crash. Age groups 25 to 44, 45 to 64 and 65 to 74 had a lower percentage of thoracic injuries when driving or riding in utility vehicles, pickup trucks, and vans, referred to collectively as light trucks and vans or LTVs, compared to passenger cars. However, age group 75+ had a higher percentage of thoracic injuries when driving or riding in LTVs compared to cars.

Data analysis showed that seat belt use has a positive impact in reducing the incidence of a moderate or more-severe thoracic injury among all age groups in tow-away crashes. For example, the incidence for unbelted occupants 75+ was an estimated 18.5 percent compared to an estimated 5.3 percent among belted occupants of the same age. However, even when controlling for restraint use, the incidence of thoracic injuries among the four age groups shows a steady increase for both belted and unbelted occupants as age increases. The analysis results by occupant seating position showed that people 75+ had a higher incidence of AIS 2+ thoracic injuries than other age groups in the same seating position. Furthermore, people 75 and older had an exceptionally higher incidence of AIS 2+ thoracic injuries when riding in the rear seat at an estimated 18.7 percent compared to drivers and front-seat passengers of the same age group.

The incidence of an AIS 2+ thoracic injury was examined by the area with the most severe impact (front, side or rear from GAD-1). The incidence of an AIS 2+ thoracic injury steadily increased in relation to occupant age regardless of the vehicle deformation location. In vehicles with predominantly frontal damage, the incidence of an AIS 2+ thoracic injury increased from an estimate of 1.3 percent for age group 25 to 44 to an estimate of 5.9 percent for age group 75+.

Data analysis of the incidence of AIS 2+ thoracic injuries by vehicle model year showed that young and middle age groups had lower incidence of thoracic injuries when driving or riding in vehicles of model year 1996 or later compared to vehicles of model years before 1996. However, for occupants 75+ the incidence of thoracic injuries was slightly higher in vehicle model years 1996 and later.

The quartiles of crash delta-v (change in velocity) were calculated for crashes that involved thoracic injury of AIS 2 or higher. An estimate of 75 percent of occupants 75+ sustained AIS 2+ thoracic injuries at a crash delta-v of 37 km/h or less, while an estimate of 75 percent of people 25 to 44 sustained AIS-2+ thoracic injuries at a crash delta-v of 46 km/h or less. The incidence of AIS 2+ thoracic injuries was higher in single-vehicle crashes for the four age groups than for two-vehicle crashes. The incidence of thoracic injury remains in a steady increasing pattern in relation to occupants' age in both single- and two-vehicle crashes.

Both age groups 65 to 74 and 75+ had higher bony structures injuries as indicated by an estimate of 79 percent and 23 percent of the occupants sustaining rib cage and sternal fractures. Lung contusions and lacerations were sustained by an estimate of 20 percent of occupants 75+. The sources of thoracic injuries in both frontal and side crashes were determined for the four age groups. The steering wheel was the most common source of injury among young and middle-age group occupants, while seat belt was reported as the source of thoracic injuries among occupants 75+.

INTRODUCTION

According to the National Center for Health Statistics, the total resident population of the United States increased from 151 million in 1950 to 296 million in 2005, representing an average annual growth rate of 1.2 percent.[3] During the same period, the population group 65 and older grew an average 2.0 percent per year, increasing from 12 to 37 million people.[3] The population group 75 and older grew even faster (on average, 2.8 percent per year), increasing from 4 to 18 million people.[3] Projections indicate that the rate of growth for the total population from now to 2050 will be slower, but older age groups will continue to grow more rapidly than the total population. By 2029, all the baby boomers (those born in the post-World War II period of 1946 through 1964) will be 65 or older. As a result, the population group 65 to 74 will increase from 6 percent to 10 percent of the total population between 2005 and 2030.[3] As the baby boomers age, the 75-and-older group will also rise from 6 percent to 9 percent of the population by 2030 and continue to grow to 12 percent in 2050.[3] By 2040 the 75+ group will exceed the 65 to 74 group. As the population ages, there is a growing need for vehicle safety to suit older occupants. The fragility associated with the aging process is thought to reduce tolerance to crash forces, making this group more vulnerable to injury in a crash.[2]

This study aims to identify and analyze injury profiles of older victims of motor vehicle crashes in comparison to the injuries sustained by younger occupants. The results could help prioritize preventive countermeasures based on incidence of injuries sustained by older motor vehicle occupants. Data in this study provide basic information for planning the evaluation of current protective measures based on the type of injuries according to frequency, incidence rate, and mortality.

METHODS

This study provides a retrospective analysis of the National Automotive Sampling System/Crashworthiness for the years 1998 to 2007. The NASS-CDS[4] is a probability sample of towaway crashes involving at least one light duty (passenger) vehicle. The NASS-CDS data can be weighted to produce national estimates. The weights result from the probability associated with each stage of selection, reflecting that crash's overall probability of selection.

Occupants included in the study were grouped into four age groups: 25 to 44, 45 to 64, 65 to 74 and 75+. Occupants under 25 were excluded because safety issues related to this group include inexperience, immaturity, and incidence taking, [5] which lead this group to crashes that differ in nature to the age groups included in this study. Older occupants were grouped in two sets, 65 to 74 and 75 and older, because physiological and pathological changes such as osteoporosis and increased fragility are known to be age-dependent and vary significantly among these two age groups. According to the Centers for Disease Control and Prevention, in 2004 the age-specific hospitalization rate for fractures associated with osteoporosis was 11.0 per 10,000 among people 65 to 74, 20.5 among people 75 to 84, and 51.3 among people 85 and older.[2]

When analyzing NASS-CDS data, occupants involved in rollovers, or who were partially or totally ejected during the crashes, were excluded from the analysis. The NASS-CDS

analysis was further limited to occupants involved in single-vehicle or two-vehicle crashes.

When analyzing NASS-CDS the highest vehicle General Area of Damage (GAD-1) was grouped as front, side, and rear. Occupants were defined as belted when both lap and shoulder portions of the seat belt were used. We excluded from the analysis the small number of occupants who used only lap or shoulder portions of the seat belts. The incidence of injury for each body region represents injuries with AIS 2 (moderate) [1] or higher (more severe). The denominator used to calculate the incidence is the total number of occupants that met the selection criteria regardless of their injury severity. Approximately 33 percent of all delta-v estimates for inspected vehicles in NASS-CDS data are reported as unknown. This should be considered a limitation when delta-v is used as an independent variable during data analysis.

To account for the sample design and its associated standard errors, the Statistical Analysis System (SAS) version 9.1 Complex Sample Surveys was used to measure the confidence interval (CI) when applicable.

RESULTS: OCCUPANT OVERVIEW

Population in the Study

This section provides an overview analysis of the estimated population that met the selection criteria and their distribution by seating position, seat belt use, crash delta-v, vehicle body type and highest general area of damage (GAD-1). An estimated 57 percent of the occupants included in the analysis are 25 to 44. Age groups 65 to 74 and 75+ accounted for an estimated 6 percent and 7 percent, respectively.

Table 1: Estimated distribution of different age groups in the study

Age Group	Weighted Count	Unweighted Count	Weighted Percent
25 to 44	6,948,274	14,259	57%
45 to 64	3,637,921	7,615	30%
65 to 74	782,958	1,988	6%
75+	807,546	1,890	7%
Total	**12,176,699**	**25,752**	**100%**

Source: NASS-CDS 1998-2007

Seating Position and Belt Use

The majority of the occupants included in the study were drivers. However, age groups 25 to 44 and 45 to 64 had more drivers than age groups 65 to 74 and 75+ (Table 2).

Table 2: Estimated distribution of seating position for the population in study

Seating Position		25 to 44	45 to 64	65 to 74	75+
Driver	Weighted Count	5,563,584	2,950,546	610,543	606,938
	Unweighted Count	11,214	6,216	1,500	1,374
	Weighted Percent	**80%**	**81%**	**78%**	**75%**
Front Seat Passenger	Weighted Count	1,169,675	600,814	148,668	183,022
	Unweighted Count	2,400	1,142	396	433
	Weighted Percent	**17%**	**17%**	**19%**	**23%**
Rear Seat Passenger	Weighted Count	206,660	86,097	23,747	17,387
	Unweighted Count	605	250	92	82
	Weighted Percent	**3%**	**2%**	**3%**	**2%**
Total	Weighted Count	6,939,919	3,637,457	782,958	807,347
	Unweighted Count	14,219	7,608	1,988	1,889
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Overall, the age groups 75+ and 65 to 74 had the highest rates of seat belt use in the applicable crashes at an estimate of 91 percent and 90 percent, respectively (Table 3).

Table 3: Estimated distribution of seat belt use for the population in study

Seat belt Use		25 to 44	45 to 64	65 to 74	75+
Belted	Weighted Count	5,800,719	3,126,614	703,445	735,272
	Unweighted Count	10,316	6,068	1,657	1,535
	Weighted Percent	**83%**	**86%**	**90%**	**91%**
Unbelted	Weighted Count	1,147,554	511,307	79,513	72,274
	Unweighted Count	3,943	1,547	331	355
	Weighted Percent	**17%**	**14%**	**10%**	**9%**
Total	Weighted Count	6,948,273	3,637,921	782,958	807,546
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Highest General Area of Damage (GAD-1)

The vehicle's front remains the most common area of damage for all age groups in the study. However, age group 75+ appeared to have higher vehicle side damage at an estimate of 35 percent of all crashes, compared to estimates of 29 percent, 31 percent and 33 percent for age groups 25 to 44, 45 to 64, and 65 to 74, respectively (Table 4). These variations in general area of damage among the four age groups is controlled for when analyzing incidence of thoracic injury later in the report.

Table 4: Estimated distribution of highest vehicle area of deformation for the population in study

Deformation Location (Highest)		25 to 44	45 to 64	65 to 74	75+
Rear	Weighted Count	480,493	264,977	52,681	41,988
	Unweighted Count	812	487	102	64
	Weighted Percent	**7%**	**7%**	**7%**	**5%**
Front	Weighted Count	4,448,602	2,261,974	474,110	485,509
	Unweighted Count	9,607	5,015	1,233	1,096
	Weighted Percent	**64%**	**62%**	**61%**	**60%**
Side	Weighted Count	2,019,178	1,110,969	256,167	280,050
	Unweighted Count	3,840	2,113	653	730
	Weighted Percent	**29%**	**31%**	**33%**	**35%**
Total	Weighted Count	6,948,273	3,637,920	782,958	807,547
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Distribution of MAIS by Age Group

Age group 75+ had a higher percentage of MAIS 2+ at an estimate of 13 percent compared to estimates of 7 percent for age group 25 to 44, 9 percent for age group 45 to 64 and 11 percent for age group 65 to 74. These variations in MAIS will be examined in this report in relation to other variables of interest such as total delta-v, seat belt use, general area of damage, and occupant seating position.

Table 5: Estimated distribution of MAIS for the population in study

MAXIMUM KNOWN OCCUPANT AIS		25 to 44	45 to 64	65 to 74	75+
MAIS < 2	Weighted Count	6,480,706	3,320,760	700,382	701,847
Minor or no injury	Unweighted Count	10,701	5,468	1,327	1,168
	Weighted Percent	**93%**	**91%**	**89%**	**87%**
MAIS-2	Weighted Count	328,166	200,771	41,993	58,735
Moderate	Unweighted Count	1,663	902	249	275
	Weighted Percent	**5%**	**6%**	**5%**	**7%**
MAIS-3	Weighted Count	96,825	79,686	22,722	29,298
Serious	Unweighted Count	1,175	744	240	230
	Weighted Percent	**1%**	**2%**	**3%**	**4%**
MAIS-4	Weighted Count	25,135	20,421	14,015	12,056
Severe	Unweighted Count	342	255	92	116
	Weighted Percent	**<1%**	**1%**	**2%**	**1%**
MAIS-5	Weighted Count	13,822	13,708	3,338	4,209
Critical	Unweighted Count	264	192	65	81
	Weighted Percent	**<1%**	**<1%**	**<1%**	**1%**
MAIS-6	Weighted Count	3,619	2,575	509	1,401
Maximum	Unweighted Count	114	54	15	20
(Untreatable)	**Weighted Percent**	**<1%**	**<1%**	**<1%**	**<1%**
Total	Weighted Count	6,948,273	3,637,921	782,959	807,546
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Number of Vehicles Involved in the Crash

Twenty percent of occupants 25 to 44 were involved in single-vehicle tow-away crashes, compared to 18 percent, 12 percent and 13 percent for age groups 45 to 64, 65 to 74, and 75+, respectively. The incidence of thoracic injury in relation to number of vehicles involved in the tow-away crashes will be examined in this report.

Table 6: Estimated number of vehicles involved in the crashes for the population in study

Number of Vehicles in Crash		25 to 44	45 to 64	65 to 74	75+
Single Vehicle Crashes	Weighted Count	1,358,904	641,900	93,692	108,957
	Unweighted Count	3,097	1,268	270	273
	Weighted Percent	**20%**	**18%**	**12%**	**13%**
Two-Vehicle Crashes	Weighted Count	5,589,370	2,996,021	689,266	698,589
	Unweighted Count	11,162	6,347	1,718	1,617
	Weighted Percent	**80%**	**82%**	**88%**	**87%**
Total	Weighted Count	6,948,274	3,637,921	782,958	807,546
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Vehicle Body Type

Overall, 85 percent of people 75+ were in passenger cars when involved in applicable towaway crashes compared to only 64 percent for age group 25 to 44. The variations in vehicle type could significantly affect the injury severity and distribution across the different age groups in the study. Therefore, it was critical to control for vehicle type when analyzing and comparing incidence of thoracic injury among the four age groups included in the analysis.

Table 7: Estimated vehicle type involved in the crashes for the population in study

Vehicle Type		25 to 44	45 to 64	65 to 74	75+
Passenger Car	Weighted Count	4,480,159	2,291,170	551,417	689,157
	Unweighted Count	8,987	4,665	1,404	1,569
	Weighted Percent	**64%**	**63%**	**70%**	**85%**
LTV	Weighted Count	2,468,115	1,346,751	231,541	118,389
	Unweighted Count	5,272	2,950	584	321
	Weighted Percent	**36%**	**37%**	**30%**	**15%**
Total	Weighted Count	6,948,274	3,637,921	782,958	807,546
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Vehicle Model Year

Vehicle model year of 1996 was selected as the cutoff due to the fact that most vehicles were equipped with advanced air bag technologies in that year. The analysis showed a slight difference in the distribution of vehicle model year among the four age groups. Overall younger age groups were driving or riding in recent vehicle model years compared to age group 75+.

Table 8: Estimated vehicle model year involved in the crashes for the population in study

Vehicle Model Year		25 to 44	45 to 64	65 to 74	75+
< 1996	Weighted Count	3,191,140	1,568,243	321,699	410,248
	Unweighted Count	6,103	3,098	886	894
	Weighted Percent	**46%**	**43%**	**41%**	**51%**
1996+	Weighted Count	3,757,134	2,069,678	461,259	397,298
	Unweighted Count	8,156	4,517	1,102	996
	Weighted Percent	**54%**	**57%**	**59%**	**49%**
Total	Weighted Count	6,948,274	3,637,921	782,958	807,546
	Unweighted Count	14,259	7,615	1,988	1,890
	Weighted Percent	**100%**	**100%**	**100%**	**100%**

Source: NASS-CDS 1998-2007

Total Crash Delta-V

The median and quartiles of delta-v were calculated for different age groups in the study. As shown in Table 9, overall the four age groups were involved in crashes with similar delta-v with a slight difference for age group 25 to 44 which scored a median of 18 km/h compared to 17 km/h for other three groups.

Table 9: Estimated distribution of total crash delta-v for the population in study[1]

Age Group	Weighted Frequency	Unweighted Frequency	25th Percentile	Median	75th Percentile
25 to 44	4,488,539	9,673	13km/h	18km/h	24km/h
45 to 64	2,451,553	5,323	12km/h	17km/h	22km/h
65 to 74	503,754	1,459	13km/h	17km/h	23km/h
75+	515,022	1,374	13km/h	17km/h	22km/h

Source: NASS-CDS 1998-2007

[1] Approximately 33% of the delta-v values are unknown

Injury Distribution by Age and Body Region

An analysis of AIS 2+ injuries by body region and age group was done. This analysis aimed to identify the body regions that were at higher incidence of injury and compare the results across the four age groups. In this section the numerator represents the total number of occupants who sustained the specific type of injury, while the denominator represents the total number of occupants within each age group. Among occupants who sustained AIS 2+ injuries, the injury with highest AIS for each body region was selected. For example a person with head injuries of AIS 2, 3 and 4 and lower extremity injuries with AIS 2 and 3, both head injury with AIS 4 and lower extremity injury with AIS 3 were included in the analysis. As shown in Table 10, the incidence of AIS 2+ injuries to any body region was higher for occupants 75+ compared to the other three age groups. The incidence of thoracic injuries showed to be the highest among age group 75+ at an estimate of 6.5 percent followed by AIS 2+ lower extremity injuries at an estimate of 5.6 percent. This report will provide detailed analysis of thoracic injuries and their incidence under different circumstances and compare the incidence among the four assigned age groups.

Table 10: Estimated moderate or more severe injury distribution by age and body region

Body Region		25 to 44	45 to 64	65 to 74	75+
Head	Weighted Count	135,257	77,410	24,420	21,225
	Unweighted Count	1,366	713	187	216
	Weighted Percent	**1.9%**	**2.1%**	**3.1%**	**2.6%**
Thorax	Weighted Count	101,904	84,667	30,464	52,584
	Unweighted Count	1,088	891	321	394
	Weighted Percent	**1.5%**	**2.3%**	**3.9%**	**6.5%**
Abdomen	Weighted Count	50,123	22,991	8,914	9,391
	Unweighted Count	623	328	103	97
	Weighted Percent	**0.7%**	**0.6%**	**1.1%**	**1.2%**
Spine	Weighted Count	45,299	28,840	12,819	14,825
	Unweighted Count	554	360	121	129
	Weighted Percent	**0.7%**	**0.8%**	**1.6%**	**1.8%**
Upper Extremity	Weighted Count	127,630	97,824	26,701	26,145
	Unweighted Count	945	687	204	216
	Weighted Percent	**1.8%**	**2.7%**	**3.4%**	**3.2%**
Lower Extremity	Weighted Count	191,849	145,189	31,420	45,434
	Unweighted Count	1663	983	284	314
	Weighted Percent	**2.8%**	**4.0%**	**4.0%**	**5.6%**

Source: NASS-CDS 1998-2007

RESULTS: THORACIC INJURIES

Incidence of Thoracic Injury by Vehicle Body Type

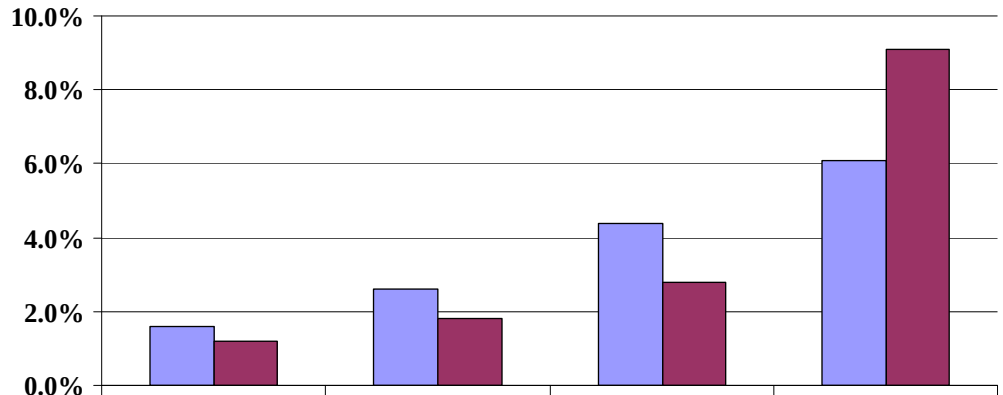
The age group 75+ had a higher estimated percentage of AIS 2+ thoracic injuries when driving or riding in any passenger vehicle type compared to the other three age groups. Age groups 25 to 44, 45 to 64 and 65 to 74 had lower percentages of thoracic injuries when driving or riding in LTVs compared to passenger cars. Incidence of AIS 2+ thoracic injuries for age group 25 to 44 in passenger cars was 1.6 percent (95% CL 1.1% – 2.2%). Incidence of AIS 2+ thoracic injuries for age group 25 to 44 in LTVs was 1.2 percent (95% CL 0.8% – 1.6%). Incidence of AIS 2+ thoracic injuries for age group 45 to 64 in passenger cars was 2.6 percent (95% CL 1.6% – 3.7%). Incidence of AIS 2+ thoracic injuries for age group 45 to 64 in LTVs was 1.8 percent (95% CL 1.0% – 2.7%). Incidence of AIS 2+ thoracic injuries for age group 65 to 74 in passenger cars was 4.4 percent (95% CL 3.2% – 5.6%). Incidence of AIS 2+ thoracic injuries for age group 65 to 74 in LTVs was 2.8 percent (95% CL 1.1% – 4.4%).

Age group 75+ had a higher percentage of thoracic injuries when driving or riding in LTVs compared to passenger cars (Figure 1). Incidence of AIS 2+ thoracic injuries for age group 75+ in passenger cars was 6.1 percent (95% CL 4.0% – 8.1%). Incidence of AIS 2+ thoracic injuries for age group 75+ in LTVs was 9.1 percent (95% CL 5.0% – 13.2%). However, as seen by the confidence limits, this difference is not statistically significant at the 95 percent level.

Full analysis results, including the weighted and unweighted totals, are provided in Appendix Table ***A1***.

Figure 1: Estimated incidence of thoracic injury by vehicle type and occupant age

Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
Passenger Car	1.6%	2.6%	4.4%	6.1%
LTV	1.2%	1.8%	2.8%	9.1%

Incidence of Thoracic Injury by Vehicle Model Year

Data analysis on the incidence of AIS 2+ thoracic injuries by vehicle model year showed that young and middle age groups had lower incidence of thoracic injuries when driving or riding in vehicles with model year 1996 or later compared to vehicle model years before 1996 (Figure 2).

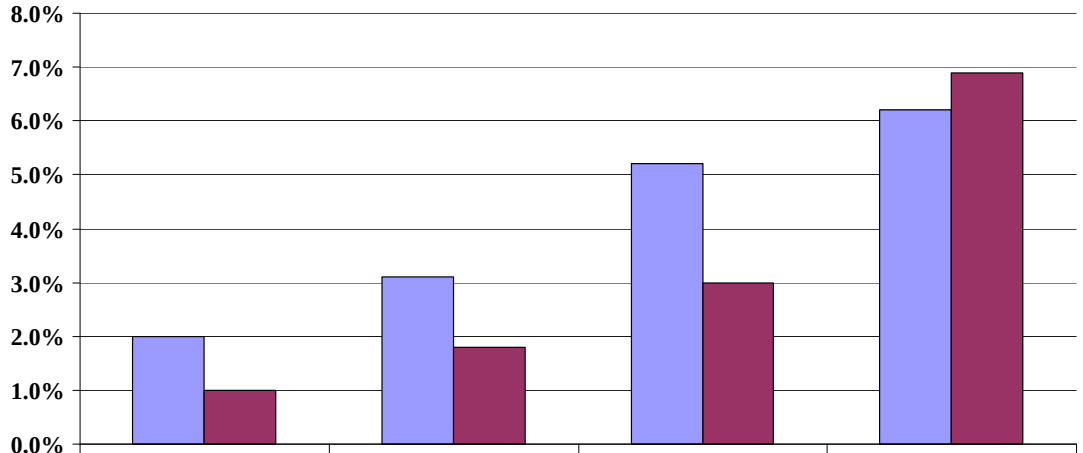
Incidence of AIS 2+ thoracic injuries for age group 25 to 44 in vehicle with model year < 1996 was 2.0 percent (95% CL 1.1% – 2.8%), while the incidence of AIS 2+ thoracic injuries in vehicle with model year 1996+ was 1.0 percent (95% CL 0.7% – 1.3%).

Incidence of AIS 2+ thoracic injuries for age group 45 to 64 in vehicle with model year < 1996 was 3.1 percent (95% CL 1.0% – 5.2%), while the incidence of AIS 2+ thoracic injuries in vehicle with model year 1996+ was 1.8 percent (95% CL 1.2% – 2.3%).

Incidence of AIS 2+ thoracic injuries for age group 65 to 74 in vehicle with model year < 1996 was 5.2 percent (95% CL 2.9% – 7.5%), while the incidence of AIS 2+ thoracic injuries in vehicle with model year 1996+ was 3.0 percent (95% CL 2.1% – 3.8%).

For occupants 75+ the incidence of thoracic injuries was slightly higher in vehicle model years 1996 and later. The effect of vehicle model year for occupants 75+ was statistically insignificant. Incidence of AIS 2+ thoracic injuries for age group 75+ in vehicle with model year < 1996 was 6.2 percent (95% CL 2.8% – 9.5%), while the incidence of AIS 2+ thoracic injuries in vehicle with model year 1996+ was 6.9 percent (95% CL 3.8% – 10.0%). However, as seen by the confidence limits, this difference is not significant at the 95 percent confidence limit. Full analysis results on the estimated distributions are provided in Appendix Table ***A2.***

Figure 2: Estimated incidence of thoracic injury in relation to vehicle model year
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
< 1996	2.0%	3.1%	5.2%	6.2%
1996+	1.0%	1.8%	3.0%	6.9%

Thoracic Injury by Age and Seat Belt Use

Data analysis showed that seat belt use has a positive effect in reducing AIS 2+ thoracic injury among all age groups. As shown in Figure 3, incidence of AIS 2+ thoracic injuries increased among unbelted occupants compared to belted occupants of any age group.

The incidence of AIS 2+ thoracic injuries for unbelted occupants 25 to 44 was an estimate of 4.4 percent (95% CL 2.3% - 6.5%) compared to an estimate of 0.9 percent (95% CL 0.5% - 1.2%) among belted occupants.

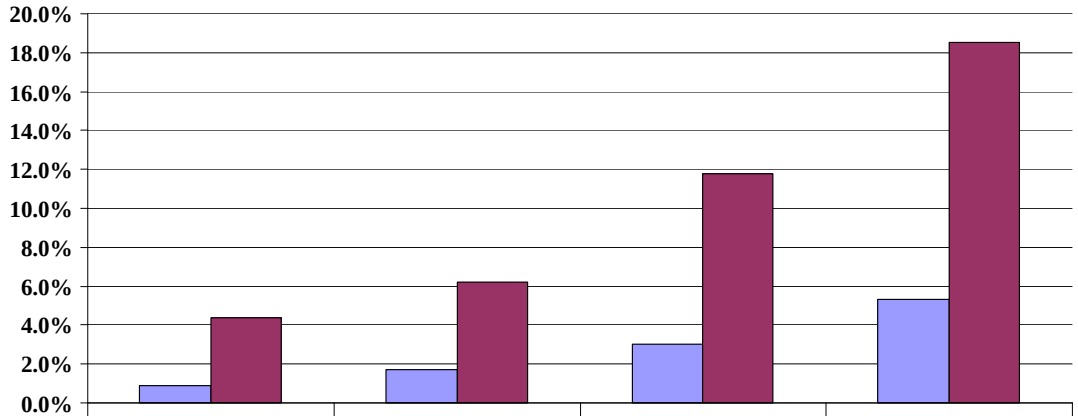
The incidence of AIS 2+ thoracic injuries for unbelted occupants 45 to 64 was an estimate of 6.2 percent (95% CL 2.3% - 10.2%) compared to an estimate of 1.7 percent (95% CL 1.2% - 2.2%) among belted occupants.

The incidence of AIS 2+ thoracic injuries for unbelted occupants 65 to 74 was an estimate of 11.8 percent (95% CL 4.8% - 18.9%) compared to an estimate of 3.0 percent (95% CL 2.3% - 3.7%) among belted occupants.

The incidence of AIS 2+ thoracic injuries for unbelted occupants 75+ was an estimate of 18.5 percent (95% CL 8.7% - 28.3%) compared to an estimate of 5.3 percent (95% CL 3.6% - 7.1%) among belted occupants. This difference accounts for more than three times increase in the incidence of AIS 2+ thoracic injuries among unbelted compared to belted occupants 75 and older.

On the other hand, comparing the incidence of thoracic injuries among the four age groups shows a steady increased incidence for both belted and unbelted occupants in relation to age. Detailed results are provided in the Appendix Table ***A3***.

Figure 3: Estimated incidence of thoracic injury in relation to seatbelt use and occupant age
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
Belted	0.9%	1.7%	3.0%	5.3%
Unbelted	4.4%	6.2%	11.8%	18.5%

Thoracic Injuries by Seating Position

Vehicle occupants were grouped as drivers, front-seat passengers and rear-seat passengers. The analysis results showed that people 75+ had higher incidence of AIS 2+ thoracic injuries in any seating position compared to other age groups (Figure 4).

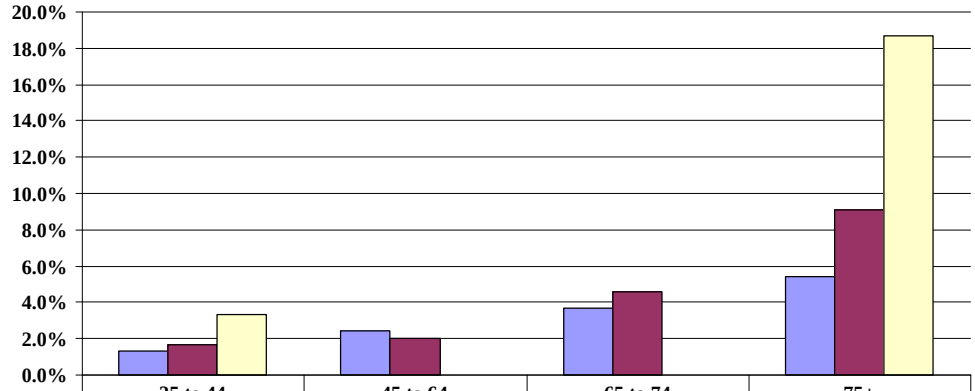
The incidence of AIS 2+ thoracic injuries for drivers 25 to 44 was an estimate of 1.3 percent (95% CL 0.7% - 1.9%) compared to an estimate of 1.7 percent (95% CL 1.0% - 2.5 percent) for front-seat passengers and an estimate of 3.3 percent (95% CL 0.9% - 5.7%) for rear-seat passengers of the same age group.

The incidence of AIS 2+ thoracic injuries for drivers 45 to 64 was an estimate of 2.4 percent (95% CL 1.3% - 3.6%) compared to an estimate of 2.0 percent (95% CL 1.4% - 2.6%) for front-seat passengers. The results on rear-seat passengers are not provided due to the small unweighted sample size.

The incidence of AIS 2+ thoracic injuries for drivers 65 to 74 was an estimate of 3.7 percent (95% CL 2.6% - 4.8%) compared to an estimate of 4.6 percent (95% CL 2.4% - 6.8%) for front-seat passengers. The results on rear-seat passengers are not provided due to the small unweighted sample size.

Elderly 75+ had an exceptionally higher incidence of AIS 2+ thoracic injuries when riding in a rear seat at an estimate of 18.7 percent (95% CL 11.9% - 25.6%) compared to an estimate of 5.4 percent (95% CL 3.6% - 7.2%) for drivers and an estimate of 9.1 percent (95% CL 3.7% - 14.5%) for front-seat passengers of the same age group. The difference between the incidence of AIS 2+ thoracic injuries among drivers and rear-seat occupants is statistically significant at the 95 percent level. However, due to the small unweighted sample size on rear-seat occupants, it was not possible to further quantify them by other variables such as status of seat belt use. For detailed results on weighted and unweighted frequencies, see Appendix Table ***A4***.

Figure 4: Estimated incidence of thoracic injury in relation to occupant seating position
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
Driver	1.3%	2.4%	3.7%	5.4%
Front Seat Passenger	1.7%	2.0%	4.6%	9.1%
Rear Seat Passenger	3.3%			18.7%

Thoracic Injuries and Vehicle Deformation Location

Incidence of AIS-2+ thoracic injury was examined by the GAD-1. GAD was grouped as front, side, and rear. However, due to the small sample size for rear deformation, the results were omitted from Figure 5. The incidence of thoracic injuries of AIS 2+ steadily increased in relation to occupant age in frontal crashes.

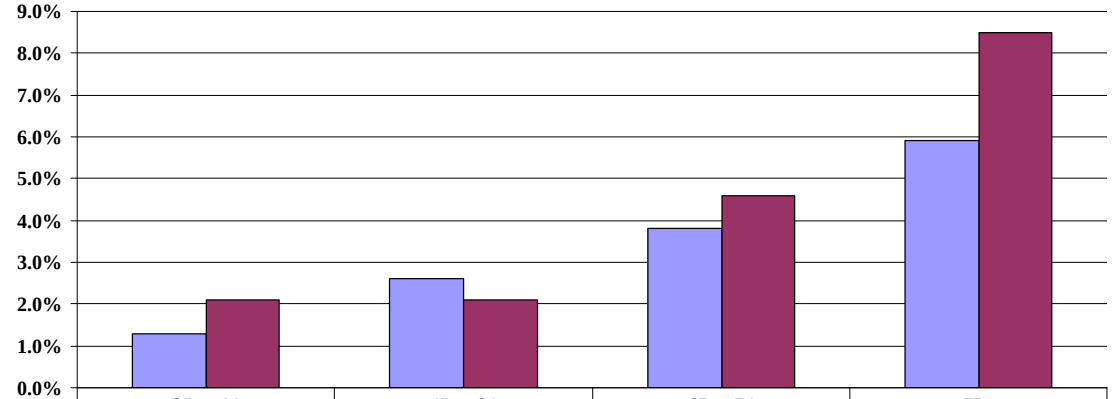
The incidence of AIS 2+ thoracic injuries in frontal crashes for occupants 25 to 44 was an estimate of 1.3 percent (95% CL 0.9% - 1.7%) compared to an estimate of 2.1 percent (95% CL 1.1% - 3.2%) in side crashes.

The incidence of AIS 2+ thoracic injuries in frontal crashes for occupants 45 to 64 was an estimate of 2.6 percent (95% CL 1.4% - 3.8%) compared to an estimate of 2.1 percent (95% CL 1.3% - 2.9%) in side crashes.

The incidence of AIS 2+ thoracic injuries in frontal crashes for occupants 65 to 74 was an estimate of 3.8 percent (95% CL 2.5% - 5.0%) compared to an estimate of 4.6 percent (95% CL 2.9% - 6.3%) in side crashes.

Occupants 75+ had an incidence of AIS 2+ thoracic injury at 5.9 percent (95% CL 5.9% - 8.6%) in frontal crashes that increased to 8.5 percent (95% CL 6.3% - 10.6%) in side crashes. For detailed results see Appendix Table ***A5***.

Figure 5: Estimated incidence of thoracic injuries in relation to vehicle deformation location
Source: NASS-CDS 1998-2007

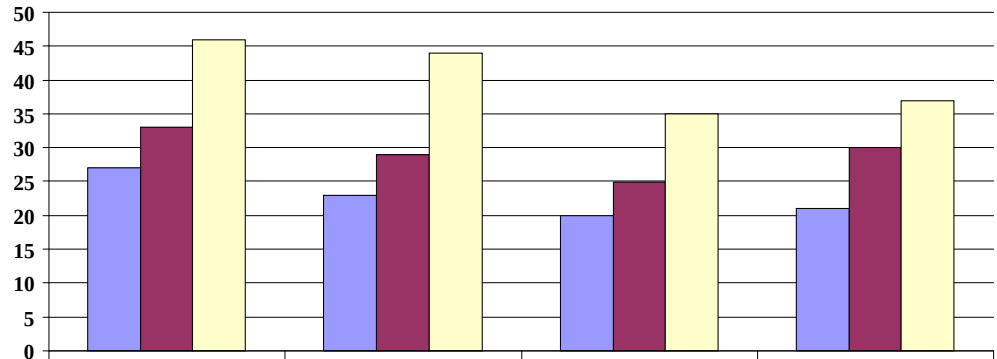


	25 to 44	45 to 64	65 to 74	75+
Front	1.3%	2.6%	3.8%	5.9%
Side	2.1%	2.1%	4.6%	8.5%

Thoracic Injuries and Crash Delta-V

Median and quartiles of crash delta-v as an indicator of crash severity were calculated for each age group. Crash delta-v was calculated for occupants with a thoracic injury of AIS 2+. Although, delta-v was unable to calculate in 33 percent of the cases, there is no reason to believe that the unknowns vary substantially from the known values. This section reports quartile statistics, which are less likely to be affected by particularly large (or small) values that may occur in either the known or unknown data. As shown in Figure 6, 75 percent of occupants 75+ sustained AIS 2+ thoracic injuries at an estimated crash delta-v of 37 km/h or less, while 75 percent of people 25 to 44 sustained AIS 2+ thoracic injuries at an estimated crash delta-v of 46 km/h or less.

Figure 6: Estimated median and percentiles of total crash delta-v and thoracic injury
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
25th Percentile	27	23	20	21
Median	33	29	25	30
75th Percentile	46	44	35	37

Number of Vehicles Involved In Crashes and Incidence of Thoracic Injuries

The incidence of AIS 2+ thoracic injuries was higher in single-vehicle crashes for the four age groups than for two-vehicle crashes. The incidence of thoracic injury remained at a steady increasing pattern in relation to occupant age in both single- and two-vehicle crashes.

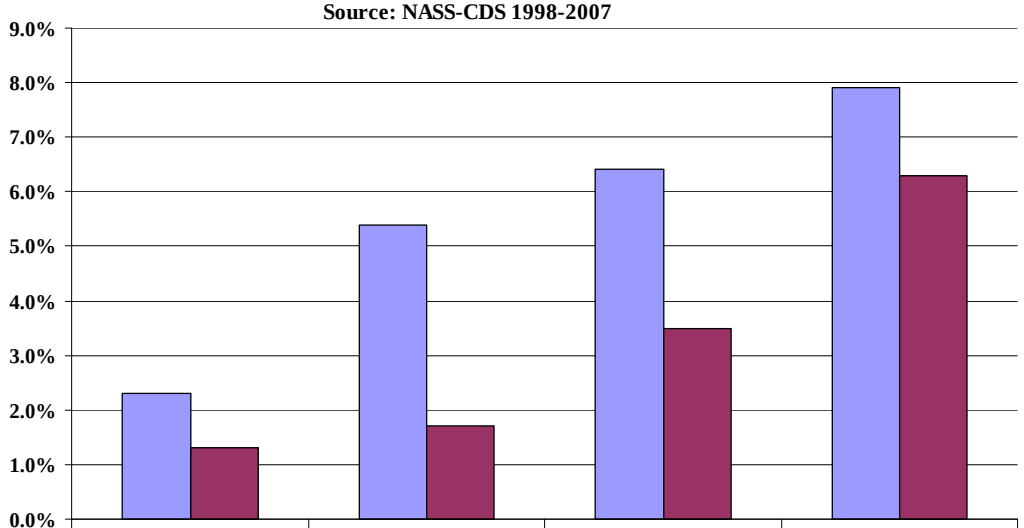
The incidence of AIS 2+ thoracic injuries in single-vehicle crashes for occupants 25 to 44 was an estimate of 2.3 percent (95% CL 1.4% - 3.1%) compared to an estimate of 1.3 percent (95% CL 0.8% - 1.8%) in two-vehicle crashes.

The incidence of AIS 2+ thoracic injuries in single-vehicle crashes for occupants 45 to 64 was an estimate of 5.4 percent (95% CL 2.0% - 8.7%) compared to an estimate of 1.7 percent (95% CL 1.2% - 2.1%) in two-vehicle crashes.

The incidence of AIS 2+ thoracic injuries in single-vehicle crashes for occupants 65 to 74 was an estimate of 6.4 percent (95% CL 2.1% - 10.7%) compared to an estimate of 3.5 percent (95% CL 2.3% - 4.8%) in two-vehicle crashes.

The incidence of AIS 2+ thoracic injuries in single-vehicle crashes for occupants 75+ was an estimate of 7.9 percent (95% CL 2.2% - 13.7%) compared to an estimate of 6.3 percent (95% CL 4.5% - 8.1%) in two-vehicle crashes. Detailed results are provided in the Appendix, Table ***A6***.

Figure 7: Estimated incidence of thoracic injuries in relation to number of vehicles involved in crashes by occupants' age
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
Single Vehicle	2.3%	5.4%	6.4%	7.9%
Two Vehicles	1.3%	1.7%	3.5%	6.3%

Type of Thoracic Structures and Injury Source

This section provides detailed information on the occupants who sustained AIS 2+ thoracic injuries. The information includes the distribution of different thoracic structures that have been injured and the NASS-CDS vehicle components that were coded as source of injury in different vehicle deformation locations by age. Table 11 provides data on the estimated total number of occupants who sustained AIS 2+ thoracic injuries and the estimated total number of the AIS 2+ thoracic injuries. The average number of AIS 2+ thoracic injuries was 1.4 per occupant. In this section the numerator represents the total number of AIS 2+ thoracic injuries, while the denominator represents the total number of occupants who sustained any AIS 2+ thoracic injuries within each age group.

Table 11: Estimated and unweighted number of occupants with AIS-2+ thoracic injuries

Age Group	Weighted number of occupant with AIS 2+ thoracic injuries	Unweighted number of occupant with AIS 2+ thoracic injuries	Weighted number of AIS 2+ thoracic injuries	Unweighted number of AIS 2+ thoracic injuries
25 to 44	101,904	1,088	146,808	1,936
45 to 64	84,667	891	118,993	1,475
65 to 74	30,464	321	42,028	526
75+	52,584	394	73,794	676
Total	**269,619**	**2,694**	**381,623**	**4,613**

Source: NASS-CDS 1998-2007

As shown in Table 12, an estimated 72 percent of the occupants sustained rib cage fractures. Lung contusion or laceration was the second-most-common thoracic injury sustained by age group 25 to 44. Thoracic aortic injuries were sustained by an estimate of 5 percent of the occupants 25 to 44.

Table 12: Estimated distribution of different AIS-2+ thoracic injuries among occupants age 25 to 44

Thoracic Structure	Weighted Count	Weighted Percent
Rib Cage Fracture	73,060	72%
Lung/Contusion/Laceration	35,340	35%
Sternum, Fracture	16,953	17%
Thoracic Cavity Injury	8,047	8%
Aorta, Thoracic	4,653	5%
Heart Myocardium/Pericardium	4,112	4%
Diaphragm, Contusion/Laceration	3,234	3%
Major Thoracic Artery/Esophagus/Trachea	1,065	1%
Pleura, Laceration	335	<1%
Other	11	<1%

Note: The Percentages do not add to 100 percent as one occupant can sustain more than one thoracic injury

Source: NASS-CDS 1998-2007

The estimated distribution of AIS 2+ thoracic injuries for age group 45 to 64 was similar to that for age group 25 to 44. Rib cage fractures remained the most common thoracic injuries and were sustained by an estimate of 72 percent of all occupants 45 to 64. Lung contusions or lacerations were the second-most-common injuries and were sustained by an estimate of 35 percent of occupants 45 to 64. Thoracic aortic injuries were sustained by an estimate of 5 percent of this age group (Table 13).

Table 13: Estimated distribution of different AIS-2+ thoracic injuries among occupants 45 to 64

Thoracic Structure	Weighted Count	Weighted Percent
Rib Cage Fracture	60,584	72%
Lung/Contusion/Laceration	29,393	35%
Sternum, Fracture	15,454	18%
Aorta, Thoracic	4,238	5%
Heart Myocardium/Pericardium	3,476	4%
Diaphragm, Contusion/Laceration	2,576	3%
Thoracic Cavity Injury	1,584	2%
Major Thoracic Artery/Esophagus/Trachea	1,167	1%
Pleura, Laceration	521	1%

Note: The Percentages do not add to 100 percent as one occupant can sustain more than one thoracic injury
Source: NASS-CDS 1998-2007

Results for age group 65 to 74 showed that bony structures start to be more common thoracic structures to be injured in the relevant crashes as indicated by an estimate of 80 percent of occupants sustained rib cage fractures and an estimate of 21 percent sustained sternum fractures (Table 14).

Table 14: Estimated distribution of different AIS-2+ thoracic injuries among occupants 65 to 74

Thoracic Structure	Weighted Count	Weighted Percent
Rib Cage Fracture	24,298	80%
Sternum, Fracture	6,261	21%
Lung/Contusion/Laceration	5,601	18%
Heart Myocardium/Pericardium	2,263	7%
Aorta, Thoracic	937	3%
Thoracic Cavity Injury	878	3%
Diaphragm, Contusion/Laceration	864	3%
Major Thoracic Artery/Esophagus/Trachea	692	2%
Pleura, Laceration	234	1%

Note: The Percentages do not add to 100 percent as one occupant can sustain more than one thoracic injury
Source: NASS-CDS 1998-2007

Similar to age group 65 to 74, occupants 75 and older had higher bony structures injury as indicated by estimates of 79 percent and 23 percent of the occupants sustaining rib cage and sternal fractures. Lung contusions and lacerations were sustained by an estimate of 20 percent of occupants 75+. Thoracic aortic injuries were diagnosed in an estimate of 5 percent of the occupants 75+ (Table 15).

Table 15: Estimated distribution of different AIS-2+ thoracic injuries among occupants 75+

Thoracic Structure	Weighted Count	Weighted Percent
Rib Cage Fracture	41,328	79%
Sternum, Fracture	12,133	23%
Lung/Contusion/Laceration	10,454	20%
Heart Myocardium/Pericardium	3,633	7%
Aorta, Thoracic	2,523	5%
Thoracic Cavity Injury	1,415	3%
Major Thoracic Artery/Esophagus/Trachea	1,081	2%
Diaphragm, Contusion/Laceration	919	2%
Pleura, Laceration	308	1%

Note: The Percentages do not add to 100 percent as one occupant can sustain more than one thoracic injury
Source: NASS-CDS 1998-2007

Attributed Sources of Thoracic Injuries

The sources of thoracic injuries in both frontal and side crashes are listed in Tables 16 and 17. The lists present the NASS-CDS attributed sources of all AIS 2+ thoracic injuries. If the occupant sustained more than one thoracic injury with different attributed sources, all the NASS attributed sources are listed. These lists help identify vehicle components that may need certain modifications to reduce the incidence of thoracic injuries and compare the results across different age groups.

In frontal crashes, the steering wheel was the most common source of AIS 2+ thoracic injuries for age groups 25 to 44, 45 to 64, and 65 to 74 at estimated percentage of 47 percent, 54 percent and 34 percent, respectively. However, for age group 75+ belt restraint webbing/buckle was the most common source of AIS 2+ at an estimate of 58 percent of all attributed sources. An air bag was reported as source of AIS 2+ thoracic injuries for age groups 45 to 64, 65 to 74 and 75+ at an estimate of 4 percent, 12 percent and 3 percent. None of the AIS 2+ thoracic injuries among occupants 25 to 44 were attributed to air bags (Table 16).

Table 16: Estimated distribution of source of thoracic injuries in frontal crashes

Source: NASS-CDS 1998-2007

	25 to 44		45 to 64		65 to 74		75+	
Injury Source	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**
Steering wheel	37,806	47%	43,612	54%	8,489	34%	10,584	26%
Belt restraint webbing/buckle	20,542	25%	20,324	25%	7,136	29%	23,570	58%
Instrument panel and below	7,382	9%	2,548	3%	3,201	13%	784	2%
Center instrument panel and below	4,211	5%	2,033	3%	526	2%	-	-
Interior surface, excluding hardware or armrests	3,383	4%	4,029	5%	1,473	6%	1,250	3%
Seat, back support	1,643	2%	1,178	1%	-	-	1,866	5%
Air bag	-	-	3,134	4%	3,038	12%	1,381	3%
Other/Unknown	5,619	7%	3,668	5%	1,018	4%	1,411	3%
Total	**80,587**	**100%**	**80,526**	**100%**	**24,879**	**100%**	**40,846**	**100%**

In side crashes, interior surface, including hardware or armrests combined were the most common source of AIS 2+ thoracic injuries accounting for 50 percent, 71 percent, 65 percent and 57 percent for age groups 25 to 44, 45 to 64, 65 to 74, and 75+, respectively. The seat or back support was reported as source of AIS 2+ thoracic injuries in 19 percent, 2 percent, 2 percent and 14 percent for occupants 25 to 44, 45 to 64, 65 to 74, and 75+, respectively. In side impacts, belt restraint webbing/buckle was the attributed source of thoracic injuries in 3 percent, 4 percent, 14 percent and 9 percent for occupants 25 to 44, 45 to 64, 65 to 74, and 75+, respectively (Table 17). These results indicate that while belt-induced injuries do occur in side-impact crashes, they are more likely to occur in frontal impacts.

Table 17: Estimated distribution of source of thoracic injuries in side crashes

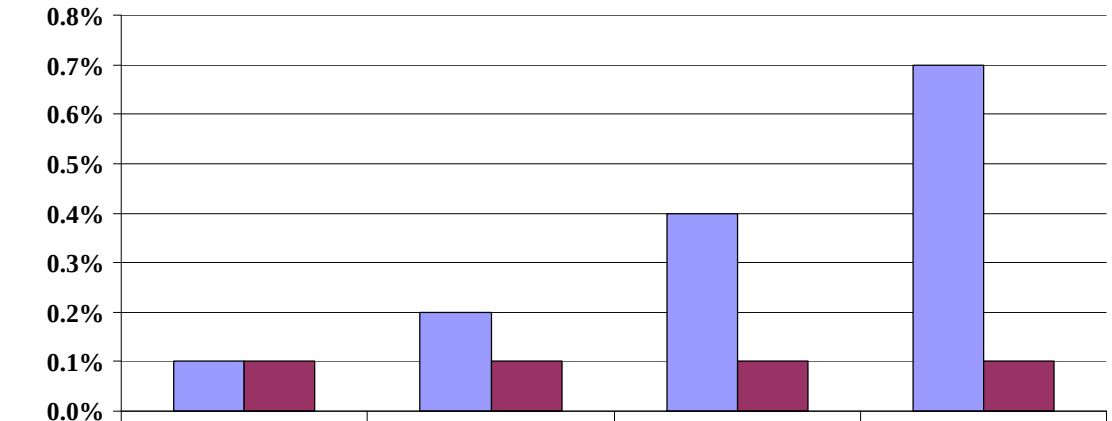
	25 to 44		45 to 64		65 to 74		75+	
Injury Source	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**	**Weighted Frequency**	**Weighted Percent**
Interior surface, excluding hardware or armrests	27,212	42%	21,730	61%	7,292	45%	11,413	35%
Seat, back support	12,508	19%	763	2%	281	2%	4,664	14%
B-pillar	5,665	9%	4,504	13%	1,650	10%	1,316	4%
Hardware or armrest	4,968	8%	3,645	10%	3,217	20%	7,217	22%
Belt restraint webbing/buckle	1,895	3%	1,271	4%	2,315	14%	2,975	9%
Steering wheel	1,727	3%	1,285	4%	411	3%	703	2%
Other occupants	1,070	2%	601	2%	269	2%	-	-
Floor or console mounted transmission lever	892	1%	793	2%	569	4%	578	2%
Air bag	-	-	-	-	-	-	1,444	4%
Other/Unknown	9,309	14%	1,082	3%	208	1%	2,388	7%
Total	**65,248**	**100%**	**35,676**	**100%**	**16,212**	**100%**	**32,698**	**100%**

Source: NASS-CDS 1998-2007

CAUSE OF DEATH

The NASS-CDS database records the injury or injuries that were determined by medical professionals or trained injury coders using official medical records to be the cause of the death. Cause of death is coded as unknown if the occupant was killed and no official medical data was obtained or the data obtained inadequately described the injuries. Injuries were coded as "thorax" if one of the recorded causes of death was due to thoracic injury; otherwise the cause of death is coded as "other." Thoracic injuries alone or in combination with injuries to other body regions were the leading cause of death for all age groups. Mortality rates among occupants included in the analysis were 0.2 percent, 0.3 percent, 0.5 percent and 0.8 percent for age groups 25 to 44, 45 to 64, 65 to 74, and 75+, respectively. The ratio of thoracic injuries as cause to other causes of death were estimated as 0.1:0.1 for age 25 to 44, 0.2:0.1 for age 45 to 64, 0.4:0.1 for age 65 to 74 and 0.7:0.1 for occupants 75+ (Figure 8).

Figure 8: Cause of death by occupants' age
Source: NASS-CDS 1998-2007



	25 to 44	45 to 64	65 to 74	75+
Thorax	0.1%	0.2%	0.4%	0.7%
Other	0.1%	0.1%	0.1%	0.1%

DISCUSSION

Thoracic injuries are emergencies requiring immediate treatment to reduce the incidence of mortality. The data analysis findings in this paper indicate higher incidence of AIS 2+ thoracic injuries in motor vehicle crashes in relation to occupants' age.

According to the results of this study, the overall incidence of AIS 2+ thoracic injuries increased from an estimate of 1.5 percent among younger occupants (25 to 44) to an estimate of 6.5 percent among occupants 75+. Similar to increased morbidity due to thoracic injuries, mortality due to thoracic injuries increased from an estimate of 0.1 percent for occupants 25 to 44 to an estimate of 0.7 percent for occupants 75+.

Age group 75+ had higher percentages of AIS 2+ thoracic injuries when driving or riding in any passenger vehicle type compared to the other three age groups. Age groups 25 to 44, 45 to 64 and 65 to 74 had lower percent of thoracic injuries when driving or riding in LTVs compared to passenger cars. However, age group 75+ had a higher percentage of thoracic injuries in the relevant crashes when driving or riding in LTVs compared to passenger cars. However, as seen by the confidence limits, this difference is not statistically significant at the 95 percent level.

Despite the decreased incidence of thoracic injuries seen among young and middle age occupants when driving or riding in vehicles with model year of 1996 or later, the lower incidence is not seen among older occupants 75+.

The analysis of incidence of thoracic injury by occupants' seating position showed that people 75+ had higher incidence of AIS 2+ thoracic injuries at any seating position

compared to other age groups. Furthermore, people 75 and older had an exceptionally higher incidence of AIS 2+ thoracic injuries when riding in rear seats at 18.7 percent.

In this study, seat belt use proved to have a positive impact in reducing thoracic injuries among all age groups including older occupants. However, when examining the source of thoracic injuries in frontal crashes among occupants 75+, seat belt was the most common source of injury. The age-related increased incidence of thoracic injuries for older occupants indicates a need to consider the restraint system in relation to the variance in injury tolerances among the passenger vehicle occupant population in planar towaway crashes.

Considering the fragility of older occupants, modified restraint systems may prove beneficial in minimizing the incidence of thoracic injuries among the older population. Fragility of older occupants is seen by their higher incidence of bony structure fractures such as those of the rib cage and sternum. Also occupants 75 and older sustained their thoracic injuries at lower crash delta-v compared to young and middle-age occupants.

Although 65 traditionally has been designated as the starting age when categorizing older people, the results of this study suggest that the incidence of thoracic injury differs significantly not only between the elderly and other age groups, but also between the two older groups included in the study (65 to 74 versus 75+).

In conclusion, older occupants have high rates of thoracic injuries when involved in planar tow-away passenger motor vehicle crashes. The higher incidence of thoracic injuries among older occupants is not related to higher crash severity, as evidenced by the lower delta-v associated with their crashes.

REFERENCES

1. Association for the Advancement of Automotive Medicine. (1990). The Abbreviated Injury Scale, 1990 Revision. Des Plaines, IL: Association for the Advancement of Automotive Medicine.

2. Centers for Disease Control and Prevention. (2006). Arthritis, Osteoporosis, and Chronic Back Conditions—United States, Healthy People 2010.

3. National Center for Health Statistics. (2006). Chart-book on Trends in the Health of Americans, Hyattsville, MD.

4. NHTSA. (2000). National Automotive Sampling System Crashworthiness Data System Coding and Editing Manual. Washington, DC.

5. NHTSA. (1993). Addressing the Safety Issues Related to Younger and Older Drivers: A Report to Congress. Washington, DC.

APPENDIX

Table A1: Thoracic injury by vehicle type

Age Group	Vehicle Type		Thorax	Non-Thorax	Total
25 to 44	Passenger Car	Weighted Count	72,240	4,407,919	4,480,159
		Unweighted Count	799	8,188	8,987
		Weighted Percent	**1.6**	**98.4**	**100**
	LTV	Weighted Count	29,664	2,438,451	2,468,115
		Unweighted Count	289	4,983	5,272
		Weighted Percent	**1.2**	**98.8**	**100**
	Total	Weighted Count	101,904	6,846,370	6,948,274
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100**
Age Group	**Vehicle Type**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	Passenger Car	Weighted Count	59,881	2,231,289	2,291,170
		Unweighted Count	627	4,038	4,665
		Weighted Percent	**2.6**	**97.4**	**100**
	LTV	Weighted Count	24,786	1,321,965	1,346,751
		Unweighted Count	264	2,686	2,950
		Weighted Percent	**1.8**	**98.2**	**100**
	Total	Weighted Count	84,667	3,553,254	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100**
Age Group	**Vehicle Type**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	Passenger Car	Weighted Count	24,090	527,326	551,416
		Unweighted Count	249	1,155	1,404
		Weighted Percent	**4.4**	**95.6**	**100**
	LTV	Weighted Count	6,374	225,168	231,542
		Unweighted Count	72	512	584
		Weighted Percent	**2.8**	**97.2**	**100**
	Total	Weighted Count	30,464	752,494	782,958
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100**
Age Group	**Vehicle Type**		**Thorax**	**Non-Thorax**	**Total**
75+	Passenger Car	Weighted Count	41,815	647,342	689,157
		Unweighted Count	333	1,236	1,569
		Weighted Percent	**6.1**	**93.9**	**100**
	LTV	Weighted Count	10,769	107,620	118,389
		Unweighted Count	61	260	321
		Weighted Percent	**9.1**	**90.9**	**100**
	Total	Weighted Count	52,584	754,962	807,546
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100**

Source: NASS-CDS 1998-2007

Table A2: Thoracic injury by vehicle model year

Age Group	Vehicle MY		Thorax	Non-Thorax	Total
25 to 44	< 1996	Weighted Count	63,225	3,127,915	3,191,140
		Unweighted Count	596	5,507	6,103
		Weighted Percent	**2.0**	**98.0**	**100.0**
	1996+	Weighted Count	38,679	3,718,455	3,757,134
		Unweighted Count	492	7,664	8,156
		Weighted Percent	**1.0**	**99.0**	**100.0**
	Total	Weighted Count	101,904	6,846,370	6,948,274
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100.0**
Age Group	**Vehicle MY**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	< 1996	Weighted Count	48,258	1,519,985	1,568,243
		Unweighted Count	494	2,604	3,098
		Weighted Percent	**3.1**	**96.9**	**100.0**
	1996+	Weighted Count	36,409	2,033,269	2,069,678
		Unweighted Count	397	4,120	4,517
		Weighted Percent	**1.8**	**98.2**	**100.0**
	Total	Weighted Count	84,667	3,553,254	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100.0**
Age Group	**Vehicle MY**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	< 1996	Weighted Count	16,811	304,888	321,699
		Unweighted Count	180	706	886
		Weighted Percent	**5.2**	**94.8**	**100.0**
	1996+	Weighted Count	13,653	447,606	461,259
		Unweighted Count	141	961	1,102
		Weighted Percent	**3.0**	**97.0**	**100.0**
	Total	Weighted Count	30,464	752,494	782,958
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100.0**
Age Group	**Vehicle MY**		**Thorax**	**Non-Thorax**	**Total**
75+	< 1996	Weighted Count	25,305	384,943	410,248
		Unweighted Count	211	683	894
		Weighted Percent	**6.2**	**93.8**	**100.0**
	1996+	Weighted Count	27,279	370,019	397,298
		Unweighted Count	183	813	996
		Weighted Percent	**6.9**	**93.1**	**100.0**
	Total	Weighted Count	52,584	754,962	807,546
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100.0**

Source: NASS-CDS 1998-2007

Table A3: Thoracic injury by seat belt use

Age Group	Seat Belt Use		Thorax	Non-Thorax	Total
25 to 44	Belted	Weighted Count	51,291	5,749,428	5,800,719
		Unweighted Count	480	9,836	10,316
		Weighted Percent	**0.9**	**99.1**	**100.0**
	Unbelted	Weighted Count	50,613	1,096,942	1,147,555
		Unweighted Count	608	3,335	3,943
		Weighted Percent	**4.4**	**95.6**	**100.0**
	Total	Weighted Count	101,904	6,846,370	6,948,274
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100.0**
Age Group	**Seat Belt Use**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	Belted	Weighted Count	52,717	3,073,897	3,126,614
		Unweighted Count	512	5,556	6,068
		Weighted Percent	**1.7**	**98.3**	**100.0**
	Unbelted	Weighted Count	31,951	479,356	511,307
		Unweighted Count	379	1,168	1,547
		Weighted Percent	**6.2**	**93.8**	**100.0**
	Total	Weighted Count	84,668	3,553,253	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100.0**
Age Group	**Seat Belt Use**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	Belted	Weighted Count	21,046	682,399	703,445
		Unweighted Count	231	1,426	1,657
		Weighted Percent	**3.0**	**97.0**	**100.0**
	Unbelted	Weighted Count	9,418	70,095	79,513
		Unweighted Count	90	241	331
		Weighted Percent	**11.8**	**88.2**	**100.0**
	Total	Weighted Count	30,464	752,494	782,958
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100.0**
Age Group	**Seat Belt Use**		**Thorax**	**Non-Thorax**	**Total**
75+	Belted	Weighted Count	39,199	696,074	735,273
		Unweighted Count	270	1,265	1,535
		Weighted Percent	**5.3**	**94.7**	**100.0**
	Unbelted	Weighted Count	13,386	58,888	72,274
		Unweighted Count	124	231	355
		Weighted Percent	**18.5**	**81.5**	**100.0**
	Total	Weighted Count	52,585	754,962	807,547
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100.0**

Source: NASS-CDS 1998-2007

Table A4: Thoracic injury by seating position

Age Group	Seating Position		Thorax	Non-Thorax	Total
25 to 44	Driver	Weighted Count	74,614	5,488,970	5,563,584
		Unweighted Count	846	10,368	11,214
		Weighted Percent	**1.3**	**98.7**	**100.0**
	Front-Seat Passenger	Weighted Count	20,306	1,152,286	1,172,592
		Unweighted Count	197	2,218	2,415
		Weighted Percent	**1.7**	**98.3**	**100.0**
	Rear-Seat Passenger	Weighted Count	6,984	205,115	212,099
		Unweighted Count	45	585	630
		Weighted Percent	**3.3**	**96.7**	**100.0**
	Total	Weighted Count	101,904	6,846,371	6,948,275
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100.0**
Age Group	**Seating Position**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	Driver	Weighted Count	71,788	2,878,758	2,950,546
		Unweighted Count	723	5,493	6,216
		Weighted Percent	**2.4**	**97.6**	**100.0**
	Front-Seat Passenger	Weighted Count	11,990	588,950	600,940
		Unweighted Count	150	994	1,144
		Weighted Percent	**2.0**	**98.0**	**100.0**
	Rear-Seat Passenger	Weighted Count	889	85,546	86,435
		Unweighted Count	***18***	237	255
		Weighted Percent	**1.0**	**99.0**	**100.0**
	Total	Weighted Count	84,667	3,553,254	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100.0**
Age Group	**Seating Position**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	Driver	Weighted Count	22,396	588,146	610,542
		Unweighted Count	234	1,266	1,500
		Weighted Percent	**3.7**	**96.3**	**100.0**
	Front-Seat Passenger	Weighted Count	6,858	141,810	148,668
		Unweighted Count	77	319	396
		Weighted Percent	**4.6**	**95.4**	**100.0**
	Rear-Seat Passenger	Weighted Count	1,210	22,538	23,748
		Unweighted Count	***10***	82	92
		Weighted Percent	**5.1**	**94.9**	**100.0**
	Total	Weighted Count	30,464	752,494	782,958
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100.0**
Age Group	**Seating Position**		**Thorax**	**Non-Thorax**	**Total**
75+	Driver	Weighted Count	32,646	574,292	606,938
		Unweighted Count	279	1,095	1,374
		Weighted Percent	**5.4**	**94.6**	**100.0**
	Front-Seat Passenger	Weighted Count	16,643	166,379	183,022
		Unweighted Count	93	340	433
		Weighted Percent	**9.1**	**90.9**	**100.0**
	Rear-Seat Passenger	Weighted Count	3,295	14,291	17,586

		Unweighted Count	22	61	83
		Weighted Percent	**18.7**	**81.3**	**100.0**
	Total	Weighted Count	52,584	754,962	807,546
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100.0**

Source: NASS-CDS 1998-2007

Table A5: Thoracic injury by vehicle highest deformation location (GAD-1)

Age Group	Deformation Location (Highest)		Thorax	Non-Thorax	Total
25 to 44	Rear	Weighted Count	739	479,755	480,494
		Unweighted Count	20	792	812
		Weighted Percent	**0.2**	**99.8**	**100.0**
	Front	Weighted Count	58,297	4,390,305	4,448,602
		Unweighted Count	648	8,959	9,607
		Weighted Percent	**1.3**	**98.7**	**100.0**
	Side	Weighted Count	42,868	1,976,310	2,019,178
		Unweighted Count	420	3,420	3,840
		Weighted Percent	**2.1**	**97.9**	**100.0**
	Total	Weighted Count	101,904	6,846,370	6,948,274
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100.0**
Age Group	**Deformation Location (Highest)**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	Rear	Weighted Count	1580	263398	264978
		Unweighted Count	***19***	468	487
		Weighted Percent	**0.6**	**99.4**	**100.0**
	Front	Weighted Count	59,537	2,202,437	2,261,974
		Unweighted Count	570	4,445	5,015
		Weighted Percent	**2.6**	**97.4**	**100.0**
	Side	Weighted Count	23,551	1,087,418	1,110,969
		Unweighted Count	302	1,811	2,113
		Weighted Percent	**2.1**	**97.9**	**100.0**
	Total	Weighted Count	84,668	3,553,253	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100.0**
Age Group	**Deformation Location (Highest)**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	Rear	Weighted Count	937	51,744	52,681
		Unweighted Count	***6***	96	102
		Weighted Percent	**1.8**	**98.2**	**100.0**
	Front	Weighted Count	17,809	456,301	474,110
		Unweighted Count	194	1,039	1,233
		Weighted Percent	**3.8**	**96.2**	**100.0**
	Side	Weighted Count	11,719	244,449	256,168
		Unweighted Count	121	532	653
		Weighted Percent	**4.6**	**95.4**	**100.0**
	Total	Weighted Count	30,465	752,494	782,959
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100.0**
Age Group	**Deformation Location (Highest)**		**Thorax**	**Non-Thorax**	**Total**
75+	Rear	Weighted Count	213	41,775	41,988
		Unweighted Count	***4***	60	64

		Weighted Percent	**0.5**	**99.5**	**100.0**
	Front	Weighted Count	28,677	456,832	485,509
		Unweighted Count	209	887	1,096
		Weighted Percent	**5.9**	**94.1**	**100.0**
	Side	Weighted Count	23,694	256,354	280,048
		Unweighted Count	181	549	730
		Weighted Percent	**8.5**	**91.5**	**100.0**
	Total	Weighted Count	52,585	754,961	807,546
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100.0**

Source: NASS-CDS 1998-2007

Table A6: Thoracic injury by number of vehicles involved in crashes

Age Group	Number of Vehicles		Thorax	Non-Thorax	Total
25 to 44	Single Vehicle	Weighted Count	30,818	1,328,086	1,358,904
		Unweighted Count	421	2,676	3,097
		Weighted Percent	**2.3**	**97.7**	**100.0**
	Two Vehicles	Weighted Count	71,086	5,518,284	5,589,370
		Unweighted Count	667	10,495	11,162
		Weighted Percent	**1.3**	**98.7**	**100.0**
	Total	Weighted Count	101,904	6,846,370	6,948,274
		Unweighted Count	1,088	13,171	14,259
		Weighted Percent	**1.5**	**98.5**	**100.0**
Age Group	**Number ff Vehicles**		**Thorax**	**Non-Thorax**	**Total**
45 to 64	Single Vehicle	Weighted Count	34,562	607,338	641,900
		Unweighted Count	279	989	1,268
		Weighted Percent	**5.4**	**94.6**	**100.0**
	Two Vehicles	Weighted Count	50,105	2,945,916	2,996,021
		Unweighted Count	612	5,735	6,347
		Weighted Percent	**2.0**	**98.0**	**100.0**
	Total	Weighted Count	84,667	3,553,254	3,637,921
		Unweighted Count	891	6,724	7,615
		Weighted Percent	**2.3**	**97.7**	**100.0**
Age Group	**Number of Vehicles**		**Thorax**	**Non-Thorax**	**Total**
65 to 74	Single Vehicle	Weighted Count	6,014	87,678	93,692
		Unweighted Count	70	200	270
		Weighted Percent	**6.4**	**93.6**	**100.0**
	Two Vehicles	Weighted Count	24,450	664,816	689,266
		Unweighted Count	251	1,467	1,718
		Weighted Percent	**3.5**	**96.5**	**100.0**
	Total	Weighted Count	30,464	752,494	782,958
		Unweighted Count	321	1,667	1,988
		Weighted Percent	**3.9**	**96.1**	**100.0**
Age Group	**Number of Vehicles**		**Thorax**	**Non-Thorax**	**Total**
75+	Single Vehicle	Weighted Count	8,651	100,306	108,957
		Unweighted Count	63	210	273
		Weighted Percent	**7.9**	**92.1**	**100.0**
	Two Vehicles	Weighted Count	43,934	654,656	698,590
		Unweighted Count	331	1,286	1,617
		Weighted Percent	**6.3**	**93.7**	**100.0**
	Total	Weighted Count	52,585	754,962	807,547
		Unweighted Count	394	1,496	1,890
		Weighted Percent	**6.5**	**93.5**	**100.0**

Source: NASS-CDS 1998-2007

DOT HS 811 101
March 2009

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

www.nhtsa.gov