The Elderly and Airbags
-Are New Standards Warranted?

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Abstract

Elderly drivers and passengers have a disproportionately higher crash involvement rate and commonly sustain more severe injuries than the general population. Since most demographic forecasts indicate a doubling in the proportion of Canadians over 65 years of age by the year 2026, it will become increasingly more important that safety standards be optimized to mitigate elderly casualties. Currently, no motor vehicle safety standards in Canada are designed to specifically address the needs of elderly persons.

A primary objective of the study was to develop a better understanding of the impact that air bags have had in reducing or exacerbating injuries in the elderly. Proposed changes to Canada's occupant restraint systems in frontal impacts (Motor Vehicle Safety Standard 208) include new injury criteria and test procedures using an assortment of anthropomorphic testing devices (ATDs), including one to represent a 5th percentile female. An initial study premise was that the introduction of the proposed 5th percentile female ATD in crash tests might provide beneficial outcomes specifically for elderly persons. Using Transport Canada databases, a comparative analysis of elderly and small-statured female motor vehicle occupants was undertaken to explore whether both groups are over-represented in certain injury patterns for similar collisions. The results of the study support the premise that the elderly will likely benefit from the proposed changes to the restraint standards. The need for special consideration in further standard development is discussed.

Résumé

Les conducteurs et passagers âgés ont un taux de participation d'accidents disproportionnellement plus élevé et subissent généralement des blessures plus graves que la population générale. Puisque la plupart des prévisions démographiques indiquent un doublement dans la proportion de Canadiens âgés de 65 ans+ d'ici l'année 2026, il deviendra de plus en plus important que des normes de sûreté soient optimisées pour atténuer la mort des personnes âgées. Actuellement, aucune norme de sûreté de véhicule à moteur au Canada n'est conçue pour satisfaire spécifiquement les besoins des personnes âgées.

Un premier objectif de l'étude était de développer une meilleure compréhension de l'impact que les sacs d'air ont eu pour réduire ou exacerbérer les blesseures des personnes âgées. Les changements proposés aux systèmes de contrainte d'occupants du Canada dans des impacts frontaux (norme de sûreté de véhicule à moteur 208) incluent de nouveaux critères de blessures et méthodes d'examens en utilisant un assortiment de dispositifs d'examens anthropomorphes (DEA), y compris un pour représenter une 5ième percentile de femmes. En premiers lieu, les études démontraient que l'introduction de la 5ième percentile femelle DEA proposée dans des examens d'accident pourrait fournir des résultats salutaires spécifiquement pour des personnes âgées. En utilisant des bases de données de Transport Canada, une analyse comparative de femmes âgées et de petite stature occupants des véhicules à moteur a été entreprise pour explorer si les deux groupes ci-dessus sont sur-représentés dans certains types de blessures pour les collisions semblables. Les résultats de l'étude confirment que les personnes âgées tireront probablement bénéfice des changements proposés aux normes de contrainte. Le besoin de considération spéciale dans le développement ultérieur des standards est discuté.

Introduction

In Canada, demographic forecasts indicate that the proportion of the population aged 65 years or greater will double by the year 2026 (Statistics Canada[1]). Although older drivers are involved in relatively few collisions due to limited exposure, once involved in a crash they are more likely to sustain severe injuries or death (Cunninghan *et al.*[2]). Several studies have confirmed that as people age, they are more likely to sustain serious or fatal injuries from the same severity crash (Evans[3], Evans[4], Bedard *et al.*[5], Mercier *et al.*[6], University of Michigan[7], Wang[8], Peek-Asa *et al.*[9], Li *et al.*[10]). Elderly drivers and occupants are especially at risk of thoracic region injuries due to increased bone fragility (University of Michigan[7], Wang *et al.*[11], Wang[8], Augenstein *et al.*[12], Foret-Bruno[13], Schiller[14], Sjogren *et al.*[15], Bulger *et al.*[16]). Currently, no motor vehicle safety standards in Canada are designed to specifically address the needs of elderly persons.

Research Objectives

The focus of the study was a comparative analysis of injuries sustained by the elderly versus both their younger counterparts and small-statured females in similar collisions. The initial objective of this research was to determine how the injuries of elderly occupants in motor vehicle collisions differ from those of the general population and to develop a better understanding of the impact that air bags have had in reducing or exacerbating injuries in the elderly.

Proposed changes to Canada's occupant restraint systems in frontal impacts (Motor Vehicle Safety Standard 208) include new injury criteria and test procedures using an assortment of anthropomorphic testing devices (ATDs), including the 5th percentile adult female ATD. A further study premise is that a comparison of injury type/severity of elderly persons versus small-statured females will determine whether the introduction of the proposed 5th percentile adult female ATD in crash tests might provide beneficial outcomes specifically for elderly persons. Consequently, the results of the study provide a means to identify opportunities where Canadian Motor Vehicle Safety Standards might be enhanced to better accommodate older occupants.

Background

Since the introduction of air bags in the early 1990s, there has been a disproportionate number of air bag induced fatalities among small-statured women involved in low speed collisions. A study by the United States National Highway Traffic Safety Administration (NHTSA) found that deployed air bags inadvertently killed 38 adults between 1990 and 1997, 14 of them being small-statured females (Dowdy[17]).

While the majority of air bag deployments serve their intended purpose, some cause injuries beyond what is expected from superficial contact with the rapidly expanding air bag (Government of Canada[18]). Current North American airbag systems are designed to deploy in crashes with frontal decelerations equivalent to that experienced in a 19 km/h crash into a fixed barrier (Segui-Gomez[19]). In real world crashes, this translates into a "must fire" threshold around 24 km/h and a "guaranteed no fire" threshold around 14 km/h. At collision severities near the deployment threshold, the airbag itself has actually been found to be a greater injury risk than the level of injury reduction being afforded (Dalmotas *et al.*[20,21], Libertiny[22], German *et al.*[23]).

Currently, the 50th percentile male Hybrid III is the most widely used frontal crash test dummy around the world. This dummy represents a man of average size at 5'10" tall and 170 pounds. The 5th percentile female Hybrid III crash test dummy is approximately 4'11" in height and weighs 108 pounds.

The analysis undertaken by Transport Canada to determine the need for the 5th percentile ATD assumed that 50 percent of the females and all of the age 50+ population are best represented by the lower injury tolerance imposed by the 5th percentile adult female dummy (Lussier[24]). An underlying objective of the current research was to determine whether or not there is need for this ATD to model the unique physical characteristics of elderly persons.

According to Richard Kent[25] of the University of Virginia Center for Applied Biomechanics, elderly persons warrant an ATD of their own. In fact, work is currently underway in this area at the Automobile Safety Laboratory, and Kent will be presenting some testing at the May 2003 ESV Conference in Nagoya that will be used in the development of a ATD to mimic an elderly human.

Methodology

This study utilized the Passenger Car Study and Air Cushion Restraint Study datasets collected by the Standards and Regulations Division (ASFBE), Road Safety and Motor Vehicle Regulation Directorate of Transport Canada. The Passenger Car Study (PCS) is a statistically representative sample of collisions involving passenger cars that occurred in Canada from 1984 to 1992. The PCS database was used to describe injuries to front-seat restrained occupants resulting from frontal collisions of various severities. It provided the benchmark against which injury patterns to occupants in vehicles equipped with air cushion restraint systems could be compared.

The Air Cushion Restraint Study (ACRS) was initiated in October of 1993 to examine the injury experience of occupants protected by supplementary air bag systems (Dalmotas[26]). This database was used to identify injury types and severities associated with collisions where an airbag had deployed. When examining the results of the comparative analyses presented in this report, it is important to consider that all differences in injury patterns between groups may not be solely due to the introduction of airbags. Several other factors may affect the injury pattern differences between the PCS and ACRS datasets, such as the change in vehicle design, the change in fleet mix and load limiters on safety restraints.

Criteria for inclusion in the current research were as follows:

- Frontal collisions (Collision Deformation Location = F)
- Principal Direction of Force (PDOF) from 10 to 2 o'clock
- Drivers and right front passengers 14 years and older
- Restrained occupants
- Air bag deployment (ACRS only)
- Availability of delta-V values
- Availability of injury information

Based on these criteria, the Passenger Car Study (PCS) and Air Cushion Restraint Study (ACRS) useable records were reduced from a total of 7,853 and 1,286 to 1,213 and 1,078 records, respectively. A summary of the data samples is given in Tables 1 and 2. For the purposes of this research, all persons aged 14 to 64 years were referred to as "young" and their data were used as a benchmark to highlight where elderly injuries are over-represented. Elderly persons were defined as those aged 65 years and older. For this report, small-statured females were defined as any female 14 to 64 years of age with a height between 145 cm and 155 cm (4'9" to 5'1") inclusive and a mass of 42 kg to 57 kg (91.8 lb to 124.2 lb) inclusive.

Table 1: Passenger Car Study Data Summary

Occupant	Drivers	Right Front Passengers	Total
Young (14-64)	792	278	**1070**
Elderly (65+)	94	49	**143**
	886	**327**	**1213**
Small-statured females (14-64)	30	7	**37**

Table 2: Air Cushion Restraint Study Data Summary

Occupant	Drivers	Right Front Passengers	Total
Young (14-64)	827	182	**1009**
Elderly (65+)	54	15	**69**
	881	**197**	**1078**
Small-statured females (14-64)	21	10	**31**

The sample size for small-statured female data is expectantly small given the physical dimensions for occupant inclusion in this group. In order to compare small-statured female injury results to those of the general population, any records including 14 to 64 year olds were not removed from the "young" group. In other words, a 23-year old injured small-statured female is included in the "young" dataset sample as well as in the "small-statured female" dataset sample. Results are not skewed due to the large number of records in the young group compared to those of the small-statured female group.

Many vehicle manufacturers redesigned the airbag systems for their model year 1998 vehicles by reducing inflator peak pressure and/or rise rate and reducing airbag volume (Summers *et al.*[27]). These redesigned airbags are known as second generation airbags. Dalmotas[26] suggested that the changes in airbag design introduced in most 1998 model cars should help to reduce the incidence of serious or fatal bag-related injury among both drivers and right front passengers. The analyses in this study do not consider the effects of the second generation airbags. However, only 6 of the 1,078 records in the Air Cushion Restraint Study database extracted for analyses involve deployment of the redesigned airbags.

Collision Severity Assessment

For analyses undertaken in this study, the impact-induced change in velocity (delta-V) was used as the indicator of collision severity. The data were grouped into the following delta-V categories, consistent with collision severity breakdowns presented in previous Transport Canada analyses, including Dalmotas *et al.*[21]:

- Minor severity collisions:
  Delta-V < 24 km/h
- Moderate severity collisions:
  Delta-V = 24-39.9 km/h
- High severity collisions:
  Delta-V = 40+ km/h

The study findings are based on a subset of the Transport Canada datasets because only cases for which the delta-V's for the crashed passenger car were known could be included. Delta-V's are most often missing (about half of cases in this analysis) because the algorithm used by crash investigators in their computation cannot be used when data about the crash or vehicle are insufficient.

The Collision Deformation Classification (CDC) is an alphanumeric coding scheme providing a concise description of the vehicle damage resulting from specific impacts. The first two characters of the Collision Deformation Classification code, used to group and extract data for this study, give the direction of principal force during impact designated by reference to hour sectors on a conventional clockface (Society of Automotive Engineers[28]). For this study, all frontal collisions, that is, those with a principal direction of force from "10" to "2" applied to the front end of the vehicle were extracted for analysis.

Column three of the classification code gives the deformation location (Society of Automotive Engineers[28]). This character broadly defines which projected area of the vehicle contains the deformation. For this study, all "Front" deformation locations were extracted for analyses as frontal collisions are the most common collision type and those considered in the occupant restraint system requirements of Section 208 of the Motor Vehicle Safety Regulations.

Multiple collisions occur when, after the initial impact, the vehicle in question is involved in a second impact or rollover. In the Passenger Car Study and Air Cushion Restraint Study, multiple CDC classifications are ranked in order of severity. In these cases, specific classifications receive a designation of primary or secondary based on the following guidelines (listed in a descending order of priority) (Society of Automotive Engineers[28]):

1. *Energy management considerations* – The CDC classification describing that impact which absorbed the greatest amount of energy or which resulted in the greatest amount of energy dissipation is designated as the primary CDC. All other classifications are designated as secondary.

2. *Greatest change in occupant space* – If two or more classifications are approximately equal with respect to energy management considerations, the classification associated with the greatest change in occupant space is designated as the primary CDC. All other classifications are designated as secondary.

When primary CDC codes involving frontal collisions were delineated for analyses for this study, therefore, the frontal impact was always the most severe, that which absorbed the greatest amount of energy.

Injury Severity Assessment

The Abbreviated Injury Scale (AIS) is a six-point ordinal scale that classifies injuries by body region (National Highway Traffic Safety Administration[29]). Injuries are ranked on a scale of 1 to 6, with 1 being minor, 5 severe, and 6 being an unsurvivable injury. The AIS code represents the threat to life associated with an injury and is not meant to represent a comprehensive measure of severity.

To provide reliable assessments of overall injury severity, especially where medical knowledge or expertise is not available, the Maximum AIS (MAIS) is often used. The MAIS is the highest severity code AIS injury sustained by the occupant in the collision (Association for the Advancement of Automotive Medicine[30]). This injury can be inflicted on any part of the body. An occupant can sustain more than one injury at the same maximum level; for example, if an occupant sustains several AIS 1 injuries but no injuries classified as higher than this, then the MAIS is still 1. The analyses gave precedence to head injuries if an occupant had a maximum head, chest injury, and neck injury at the same AIS level (National Highway Traffic Safety Administration[31]). The Maximum AIS is used in this research to compare injuries in the PCS dataset to injuries in the ACRS dataset.

In the Air Cushion Restraint Study, injuries are coded using the “NASS 1993 Injury Coding Manual” and the “NASS 1993 Crashworthiness Data System Data Collection, Coding and Editing Manual” (National Highway Traffic Safety Administration[32]), based on AIS-90. Injury severity is coded based on the AIS-90 scale, and the Maximum AIS value is determined. The Passenger Car Study (PCS) dataset uses the NASS Injury Coding Manual based on AIS-80 for injury coding. The PCS dataset identifies injury severity based on the Abbreviated Injury Scale. AIS-80 does not code the MAIS as a data element. The MAIS value, however, was determined for each occupant in the PCS dataset sample for the purposes of this research.

For each delta-V category, an *average* Maximum Abbreviated Injury Scale (MAIS) score was calculated. The Abbreviated Injury Scale is an ordinal scale, and a specific injury severity of 4.34, for example, does not actually exist. The average MAIS value was used only to compare injury severity among population groups, similar to the use of Grade Point Averages to compare students' overall academic results. Changes in the calculated averages merely indicate shifts in the distribution of observed injury severities. The relative magnitude of changes for one group of subjects cannot be reasonably compared to that of another group.

In addition to considering the severity of injuries sustained in motor vehicle collisions, the location of the most severely injured body region was examined. The NASS 1993 manual identifies injured body regions using the Abbreviated Injury Scale classification shown in Table 3.

Table 3: Abbreviated Injury Scale (AIS) Body Regions

Code	AIS Body Region
1	Head
2	Face
3	Neck
4	Thorax
5	Abdomen
6	Spine
7	Upper Extremity
8	Lower Extremity
9	Unspecified

Source: University of Western Ontario 2002

In Transport Canada's Passenger Car Study, injured body regions were coded using both the Injury Severity Score (ISS) and the Occupant Injury Classification (OIC) body regions. In order to compare the most severely injured body regions from the Passenger Car Study and the Air Cushion Restraint Study, the OIC body regions in the PCS database were converted to the NASS AIS body regions using the conversions obtained in Griffin[33].

Caveats of Analyses

The results of comparisons between datasets may be somewhat biased due to several factors. When comparing the Passenger Car Study results to those of the Air Cushion Restraint Study, the following should be considered:

- The selection criterion for cases sampled in Phase II of the Air Cushion Restraint Study required at least one occupant to have been transported to hospital for examination. This Phase contained 290 of the 1,078 ACRS records that were useable for this research. These records may have been slightly biased with higher severity collisions than the other two phases. It was found that the Phase II data showed a higher average MAIS score than both Phase I and Phase III for all delta-V groups. Specifically, the inclusion of Phase II data in these analyses was found to inflate the average MAIS score by 0.08 for low severity collisions, 0.13 for moderate severity collisions and 0.19 for high severity collisions.

- Although it would be proper to exclude multiple event collisions from the analyses, it was not done due to a limited number of comparable cases. Furthermore, the cases selected were done so based on the configuration of the most severe coded CDC. In other words, the frontal impact was considered the most severe for all cases extracted. However, it is possible that some of the injuries analyzed were not a result of the frontal impact but, in fact, by a subsequent impact. Of greatest concern would be cases where a frontal impact was followed by a rollover event. It was found that of the cases extracted from the Passenger Car Study, only 3.6 percent of vehicles were involved in rollovers following the frontal impact. In the Air Cushion Restraint Study sample, only 2.7 percent of vehicles experienced a subsequent rollover.

- Since its inception, the Abbreviated Injury Scale (AIS) has undergone several revisions (1980, 1985, 1990) to accommodate the diverse needs of medicine, biomechanics, public health, insurance and economics (Garthe *et al.*[34]). The analyses in this study compared the severity of injuries sustained in the Passenger Car Study (AIS-80) with those of the Air Cushion

Restraint Study (AIS-90). Based on the changes between the AIS scale revisions, it can be inferred that injuries in the Air Cushion Restraint Study sample may have been assigned lower MAIS injury scores than injuries of the same nature in the Passenger Car Study. This suggests that any increase in injury severity associated with the introduction of airbags may actually be slightly greater than presented in the results. Likewise, any decrease in injury severity for similar severity collisions from the Passenger Car Study to the Air Cushion Restraint Study may be slightly less than presented due to the variations in the AIS scales.

Results

The first of two research objectives was to develop a better understanding of injury outcomes among the elderly and to establish whether the elderly warrant specific inclusion in the motor vehicle safety standard development process in Canada. This was achieved through detailed analyses of maximum and average injury scores sustained among elderly and younger aged occupants involved in motor vehicle collisions of various severities, emphasizing the changes resulting from the introduction of airbags. Furthermore, injury patterns were contrasted to identify regions where the aged have been shown to be particularly vulnerable.

It was found that before the introduction of airbags, the elderly, unlike the base population, sustained the greatest percentage of serious injuries to the thorax in all collision severities. This high percentage of thoracic injuries in the elderly supports the literature on the elderly's susceptibility to chest region injuries due to bone frailties. With the introduction of airbags, both the young and elderly groups sustained the highest distribution of injuries to the face and upper extremities in all collision severities. Morris *et al*.[35] found similar results and suggested that contact with the airbag would account for the increased number of upper extremity injuries.

With the introduction of airbags, injuries occurred more frequently in lower severity collisions. In this study, elderly persons were found to sustain higher MAIS injuries in low severity collisions than their younger counterparts. The substantial increase in average MAIS for the elderly indicates that elderly persons are sustaining more serious injuries in minor severity collisions with the airbag than without it. As discussed earlier, airbags sometimes tend to exacerbate rather than prevent injuries in minor severity collisions.

For the elderly, the provision of airbags in moderate collisions tends to reduce the number of serious and fatal injuries when airbags are introduced. A substantial increase in the number of minor injuries (MAIS 1), however, is also apparent with airbag deployment. Although second generation airbags may address some of this increase, the data suggest that elderly persons require further protection from minor injuries in these collisions. Study results show that airbags are indeed effective in preventing injuries to the elderly in high severity collisions.

Comparative Injury Analyses of Elderly and Small-Statured Female Motor Vehicle Occupants

The main part of this research involved a comparison of elderly versus small-statured female airbag-induced injuries sustained in similar severity frontal collisions to extrapolate any potential benefits resulting from the proposed modifications to Section 208 of Canada's Motor Vehicle Safety Standards (specifically the inclusion of a 5th percentile female ATD). These data were also analyzed to determine whether commonalities exist between the injury patterns of small-statured females and elderly persons involved in similar severity collisions, the premise being that proposed changes to CMVSS 208 to include small-statured females may also benefit elderly persons. The following sections outline the key findings.

Distribution of Maximum Injury Severity

The Maximum Abbreviated Injury Score (MAIS) is the highest severity code AIS injury sustained by an occupant in a collision (Association for the Advancement of Automotive Medicine[30]).

With the introduction of airbags, approximately 23 percent and 37 percent of the elderly and small-statured female group, respectively, experienced a shift from "no injury" to MAIS 1 in low severity collisions. The base population experienced a shift of only 14 percent. Further, about 20 percent of both the elderly and small-statured female groups sustained MAIS 2+ injuries in these collisions. These values are substantially higher than the six percent MAIS 2+ injury occurrence for the base population. This over-representation by both elderly and small-statured female occupants suggests that in low severity collisions, the elderly may benefit from the introduction of the small female ATD in crash tests.

In moderate severity collisions with airbag deployment, changes to motor vehicle standards to further increase protection for small females may again be found to benefit elderly occupants. In these collisions, as shown in Figure 1, small females and elderly persons sustained similar patterns of injuries that were different than those of the base population. Among the elderly group, 85 percent sustained MAIS 1 injuries, with ten percent sustaining no injury. Similarly, 75 percent of small females sustained MAIS 1 injuries with eight percent sustaining no injury. Sixty percent of the younger age group sustained MAIS 1 injuries and 26 percent sustained no injury in these collisions.

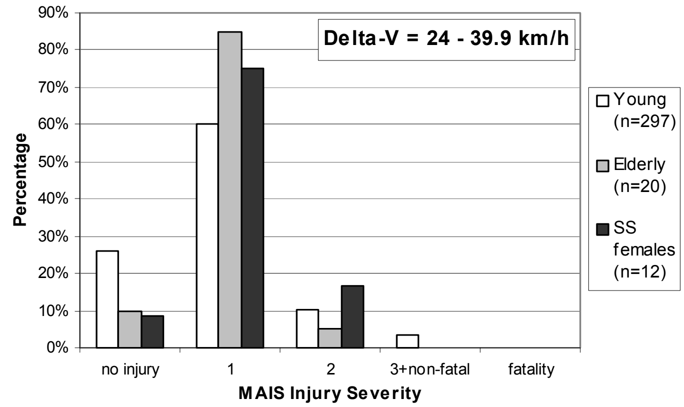

Figure 1: Occupant Injury, Moderate Severity Collisions *With* Airbags

Average Maximum Injury Severity

An alternative method used to examine injury severity was developed on an average MAIS score among age groups and collision severities. As mentioned, the Abbreviated Injury Scale is an ordinal scale, and a calculated average injury severity score of 4.34, for example, merely reflects the distribution of ordinal scores for a study group. It is used for comparative purposes.

Table 4 provides a summary of the average MAIS by age group and collision severity. The data in the table indicate that in minor severity collisions, all three groups experienced an increase in average MAIS with the introduction of airbags. Although these averages are based on ordinal AIS scores, it is clear that the elderly and small-statured females experience a greater overall shift in injury distributions to more severe levels in low-speed collisions involving airbags. The shift in injuries for both the elderly and small-statured females suggests that the proposed changes to CMVSS 208 to include a 5^{th} percentile ATD may prove to be beneficial to the elderly as well.

Table 4: Summary of Average MAIS

Collision Severity	Average Maximum Abbreviated Injury Score (MAIS)		
	Without Airbags (PCS)	With Airbags (ACRS)	MAIS Reduction
Delta-V < 24 km/h			
Young (14-64)	0.56	0.70	**-0.14**
Elderly (65+)	0.78	1.03	**-0.25**
Small-statured females (14-64)	0.71	1.29	**-0.58**
Delta-V = 24-39.9 km/h			
Young (14-64)	1.25	0.93	**0.32**
Elderly (65+)	2.12	0.95	**1.17**
Small-statured females (14-64)	1.36	1.08	**0.28**
Delta-V = 40+ km/h			
Young (14-64)	2.84	1.96	**0.88**
Elderly (65+)	3.70	1.43	**2.27**
Small-statured females (14-64)	2.89	1.60	**1.29**

The average MAIS sustained by small-statured females in minor severity collisions, as shown in the data of Figure 2, was almost twice as high (1.29 versus 0.71) with the airbag than without. This is consistent with that observed for elderly occupants in low severity collisions where an increase in average MAIS from 0.78 to 1.03 was observed with the introduction of airbags. The increases in average MAIS scores for the elderly and small-statured females with the introduction of airbags were substantially higher than that observed for younger occupants (0.56 to 0.70). Again, the relatively high frequency of injuries in low severity collisions with airbags for both the elderly and small-statured females suggests that the proposed changes to CMVSS 208 to include a 5^{th} percentile ATD may prove to be beneficial to the elderly as well.

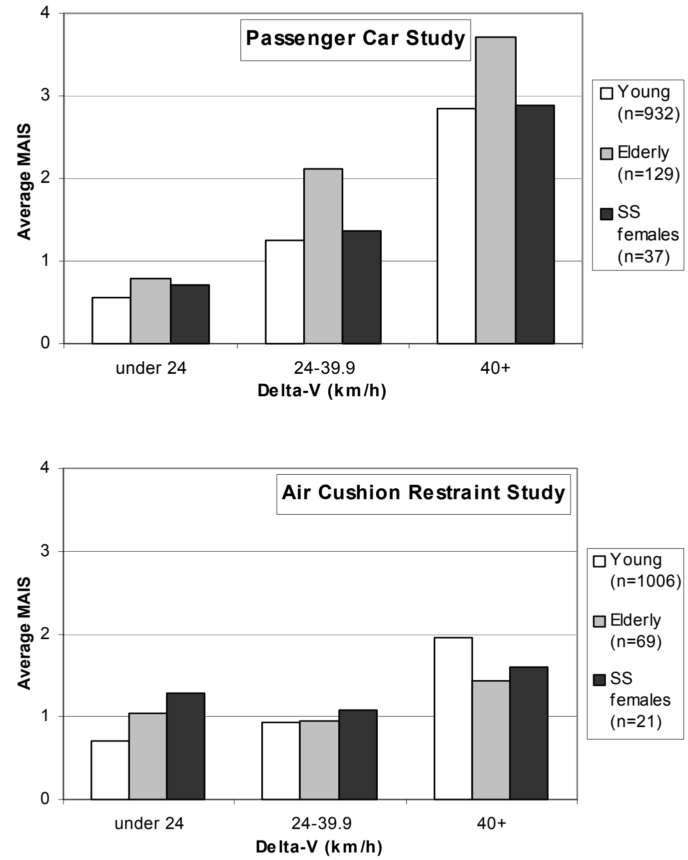

Figure 2: Average Occupant Injury by Collision Severity (With and Without Airbags)

Injury Patterns by Body Region

For this study, body regions were classified based on the Abbreviated Injury Scale Body Regions. Table 5 provides a summary of injured body regions by population group. The two body regions most frequently found to be the site of the most severe injury are identified in bold for each category.

Table 5: Distribution of Most Severely Injured Body Region by Collision Severity

Collision Severity	Injured Body Region	Without Airbags (PCS)	With Airbags (ACRS)
Delta-V < 24 km/h			
Young (14-64)	Face	8%	**36%**
	Spine	**34**	5
	U. Extremity	**19**	**32**
Elderly (65+)	Face	4	**40**
	Thorax	**38**	7
	Spine	**33**	3
	U. Extremity	4	**27**
Small-statured females (14-64)	Spine	**25%**	**25%**
	L. Extremity	**38**	**38**
Delta-V = 24-39.9 km/h			
Young (14-64)	Face	13%	**41%**
	Thorax	**19**	16
	Spine	**22**	3
	U. Extremity	13	**19**
Elderly (65+)	Face	**25**	**33**
	Thorax	**38**	**28**
Small-statured females (14-64)	Face	**21%**	**73%**
	Thorax	**21**	0
	Spine	**29**	9
	U. Extremity	7	**18**
Delta-V = 40+ km/h			
Young (14-64)	Head	**20%**	**25%**
	Face	14	**32**
	L. Extremity	**20**	8
Elderly (65+)	Face	7	**71**
	Neck	0	**14**
	Thorax	**50**	**14**
	Spine	**14**	0
Small-statured females (14-64)	Head	**33%**	**20%**
	Face	0	**80**
	U. Extremity	**22**	0
	L. Extremity	**22**	0

The data in Table 5 suggest that when an airbag is deployed, small-statured females experience a high proportion of facial injuries (73%) in moderate severity collisions. Elderly occupants also sustained injuries to the face (33%) but suffered a high percentage of thoracic injuries (28%) where the small-statured females sustained none. These results clearly indicate the need for increased chest area protection for the elderly.

In high severity collisions, the distribution of injuries to both small-statured females and the elderly group appears to have shifted from the head (33%) and the thorax (50%) to the face (71% and 80% respectively) with the introduction of airbags. The small sample size for the small-statured female group in high severity collisions was so small (n=7) that the results may be considered inconclusive.

Discussion

With Canada's aging population, it is extremely important that issues related to and affecting elderly persons be candidly considered. In the automotive industry, the federal government creates laws and regulations to set standards for the safety and environmental performance of new vehicles manufactured in or imported into Canada, and for used vehicles imported from the United States (Transport Canada[36]). To be effective, these regulations must be enforced fairly, firmly and consistently across the nation. They should also be continually monitored and modified if required to reflect changing demographics and technological advances.

Proposed changes to Standard 208 should increase protection to small-statured females in motor vehicle collisions. It was found that these standard changes may also prove to reduce the number of airbag-induced injuries in the elderly, specifically in minor and moderate severity collisions.

Elderly drivers and passengers are more susceptible to airbag injuries than their younger counterparts in both minor and moderate severity collisions. This suggests that motor vehicle occupant protection standards could be enhanced to address the unique needs of elderly persons. Specifically, study results indicate a need for better chest area protection for the elderly in moderate severity collisions.

Both the elderly and small-statured females sustained disproportionately more severe injuries than the base population in low severity collisions involving airbags. The predominant location for the most severe injury to the elderly in these low speed collisions was the facial area. These findings suggest that in minor collisions with airbag deployment, changes to motor vehicle standards to increase protection for small females may also be found to benefit elderly occupants. In these cases, Transport Canada's assumption that persons aged 50 years and older will benefit from the proposed changes to CMVSS 208 is likely correct, and a specific statement in the regulation change regarding elderly protection is justified.

The study findings for elderly persons suggest that in low severity collisions, the face and upper body are often injured by the deploying airbag. Dual-stage airbags were introduced in some 1998 model and newer vehicles and may prove to reduce the number of upper body injuries. The current research was based on data collected prior to the introduction of this technology. An area of further study would be to examine whether or not the change in airbag technology provides increased protection for elderly persons in motor vehicle collisions.

One means to address the occupant protection for elderly persons is to include an anthropomorphic testing device designed to represent an elderly human in crash tests. According to Richard Kent[25] of the University of Virginia Center for Applied Biomechanics, work in the development of an elderly ATD is currently underway at the center's Automobile Safety Laboratory.

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