Elderly Occupant Injury: A Detailed Analysis of Injury Patterns and Quality of Life Indicators

Catherine A. McCullough
Mark Scarboro
National Highway Traffic Safety Administration
United States Department of Transportation
United States of America
Mark Sochor, MD, MS, FACEP
University of Michigan Transportation Research Center
United States of America
Ramita Sharma
OnPoint
United States of America
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ABSTRACT

As the population in the United States ages there will be an increase of the exposure of the elderly to motor vehicle collisions. The growing population of elderly (65 years and older) Americans is the fastest growing segment of the population. It is estimated that more than 40 million older adults will be licensed drivers by 2020. [1]

According to the National Highway Traffic Safety Administration (NHTSA), Traffic Safety Facts, in 2005, 191,000 older individuals were injured in traffic crashes accounting for seven percent of all the people injured in traffic crashes during the year. These older individuals made up 15 percent of all traffic fatalities and 14 percent of all vehicle occupant fatalities.

There were over 28 million older licensed drivers in 2004 (2005 data not available) - a 17 percent increase from 1994. In contrast, the total number of licensed drivers increased by only 13 percent from 1994 to 2004. Older drivers made up 15 percent of all licensed drivers in 2004, compared with 14 percent in 1994. [2]

Injuries sustained by these individuals tend to be more life altering and life threatening than the same injuries sustained by younger individuals in similar motor vehicle collisions. This paper will examine the injuries sustained by individuals age 65 and older and compare them with injuries sustained by younger individuals (broken down in three additional age groups) in motor vehicle collisions. The long-term effects on their quality of life will also be analyzed.

This paper will focus on those occupants where a Short Form 36 (SF-36) baseline score and at least one follow-up score (at 9 or more months) is available. We will focus on occupants with an Abbreviated Injury Severity Score (AIS) of 3+ or an Injury Severity Score (ISS) of 8. Relating factors such as crash type, principal direction of force, age and others will be considered. The range of scores in the various levels will be compared and contrasted for the four age groups.

INTRODUCTION

The Crash Injury Research and Engineering Network (CIREN) is a multi-disciplinary collaboration of trauma physicians, engineers, epidemiologists, crash investigators and other social scientists in industry and government researching the "cause and effect" of serious and/or disabling injuries sustained as a result of an automotive collision. CIREN is a network of eight Level 1-trauma centers spanning the United States and investigating approximately 350 crashes per year that result in serious and/or disabling injuries.

CIREN is also the name of a research tool developed, updated, enhanced, and maintained by The Volpe National Transportation Center (Volpe) in Cambridge, Massachusetts, to help researchers collect and review injury data. Variables for CIREN crash reconstruction data are an extension of the National Automotive Sampling System (NASS) Oracle data model. Variables for the medical injury data are based on a variety of sources, including the National Trauma Registry, the Orthopedic Trauma Association, and the Uniform Pre-Hospital EMS Data Elements.

CIREN is the only research program that combines detailed medical data with detailed crash data Each CIREN Case is one injured occupant in a motor vehicle crash. Multiple CIREN cases can be linked to one NASS case, which is associated with a single crash. There are 3159 cases in the CIREN database (medical side) linked to 2793 NASS cases (crash side).

It is estimated that more than 40 million older adults will be licensed drivers by 2020. It is anticipated as the population ages that these individuals will continue to be at risk unless

countermeasures are developed to mitigate these injuries. This concern has been addressed by congress through the House Committee Appropriation Report that states, "The committee directs NHTSA as part of its CIREN program, to collect data that will measure the impact of crashes on older populations and that would assist in the possible development of a crash test dummy representing the older populations."

This paper will review the injury patterns using the differing body regions (head, neck thorax, pelvis, etc.) of elderly occupants and compare and contrast those of their younger counterparts from CIREN. This paper will also evaluate the initial outcome of injury to the elderly occupant in comparison to the differing age groups (16-30 years old, 31-47 years old, 48-64 years old and 65 and greater years old). Injury for the differing body regions will be calculated for all four age groups. An analysis of elderly occupant SF-36 (quality of life and physical limitations) scores will be compared with the differing age groups.

The CIREN utilizes several unique processes and tools to research automotive crashes and the resulting injuries. One such tool utilized is the Medical Outcomes Study 36 – Item Short Form Survey (SF-36). The SF-36 has become one of the most widely used scoring tools for measuring outcomes after multiple trauma events.

BACKGROUND ON THE SF-36

The Short Form 36 (SF-36) was derived from the work of the Rand Corporation of Santa Monica during the 1970's. Rand's Health Insurance Experiment compared the impact of alternative health insurance systems on health status and utilization. The SF-36 was designed for use in clinical practice and research, health policy evaluations, and general population surveys. The outcome measures developed for the study have been widely used. They were subsequently refined and used in Rand's Medical Outcomes Study (MOS), which focused more narrowly on care for chronic medical and psychiatric conditions. [3]

The form is used in identifying and tracking limitations in physical or social activities because of health problems relating to a medical condition (asthma, diabetes, traumatic injury, etc.). It is a generic measurement and does not target specific ages, sex, or disease. Population and large-group descriptive studies and clinical trials to date demonstrate that the SF-36 is very useful for descriptive purposes such as documenting differences between sick and well patients and for estimating the relative burden of different medical conditions. [4] The SF-36 measures eight health concepts (See Table 1) [5].

The SF-36 outcome tool has been shown to be less than ideal when testing for outcomes related to brain trauma, especially in the areas of cognitive function. MacKenzie et al. indicated the SF-36 required additional cognitive testing supplements to develop a more accurate outcome indicator for individuals who sustain multiple traumas involving head injury. [6]

Although the SF-36 can be self administered, CIREN uses trained interviewers to administer the questionnaire at the time of the traumatic event to develop a baseline to determine the physical and emotional health status of a person at that time compared to how they were prior to the event. The same 36 questions are asked at 6-months and 12-month post event whenever possible. The SF-36 scores are derived from answers given to those standardized questions. Generally, the lower the score in any given category indicates a decreased ability in that area for the occupant. This data is invaluable in determining overall medical outcomes and societal costs.

The experience to date with the SF-36 has been documented in nearly 4,000 publications. Scales that load highest on the physical component are most responsive to treatments that change physical morbidity, whereas scales loading highest on the mental component respond mostly to drugs and therapies that target mental health. [7]

METHODS

The CIREN database was queried for years 1997 to 2006 to extract all crashes where an SF 36 baseline score and at least one set of follow-up scores (at 9 or more months) post crash are available. Normally, SF-36 is obtained at baseline, 6 and 12 months. However, in this dataset some responses were obtained at 10 or 11 months due to difficulty in contacting the subject for their follow-up. The range of scores in the various levels were compared and contrasted for the four age groups. Typically, elderly has been

Table 1.
SF-36 Health Status Concepts

Health Concept		Description
PF	Physical Functioning	The PF score indicates the amount health limits physical activities such as walking, lifting, bending, stair climbing and exercise. A low score indicates limitations in performing all activities. A high score indicates the ability to perform all types of physical activities including vigorous exercise.
RP	Role Physical	The RP score indicates the level that physical health interferes with work or other daily activities. A low score indicates that physical health creates problems with daily activities including accomplishing less than wanted, limitations in the kind of activities, or difficulty in performing activities. A high score indicates that physical health has not caused problems with work or daily activities.
BP	Bodily Pain	The BP score indicates the intensity of pain and its effect on normal work in and out of the home. A low score indicates very severe and extremely limiting pain. A high score indicates no pain or limitations due to pain.
GH	General Health Perceptions	The GH score evaluates health, current and future outlook as well as resistance to illness. A low score indicates individual/personal health perceptions as poor and likely to get worse. A high score indicates individual/personal health perceptions as excellent.
V	Vitality	The V score indicates the extent of energy level. A low score indicates you feel tired and worn out all of the time. A high score indicates you have felt full of pep and energy during the past four weeks.
SF	Social Functioning	The SF score indicates a level to which physical or emotional problems interfere with daily social activities. A low score indicates extreme and frequent interference. A high score indicates no interference during the past four weeks.
RE	Role Emotional	The RE score indicates a level that emotional problems interfere with work or other daily activities. A low score indicates emotional problems interfere with activities including decreased time spent on activities, accomplishing less, and not working as carefully as usual. A high score indicates no interference with activities due to emotional problems.
MH	Mental Health	The MH score identifies general mental health including depression, anxiety and behavior. A low score indicates a feeling a nervousness and depression all of the time. A high score indicates you have felt peaceful, happy, and calm during the past four weeks.

*** Physical Functioning, Role Physical, Bodily Pain and General Health scores are combined to obtain the Physical Component Summary.**
**** Vitality, Social Functioning, Role-Emotional and Mental Health are combined to obtain the Mental Component Summary**

defined as 65 years of age and older which we used to constitute the beginning age range for the oldest group (the oldest member in this group was 94). It should be noted that we did not include occupants under the age of 16 since they have their outcomes assessed using the Pediatric Quality of Life tool. With that in mind, the age range for the first age group was set at 16. The difference in years between 16 and 65 was divided into three equal groups with rounding up occurring for the two next older groups and we arrived at the age breakdown for the groups used in this paper.

Relating crash and injury variables including but not limited to crash type, principal direction of force (PDOF), DeltaV, restraint use, Abbreviated Injury Score (AIS), Injury Severity Score (ISS), Maximum Severity Score (MAIS) along with age and sex were also considered. We focused on injuries AIS 3 or greater or an ISS of 8 or greater. Data was reviewed to help determine the significance of an injury to a specific body region beyond that of "threat to life" measure provided by AIS.

The SF-36 scores are derived from the answers given by the case occupant on 36 standardized questions. The questions inquire about issues ranging from their opinion of General Health now and six months or a year ago; ability to climb stairs, lift groceries, physical limitations at work or daily activities to feelings of depression, pain issues and energy issues. The results are used in calculating scores for eight categories, four physical related and four mental related. The final composite scores are based on a 100 point score. The lower the score in any given SF-36 category indicates a decreased ability in that category for the occupant. The individual scores were then converted into percentages and are presented that way in our tables and graphs. For example: if a subject rated his or her General Health (GH) at baseline (pre traumatic event) = 90 points and 12 months later (post traumatic event) rated his or her GH = 60 points this would represent a 33% drop in GH. For the purposes of this paper, these drops are reported as negative percentages.

RESULTS

There were a total of 469 CIREN occupants (216 male and 253 female) that had completed SF-36 data including baseline and at least one score at 10 months or more at the time of analysis. (See Table 2).

Table 2.
Subject Distribution by Age Group and Gender

	Age Group			
Gender	**Group1 (16-30)**	**Group 2 (31-47)**	**Group 3 (48-64)**	**Group 4 (65+)**
Male	88	56	46	26
Female	107	57	62	27
Total	**195**	**113**	**108**	**53**

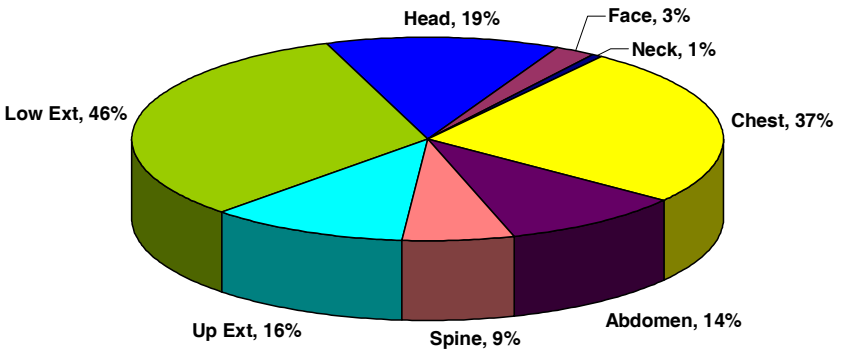
There were some basic similarities and differences in the study group demographics as shown in Table 3. The gender distribution in each group is nearly even with a slight majority going to female in every group. On average, the case occupants were all within 3 cm (1.2 in) of height and 13 kg (28.6 lb) in weight of one another. Their average MAIS scores ranged from 3.1 to 3.3, with the most severe being in the youngest (age 16-30) and the oldest (age 65+) age groups. The ISS score ranged from 17 in three of the groups to 19 in the youngest group. The deltaV's are all at 40 kph (24 mph) with the exception of the older group which averages 35 kph (21 mph). This group on average sustained the same severity of injury or slightly higher as the other groups but at 5 kph (3 mph) lower.

An analysis of the injuries sustained by the study group as a whole revealed that almost half (46%) sustained AIS 3+ lower extremity injuries followed by chest injuries at 37% and head injuries at 19% (See Figure 1). Since this is a count of all AIS3+ injuries, occupants could be counted twice if they sustained injuries in different body regions.

A closer look at these injuries by age (See Figure 2) shows the elderly to have consistent injury for the chest, spine and lower extremities. Head injuries indicate similar distributions with the exception of the 16 to 30 year old group where a spike of twenty-six percent is appreciated. The abdomen injury distribution is similar to the head with the 16 to 30 year old group spiking to nineteen percent. Spinal injury is evenly distributed between all groups. Lastly, the upper extremity injury distribution indicates an opposite trend to those seen in the head and abdomen. The

Table 3.
Study Group Demographics

	Total Group	**Group 1 (16-30)**	**Group 2 (31-47)**	**Group 3 (48-64)**	**Group 4 (65+)**
Male% / Female%	46 / 54	44 / 56	50 / 50	43 / 57	49 / 51
Mean Age	40	22	40	56	74
Mean MAIS	3.25	3.3	3.12	3.21	3.3
Mean ISS	18	19	17	17	17
Mean delta-V (kph)	40	40	40	40	35
Mean Height (cm)	169	170	169	169	167
Mean Weight (kg)	80	74	84	87	79



*Occupants can be counted multiple times if equal maximum injury severity scores are in different body regions. (Chart exceeds 100%)

Figure 1. Percent AIS-3+ Injury by Body Region

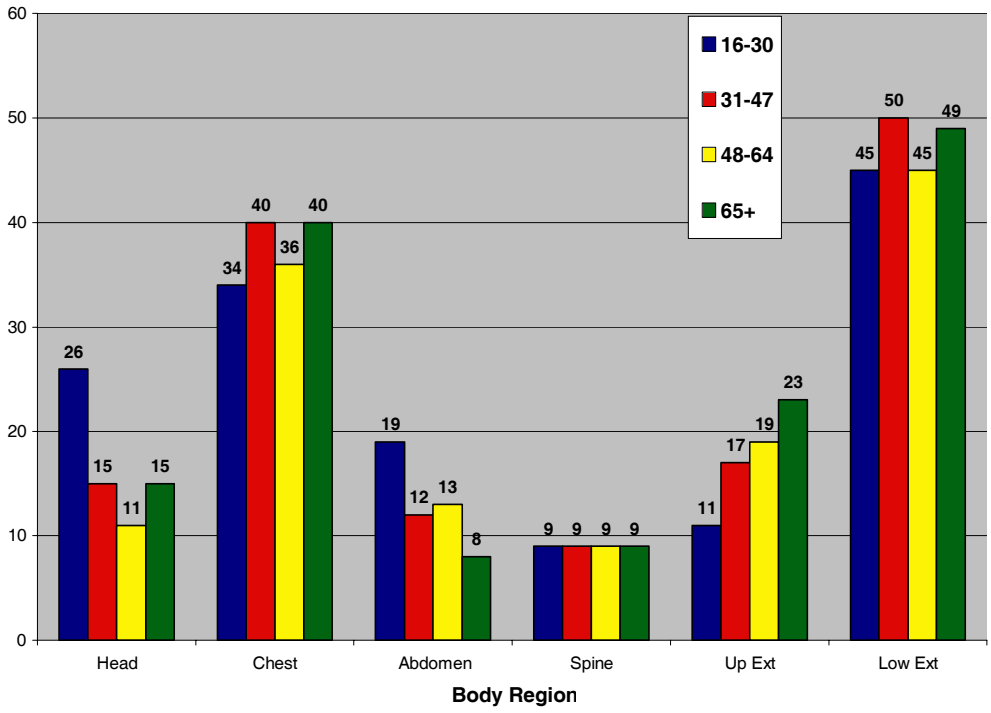


Figure 2. Percent AIS3+ Injury by body Region and Age

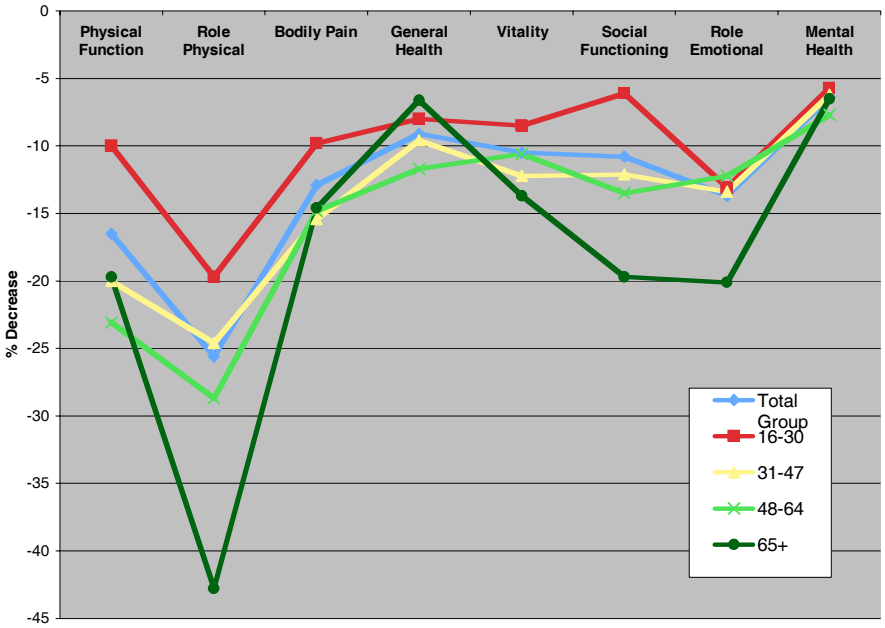


Figure 3. Mean SF-36 Decrease for all age groups individually and as a total composite

spike for the 65+ group was not as dramatic as those seen for the 16 to 30 group in the head and abdomen, but the difference between the 16 to 30 group and the 65+ group results in a twelve percent difference.

The distribution of the study population by occurrence of AIS 3+ injury by body region is shown in Figure 1. A closer analysis of these injuries by body region and age is shown in Figure 2.

The distribution of injury by age shows the elderly (group 4) to have consistent injury patterns to the general population (all Ages) with the exception of head injury and abdominal injury (See Figure 2). In both head and abdominal injury, the elderly have on average 11% less AIS 3+ injuries to these regions.

As previously indicated, SF-36 measures eight health areas (four physical related and four mental) based on the patient's perception of how well they are doing (or not doing) in those areas at specific points in time after the crash.

For elderly occupants (group 4) Role physical showed the lowest score and was 17.2 % lower than the average score over all age groups and 23.1 % lower than the 16 to 30 year old group. Role Emotional was the next lowest score at -20.1% followed by Social Functioning and Physical Function both at -19.7%. (See Table 4)

The largest differences between the average scores of the total group and the 65+ group were in Role Physical (-17.2% difference), Role Emotional (– 6.4% difference) and Social Functioning (-8.9% difference). All other categories for Group 4 were within 3% of the average score.

Figure 3 shows the relative difference the patients perceived in their physical health (PF, RP, BP and GH) and their Mental Health (V, SF, RE, and MH). Elderly occupants rated Role Physical (RP) as the area where they were affected the most, followed by Social Functioning (SF) and Role Emotional (RE). These are the areas where they perceived they were not doing as well as they were before the traumatic event. Their perception of their decreased Role Physical (42.8%) and Role Emotional (20.1%) is likely to be related to their low Social Functioning (19.7%) role.

Conversely, this same group rated their General Health (GH) higher than other age groups. This indicates that the elderly group had a brighter outlook on their individual health outlook than individuals from the other age groupings. (A low score indicates individual/personal health perceptions as poor and likely to get worse. A

Table 4.
Mean Change in SF-36 Scores at 10-12 Months

Health Concept	Total Group	Group 1	Group 2	Group 3	Group 4
Physical Function	-16.5	-10	-20	-23.1	-19.7
Role Physical	-25.6	-19.7	-24.6	-28.7	-42.8
Bodily Pain	-12.9	-9.8	-15.4	-14.8	-14.6
General Health	-9.1	-8	-9.6	-11.7	-6.6
Vitality	-10.5	-8.5	-12.2	-10.6	-13.7
Social Functioning	-10.8	-6.1	-12.1	-13.5	-19.7
Role Emotional	-13.7	-13.1	-13.4	-12.2	-20.1
Mental Health	-6.4	-5.7	-6.2	-7.7	-6.5

high score indicates individual/personal health perceptions as excellent). There does not seem to be any logical explanation for this and would certainly be a source for further study and analysis. The eldest group assessed their individual change in Mental Health (MH) consistent with the other age groups. (Also refer to Table 4)

An additional analysis was done on each of the AIS group's drop in SF-36 scores, comparing them to the older group and the total group's average. As Figure 4 indicates, there are not significant drops in SF-36 scores in any age group like those in the older group until you reach the MAIS5 level. Granted the AIS5 level scores are much lower in a few categories, but there are many scores at or near the older group (RP, BP, V, SF and MH).

We used SAS 9.1's ANOVA procedure to perform a Dunnett's test on the data, comparing the oldest group (group 4) to each of the other groups in each of the eight health concept areas addressed by the SF-36. This showed significance for Role Physical when comparing the two youngest age groups to the elderly group at a 95% confidence level. Social Functioning between the youngest and oldest age groups at the 95% confidence level was also significant. No significance was identified between the elderly and the other age groups in any of the other health concept areas.

DISCUSSION

As the general driving population ages, they will be involved in more motor vehicle crashes. Elderly occupants involved in crashes take longer to recover and have higher complication rates than younger patients. This observed vulnerability of older adults because of their lower physiological reserve highlights the importance of "investigating the outcomes of traumatic injuries and identifying risk factors for suboptimal recovery" in elderly patients. [8]

The unprecedented increase in the elderly population in the United States over the next several years will bring with it an increase in the injury burden of the elderly in terms of quality of life and medical costs /outcomes. That is why it is imperative to have a better understanding of the effects of serious injury on the elderly. While medical care in the United States has made great strides in taking care of the trauma population as a whole it is well known that standard treatment approaches do not produce the same outcome for all age groups. Recovery rates for similar injuries have been shown to differ substantially between the young and the elderly. The strongest predictors of long-term functional status of severely injured patients have been shown to be age and co-morbidities. [9]

By studying outcomes with the SF-36, insight is gained into how differing age populations perceive their ability to function post traumatic event. This tool has the potential to allow health care and injury researchers the ability to monitor the effectiveness of differing medical interventions for traumatically injured patients. To date much research has been performed to validate the SF-36 and the injury research community has begun to utilize this tool to give "insight into the distribution and determinants of

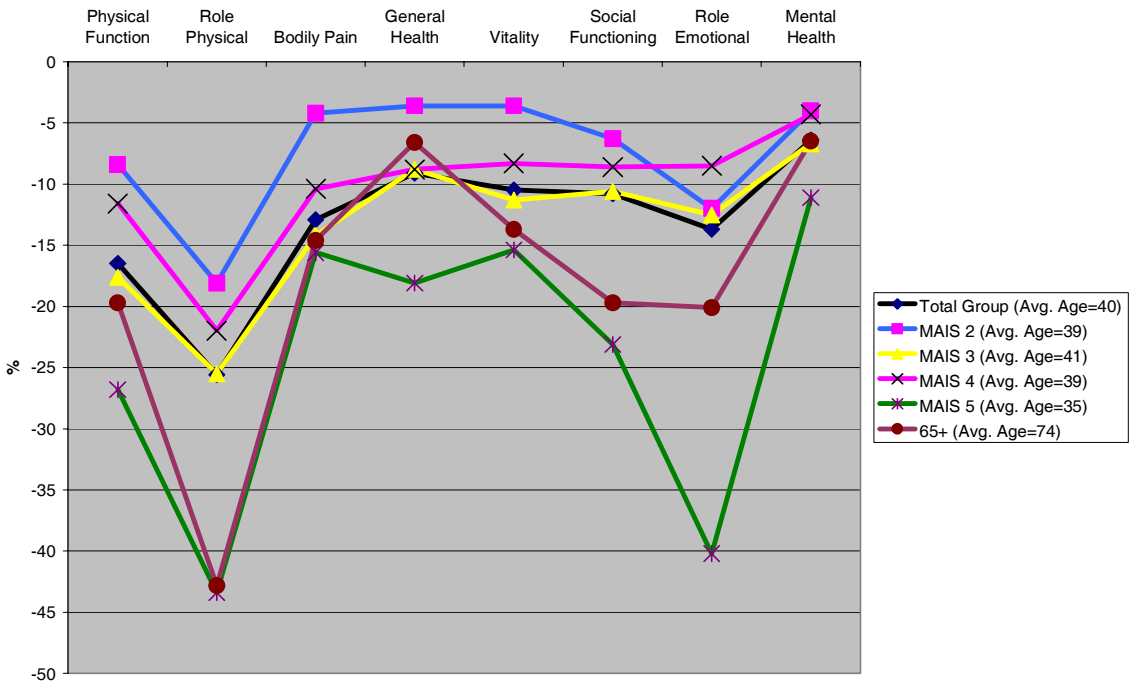


Figure 4. Comparison of Mean SF-36 Decrease - Injury Severity and Older Occupants

both short and long-term disability" and how this tool can be utilized to "prioritize the development of prevention policies and to improve trauma care". [10]

The CIREN population utilized in this study experienced a high frequency of orthopedic injuries. This type of injury has been studied utilizing the SF-36 and the Sickness Impact Profile work scale and it has been shown that patients with orthopedic injuries have relatively worse functional recovery, and this worsens with time. [11]

The data presented in this paper indicate that not only do elderly occupants have more difficulty with their traumatic injuries affecting their work and daily activities but their mental health is affected as well. The elderly consistently show larger differences in SF-36 scores in the categories of Role Physical, Social Functioning, and Role Emotional. Interestingly, the elderly in this database feel their personal General Health perceptions are not as poor as the other age groupings. It is unknown if this "rosey" outlook could keep the elderly from seeking help with any limitations they may have.

The mental scores consisting of V, SF, RE and ME indicated stronger return to baseline for the 16 to 30 year old group compared to the remaining groups, yet this group indicated the greatest occurrence of head injury. The 65+ year old group was second to the 16 to 30 year old group for maximum head injury and rank below all groups in mean mental scores. Return to baseline for mental scores are better for every group compared to the 65+ group, even by the group who suffered more severe head injuries. Again, this highlights the potential need for differing types of rehabilitation for the elderly as it relates to specific types of injuries. The traditional acute intervention and rehabilitation methods used currently may not be meeting the needs of the elderly population.

Physical scores (PF, RP, BP, GH) indicated some substantial decreases from original baseline functions. Although this would be expected with all study groups indicating lower extremity injury as their most severe injury or one of their most severe injuries 43 to 56 percent of the time the 65+ group with 49 percent lower extremity maximum injury score far below all others in the RP category. This is consistent with the studies that have shown age and co-morbidities play a significant role in the functional recovery from trauma for the elderly patient.

This paper shows in our elderly study group that older occupants injured in crashes on average recover their activities of daily living at a much slower rate than the younger occupants. The younger occupants indicate injury at a higher degree of severity in the same body region or at a higher degree of severity in different body regions (multiple or single) and score closer to original baseline than those sustaining equal or less severe injury.

The distribution of injury by age shows the elderly (group 4) to have consistent injury patterns to the general population (all ages) with the exception of head injury and abdominal injury. In both head and abdominal injury, the elderly have on average 11% less AIS 3+ injuries to these regions. The reasons for this are unclear at this time and warrant further study. This phenomenon may be partially explained by the fact that the elderly were involved in crashes that had a delta V of 5 kph (3 mph) less than the other age groups. However, it is the authors' belief that this small reduction in the amount of kinetic energy is not great enough to explain the difference observed on the SF-36 tool.

Figure 3 shows the relative difference the patients perceived in their physical health (PF, RP, BP and GH) and their Mental Health (V, SF, RE, and MH). Elderly occupants rated Role Physical as the area where they were affected the most. This same age group also rated their personal General health better than the other age groups. This indicates that the elderly seem to have a more optimistic view of their ability to recover from their injuries over the next year than the other age groups.

The other two marked lower categories were in Social Functioning and Role Emotional (See Table 3). It is hypothesized that the scores for these categories could be related to the fact that the elderly subject (as shown by the RP score) struggles with performing daily activities and accomplishes less per day. All of these categories (RP, SF, and RE) ask the subject to comment on how physical and/or emotional problems interference with work and daily activities. Lack of physical mobility challenges young and old. The old are challenged with many comorbid conditions such as arthritis and Parkinson's and when compounded with their traumatic injury, their locomotion could decrease even more. This inability to be mobile could also exacerbate their decreased mental SF-36 scores. .

Further study of the injured elderly who do not appear to be recovering as expected may highlight the cases that have developed complications and these cases could be studied in more detail to potentially identify possible interventions that will avoid common complications in these patients. Potential future studies could include follow-up on the subjects who have died prior to the 6 and 12-month follow-up survey.

CONCLUSIONS:

As the NASS is utilized to show general trends in injury from motor vehicle crashes, CIREN gives the injury researcher a unique tool in the SF-36.

Since this is the first motor vehicle crash database of this size to capture SF-36 scores, it has the potential to become a tool to assess which post crash interventions yield the greatest return to normal function for these elderly patients.

REFERENCES

1. Dellinger, Ann M, Langlois, Jean A, Li, Guohua. "Fatal Crashes Among Older Drivers: Decomposition of Rates into Contributing Factors", American Journal of Epidemiology 2002: 155(3): 234-241

2. National Highway Traffic Safety Administration. Traffic Safety Facts 2005 Older Population, Washington, D.C., United States of America, DOT HS 810 622

3. Rand Corporation and John E. Ware, 1990, "The Short Form 36 Health Survey", General Status and Quality of Life"

4. Turner-Bowker, D., P. J. Bartley, et al. (2002). SF-36® Health Survey & "SF" Bibliography: Third Edition (1988-2000). Lincoln, RI, Quality Metric Incorporated.

5. SF-36 Health Survey – Pacific Coast Wellness Center

6. MacKenzie Ellen J, McCarthy ML, Ditunno JF, et al. "Using the SF-36 For Characterizing Outcome After Multiple Trauma Involving Head Injury", Journal of Trauma: 527-534.

7. The SF Community – SF36 Health Survey Update" www.sf36.org/tools/sf36.shtm (accessed February 2007)

8. Richmond, T. S., H. J. Thompson, et al. (2006). "A Feasibility Study of Methodological Issues and Short-Term Outcomes in Seriously Injured Older Adults." American Journal of Critical Care 15(2): 158-65.

9. Holtslag, H. R., M. W. Post, et al. (2007). "Long-Term Functional Health Status of Severely Injured Patients." Injury 38(3): 280-289.

10. Meerding, W. J., C. W. Looman, et al. (2004). "Distribution and Determinants of Health and Work Status in a Comprehensive Population of Injury Patients." Journal of Trauma 56(1): 150-161.

11. Michaels, A. J., S. M. Madey, et al. (2001). "Traditional Injury Scoring Underestimates The Relative Consequences Of Orthopedic Injury." Journal of Trauma 50(3): 389-395; discussion 396.