Crash Injuries and Long-Term Consequences: The CIREN Experience

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ABSTRACT

The Crash Injury Research and Engineering Network (CIREN) is a multi-disciplinary collaboration of trauma physicians, engineers, epidemiologists, crash investigators and other social scientists researching the "cause and effect" of serious and/or disabling injuries sustained as a result of an automotive collision. CIREN is a network of 10 level 1-trauma centers spanning the United States and investigating approximately 400 crashes per year that result in serious and/or disabling injuries.

The CIREN utilizes several unique processes and tools to research automotive crashes. 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. The purpose of this study is to evaluate the SF-36 scores for CIREN occupants, one year after their crash. Over three hundred CIREN occupants have been followed and responded to the SF-36 on the one-year timeline. These scores were analyzed in conjunction with crash dynamics and occupant factors in an attempt to determine which crash scenarios and injuries result in long-term physical and or mental consequences.

This paper reviews the SF-36 scores for 346 CIREN occupants who were interviewed 12 months after their crash. We attempt to isolate injuries or injury types that show significant long-term consequences and possibly serious injuries that show little long-term issues. Associated factors are analyzed such as crash type, vehicle parameters, age and others.

INTRODUCTION

The concept of outcomes is an immense one, on one end of the spectrum it may be a tangible count like lost wages or hospital costs and on the other end it might be represented by a much more difficult problem to capture as seen in a crash occupant's undiagnosed depression, brought about by a mild concussion.

In the United States the economic impact of automotive crashes is estimated at $231 billion per year, this is the equivalent of $820 for every living person in the country [1].

With the ever-increasing safety technology available to occupants of vehicles (air bags, safety belts, etc.) more individuals are surviving crashes that were once nearly always fatal. One of the main inclusion criteria for the Crash Injury Research and Engineering Network (CIREN) is the case occupant's vehicle be no more than 8 model years old from the current model year available. Crashes resulting in serious and/or disabling injuries are another one of the main inclusion criteria for the CIREN program. This concentration allows CIREN to collect in-depth crash and injury data on the most costly crashes occurring on our roadways. Crashes resulting in serious injuries account for approximately 12% of all crashes nationwide, however this 12% constitutes approximately 77% of the economic impact related to automotive crashes [2].

In many crash cases the significant portion of the costs are not incurred during the initial hospitalization phase, but in the days, months and years after the crash and initial hospitalization. These costs are born in additional hospital admissions, surgical procedures, lost wages, out of pocket medical expenditures, and long-term mental and/or physical impairment just to name a few.

Recent history studies have shown significant long-term consequences associated with certain types of injuries [3,4]. Serious brain injuries resulting in anatomical lesions have long been known to have extremely long-term costs and consequences. The SF-36 outcome tool (detailed below) has been shown to be less than ideal when testing for outcomes related to head 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 trauma involving head injury [7].

Most recently Read, et al. (2004) examined 65 occupants from CIREN crashes utilizing SF-36 and other outcome tools such as testing for post-traumatic stress disorder (PTSD) as well as personal interviews and questionnaires. Read, et al. showed 22% of the population that suffered an ankle/foot fracture who were employed prior to their crash stated they were unable to return to work at 1 year due to their injury, compared to 3% of the occupants that did not suffer an ankle/foot injury [5].

The majority of outcome studies related to blunt trauma are pursued retrospectively from state or system based trauma data registries. The CIREN program prospectively follows the case occupant for the 12 months following the occupant's crash collecting the SF-36 scores at baseline (while in the hospital) and again at 6 and 12 months post crash. Therefore, a detailed examination of the available SF-36 data and related crash and injury parameters was developed for this study.

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 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 [8].

The SF-36 was designed for use in clinical practice and research, health policy evaluations, and general population surveys. The form is used in identifying and tracking limitations in physical or social activities because of health problems relating to the traumatic event. It is a generic measurement and does not target specific ages, sex, or disease. The SF-36 measures eight health concepts (see Table 1).

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 questions are asked at 6-months and 12-months post event. These data are invaluable in determining overall medical outcomes.

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.
RP	Role Physical	The RP score indicates the level that physical health interferes with work or other 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.
GH	General Health Perceptions	The GH score evaluates health, current and future outlook as well as resistance to illness.
V	Vitality	The V score indicates the extent of energy level.
SF	Social Functioning	The SF score indicates a level to which physical or emotional problems interfere with daily social activities.
RE	Role Emotional	The RE score indicates a level that emotional problems interfere with work or other daily activities.
MH	Mental Health	The MH score identifies general mental health including depression, anxiety and behavior.

* 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

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 most to drugs and therapies that target mental health [9

METHODS

The CIREN database was queried for years 1997-2004 to extract all cases where a complete baseline and 12-month SF-36 data were available. In conjunction with the available SF-36 data, crash reconstruction data, injury coding and complete clinical data were required to be complete and available in the database. Several crash and injury variables were extracted for every case. Including, but not limited to, demographics, restraint status, principal direction of force (PDOF), crush and intrusion measurements, Delta V, Injury Severity Score (ISS), Maximum Abbreviated Injury Scale (MAIS), and injury codes for analysis.

The SF-36 scores are derived from the answers given by case occupants on 36 standardized questions. The questions inquire about issues ranging from the their opinion of general health now and a year ago, ability to climb stairs, lift groceries, physical limitations at work or daily activities to feelings of depression, pain issues and energy levels. 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 scale. The lower the score in any given SF-36 category indicates a decreased ability in that category for the occupant.

The medical data in CIREN is prospectively captured at each of the 10 CIREN trauma centers while the occupant is in the hospital. All injuries captured in CIREN are coded using the Abbreviated Injury Scale (AIS) and the International Classification of Disease 9th Edition (ICD-9). Radiology images and clinical photographs are utilized to record and detail each applicable injury. Every injury recorded is reviewed by the clinical CIREN team to validate and detail the injury coding. In addition to these coding methodologies all upper and lower extremity fractures and joint dislocations are coded using the Orthopaedic Trauma Association (OTA) coding system. The OTA system requires review of appropriate radiology images and clinical reports to achieve correct coding of injuries.

The crash data in CIREN is captured by inspection of the crash scene and the vehicle(s) involved in the crash. The crash investigations are conducted using the National Automotive Sampling System (NASS) protocol and standards [6]. This protocol is then enhanced with additional procedures utilized in CIREN. The known anthropometric measurements (height, weight, seated height, etc…) of the occupant are available to the crash investigator. Also, injury and fracture pattern data is available to the crash investigator prior to field investigation. These procedures add greater reliability to the placement and position of the occupant in the vehicle and aid in the determination of occupant kinematics and possible contact points.

The multidisciplinary CIREN teams at each site consist of at least a crash investigator, trauma physician, engineer and data coordinator. They review each injury in the case to determine a probable mechanism of injury causation. Every injury mechanism is coded with a level of confidence (certain, probable, or possible) in conjunction with the evidence and data available.

In conjunction with the injury and crash variables queried from the CIREN database a thorough case study was conducted via the CIREN graphical users interface in an attempt to establish for each case the AIS body region most significantly injured for each case. Data points beyond MAIS, ISS and AIS were reviewed to aid in determining the significance of an injury to a specific body region beyond that of "threat to life" measure provided by AIS. Case review data included AIS/ICD-9/OTA codes, radiology images and reports, surgical codes and reports, comorbidity, complications, Glasgow Coma Scale (GCS) scores, ventilation requirements, disposition status and discharge summaries. All injuries were reviewed to determine one key injury and/or injured body region for each case. In cases where this objective could not clearly be determined the case was categorized as multiple injury. In many cases it was quite evident by the amount of surgeries, complications and clinical indicators that one particular injury or injured body region was the most significant in the case. In many cases this did not often correlate with the MAIS scores in each case. Injuries that often had a higher threat to life score via MAIS were treated non-operatively while lower scoring injuries resulted in multiple surgical interventions and a higher incidence of complications.

RESULTS

There were a total of 346 CIREN occupants that had completed case data including baseline and 12 month SF-36 scores at the time of analysis. The general description of the study population is displayed in

Table 2. Fifty three percent were female and the mean age was 40 years (range, 15-86). Pre-morbid conditions were documented in 43% of the population. The top 3 premorbid conditions were hypertension, asthma and diabetes.

Table 2.
Demographic Data

Number of occupants	346
Gender - Female	182 (53%)
Mean age - years	40
Pre-morbid condition	147 (43%)

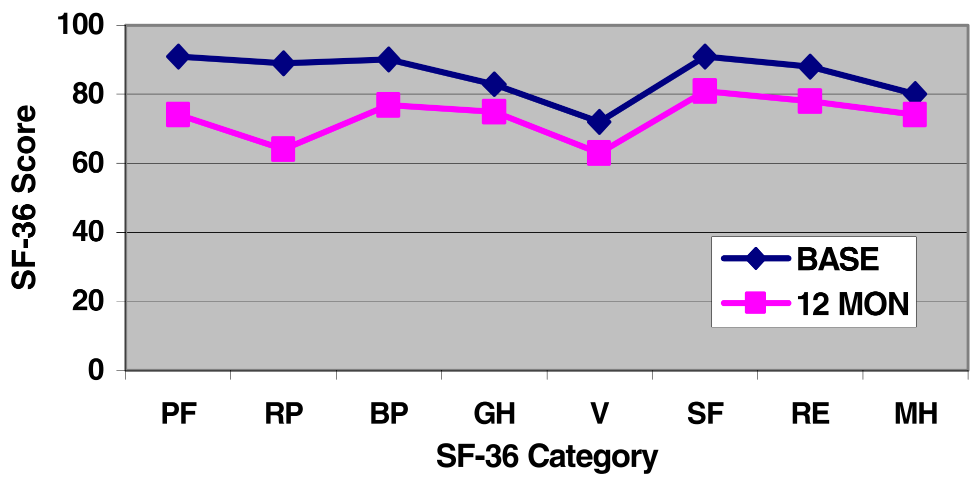
Crash data and injury parameters are detailed in Table 3. The role of the CIREN occupant in the population was typically as the driver (82%). The dominant crash type for this population was frontal (70%). Restraint use illustrated safety belt compliance at a level of 78%, and belted with an air bag deployment was 60%. The mean delta V for this population (when calculable N=231) was 41 kph (25.6 mph) and the mean maximum crush measurement was 70 cms (27.6 in.).

Injury severity was significant for this population as would be expected with the CIREN inclusion criteria. The mean Injury Severity Score (ISS) was 15 (range, 4-50) and the mean Maximum AIS (MAIS) was 3 indicating an injury severity level of serious.

Table 3.
Crash Data

Role	
Driver	285 (82%)
Crash Type	
Frontal	241 (70%)
Nearside	67 (20%)
Farside	25 (7%)
Rear	5 (1%)
Roll	6 (2%)
Restraint Status	
Belted w/ deployed air bag	208 (60%)
Deployed air bag only	65 (19%)
Belted only	61 (18%)
Unrestrained	10 (3%)
Unknown	2 (<1%)
Mean Delta V (N=231)	41 kph (25.6 mph)
Mean maximum crush	70 cms (27.6 in)
Mean ISS	15
MAIS Distribution	
2	85 (24%)
3	203 (59%)
4	41 (12%)
5	17 (5%)

The mean change in SF-36 scores for the entire population is displayed in Figure 1. All four physical and all four mental categories show a decrease from the occupant's original baseline.



<u>Figure 1. Mean Change in SF-36 Scores From Baseline to 12 Months (N=346)</u>

The distribution of the study population Body Region Injury Categories (BRIC) is displayed in Figure 2. It was determined through the individual case review that nearly 40% of the population sustained only a minimal case counts for these BRIC's and high standard deviations resulted in eliminating these categories from continued review.

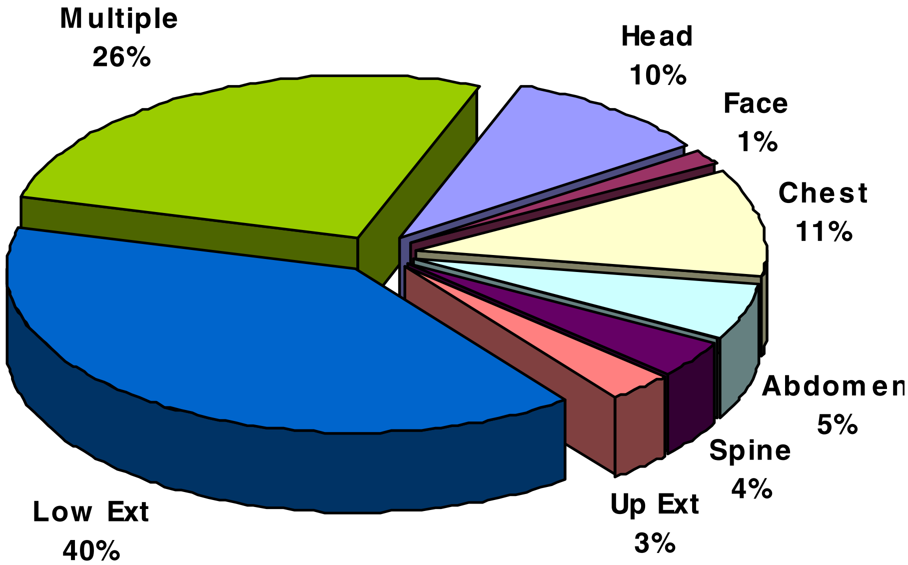


Figure 2. Distribution of BRIC's (N=346)

significant lower extremity injury. In 26% of the cases reviewed significant injuries were sustained in two or more body regions. Cases resulting in two or more BRIC's were grouped together in the "Multiple" category.

Due to the relatively low N values for BRIC's face (N=5), abdomen (N=19), spine (N=13), and up ext (N=10) additional exploration was not pursued. Although substantially decreased scores were observed in upper extremity and spine cases, the

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The mean differences in SF-36 scores for the established BRIC's with N values over 30 are detailed in Table 4. General Health and Role Emotional were statistically significant for occupants sustaining only significant injury to the head (P-value<.01). Occupants who sustained only significant chest injury indicated statistical significance in the mental health category. Lower extremity and multiple category occupants were significant in all categories

Table 4. Mean SF-36 Changes From Baseline To 12 Months By BRIC

Body Region	Occupants (N)	PF	RP	BP	GH	V	SF	RE	MH
Head	34	-8.1	-7.6	-0.3	-6.8*	-6.5	-7.4	-19.8*	-3.1
Chest	37	-3.2	-7.4	-7.6	-4.0	-3.6	-6.3	-6.3	-6.5*
Low Ext	137	-22.9*	-33.6*	-17.4*	-7.8*	-8.7*	-12.9*	-10.1*	-3.9*
Multiple	91	-20.6*	-35.0*	-18.1*	-8.5*	-9.6*	-13.9*	-11.0*	-4.5*

* - indicates statistical significance at <.01 level using SAS Proc Univariate

The head injury group indicated significant decreases in their perceptions of their overall general health 12 months after their crash. The same group indicated significant limitations in their usual role activities because of emotional problems or issues. The chest injury group indicated a significant decrease in the population's mental health score resulting in possible psychosocial distress, anxiety and or depression. The lower extremity and multiple group scores indicate a wide spectrum of problematic issues affecting these individuals 12 months after their crash. The correlation between the lower extremity group and the group sustaining significant injury to two or more BRIC's is quite close as seen in Figure 3. The correlation is further justified by the BRIC distribution for the multiple group in Table 5.

The multiple injury group (N=91) contained significant injury combinations involving all eight original body regions. The distribution of the involved body regions for the multiple group is demonstrated in Table 5. With the lower extremities having the highest amount of involvement within the multiple group, it is another indicator that the injuries sustained to this body region continue to be a major factor-affecting outcome even when other significant injuries are involved.

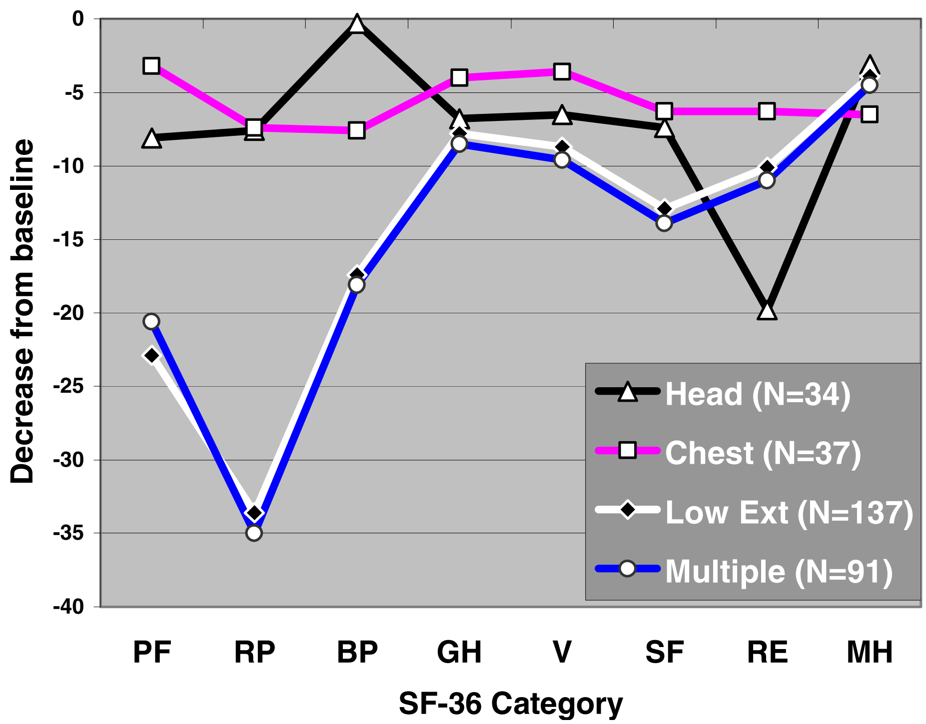

Figure 3. Mean SF-36 Changes From Baseline to 12 Months By BRIC

Table 5.
Distribution of BRIC's in Multiple Group

BRIC	Number of Occupants	Percent of Multiple Group
Head	22	24
Face	6	7
Neck	2	2
Chest	47	52
Abdomen	18	20
Spine	9	10
Upper Extremity	32	35
Lower Extremity	63	69

With the injury coding detail available in CIREN, an additional distribution breakdown within the three isolated BRIC's could be achieved. The head group was diagnosed with anatomical injuries 56% of the time, while 44% of the injuries were concussive in nature. The chest group was diagnosed with significant bony injury (ribs) 54% of the time. Internal organ injury (lungs, etc…) accounted for 43% of the significant chest cases and 3% were vascular type injury (aorta). The lower extremity group was 97% bony injury and 3% muscle/tendon/ligament type injury.

surpassed the lower extremity group by 1 kph. The mean ISS and MAIS again as expected were highest in the multiple group. However, it should be noted that the lower extremity group with outcomes as poor as the multiple group indicated less threatening injuries by it's low mean ISS and MAIS scores.

The OTA codes allow the lower extremity population to be detailed to an even finer level for evaluation of injury and outcome. Utilizing the OTA codes available in CIREN the lower extremity group was farther divided into two new categories. One subgroup included all significant lower extremity injuries involving an articular surface. The second subgroup contained the remaining significant lower extremity injuries not involving an articular surface. Articular surfaces are found where two or more bones come together to form a joint such as the knee or elbow. For the 137 cases sustaining only significant lower extremity injury, 67%(92) sustained articular injury and 33%(45) sustained non-articular injury. Review of the mean changes in the SF-36 scores for these two groups indicate a negative impact in outcomes when articular surfaces are involved (see Figure 4).

Table 6.
Demographic and Crash Data by Category

BRIC		HEAD	CHEST	LOW EXT	MULTIPLE
Number of occupants		34	37	137	91
Gender - Female		18 (53%)	18 (49%)	71 (52%)	55 (60%)
Mean age - years		34	51	38	42
Pre-morbid condition		15 (44%)	17 (46%)	55 (40%)	34 (37%)
Role	Driver	29 (85%)	32 (87%)	122 (89%)	69 (75%)
Crash type	Frontal	15 (44%)	21 (57%)	112 (82%)	66 (73%)
	Nearside	9 (27%)	14 (38%)	17 (13%)	18 (20%)
	Farside	7 (21%)	2 (5%)	6 (4%)	3 (3%)
	Rear	3 (9%)	0	0	1 (1%)
	Roll	0	0	1 (1%)	3 (3%)
Restraint status	Belted w/ deployed air bag	17 (50%)	18 (49%)	89 (65%)	56 (61%)
	Deployed air bag only	4 (12%)	8 (22%)	33 (24%)	15 (17%)
	Belted only	10 (29%)	8 (22%)	13 (10%)	16 (18%)
	Unrestrained	3 (9%)	3 (8%)	1 (<1%)	3 (3%)
	Unknown	0	0	1 (<1%)	1 (1%)
Mean DeltaV - kph (mph)		31 (19.3)	34 (21.1)	43 (26.7)	44 (27.3)
Mean maximum crush - cms (in)		55 (21.7)	59 (23.2)	75 (29.5)	82 (32.3)
Mean ISS		15	17	11	22
Mean MAIS		3.1	3.2	2.7	3.4

Demographic and crash details were explored for each of the BRIC's with N values greater than 30 (see Table 6). All four groups were similar in demographic and crash configuration with a few notable differences. The mean age for the groups had a range of 4-18 years between the groups. The lower extremity and multiple groups, which had the worse SF-36 scores, were involved in a high percentage of frontal crashes. These groups also had the highest percentages of air bag and safety belt use, 65% and 61% respectively. The highest mean delta V as expected was in the multiple group, however it only

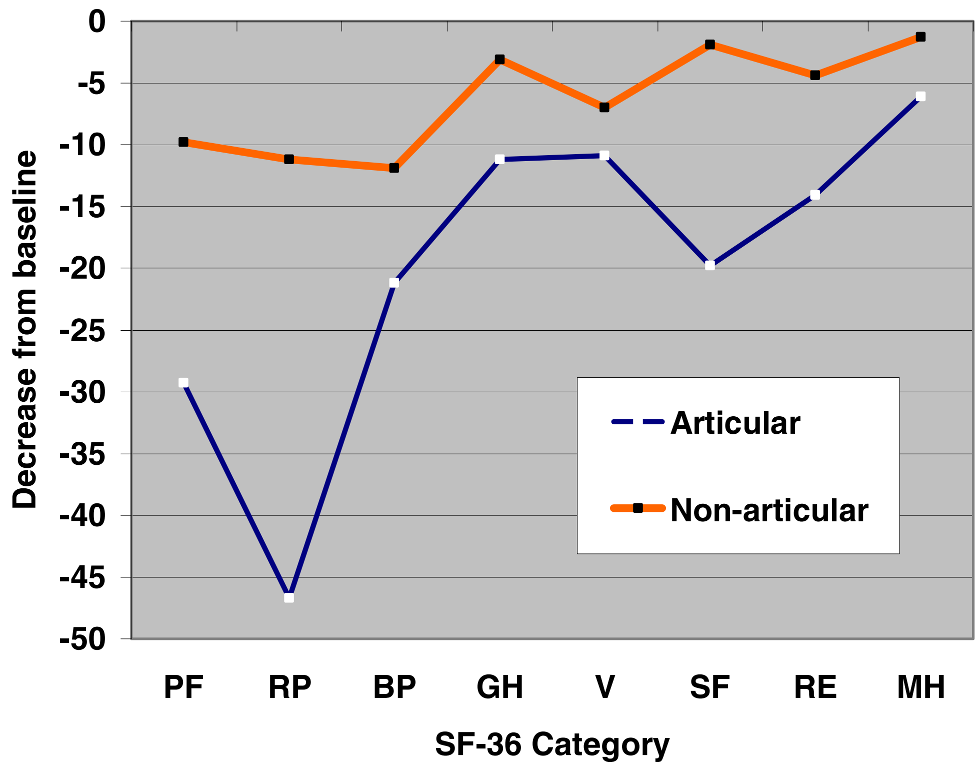

Figure 4. Changes In SF-36 From Baseline To 12 Months By Articular And Non-Articular Surfaces

CONCLUSIONS

Outcomes after motor vehicle crashes result in a wide spectrum of costs, consequences and other issues. On one end of the spectrum it might be as simple as an insurance settlement and vehicle repairs. On the other end is the ultimate poor outcome, death. In between those two points are possibilities beyond imagination. The intention of this study was to look at one of the unique parts of the CIREN program, the SF-36 outcome data. The basic concept was to review the data for individuals 12 months after their crash and to examine their outcomes. In particular to examine if any unique injury could be associated with poorer outcomes 1 year after the crash event.

After a case-by-case review of the 346 cases, significant BRICs were established. With these categories established the outcome data showed significant decreases in SF-36 scores related to head, chest, lower extremity and multiple injury categories.

Although the SF-36 has been shown not to be the best tool for measuring outcome after head trauma [7], our isolated head injury group did show statistically significant decreased scores in General Health and Role Emotional, which could lead to such psychosocial factors as depression and other quality of life issues. Nearly half of the head injury group suffered non-anatomical injuries (concussion), although this type of injury is often referred to as a mild brain injury, the outcome data indicate relevant long-term issues. Many of the more severe brain injury in CIREN do not receive SF-36 scores due to the occupant's inability to answer the questions during the follow-up phase.

The chest group had statistically significant decreased scores in Mental Health, which again could impact the occupant's quality of life. These small emotional and behavioral changes often take a long time to diagnose and treat, if they are properly diagnosed at all. The impact on family and dependents over time can be substantial.

By far the most dramatically impacted groups were the lower extremity and multiple groups. Both of these groups were statistically significant in decreased SF-36 scores in all categories. The SF-36 scores clearly show the lower extremity group suffers long-term consequences and decreased function at a level comparable to the multiple group. The mental category scores are statistically as significant as the physical category scores giving some indication that the effects of these lower extremity injuries have a global effect on the occupant's quality of life.

The multiple group cases are from the most severe crashes, resulting in significant injury in at least two body regions, in some cases as high as four. The crashes for this group had the highest delta V and maximum crush average. The ISS and MAIS average scores were higher for the group as well. Sixty-nine percent of the multiple group cases involved significant lower extremity injury, indicating that even with other body regions sustaining significant injury the lower extremity injury continues to impact the long-term scenario.

The dramatic decreases in Physical Function and Role Physical for both groups indicate the possibility of considerable impact on the occupant's ability to be mobile. Deficits in these two categories greatly impact the basics of locomotion and daily living. Low scores in these categories can indicate issues ranging from job performance / retention to the some of the more basic activities of daily living, such as the ability to stand and walk.

This study also utilized the unique OTA coding in CIREN to farther evaluate the injury details of the lower extremity group. This comparison clearly demonstrates that certain lower extremity injuries have much more significant impacts on the SF-36 scores, especially Physical Function and Role Physical. The ability to capture injury detail to this level really allows the outcomes to be correctly associated with precise lower extremity injury. Other more common coding systems such as AIS and ICD-9 do not attain this level of detail for musculoskeletal trauma and therefore could not achieve this distinction in the lower extremity group.

As more occupants survive crashes secondary to increased presence of air bags, safety belt use and other safety enhancements we may see more disabled occupants. Head and thoracic injuries have been reduced with the evolution of restraint technology, yet lower extremity injuries are the most frequently injured body region. To properly evaluate outcomes, data must be represented appropriately for the task. With the high frequency of lower extremity injuries occurring and many of them involving articular surfaces, this is an issue that warrants further consideration.

REFERENCES

1. National Highway Traffic Safety Administration. Motor vehicle traffic crash fatality and injury estimates for 2000. Washington, D.C.: United States Department of Transportation, National Highway Traffic Safety Administration; 2000

2. National Highway Traffic Safety Administration. CIREN Program Report 2002. Washington, D.C.: United States Department of Transportation, National Highway Traffic Safety Administration; 2002

3. Siegel JH, Mason-Gonzalez S, Dischinger PC, et al. Causes and costs of injuries in multiple trauma patients requiring extrication from motor vehicle crashes. J Trauma. 1993;35:920-931.

4. MacKenzie EJ, Siegel JH, Shapiro S, Moody M, Smith RT. Functional recovery and medical costs of trauma: an analysis by type and severity of injury. J Trauma. 1998;28:281-297.

5. Read KM, Kufera JA, Dischinger PC, et al. Life-altering outcomes after lower extremity injury sustained in motor vehicle crashes. J Trauma 2004;57:815-823.

6. National Center for Statistics and Analysis. National Highway Traffic Safety Administration. www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/NASS.html. Accessed January 2005.

7. MacKenzie EJ, McCarthy ML, Ditunno JF, et al. Using the SF-36 for characterizing outcome after Multiple trauma involving head injury. J Trauma 2002; 52: 527-534.

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

9. "The SF Community – SF36 Health Survey Update" www.sf36.org/tools/sf36.shtml