
Causes of Spinal Cord Injury

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Background: Knowledge of the causes of spinal cord injury (SCI) and associated factors is critical in the development of successful prevention programs. **Objective:** This study analyzed data from the National SCI Database (NSCID) and National Shriners SCI Database (NSSCID) in the United States to examine specific etiologies of SCI by age, sex, race, ethnicity, day and month of injury, and neurologic outcomes. **Methods:** NSCID and NSSCID participants who had a traumatic SCI from 2005 to 2011 with known etiology were included in the analyses (N=7,834). Thirty-seven causes of injury documented in the databases were stratified by personal characteristics using descriptive analysis. **Results:** The most common causes of SCI were automobile crashes (31.5%) and falls (25.3%), followed by gunshot wounds (10.4%), motorcycle crashes (6.8%), diving incidents (4.7%), and medical/surgical complications (4.3%), which collectively accounted for 83.1% of total SCIs since 2005. Automobile crashes were the leading cause of SCI until age 45 years, whereas falls were the leading cause after age 45 years. Gunshot wounds, motorcycle crashes, and diving caused more SCIs in males than females. The major difference among race/ethnicity was in the proportion of gunshot wounds. More SCIs occurred during the weekends and warmer months, which seemed to parallel the increase of motorcycle- and diving-related SCIs. Level and completeness of injury are also associated with etiology of injury. **Conclusions:** The present findings suggest that prevention strategies should be tailored to the targeted population and major causes to have a meaningful impact on reducing the incidence of SCI. **Key words:** epidemiology, etiology, prevention, spinal cord injuries

Spinal cord injury (SCI) is not as common as many other injuries, yet its physical and psychosocial consequences are devastating. Very few people experience complete neurologic recovery after SCI.^{1,2} A significant proportion of SCIs result in neurologically complete and tetraplegic deficits. Lifetime costs of managing SCI and related secondary conditions are staggering and pose a significant burden to individuals with SCI, their families, and society.^{3,4} Hence, given the immense personal and financial burdens of SCI, prevention is critical.

Primary prevention of SCI is currently a global effort. For example, the International Spinal Cord Society (ISCoS) recently launched a global mapping project that provides a structure for an ongoing data repository to inform stakeholders of the development and coordination of prevention strategies.⁵ The reported SCI incidence rate in the United States (39 per million) is close to Canada (35 per million), but it is considerably higher than the figures reported in Western Europe (16 per million) and Australia (15 per million). In addition to differences in methodology, population characteristics, and pre-hospital mortality rates, the increase of SCI incidence in the North America seems to be associated with a higher percentage of violence-related SCIs (18%) compared to Western Europe (8%) and Australia (2%).⁵

Within the United States, SCI incidence differs geographically. Data from the state SCI registries in the 1980s and 1990s showed that the annual rates (per million) were 25 new cases in West Virginia,⁶ 28 in Arkansas,⁷ 30 in Virginia,⁸ 39 in Utah,⁹ 40 in Oklahoma,¹⁰ 43 in New York,¹¹ 45 in Colorado,¹² 46 in Louisiana,¹³ 46 in Georgia,¹⁴ 56 in Rhode Island,¹⁵ 59 in Mississippi,¹⁶ and 83 in Alaska.¹⁷

There are no recent population-based studies that support an increase or decrease in SCI incidence in the United States. Study findings from the National SCI Database (NSCID), however, suggest a changing injury profile over time.^{18,19} The percentage of SCIs due to falls has steadily increased over the last 4 decades, from 17% in the 1970s to 28% in 2005 to 2011. The percentage of SCIs due to violence increased substantially between 1973 and 1999 (up to 29%), but significantly dropped after 2000 (14%). Sports and recreational activities as the cause of SCI continuously declined for about 30 years and then stayed steady over the last 10 years, from 14% in the 1970s to 8% in 2005 to 2011. Motor vehicle crashes have consistently

been the leading cause of SCI over the last 40 years, accounting for about 40% to 50% of all SCIs reported to the NSCID.

Utilizing data from the NSCID and the comparable National Shriners SCI Database (NSSCID) since 2005, this article analyzes specific causes of SCI, rather than the grouped etiologies that have been widely reported in previous investigations. The etiology of SCI is analyzed with respect to age, gender, race/ethnicity, day of the week, month of the year, and neurological level and severity. This information is critical in order to identify specific target populations and risk behaviors for prevention, evaluate the relevance of any ongoing prevention strategies, and determine the needs for health services and care for SCI.

Methods

Data sources

The NSCID began in 1973 and is believed to capture data from approximately 13% to 15% of new SCIs every year in the United States. Since its inception, 28 federally funded SCI Model System centers have contributed data to NSCID, including demographics, injury and medical characteristics, and functional independence during the initial hospitalization and at postinjury years 1 and 5 and every 5 years thereafter.²⁰ Psychosocial outcomes and assistive technology information have also been obtained at each follow-up. The NSCID defines SCI as the occurrence of an acute traumatic lesion of neural elements in the spinal canal, resulting in temporary or permanent sensory and/or motor deficit. The clinical definition of SCI excludes intervertebral disc disease, vertebral injuries in the absence of SCI, nerve root avulsions and injuries to nerve roots and peripheral nerves outside the spinal canal, cancer, spinal cord vascular disease, and other nontraumatic spinal cord diseases. Details about this database have been described elsewhere.²¹ A parallel NSSCID that enrolls children with SCI who received care from the 3 SCI units of the Shriners Hospital for Children in Sacramento, California; Chicago, Illinois; and Philadelphia, Pennsylvania was established in 1987. Data have been collected prospectively since 1987 using the same protocol

as the NSCID.²² The vast majority of children enrolled in the NSSCID are from the United States.

Study participants

The present analyses are limited to persons enrolled in the NSCID and NSSCID who sustained a traumatic SCI between 2005 and 2011 (N=7,882). After excluding those with unknown etiology of injury (n=48), a total of 7,429 persons from 19 SCI Model System Centers and 405 persons from the 3 Shriners SCI units were included in this study. The participating SCI Model System centers and corresponding sample size are as follows: Alabama (n=432), California (n=76, from 2 centers), Colorado (n=946), District of Columbia (n=197), Florida (n=41), Georgia (n=1,907), Illinois (n=350), Massachusetts (n=232), Michigan (n=243), Missouri (n=34), New York (n=286), New Jersey (n=485), Ohio (n=265), Pennsylvania (n=968, from 2 centers), Texas (n=482), Virginia (n=29), and Washington (n=456). **Table 1** shows the participants' characteristics.

Variables, measures, and grouping

Demographic and injury characteristics were collected by trained personnel at each hospital using a standardized protocol during initial hospital care. Age at injury, sex, race, ethnicity, and etiology of injury were obtained either from the hospital admission record or by personal interview. Neurological examinations were performed by physicians or specially trained nurses or physical/occupational therapists in accordance with the version of the International Standards for Neurological Classification of SCI that was in use at the time the examinations were performed.²³ Additional data collection procedures as well as forms and instructions are available on the NSCISC Web site (<https://www.nscis.uab.edu/>).

Statistical analysis

Frequency and percentage were used to describe the most common specific causes of SCI by age, sex, and race/ethnicity. The month and day of injury as well as neurological outcomes were also examined by injury etiologies. All data were

Table 1. Demographic and injury profile of study participants (N=7,834)

Characteristics	n	(%)
Age group, years		
0-15	384	(4.9)
16-30	3,015	(38.5)
31-45	1,645	(21.0)
46-60	1,686	(21.5)
61 and above	1,103	(14.1)
Unknown	1	–
Sex		
Male	6,132	(78.3)
Female	1,700	(21.7)
Unknown	2	–
Race		
White, Non-Hispanic	5,051	(66.8)
Black, Non-Hispanic	1,562	(20.7)
Hispanic	692	(9.2)
Other	252	(3.3)
Unknown	277	–
Level of injury		
C1-C4	2,323	(30.6)
C5-C8	2,091	(27.6)
T1-T6	1,147	(15.1)
T7-S3	1,965	(25.9)
Normal	55	(0.7)
Unknown	253	–
Completeness of injury (AIS)		
A	3,300	(43.6)
B	1,011	(13.4)
C	1,177	(15.6)
D	2,032	(26.9)
E	46	(0.6)
Unknown	268	–
Day of injury		
Monday	1,004	(12.8)
Tuesday	916	(11.7)
Wednesday	976	(12.5)
Thursday	979	(12.5)
Friday	1,118	(14.3)
Saturday	1,483	(18.9)
Sunday	1,358	(17.3)
Month of injury		
January	589	(7.5)
February	490	(6.3)
March	697	(8.9)
April	672	(8.6)
May	750	(9.6)
June	740	(9.5)
July	851	(10.9)
August	715	(9.1)
September	635	(8.1)
October	585	(7.5)
November	555	(7.1)
December	555	(7.1)

Note: AIS = American Spinal Injury Association Impairment Scale.

analyzed and reported in compliance with the International Analytic Standard, as appropriate.²⁴

Results

The NSCID and NSSCID document 37 causes of injury (**Table 2**). The most common etiologies of SCI were automobile crashes (31.5%) and falls (25.3%), followed by gunshot wounds (10.4%), motorcycle crashes (6.8%), diving incidents (4.7%), and medical/surgical complications (4.3%). These 6 causes collectively accounted for 83.1% of total SCIs reported to the NSCID and NSSCID since 2005.

The most common age of injury was between the ages of 16 and 30 years (38.5%), followed by ages 31 to 45 and 46 to 60 years (21.0% and 21.5%, respectively; **Table 1**). The etiology profile varied substantially by age (**Table 3**). Automobile crashes were the leading cause of SCI until age 45 years and then dropped to number 2, whereas falls were the leading cause after age 45 years. In fact, falls accounted for about 75% of all SCIs among persons 76 years of age and older. Gunshot wounds were the second leading cause for persons aged 16 to 30 years (19.0%) and the third most common cause for those 0 to 15 years old (8.1%), but this etiology declined rapidly with advancing age. Motorcycle crashes ranked third for persons 31 to 45 and 46 to 60 years of age (10.9% and 7.1%, respectively). Medical/surgical complications were the second leading cause for children younger than 16 years (12.8%) and the third leading cause for persons older than 60 years (10.9%).

Overall, 78.3% of all reported SCIs occurred among males (**Table 1**). The first 2 leading causes, automobile crashes and falls, collectively accounted for 53.5% of all SCIs in males and 68.6% in females (**Table 4**). Gunshot wounds, motorcycle crashes, and diving caused more SCIs in males than females (11.7% vs 5.8%, 8.0% vs 2.4%, and 5.3% vs 2.4%, respectively). In contrast, medical/surgical complications ranked number 6 for males, but were the third leading cause for females (3.3% vs 7.6%). The major difference in etiology profile among the race/ethnicity group was in the proportion of gunshot wounds that caused 33.0% of all SCIs in blacks, 14.6% in Hispanics, 9.5% in other races, but only 3.0% in whites.

Table 2. Specific etiology of spinal cord injury, 2005-2011

Rank	Specific etiology	n	(%)
1	Auto crash, including jeep, truck, dune buggy, and bus	2,465	(31.47)
2	Fall, including jumping and being pushed accidentally (not as an act of violence)	1,981	(25.29)
3	Gunshot wound	816	(10.42)
4	Motorcycle crash: 2-wheeled, motorized vehicles including mopeds and motorized dirt bikes	533	(6.80)
5	Diving	366	(4.67)
6	Medical/surgical complications: impairment of spinal cord function resulting from adverse effects of medical, surgical or diagnostic procedures and treatment	333	(4.25)
7	Hit by falling/flying object, including ditch cave in, avalanche, rockslide	177	(2.26)
8	Bicycle, tricycles, and unicycles	166	(2.12)
9	All-terrain vehicle and cycle (ATV/ATC): 3-wheeled and 4-wheeled	140	(1.79)
10	Pedestrian, including falling/jumping into the path of a vehicle	100	(1.28)
11	Other sport: auto racing, glider kite, slide, swimming, bungee jumping, scuba diving, roller blading, jet-skiing, cheerleading, etc	82	(1.05)
12	Other unclassified: lightning, kicked by an animal, machinery accidents	76	(0.97)
13	Other vehicular: tractor, bulldozer, go-cart, steamroller, train, road grader, forklift, etc	71	(0.91)
14	Winter sports: sledding, snow tubing, tobogganing, playing ice hockey, snowboarding, etc	67	(0.86)
15	Personal contact, including being hit with a blunt object, falls as a result of being pushed (as an act of violence)	60	(0.77)
16	Surfing, including body surfing	60	(0.77)
17	Snow skiing	55	(0.70)
18	Horseback riding	54	(0.69)
19	Football	35	(0.45)
20	Wrestling	26	(0.33)
21	Other penetrating wounds: stabbing, impalement, etc	25	(0.32)
22	Fixed-wing aircraft	24	(0.31)
23	Snowmobile	20	(0.26)
24	Boat	14	(0.18)
25	Air sports: parachuting, para-sailing, etc	12	(0.15)
26	Gymnastic activities other than trampoline	12	(0.15)
27	Trampoline	11	(0.14)
28	Rodeo, including bronco/bull riding	10	(0.13)
29	Field sports: field hockey, lacrosse, soccer, rugby, etc	8	(0.10)
30	Rotating wing aircraft	7	(0.09)
31	Baseball/softball	6	(0.08)
32	Water skiing	6	(0.08)
33	Basketball/volleyball	5	(0.06)
34	Hang gliding	4	(0.05)
35	Skateboard	3	(0.04)
36	Track and field: pole vault, high jump, etc	3	(0.04)
37	Explosion: bomb, grenade, dynamite, and gasoline	1	(0.01)

More SCIs occurred on Saturday (18.9%) and Sunday (17.3%) than on any other day (**Table 1**), which was likely explained by a higher number of SCIs as a result of motorcycle crashes and diving incidents during the weekends (**Table 5**). On the contrary, fewer SCIs as a result of medical/surgical complications occurred on Saturday and Sunday (6.3% and 5.4%, respectively) than on Monday and Tuesday (19.8% and 21.0%, respectively). SCI seems to occur in cycles. The fewest SCIs occur in February (6.3%); they steadily increase until July (10.9%) and then steadily decline until the next February. This seasonal variation seemed to

parallel the increase in motorcycle- and diving-related SCIs that occur in the warmer months.

Level and completeness of injury is associated with etiology of injury (**Table 6**). Gunshot wounds and medical/surgical complications typically resulted in paraplegia, especially T7-S3 (45.9% and 43.7%, respectively). Diving injury, in contrast, almost always resulted in tetraplegia (44.0% C1-C4 and 52.4% C5-C8). A substantial number of falls and medical/surgical complications resulted in functional motor incomplete injuries (American Spinal Injury Association Impairment Scale [AIS] D, 39.7% and 40.8%, respectively). The majority

Table 3. Top 10 specific etiologies of spinal cord injury by age

Etiology	Age group, years									
	0 - 15 (n=384)		16 - 30 (n=3,015)		31 - 45 (n=1,645)		46 - 60 (n=1,686)		61 & above (n=1,103)	
	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)
Automobile	1	(40.1)	1	(38.4)	1	(32.2)	2	(25.6)	2	(17.4)
Fall	4	(7.6)	3	(10.0)	2	(23.0)	1	(38.4)	1	(56.8)
Gunshot	3	(8.1)	2	(19.0)	4	(9.7)	7	(2.7)	10	(0.7)
Motorcycle	9	(2.3)	5	(6.6)	3	(10.9)	3	(7.1)	4	(2.2)
Diving	5	(5.7)	4	(8.5)	5	(4.2)	-	-	-	-
Medical/surgical	2	(12.8)	-	-	9	(1.6)	4	(6.5)	3	(10.9)
Falling object	10	(1.8)	7	(1.7)	6	(3.3)	6	(2.8)	5	(1.5)
Bicycle	10	(1.8)	-	-	7	(2.8)	5	(3.6)	4	(2.2)
ATV/ATC	7	(3.9)	6	(2.5)	8	(1.8)	-	-	-	-
Pedestrian	8	(3.1)	10	(1.0)	10	(1.4)	8	(1.7)	-	-
Other sport	6	(4.2)	8	(1.5)	-	-	-	-	-	-
Winter sports	-	-	9	(1.4)	-	-	-	-	-	-
Other vehicular	-	-	-	-	-	-	10	(1.4)	6	(1.5)
Surfing	-	-	-	-	-	-	-	-	9	(0.8)
Other unclassified	-	-	-	-	-	-	-	-	7	(1.3)
Horseback riding	-	-	-	-	-	-	9	(1.5)	8	(0.9)
Fixed-wing aircraft	-	-	-	-	-	-	-	-	9	(0.8)

Note: ATV/ATC = all-terrain vehicle/all-terrain cycle.

Table 4. Top 10 specific etiologies of spinal cord injury by sex and race

Etiology	Sex				Race/ethnicity					
	Male (n=6,132)		Female (n=1,700)		White (n=5,051)		Black (n=1,562)		Hispanic (n=692)	
	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)
Automobile	1	(27.9)	1	(44.4)	1	(32.0)	2	(28.9)	1	(34.2)
Fall	2	(25.6)	2	(24.2)	2	(27.1)	3	(19.6)	2	(23.3)
Gunshot	3	(11.7)	4	(5.8)	6	(3.0)	1	(33.0)	3	(14.6)
Motorcycle	4	(8.0)	5	(2.4)	3	(8.2)	5	(3.4)	4	(5.1)
Diving	5	(5.3)	5	(2.4)	4	(5.9)	-	-	6	(3.6)
Medical/surgical	6	(3.3)	3	(7.6)	5	(4.3)	4	(3.8)	5	(4.9)
Falling object	7	(2.7)	-	-	8	(2.5)	8	(1.2)	7	(3.0)
Bicycle	8	(2.4)	9	(1.2)	7	(2.7)	-	-	9	(1.4)
ATV/ATC	9	(1.8)	7	(1.6)	9	(2.4)	-	-	-	-
Pedestrian	-	-	6	(2.2)	-	-	7	(1.6)	8	(2.3)
Horseback riding	-	-	8	(1.5)	-	-	-	-	-	-
Other sport	10	(1.1)	-	-	10	1.2	-	-	-	-
Other unclassified	-	-	-	-	-	-	9	(1.0)	10	(1.2)
Other vehicular	-	-	-	-	-	-	10	(0.7)	-	-
Personal contact	-	-	10	(1.0)	-	-	6	(2.1)	-	-

Note: ATV/ATC = all-terrain vehicle/all-terrain cycle.

Table 5. Day and month of injury by etiology

Characteristics	Specific etiology, %					
	Automobile (n=2,465)	Fall (n=1,981)	Gunshot (n=816)	Motorcycle (n=533)	Diving (n=366)	Medical/surgical (n=333)
Day of injury						
Monday	12.1	15.1	14.2	9.6	10.1	19.8
Tuesday	11.5	12.7	12.3	8.8	6.0	21.0
Wednesday	12.0	13.5	15.3	7.7	7.9	13.8
Thursday	12.0	13.9	9.9	12.8	8.5	17.7
Friday	15.2	14.0	15.1	11.3	10.9	15.9
Saturday	18.8	16.6	17.3	25.3	27.0	6.3
Sunday	18.5	14.1	15.9	24.6	29.5	5.4
Month of injury						
January	8.7	8.0	7.8	3.4	0.3	6.0
February	6.6	6.9	5.6	2.6	1.4	8.7
March	10.6	8.1	9.7	8.6	2.5	8.7
April	8.6	8.7	8.3	11.4	3.6	11.4
May	10.3	8.6	9.2	11.3	9.3	7.5
June	7.7	9.1	9.1	13.1	23.5	8.7
July	8.7	9.6	9.4	16.9	29.0	7.8
August	7.1	9.3	9.3	9.8	19.1	6.9
September	7.1	8.3	7.7	9.4	8.2	8.7
October	8.4	8.1	8.0	5.8	2.2	6.0
November	7.7	8.6	6.9	5.3	0.3	9.3
December	8.6	6.7	8.9	2.4	0.8	10.2

Table 6. Neurologic outcomes of the most common specific etiologies

Outcome	Specific etiology, %					
	Automobile (n=2,394)	Fall (n=1,920)	Gunshot (n=791)	Motorcycle (n=512)	Diving (n=361)	Medical/surgical (n=309)
Level of injury						
C1-C4	30.9	35.1	15.4	27.9	44.0	19.4
C5-C8	30.8	30.3	12.8	16.4	52.4	15.9
T1-T6	16.2	9.2	25.7	32.6	2.2	19.4
T7-S3	21.7	24.3	45.9	22.7	0.6	43.7
Normal	0.5	1.1	0.3	0.4	0.8	1.6
AIS						
A	(n=2,375) 49.9	(n=1,919) 30.2	(n=792) 64.6	(n=514) 51.8	(n=359) 41.8	(n=304) 22.4
B	13.2	10.7	10.2	14.6	30.9	11.8
C	13.9	18.5	12.0	14.4	11.7	23.7
D	22.7	39.7	13.0	18.9	15.0	40.8
E	0.3	1.0	0.1	0.4	0.6	1.3

Note: AIS = American Spinal Injury Association Impairment Scale.

of gunshot wounds and motorcycle crashes resulted in a complete injury (64.6% and 51.8%, respectively).

Discussion

Demographic and injury profiles of the 7,834 persons with SCI enrolled in the NSCID and NSSCID in the past 7 years are generally consistent with previous findings from the population-based studies in the United States during the 1970s to 1990s that reported a higher SCI incidence in males, among those 16 to 30 years of age, among blacks (particularly violence-related SCIs), and during weekends and warmer months.^{6,7,9,10,16,25-27} The present study findings of substantial variations of specific etiologies of injury by age, sex, race/ethnicity, day, and month further highlight the need for prevention strategies to be tailored to the targeted population and major causes of SCI to increase their impact on reducing the incidence of SCI. The strongest efforts at preventing SCI should focus on young males and automobile crashes. Prevention targeting blacks must address violence issues. Prevention programs designed for adolescents and young adults should address risk-taking behaviors, whereas prevention programs for the elderly should be aimed at falls.

The observation of a strong relationship between etiologies and level/completeness of injury also provides insight regarding the mechanisms of injury, which will aid in the design of equipment and other safety measures to reduce the incidence of SCI. In addition to personal characteristics and mechanical causes, there are behavioral and environmental factors that need to be considered in the development and coordination of prevention efforts, for instance, alcohol use, seatbelt use, distracted driving, road conditions, laws and law enforcement, which are beyond the scope of this study.

Limitations

Because of the referral nature of the NSCID and NSSCID, these study results need to be interpreted with caution. The reported proportion of SCIs across different etiologies is a function of the frequency of participation in each activity as well

as the risk of SCI for each activity, both of which vary substantially by personal characteristics. For example, the fact that fewer diving-related SCIs were reported among people aged 46 years or older does not necessarily suggest that diving is safer for this age group than for others. It is likely due to the fact that participation in diving activity declines substantially with advancing age. Similarly, the increase of SCIs caused by medical/surgical complications on Monday and Tuesday might simply be because more procedures are scheduled for those days than other days.

When comparing percentages across different groups, one should remember that a smaller percentage means a relatively small share compared to other entities within the group, but does not necessarily imply a lower risk. For example, automobile crashes caused 17.4% of SCIs among persons 61 years of age and older, but 38.4% for persons age 16 to 30 years. This is not likely due to a lower risk of car crashes in the older group, but rather is more likely explained by a significant portion of falls-related SCIs in the elderly so that car crashes consequently have a relatively smaller share of total injuries.

These are hospital-based cases. It is not feasible to identify appropriate denominator data to calculate actual incidence rates of SCI and estimate the risks across groups. The figures are influenced by the locations of the SCI centers that contributed data to the NSCID and NSSCID during the study period, which might not be applicable to all SCIs occurring in the United States or other countries.

Conclusion

Prevention of SCI must be multifaceted and consider personal characteristics and mechanical causes as well as the social and political context of the injury. As prevention programs likely compete for recognition of benefits and costs against other regional and national agendas and resource priorities, strategies should be aimed at the targeted population and major causes to have the greatest impact on reducing the incidence of SCI. The present study sheds light on recent statistics of the etiology of SCIs in the United States with the hope of developing and implementing cost-effective prevention programs in the years to come.

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