Aging and Spinal Cord Injury: External Causes of Injury and Implications for Prevention

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Background: Despite a consistent trend toward older age at time of spinal cord injury (SCI), little is known about the external causes of SCI in the elderly. **Objective:** To examine environmental circumstances, documented by *International Classification of Diseases, 10th Revision, Clinical Modification* codes, at time of SCI among older adults. **Method:** Data on individuals injured in 2005 or later were retrieved from the National SCI Database. Demographics, injury profiles, and external causes of injury were compared between the study group (age >60 years, $n = 1,079$) and reference group (age 16-45 years, $n = 3,579$) using chi-square and Student *t* tests. **Results:** Among the elderly, falls were the most common etiology of SCI (60%), followed by transport accidents (24%) and complications of medical and surgical care (12%). In the younger group, transport accidents were the most common etiology of SCI (49%), followed by falls (22%) and assault (21%). Falls on the same level (30%), from stairs and steps (22%), and other slipping, tripping, and stumbling (11%) were the most common mechanisms of falls in the elderly group. Among motor vehicle accidents, car occupant injured in a collision with another car was the most common mechanism of injury among the elderly (28%). **Conclusion:** There is an urgent need for effective fall prevention programs among the elderly to reduce SCI in this expanding population. Details on the mechanisms of falls and other major causes of SCI among the elderly provided in this study should inform the development of future interventions for high-risk persons, activities, and environments. **Key words:** aging, epidemiology, primary prevention, spinal cord injuries

With the aging of the United States population, there has been a consistent trend toward older age at time of traumatic spinal cord injury (SCI). Data from the National Spinal Cord Injury Database (NSCID) show that the average age at time of injury has increased from 29 years in the 1970s to 42 years in 2010s.¹ Furthermore, the percentage of persons who were over 60 years of age at time of injury increased from 4.6% in the 1970s to 13.2% during 2005-2008.² This is particularly concerning because age has been shown to negatively impact rehabilitation outcomes after SCI. In particular, older patients with SCI usually experience a longer hospital stay and greater disability and mortality than their younger peers.³⁻⁵

Similar to previous reports in the United States and other countries,⁶⁻⁹ our earlier epidemiology study demonstrated that falls constitute the most common cause of SCI among older adults,

followed by motor vehicle accidents.¹⁰ Methods to prevent the mechanisms that lead to SCI in the elderly would likely have a profound impact on the quality of life for many individuals in the United States and worldwide. However, little is known about the environmental events and circumstances surrounding SCI among the elderly.

In the present study, we analyzed data from the NSCID to document the usual circumstances surrounding the occurrence of SCI among persons over 60 years of age at the time of injury in reference to their younger counterparts (age 16-45 years). Demographic and injury profiles were also compared between these 2 age groups. We anticipate that descriptive statistics generated from this study will help develop appropriate programs aimed at high-risk persons, activities, and environmental factors for preventing or reducing SCI in the elderly.

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Methods

Data source

The NSCID contains information on persons in the United States with traumatic SCI who received initial hospital care from one of the 28 SCI Model Systems Centers since 1973. Data collection, including demographics, medical characteristics, physical functioning, and psychosocial outcomes, occurs during initial hospitalization, at postinjury years 1, 5, and 10, and every 5 years thereafter. Details about the NSCID have been described elsewhere.¹¹ Institutional review board approval was obtained at the National SCI Statistical Center as well as locally at each participating SCI Model Systems center before data collection.

Study participants

There were 6,416 persons with SCI from 21 SCI Model Systems Centers reported to the NSCID

between September 2005 and September 2014, the period during which external causes of injury were documented. After excluding 87 individuals with unknown external causes of injury, 1,079 (17%) individuals who were older than 60 years and 3,579 (57%) individuals who were 16 to 45 years old were eligible for this study. This age categorization is recommended by the International SCI Data Standards.¹² **Table 1** summarizes the demographic, injury, and medical characteristics of study participants.

External causes of injury

In addition to the 37 descriptive causes of injury,¹⁰ the NSCID utilizes the *International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM)* code to capture further how the SCI occurred, the intent (accidental or intentional), place, and activity.¹³ The *ICD-10* coding structure has been applied in injury

Table 1. Demographic and injury profile of study participants (N = 4,658)

Characteristics ^a	Age ≥61 years (n=1,079)	Age 16-45 years (n=3,579)	P
Age, mean (SD), years	69.9 (7.3)	28.3 (8.6)	<.0001
Sex, male	776 (71.9)	2,922 (81.7)	<.0001
Race			<.0001
White	805 (76.9)	1,986 (56.5)	
Black	158 (15.1)	978 (27.8)	
Hispanic	46 (4.4)	422 (12.0)	
Other	38 (3.6)	130 (3.7)	
Marital status			<.0001
Single	86 (8.1)	2,449 (68.9)	
Married/significant other	682 (64.0)	792 (22.3)	
Divorced/separated/widowed	298 (28.0)	312 (8.8)	
Education			<.0001
Less than high school	107 (11.3)	863 (25.3)	
High school	451 (47.4)	1,902 (55.8)	
College or higher	370 (38.9)	607 (17.8)	
Other	23 (2.4)	34 (1.0)	
Occupation			<.0001
Employed	316 (29.7)	2,149 (60.7)	
Student/trainee	2 (0.2)	621 (17.5)	
Retired	655 (61.6)	6 (0.2)	
Other	91 (8.6)	764 (21.6)	

(Continued)

Table 1. Demographic and injury profile of study participants (*N* = 4,658) (CONT.)

Day of injury			<.0001
Monday	173 (16.0)	448 (12.5)	
Tuesday	135 (12.5)	384 (10.7)	
Wednesday	167 (15.5)	399 (11.2)	
Thursday	160 (14.8)	401 (11.2)	
Friday	155 (14.4)	497 (13.9)	
Saturday	149 (13.8)	733 (20.5)	
Sunday	140 (13.0)	717 (20.0)	
Month of injury			.001
January	86 (8.0)	242 (6.8)	
February	79 (7.3)	209 (5.8)	
March	74 (6.9)	317 (8.9)	
April	92 (8.5)	303 (8.5)	
May	106 (9.8)	335 (9.4)	
June	84 (7.8)	319 (8.9)	
July	86 (8.0)	411 (11.5)	
August	105 (9.7)	315 (8.8)	
September	79 (7.3)	314 (8.8)	
October	88 (8.2)	286 (8.0)	
November	96 (8.9)	273 (7.6)	
December	104 (9.6)	255 (7.1)	
Work-related injury, yes	43 (4.0)	315 (8.9)	<.0001
Associated injury, yes	200 (20.2)	1,563 (48.6)	<.0001
Vertebral injury, yes	602 (60.7)	2,867 (89.1)	<.0001
Level of injury			<.0001
Cervical	681 (72.9)	1,559 (47.6)	
Thoracic	169 (18.1)	1,344 (41.0)	
Lumbar	74 (7.9)	357 (10.9)	
Sacral	3 (0.3)	9 (0.3)	
Normal	7 (0.8)	8 (0.2)	
AIS grade			<.0001
A	145 (15.1)	1,576 (46.8)	
B	79 (8.2)	530 (15.7)	
C	184 (19.2)	462 (13.7)	
D	545 (56.8)	793 (23.5)	
E	7 (0.7)	8 (0.2)	
Neurological category			<.0001
C1-C4, AIS A, B, C	167 (17.7)	556 (16.7)	
C5-C8, AIS A, B, C	84 (8.9)	535 (16.1)	
T1-S3, AIS A, B, C	140 (14.9)	1,434 (43.1)	
AIS D, E	552 (58.5)	801 (24.1)	

(Continued)

Table 1. Demographic and injury profile of study participants ($N = 4,658$) (CONT.)

Rehabilitation length of stay, mean (<i>SD</i>), days	49.8 (60.1)	54.6 (39.4)	.02
Discharge disposition			
Private residence	734 (68.3)	3,230 (90.7)	<.0001
Hospital/nursing home/assisted living	295 (27.5)	291 (8.2)	
Deceased	39 (3.6)	11 (0.3)	
Other	6 (0.6)	31 (0.9)	

Note: Values are given as n (%), unless otherwise indicated. AIS = American Spinal Injury Association Impairment Scale.

^aRecords with unknown or missing values were excluded from analysis.

research since 1994.¹⁴⁻¹⁶ In a study that examined the usefulness of the *ICD-10-CM* system in documenting public health diseases, Watzlaf et al¹⁷ concluded that compared with *ICD-9-CM*, *ICD-10-CM* captures external causes of injury more straightforwardly and clearly.

Variables and measures

Trained personnel obtained demographic, injury, and medical characteristics from medical records and by personal interview. Neurological examinations were performed within 7 days of discharge 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.¹⁸

Based on the International SCI Data Standards,¹⁹ vertebral injury was defined as any break, rupture, or crack in any bone that is part of the vertebral column from the occiput to the coccyx. Associated injury referred to the presence of any of the following injuries occurring at the time of SCI: traumatic brain injury (Glasgow Coma Scale ≤ 12), nonvertebral fractures, severe facial injuries affecting sense organs, major chest injury, traumatic amputations of an arm or leg, severe hemorrhaging, and damage to any internal organ requiring surgery.

A work-related case was defined as any injury incurred in the course of employment, according to the Operational Guidelines for Determination of Injury at Work developed in 1992.²⁰ Additional NSCID data collection procedures as well as forms

and instructions are located on the National SCI Statistical Center Web site (<https://www.nscisc.uab.edu/>).

Data analysis

Descriptive statistics (mean, *SD*, frequency, and percentage) were used to describe demographic and medical characteristics of study participants as well as external causes of injury by age groups. Student *t* test and chi-square test, as appropriate, were used to assess the differences between the 2 age groups at a statistical significance level of .05.

Results

Participant characteristics

As shown in **Table 1**, the percentages of individuals who were female, White, married, college graduates, or retirees were higher in the elderly group than in the younger comparison group. Work-related injury was less common in the elderly group. We did not find any meaningful trend with respect to the day of week or the month of year when the SCI occurred among the elderly. In contrast, persons who were 16 to 45 years old sustained SCI more frequently during the weekends and in July, but least commonly in February.

Individuals who sustained an SCI at age 61 years or older were less likely than those who sustained SCI at a younger age to have associated injury (20% vs 49%) and vertebral injury (61% vs 89%), but

were more likely to have cervical (73% vs 48%) and American Spinal Injury Association Impairment Scale (AIS) D injury (57% vs 24%). Among the elderly, the rehabilitation length of stay was slightly shorter than that of the younger group (50 vs 55 days), yet a higher percentage of elderly patients were discharged to a nursing home (28% vs 8%) or died during initial hospitalization (3% vs 1%).

External cause of injury

Among the elderly, slipping, tripping, stumbling, and falls constituted the most common etiology, accounting for 60% of all SCIs that occurred in this group (**Table 2**). Transport accidents were the second leading cause of SCI among the elderly (24%), followed by complications of medical and surgical care (12%). Intentional self-harm and assault were rare causes of SCI in the elderly population compared with their younger counterparts (0.0% vs 0.8% and 1% vs 21%, respectively).

Based on the *ICD-10-CM* coding structure, accidental falls were further classified into 19 mechanisms (**Table 3**). A large percentage of the fall-induced SCIs among the elderly occurred on the same level (30%). Falls from stairs was the second most common scenario among the elderly

(22%), followed by other slipping, tripping, and stumbling (11%) such as falls from or off the toilet and in the shower or empty bathtub. In contrast, among younger individuals, the most common mechanisms of injury included falls from a building (21%), ladder (8%), or tree (7%), and about 39% of these falls were work-related. SCIs resulting from falls, jumps, or diving into water, of which the majority was related to sports and recreational activities, accounted for a very small proportion of injuries in older adults with fall-related SCI compared with the proportion of younger peers (1% vs 31%).

The majority of transport accidents involved motor vehicles (V20-V79), with motor vehicles involved in 69% of transport accident-related SCI cases in older persons and 79% of transport accident-related SCI cases in younger persons. Further details about the motor vehicle accidents, documented by the *ICD-10-CM* system, are provided in **Table 4**. Among the elderly, injury sustained by the car occupant in transport accidents was most common, particularly in collisions with another car, van, pick-up truck, or sports utility vehicle (28%). Noncollision transport accidents, such as a car overturning without collision, accounted for 16% of motor vehicle accidents among the elderly but 27% in

Table 2. Classification of external causes of injury by the *ICD-10-CM* coding structure

<i>ICD-10-CM</i> code	Description	Age ≥61 years (n=1,079)	Age 16-45 years (n=3,579)
V00-V99	Transport accidents	261 (24.2)	1753 (49.0)
W00-W19	Slipping, tripping, stumbling and falls	644 (59.7)	768 (21.5)
W20-W64	Exposure to inanimate/animate mechanical forces	23 (2.1)	133 (3.7)
W65-W74	Accidental drowning and submersion	2 (0.2)	4 (0.1)
W85-X58	Accidental exposure to electric current, radiation, extreme temperature and pressure, smoke, fire, and other factors	3 (0.3)	10 (0.3)
X71-X83	Intentional self-harm	0 (0.0)	28 (0.8)
X92-Y08	Assault	11 (1.0)	762 (21.3)
Y21-Y33	Event of undetermined intent	3 (0.3)	42 (1.2)
Y35-Y38	Legal intervention, operations of war, military operations, and terrorism	2 (0.2)	8 (0.2)
Y62-Y84	Complications of medical and surgical care	128 (11.9)	51 (1.4)
Y90-Y99	Supplementary factors related to causes of morbidity classified elsewhere	2 (0.2)	20 (0.6)

Note: Values are given as n (%).

Table 3. Slipping, tripping, stumbling, and falls (W00-W19) as a cause of spinal cord injury

ICD-10-CM code	Description	Age ≥61 years (n=644)	Age 16-45 years (n=768)
W00	Fall due to ice and snow	17 (2.6)	8 (1.0)
W01	Fall on same level from slipping, tripping, and stumbling	190 (29.5)	44 (5.7)
W03	Other fall on same level due to collision with another person	0 (0.0)	7 (0.9)
W04	Fall while being carried or supported by other persons	0 (0.0)	2 (0.3)
W05	Fall from non-moving wheelchair	1 (0.2)	0 (0.0)
W06	Fall from bed	27 (4.2)	10 (1.3)
W07	Fall from chair	12 (1.9)	5 (0.7)
W08	Fall from other furniture	5 (0.8)	4 (0.5)
W09	Fall on and from playground equipment	0 (0.0)	9 (1.2)
W10	Fall on and from stairs and steps	141 (21.9)	34 (4.4)
W11	Fall on and from ladder	35 (5.4)	64 (8.3)
W12	Fall on and from scaffolding	3 (0.5)	19 (2.5)
W13	Fall from, out of or through building or structure	37 (5.7)	162 (21.1)
W14	Fall from tree	11 (1.7)	54 (7.0)
W15	Fall from cliff	1 (0.2)	7 (0.9)
W16	Fall, jump or diving into water	8 (1.2)	239 (31.1)
W17	Other fall from one level to another	24 (3.7)	51 (6.6)
W18	Other slipping, tripping and stumbling and falls	69 (10.7)	18 (2.3)
W19	Unspecified fall	63 (9.8)	31 (4.0)

Note: Values are given as n (%).

the younger age group. Motorcycle injury was relatively uncommon among the elderly group compared with the young group (12% vs 21%). Regarding the driver or passenger role at the time of injury, there was no substantial difference between these 2 age groups (60% vs 50%).

There was no substantial difference between the 2 age groups in types of medical and surgical complications that resulted in SCI. The majority of these cases were due to an abnormal reaction in the individual or to a later complication of a surgical operation and other surgical procedures (Y83; 67% among the elderly and 61% among the younger group). Other medical procedures as the cause of an abnormal reaction in the patient or of a later complication without mention of misadventure at the time of the procedure (Y84) accounted for 16% and 10% of injuries in older and younger SCI cases, respectively. Misadventures to patients during surgical and medical care (Y62-Y69) and medical devices associated with adverse

incidents in diagnostic and therapeutic use (Y70-Y82) occurred at the same frequency (9%) among older SCI patients, whereas the corresponding frequencies for the younger age group were 16% and 14%, respectively.

Discussion

In this large study of older adults who acquired SCI in a recent 10-year period, we confirm that accidental falls are the leading cause of SCI, followed by transport accidents. Our study cohort is unique in that SCI cases resulting from medical and surgical complications, which make up the third largest group among the elderly with SCI, are enrolled in the database. This group is not usually documented by studies of traumatic SCI.⁶⁻⁹ The demographic and injury profiles of SCI in our study are generally consistent with previous reports in the aging population, including a high percentage of cervical and motor functionally

Table 4. Motor vehicle accidents (V20-V79)^a as a cause of spinal cord injury

	Participant injured in:				
Collided with:	Motorcycle	Car	Van, P/up, SUV	Bus, heavy transport	Total
Age >60 years					
Pedestrian or animal	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2- or 3-wheeler	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Car, van, P/up, SUV	6 (3.4)	50 (27.9)	7 (3.9)	0 (0.0)	63 (35.2)
Heavy transport, bus	1 (0.6)	8 (4.5)	0 (0.0)	3 (1.7)	12 (6.7)
Train, railway vehicle	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Non-motor vehicle	0 (0.0)	3 (1.7)	0 (0.0)	0 (0.0)	3 (1.7)
Fixed object	2 (1.1)	27 (15.1)	4 (2.2)	1 (0.6)	34 (19.0)
Other/Unspecified	5 (2.8)	31 (17.3)	1 (0.6)	2 (1.1)	39 (21.8)
Noncollision (rollover)	7 (3.9)	17 (9.5)	4 (2.2)	0 (0.0)	28 (15.6)
Total	21 (11.7)	136 (76.0)	16 (8.9)	6 (3.4)	179 (100.0)
Age 16-45 years					
Pedestrian or animal	2 (0.1)	19 (1.4)	0 (0.0)	0 (0.0)	21 (1.6)
2- or 3-wheeler	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)
Car, van, P/up, SUV	72 (5.4)	202 (15.1)	22 (1.6)	2 (0.1)	298 (22.3)
Heavy transport, bus	4 (0.3)	21 (1.6)	4 (0.3)	2 (0.1)	31 (2.3)
Train, railway vehicle	0 (0.0)	1 (0.1)	0 (0.0)	1 (0.1)	2 (0.1)
Non-motor vehicle	2 (0.1)	7 (0.5)	2 (0.1)	0 (0.0)	11 (0.8)
Fixed object	60 (4.5)	220 (16.4)	36 (2.7)	1 (0.1)	317 (23.7)
Other/Unspecified	59 (4.4)	216 (16.1)	10 (0.7)	8 (0.6)	293 (21.9)
Noncollision (rollover)	86 (6.4)	211 (15.8)	65 (4.9)	3 (0.2)	365 (27.3)
Total	286 (21.4)	897 (67.0)	139 (10.4)	17 (1.3)	1,339 (100.0)

Note: Values are given as *n* (%); P/up = pick-up truck; SUV = sports utility vehicle.

^aParticipants injured in 3-wheeled motor vehicle (V30-V39) were not included because of small sample size (0 older and 14 younger cases).

incomplete injuries.^{6-9,21,22} Thus, this study further expands previous studies to document the environmental circumstances associated with SCI, using the *ICD-10-CM* system, among the elderly.

Our observations suggest that most fall-induced SCIs among the elderly occur at home and are the result of slipping, tripping, stumbling, and falling on the same level; from stairs, steps, beds, chairs, and toilets; and in showers and bathtubs. These results are similar to those of a study by Buczak-Stec et al¹⁴ in which the *ICD-10* coding structure was used to document fall-related hospital admissions in the elderly population in Poland. Therefore, home safety is crucial to reduce falls and ultimately SCI among the elderly. The living environments should

be improved by removing clutter, loose carpets, and uneven floor surfaces and by providing good lighting, hand rails, appropriate toilets and beds, among other modifications.

In addition to home modification, a compendium of 22 evidence-based fall prevention programs recently put together by the Centers for Disease Control and Prevention (CDC) emphasizes exercise and multifaceted interventions.²³ In a recent review, Rubenstein et al²⁴ classified existing fall intervention strategies into 5 groups: multidimensional fall risk assessment to reduce risk, exercise intervention, environmental assessment and modification, multifactorial intervention, and institutional interventions. Fall prevention

programs targeting older adults should underscore SCI as one of the serious consequences associated with falls. The Stopping Elderly Accidents, Deaths and Injuries (STEADI) tool kit is another resource created by the CDC for health care providers to use in assessing and addressing fall risk with their older patients.²⁵

Previous survey research and reports showed that older drivers tend to avoid driving during bad weather and at night, drive fewer miles, wear seat belts more often, and are less likely to drink and drive than are younger drivers.^{26,27} Yet transport accidents account for about 24% of total SCI patients who were older than 60 years at the time of injury in our study cohort. Action plans to enable older adults to stay safe on the road that are recommended by the CDC and other resources focus on exercises to maintain strength and endurance, review of medications to reduce side effects, adjustment of driving schedule as appropriate, minimization of distractions, performance of regular eye checks to maintain good vision, and adequate sleep and rest.²⁶

Limitations

The study findings have to be interpreted with caution because of several limitations. Study participants were recruited from SCI Model System hospitals, which might not be fully representative of all persons with SCI in the United States and other countries. One point that deserves mentioning is that the NSCID study population tends to underrepresent neurologically mild SCI cases, which are relatively common among older adults and often result from falls on the same level.

This study is also constrained by the limitation of the *ICD-10-CM* coding structure. For example, the *ICD-10-CM* does not capture the use of alcohol and drugs or the sequence of events (underlying versus direct mechanism) leading to the SCI. The World Health Organization's International

Classification of External Cause of Injury (ICECI) includes 7 core modules: mechanism of injury, objects/substances producing injury, place of occurrence, activity when injured, the role of human intent, use of alcohol, and use of (other) drugs. Additional data on special topics can be collected because this system also includes 5 etiology modules: violence, transport, place, sports, and occupational injury.²⁸ The ICECI could be an alternative or supplement for better documenting the multidimensional and hierarchical nature of the injury and the international comparability across studies, as suggested by a previous study.²⁹

Conclusion

This is the first large study that reports environmental events and circumstances as external causes of SCI among the elderly, using the *ICD-10-CM* coding structure. This study provides details on the mechanisms of falls, transport accidents, and medical/surgical complications as well as various medical consequences among the elderly. Future interventions should be developed for high-risk persons, activities, and environments. In light of the aging population in the United States and the data supporting falls as the most common causes of SCI in the elderly, there is a particularly urgent need for effective fall prevention programs to reduce SCI in this population.

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The authors declare no conflicts of interest.

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