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ORIGINAL ARTICLE

Incidence of traumatic spinal cord injury in Denmark, 1990–2012: a hospital-based study

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Study design: Hospital-based incidence study.
Objectives: To assess the incidence of traumatic spinal cord injuries (TSCIs) and TSCI incidence trends in relation to cause, age, gender, level and completeness of injury.
Setting: Spinal Cord Injury Centre of Western Denmark.
Methods: We reviewed medical records of TSCI patients admitted between 1 January 1990 and 31 December 2012. Proportions, incidence rates and incidence rate ratios were calculated for five time periods; 1990–94, 1995–99, 2000–04, 2005–09 and 2010–12, and were stratified on age, gender, cause, level and completeness of TSCI. TSCI incidence was calculated as the number of new cases divided by person-years at risk.
Results: Included were 691 patients (males 81.9%). Within the study period, median age at time of injury rose from 29.0 to 47.5 years. The overall annual TSCI incidence during the study period 1990–94 to 2010–12 was 10.2 per million person-years at risk and varied from 8.3 to 11.8. The proportion of transport-related injuries fell from 56.9% in the first to 36.8% in the most recent time period. Fall-related injuries rose from 11.1 to 35.5%. The proportion of incomplete tetraplegia increased from 32.0% in the first to 40.5% in the last time period.
Conclusions: The overall TSCI incidence is low and remained stable from 1990 to 2012. The proportion of transport-related injuries fell, while age at time of injury and proportion of fall-related injuries and proportion with incomplete tetraplegia all increased.
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INTRODUCTION

The annual incidence of traumatic spinal cord injury (TSCI) varies from 10 to 83 per million inhabitants according to population- and hospital-based epidemiologic data, with most countries reporting an annual incidence of 15–30 per million.[1,2] The annual average incidence of TSCI in Europe has risen from approximately 14 to 19 per million during the past 30 years.[2] Most countries have seen an increase in age at time of injury, percentage of tetraplegia and incomplete lesions.[2] Studies from the Nordic countries generally report lower TSCI incidence rates than the rest of Europe.[1,2] In Norway, the annual incidence rose from 6.2 to 26.3 per million from 1952 to 2001; the incidence of fall-related injuries increased as did age when TSCI was incurred.[3] In Finland, the mean annual incidence rate is estimated to 13.8 per million inhabitants; a significant rise in incidence among persons older than 55 years is seen over a 30-year period.[4] In Sweden, the estimated annual incidence is 19.5 per million and falls are the leading cause of injury.[5] In Iceland, the estimated incidence is 30.5 per million.[6] In Denmark, the estimated annual incidence was 9.2 per million inhabitants from 1975 to 1984.[7] Data on incidence, prevalence and cause of injury are critical to prevention and planning of clinical and community services for this patient group.[1] The most recent Danish data on TSCI were published in 1990;[7] thus, updated data are needed. This study aims to assess the incidence of TSCI and TSCI incidence trends in relation to cause, age, gender, level and completeness of injury.

MATERIALS AND METHODS

This incidence study included all TSCI cases admitted to the Spinal Cord Injury Centre of Western Denmark between 1 January 1990 and 31 December 2012. TSCI patients who died before reaching a hospital or the rehabilitation centre were not included; nor were patients with minor motor and sensory dysfunction and patients with no rehabilitation potential. The catchment area of the Spinal Cord Injury Centre of Western Denmark covers Jutland and Funen; the population counted 2.8 million person in 1990 and 3.0 million in 2012, which corresponds to approximately 60% of the Danish population. Within its catchment area, the centre is responsible for primary rehabilitation and lifelong follow-up of all TSCI persons regardless of their age.

Definition of TSCI

TSCI is defined according to Kraus *et al.*[8] as an acute, traumatic lesion of the spinal cord with varying degrees of motor and/or sensory deficit or paralysis. Injury of the cauda equina was included in the definition, but isolated injury of other nerve roots was excluded.[9,10] Level and completeness of TSCI was determined on admission to primary rehabilitation at the Spinal Cord Injury Centre of Western Denmark usually weeks to months after the injury.

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Data collection

The study participants' records were reviewed by one of the authors (EMH) in collaboration with a research assistant to extract data on age at time of injury, year of injury, cause of injury and level and completeness of injury. Data were extracted with reference to the International Spinal Cord Injury Core Data Set. [9,11]

Data analyses

The age groups were defined as: <30, 30–60 and >60 years. The year of injury was categorized into periods of 5 years in accordance with the International Spinal Cord Injury Core Data Set[9]: 1990–94, 1995–99, 2000–04, 2005–09, except for the last period, 2010–12, which included only 3 years. Causes of TSCI were categorized as transport-related injuries, falls, sports and recreational injuries, and other injuries. The last category included eight people injured due to assaults. Level and completeness were categorized as paraplegia vs tetraplegia and incomplete vs complete.

Statistical analyses

The characteristics of the study population are described in terms of frequencies and proportions. For age, median and range are reported. TSCI incidence was calculated as the number of new cases divided by person-years at risk. Data on person-years were retrieved from Statistics Denmark.[12] TSCI incidence rate ratios (IRRs) and TSCI severity were calculated using Poisson regression models adjusted for gender, age groups and time period. The χ^2 test of goodness-of-fit test (deviance) of the Poisson regression was used for model control. The statistical analyses were performed using Stata version 12 (StataCorp., College Station, TX, USA).

Ethics

The study was approved by the Danish Data Protection Agency (journal number 2013-41-2131) www.datatilsynet.dk.

RESULTS

A total of 691 patients with TSCI were admitted to the Spinal Cord Injury Centre of Western Denmark during the period 1990–2012. Their characteristics are shown in Table 1. The female to male ratio varied from 1:3.8 to 1:5.3 during the period. The median age at injury rose from 29.0 during the first time period to 47.5 during the most recent time period. Overall, 41.8% was injured at age <30 years, 44.7% at age 30–60 years and 13.5% was >60 years. During the study period, the proportion of persons injured at age <30 years decreased, whereas the proportion of those aged 30–60 years and >60 years at the time of injury increased. The overall annual TSCI incidence was 10.2 per million person-years at risk. Over the study period, the annual incidence varied between 8.3 and 11.8 per million person-years at risk (Table 2).

During the entire period, transport was the leading cause of injury (50.2%) and falls the second (22.7%) (Table 1). The cause-specific incidence of TSCI by gender and age at injury is shown in Table 3. During the study period, the annual incidence of transport-related injuries among men under the age of 30 years fell from 17.2 to 4.1 indicating a decreasing trend. The annual incidence of such injury among men above the age of 60 years rose from 1.6 to 5.9 per million person-years at risk (Table 3). The incidence of fall-related injuries among men showed an increasing trend. Among 30- to 60-year-old men, the incidence rose from 4.2 in 1900–1994 to 7.6 in 2010–2012. Among men >60 years, the annual incidence rose from 2.4 in 1990–1994 to 9.9 per million person-years at risk in the period 2005–2009, although a decrease to 5.9 was observed in the most recent time period. The incidence among women varied between 2.6 and 4.3 for all causes and all ages throughout the study period without any increasing or decreasing trend.

Table 4 shows the adjusted IRR of TSCI according to cause of injury. For transport-related injury, the incidence was associated with younger age at the time of injury. Compared with the youngest age category (<30 years), the IRR was 0.74 for 30- to 60-year-olds and 0.34 for age >60 years. In contrast, the incidence of fall-related injury was associated with older age at injury: IRR 6.51 for the 30- to 60-year-olds and 7.47 for age >60 years compared with age <30 years. For transport-related injuries, the incidence was associated with time period. Using the time period 1990–1994 as a reference, the IRR was 0.52 in the period 2010–2012. For fall-related injuries, the IRR was 2.35 in the period 2000–2004, and similar in the later time periods.

Table 5 features the level and completeness according to cause of TSCI for the different time periods. The proportion of incomplete tetraplegia irrespective of cause varied between 29.5 and 40.5% during

Table 1 Characteristics of the TSCI patients by time period

Characteristics	*Time period*					
	1990–1994 n = *153*	*1995–1999* n = *129*	*2000–2004* n = *174*	*2005–2009* n = *159*	*2010–2012* n = *76*	*Total* N = *691*
Age and gender						
Age at injury median	29.0	33.0	35.5	43.0	47.5	35.0
Age at injury range	0–75	13–73	12–78	12–83	15–82	0–83
<30 years at injury (%)	57.5	45.0	40.2	30.8	31.6	41.8
30–60 years at injury (%)	36.0	48.0	44.8	49.1	47.4	44.7
> 60 years at injury (%)	6.5	7.0	15.0	20.1	21.0	13.5
Male (%)	83.7	79.1	83.3	79.9	84.2	81.9
Female (%)	16.3	20.9	16.7	20.1	15.8	18.1
Causes of TSCI						
Transport (%)	56.9	51.2	53.5	45.9	36.8	50.2
Falls (%)	11.1	11.6	24.7	34.6	35.5	22.7
Sport (%)	22.2	31.0	15.0	8.8	17.1	18.4
Other (%)	9.8	6.2	6.9	10.7	10.5	8.7

Abbreviation: TSCI, traumatic spinal cord injury.

Table 2 Incidence of TSCI in Western Denmark from 1990 to 2012

Time period	*Total*			*Male*			*Female*		
	Cases	*Person-years (million)*	*Incidence*	*Cases*	*Person-years (million)*	*Incidence*	*Cases*	*Person-years (million)*	*Incidence*
1990–1994	153	14.3	10.7	128	7.1	18.0	25	7.2	3.5
1995–1999	129	14.6	8.7	102	7.2	14.1	27	7.3	3.7
2000–2004	174	14.7	11.8	145	7.3	19.7	29	7.4	3.9
2005–2009	159	15.0	10.6	127	7.5	17.0	32	7.5	4.6
2010–2012	76	9.1	8.3	64	4.6	14.1	12	4.6	2.6
Total	691	67.7	10.2	566	33.7	16.8	125	34.0	3.7

Abbreviation: TSCI, traumatic spinal cord injury.

Table 3 Incidence of TSCI per million person-years at risk by time period, according to gender, cause and age at injury

Causes	*Age group*	*Time period*				
		1990–1994	*1995–1999*	*2000–2004*	*2005–2009*	*2010–2012*
Male						
Transport	<30	17.2	9.2	15.5	8.6	4.1
	30–60	6.9	7.5	8.8	9.5	5.4
	>60	1.6	1.6	6.1	3.3	5.9
Falls	<30	0.3	0.3	1.1	0.7	1.8
	30–60	4.2	2.3	6.6	7.9	7.6
	>60	2.4	3.2	8.3	9.9	5.9
Sports	<30	4.7	7.6	3.9	2.9	4.1
	30–60	3.5	2.9	2.5	1.3	2.2
	>60	0.8	0.8	0.8	0.0	0.0
Other	<30	2.7	0.0	1.1	2.1	1.2
	30–60	1.7	1.9	1.9	1.9	2.2
	>60	0.8	0.0	0.8	1.3	1.0
All causes	<30	24.9	17.2	21.5	14.3	11.2
	30–60	16.3	14.6	19.7	20.6	17.3
	>60	5.6	5.6	15.9	14.5	12.9
All causes	All ages	18.0	14.1	19.7	17.0	14.1
Female						
Transport	<30	2.9	1.8	1.9	1.5	1.3
	30–60	1.8	2.7	2.6	2.3	0.6
	>60	0.6	0.6	0.0	1.7	1.7
Falls	<30	0.0	0.0	0.0	0.8	0.6
	30–60	0.4	0.7	1.3	1.6	1.1
	>60	0.0	0.6	2.5	3.4	0.9
Sport	<30	1.8	0.7	1.5	0.8	0.6
	30-60	0.7	2.0	0.3	0.0	0.6
	>60	1.3	0.0	0.6	0.0	0.0
Other	<30	0.4	0.4	0.0	0.4	0.6
	30–60	0.0	0.3	0.7	0.3	0.0
	>60	0.0	0.0	0.0	0.6	0.0
All causes	<30	5	2	3.3	3.4	3.1
	30–60	2.7	5.7	4.9	4.2	2.2
	>60	1.9	1.3	3.1	5.6	2.6
All causes	All ages	3.5	3.7	3.9	4.3	2.6

Abbreviation: TSCI, traumatic spinal cord injury.

Table 4 Adjusted estimates of incidence rate ratios (IRRs) of TSCI by cause of TSCI

	Cause of TSCI				
	Transport IRR	*Falls IRR*	*Sports IRR*	*Other IRR*	*All causes IRR*
Gender[a]					
Male	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
Female	0.21	0.22	0.28	0.22	0.22
Age group[b]					
<30	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
30–60	0.74	6.51	0.56	0.99)	0.99
>60	0.34	7.47	0.16	0.64	0.64
Time period[c]					
1990–1994	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
1995–1999	0.75	0.85	1.16	0.83	0.83
2000–2004	1.05	2.35	0.76	1.10	1.10
2005–2009	0.82	2.91	0.41	1.00	1.00
2010–2012	0.52	2.33	0.63	0.78	0.79

Abbreviation: TSCI, traumatic spinal cord injury.
[a]Model: IRR for gender is adjusted for age group and time period.
[b]Model: IRR for age group is adjusted for gender and time period.
[c]Model: IRR for time period is adjusted for gender and age group.

the study period with an increasing trend in the most recent time periods. Overall, the largest proportion of incomplete tetraplegia 41.3% was found for fall-related injuries, whereas incomplete tetraplegia due to transport and sports-related injuries represented 31.4 and 38.6%, respectively. Table 6 shows the adjusted IRRs of TSCI by level and completeness of TSCI. After adjustment for gender and age at time of injury, the association between incomplete tetraplegia and time period varied between 0.75 and 1.18 and showed no consistent pattern. Incomplete tetraplegia was associated with age at time of injury: IRR 1.48 for those aged 30–60 years and 1.52 for age above 60 years, compared with the age below 30 years.

DISCUSSION

We found an overall annual TSCI incidence of 10.2 per million person-years at risk, varying between 8.3 and 11.8 in the period 1990–2012 with no decreasing or increasing trend. This is one of the lowest reported TSCI incidences in Europe.[1] Also, this is a low TSCI incidence compared with the other Nordic countries[3–6] as well as the Netherlands.[13] Biering-Sørensen *et al.*[7] reported an annual incidence

Table 5 Level and completeness of TSCI, by cause of injury, by time period (proportion)

Time period	Transport				Falls				Sports				Other				All causes			
	Paraplegia		Tetraplegia		Paraplegia		Tetraplegia		Paraplegia		Tetraplegia		Paraplegia		Tetraplegia		Paraplegia		Tetraplegia	
	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C
1990–1994	21.8	33.3	27.6	17.2	41.2	41.2	17.7	0.0	17.8	14.7	52.9	14.7	33.3	33.3	26.7	6.7	24.2	30.1	32.0	13.7
1995–1999	28.8	34.9	28.8	7.6	13.3	40.0	46.7	0.00	25.0	20.0	27.5	27.5	37.5	12.5	12.5	37.5	26.4	29.5	29.5	14.7
2000–2004	23.9	23.9	31.5	20.7	27.9	25.6	41.9	4.7	11.5	30.8	30.8	26.0	54.5	27.3	18.2	0.0	25.0	25.6	33.1	16.3
2005–2009	16.4	34.3	34.3	15.1	24.5	13.2	52.8	9.4	14.3	7.1	42.9	35.7	31.3	37.5	18.8	12.5	20.5	25.0	39.7	14.7
2010–2012	15.4	34.6	42.3	7.7	25.9	29.6	29.6	14.8	30.8	23.1	46.2	0.0	25.0	12.5	62.5	0.0	23.0	28.4	40.5	8.1
Total	22.1	31.4	31.4	15.1	26.5	25.2	41.3	7.1	19.7	19.7	38.6	22.1	36.2	27.6	25.9	10.3	23.8	27.5	34.5	14.2

Abbreviations: C, complete; I, Incomplete; TSCI, traumatic spinal cord injury.

Table 6 Adjusted estimates of incidence rate ratios (IRRs) of TSCI by level and completeness of injury

	Level and completeness			
	Incomplete paraplegia IRR	Complete paraplegia IRR	Incomplete tetraplegia IRR	Complete tetraplegia IRR
Gender[a]				
Male	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
Female	0.33	0.16	0.21	0.21
Age group[b]				
<30	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
30–60	0.75	0.89	1.48	0.85
>60	0.44	0.22	1.52	0.39
Time period[c]				
1990–1994	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
1995–1999	0.90	0.81	0.75	0.88
2000–2004	1.13	0.93	1.11	1.29
2005–2009	0.84	0.83	1.18	1.06
2010–2012	0.74	0.74	0.94	0.46

Abbreviation: TSCI, traumatic spinal cord injury.
[a]Model: IRR for gender is adjusted for age group and time period.
[b]Model: IRR for age group is adjusted for gender and time period.
[c]Model: IRR for time period is adjusted for gender and age group.

of 9.2 per million person-years at risk in Denmark from 1975 to 1984. Although, the TSCI incidence calculated by Biering-Sørensen *et al.* is based on data including Greenland and the Faroe Islands, we consider the TSCI incidence in Denmark has remained largely stable over the past almost 40 years (1975–2012). We found an overall female to male ratio of 1:4.5 which is lower than the 1:3.8 ratio presented in a worldwide review by Wyndaele *et al.*[2] However, the gender distribution in our study matches that reported for Norway and Finland.[3,4] Similar to a study from Finland, we found that the age at the time of injury rose over time for both genders,[4] indicating an increasing trend in age at injury in Denmark. Approximately 40% of the patients were <30 years at the time of injury, which is comparable to the percentage previously reported for Denmark[7] and to recent data from Iceland.[6] In contrast, this figure was recently reported to lie below 20% in the Netherlands.[13]

The total proportion of transport-related injuries was 50.2%, which is comparable to the 47% reported in Danish data from 1975 to 1984.[7] We found an overall decrease in transport-related injuries from 56.9% in the first 5-year period to 36.8% in the last period. Our findings correspond with a recent review[1] showing that the level of transport-related injuries is stable or decreasing in developed countries. The incidence of TSCI transport-related injuries among men under the age of 30 years decreased from 17.2 to 4.1 from the first to the last time period. Data from Statistics Denmark reveal a decrease in all types of transport-related injuries in Denmark during the study period,[12] which may be due to preventions strategies[14] such as safer cars, speed limits and changes in road design. However, transport-related injuries remain more frequent in Denmark than in the other Nordic countries[3,4,6] as well as the Netherlands,[13] which may be due to a less strict Danish alcohol policy, although the legal alcohol limit for drivers was tightened during the study period.

The IRR for fall-related injuries adjusted for gender and time period shows that the risk of TSCI due to a fall is 7.47 times higher among those above the age of 60 than among those <30 years old. The observed increasing trend in the incidence of TSCI due to fall among elderly people (>60 years) is in accordance with findings from other Nordic studies,[3,4] and Western Europe in general.[15]

The proportion of incomplete tetraplegia all-causes indicates an increasing trend particularly outspoken in the most recent time periods as evidenced by an increase from 33.1% in 2000–2004 to 40.5% in 2010–2012. Biering-Sørensen *et al.*[7] found incomplete tetraplegia for 29%, which supports our findings of a trend towards a growing number of cases with incomplete tetraplegia. Studies from the Netherlands also support our findings of an increasing trend as the proportion of incomplete tetraplegia was 57% in 1994[16] and 69% in 2014.[13] Our findings are in line with an increasing number of cases with incomplete tetraplegia worldwide.[2,17]

This study has some limitations, which may influence the overall TSCI incidence and trends. Patients with only minor motor and sensory dysfunctions are not always referred to our Spinal Cord Injury Centre instead they are referred to regional hospitals. During our study period, this patient group most likely has increased due to improved diagnostic procedures, meaning that more patients are diagnosed with minor TSCI whereas earlier these patients may not have been diagnosed TSCI. Furthermore, improved acute care may have resulted in fewer patients with severe TSCI and more patients with only minor TSCI. As these minor TSCI patients are always not referred to our SCI rehabilitation centre, the overall incidence may be an underestimate.

In contrast, the number of TSCI patients who survive the accident and the acute phase may have increased, although we do not have figures for this in Denmark.

As the level and completeness of TSCI was determined on admission to the Centre weeks to months after the injury, we cannot eliminate misclassification within the categories of TSCI. In addition, diagnostic procedures have changed over time, which may also have influenced the incidence of TSCI level and completeness. We consider a potential misclassification to be non-differential.

We consider the population in West Denmark does not differ from East Denmark, therefore the calculated incidence may be generalized to Denmark.

When comparing our calculated incidence with the previous Danish incidence estimated by Biering-Soerensen *et al.*,[7] the catchment areas and the admissions criteria are to be taken into account as they differ. In the study of Biering-Soerensen *et al.,* patients from Greenland and the Faroe Islands were included, but only few patients under the age of 18, and no patients requiring respirator support were included. At our centre, all TSCI are included independent of age (9.8% of the total study population was <18 years) and need for respirator support, although we do not have overseas patients. These aspects may influence the overall incidence in both directions.

CONCLUSION

The annual incidence of TSCI in Denmark is low; 10.2 per million person-years at risk and has remained stable from 1990 to 2012. The proportion of transport-related injuries fell, while age at time of injury and proportion of fall-related injuries and proportion with incomplete tetraplegia all showed an increasing trend. Our findings have clinical implications as particularly older patients who sustain incomplete tetraplegia require intensive rehabilitation in order to be able to recover and return home.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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