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ORIGINAL ARTICLE

A 50-year follow-up of the incidence of traumatic spinal cord injuries in Western Norway

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Study design: Retrospective population-based epidemiological study.
Objective: To assess the prevalence and temporal trends in the incidence of traumatic spinal cord injuries (TSCI), and demographic and clinical characteristics of an unselected, geographically defined cohort in the period 1952–2001.
Methods: The patients were identified from hospital records. Crude rates and age-adjusted rates were calculated for each year. The multivariate relationship between cause of injury, age at injury, decade of injury and gender was examined using a Poisson regression model.
Results: Of 336 patients, 199 patients were alive on 1 January 2002, giving a total prevalence of 36.5 per 100 000 inhabitants. The average annual incidence increased from 5.9 per million in the first decade to 21.2 per million in the last. Mean age at injury was 42.9 years and the male to female ratio 4.7:1. Fall was the most common cause of injury (45.5%), followed by motor vehicle accidents (MVA) (34.2%). The incidence of MVA-related injuries increased during the observation period, especially among men <30 years. The lesion level was cervical in 52.4%, thoracic in 29.5% and lumbar/sacral in 18.2%. The lesion was clinically incomplete in 58.6% and complete in 41.4%. The incidence of fall-related injuries and the proportion of incomplete cervical lesions increased during the observation period, especially among men >60 years.
Conclusions: The incidence of TSCI has increased during the past 50 years. Falls and MVA are potentially preventable causes. The increasing proportion of older patients with cervical lesions poses a challenge to the health system.
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Keywords: traumatic spinal cord injury; epidemiology; incidence; prevalence; etiologies

Introduction

Traumatic spinal cord injury (TSCI) causes permanent dysfunction in several organ systems and leads to frequent complications. The condition causes life-long loss of function and reduced quality of life, and has an impact on morbidity and mortality. As there is no cure for TSCI, prevention is of paramount importance. Knowledge of incidence, prevalence and injury causes is vital for prevention and for planning clinical and community services for this patient group. The yearly incidence of TSCI is listed as 9.2–57.8 per million.[1] Comparative studies of TSCI in different regions of the world have shown large epidemiological differences.[2–5] This variation may in part be caused by differences in definition, classification and procedures of patient identification, as well as differences in geography and culture.[2] In this study, we assess the prevalence and temporal trends in the incidence of TSCI, and demographic and clinical characteristics of an unselected, geographically defined cohort in the period 1952–2001.

Materials and methods

Study population
This retrospective study aimed to include all inhabitants who sustained a TSCI in the period 1952–2001 in two Norwegian counties, Hordaland and Sogn og Fjordane. The counties have long coastlines and numerous fjords, and inland mountains and valleys. The total area is 34 063 km^2. The population in the two counties was 412 015 on 1 January 1952, and 545 533 on 1 January 2002. The main city is Bergen with 233 291 inhabitants on 1 January 2002. Almost half the population lives in small villages and rural areas. On 1 January 2002, the total population density was 16

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inhabitants per km^2; in Sogn og Fjordane County 6 inhabitants per km^2 and in Hordaland County 29 inhabitants per km^2 (data from Statistics Norway).

Definition of TSCI
TSCI was defined according to Kraus *et al*.[6] as an acute, traumatic lesion of the spinal cord with varying degrees of motor and/or sensory deficit or paralysis. Although injuries of cauda equina were included, the definition excluded isolated injuries of other nerve roots.[7] Patients with a file at any of the hospitals in the two counties were included.[8] Patients with neurological deficits lasting less than 1 week and patients with injuries because of medical procedures/treatment were not included.

Case ascertainment
The records of all patients with a diagnostic code suggesting TSCI at discharge from any of the eight hospitals in the two counties in the period from 1952 to 2001 were reviewed by the first author (EMH).[8,9] The analysis was limited by including only hospital data. Records of spinal cord injury-related deaths before reaching hospital were not available.

Prevalence and incidence
The prevalence rate was defined as the number of patients with TSCI per 100 000 inhabitants living in Hordaland and Sogn og Fjordane Counties on 1 January 2002. The crude annual incidence rate of TSCI was defined as the number of new cases per million inhabitants per year. Patients with onset of TSCI when living in the two counties during 1952–2001 were included in the incidence calculations.

The patients were stratified retrospectively according to level of injury, and grouped according to a cervical, thoracic or lumbar/sacral level, and also in complete (ASIA A according to the classification of the American Spinal Injury Association) or incomplete (ASIA B-D) injuries.[7] They were grouped into five categories based on year of injury: 1952–1961, 1962–1971, 1972–1981, 1982–1991 and 1992–2001. These groups were further subdivided into a total of 10 5-years groups. Patients were also grouped in decades according to age at time of injury.

The causes of injury were listed in 12 different groups; motor vehicle accidents (MVA) by car, motorcycle, bicycle or pedestrians. Falls were divided according to the height of falling: $\leqslant$1 m (low level), 1–5 m and $>$5 m (high-energy trauma).[10] Sports injuries were listed as swimming, skiing or other sport-related injuries. The final causes were violence and other injuries that mostly were work-related injuries in which the patient was hit by an object.

The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate.

Statistical analysis
For categorical variables, crude data, frequencies and percentages are reported. For continuous variables, means and standard deviations (s.d.) are reported. To compare groups, the χ^2 test was used for proportions, and Gosset's *t*-test and analysis of variance (ANOVA) for continuous variables adhering to the normal distribution.

Crude rates and age-adjusted rates were calculated for each year by dividing the observed number of TSCI cases in each year by size of the referent population of the two counties the same year. As TSCI is a rare event in the referent population, Poisson regression is an appropriate tool for the analysis of TSCI rates. The trend test for the annual number of new patients was based on the assumption that these numbers of cases in each year show an independent Poisson distribution. The computed goodness-of-fit test of the Poisson regression model proved the model to be appropriate for all causes of injury.

For crude rates, multiple Poisson regression analyses with causes of injury as dependent variables were conducted to examine the associations of each cause of injury with gender, age (10 decades) and decade of injury (5 categories). A χ^2 test of goodness-of-fit (deviance) of the Poisson regression model was performed. Results are reported as incidence ratios with 95% confidence intervals (CI). Exact estimates were calculated when possible, or else asymptotic results are given.

Using the population of Hordaland and Sogn og Fjordane on 1 January 2002 as the population-at-risk, the age- and gender-specific prevalence rates were calculated. The observed age-dependent incidences were compared with population data obtained from Statistics Norway. Statistics Norway and the National Population Registry provided information on each patient's place of residence on the prevalence day.

The level of statistical significance was set at 0.05. All *P*-values are two-tailed. Statistical analyses were conducted with SPSS 16 (SPSS, Chicago, IL, USA) and STATA 9.2 (College Station, TX, USA). Stat/LogXact 7 (Cytel Software, Cambridge, MA, USA) was used for Poisson regression analysis.

Results

Epidemiology and demographics
Prevalence. A total of 336 patients were identified, which is 258 (76.8%) in Hordaland County and 78 (23.2%) in Sogn og Fjordane County. On 1 January 2002, 199 patients were alive, giving a total crude prevalence rate in the two counties of 36.5 per 100 000 inhabitants; in Hordaland County 35.1 (95% CI: 29.8–41.1), and in Sogn og Fjordane County 41.9 (95% CI: 30.6–56.1). The prevalence rate among women was 10.4 (95% CI: 6.6–15.6) in Hordaland County, and 17.0 (95% CI: 7.8–32.3) in Sogn og Fjordane County, and the prevalence rate among men was 60.1 (95% CI: 50.3–71.4) in Hordaland County and 66.2 (95% CI: 46.4–91.7) in Sogn og Fjordane County. The male excess was highest in the age groups over 60 years. As there are no statistical differences in the prevalence rates of the two counties, the data were combined in the following analyses.

Incidence. The annual incidence rate measured in 5-year intervals increased from 6.2 per million in 1952–1956 to 26.3 in 1997–2001 ($P<0.001$, test for trend) (Table 1).

Gender and age. The male to female ratio for the whole cohort was 4.7:1. The percentage of women varied through the whole period between 6.9 and 24.4%. The age at injury varied from 2.6 to 96.6 years. The mean age at injury was 42.9 (s.d.: 21.6) years; in women 47.7 (s.d.: 23.4) years and in men 41.9 (s.d.: 21.2) years ($P<0.0001$, Student's *t*-test). The age distribution peaked in the third decade for males and the eight decade for females. For the whole group, the mean age at injury increased from 40.2 years in the period 1952–1956 to 48.9 years 1997–2001 ($P=0.451$, one-way ANOVA); for women from 24.7 to 57.7 years ($P=0.037$, one-way ANOVA) and for men from 41.5 to 46.3 years ($P=0.352$, one-way ANOVA).

Table 1 Traumatic spinal cord injuries 1952–2001 in Hordaland and Sogn og Fjordane Counties, Norway: number of cases and crude annual incidence rates per 1 million inhabitants

Years	*Cases*	*Average population*	*Incidence*[a] *95% CI*[b]
1952–1956	13	418 625	6.2 (3.3, 10.6)
1957–1961	12	435 286	5.5 (2.9, 9.6)
1962–1966	18	451 137	8.0 (4.7, 12.6)
1967–1971	29	468 243	12.4 (8.3, 17.8)
1972–1976	33	484 556	13.6 (9.4, 19.1)
1977–1981	40	494 553	16.2 (11.6, 22.0)
1982–1986	45	502 298	17.9 (13.1, 24.0)
1987–1991	33	513 367	12.9 (8.9, 18.1)
1992–1996	42	527 079	15.9 (11.5, 21.5)
1997–2001	71	539 969	26.3 (20.5, 33.2)

[a]$P<0.001$ for increasing trend from 1952 to 2001.
[b]Confidence intervals (CIs) based on the Poisson distribution.

Causes of TSCI
The most common cause of injury was falls (45.5%), followed by MVA (34.2%), other injuries (11.6%) and sports injuries (8.6%). The incidence of MVA-related injuries increased during the observation period, especially among people younger than 30 years (Table 2). The incidence of fall-related injuries also increased during the observation period, especially among people older than 60 years.

Table 3 shows the incidence ratio of injury from each cause obtained from multiple Poisson regression analyses. Injuries caused by motorcycles were significantly associated with decreasing age, whereas fall $\leqslant 1$ m and fall 1–5 m were significantly associated with increasing age at time of injury. The incidence risk for fall $\leqslant 1$ m increased with 1.08 per age decade. The incidence of these three causes and car accidents showed a significantly increased time trend. The incidence risk for car accidents increased with 1.67 per decade in the period 1952–2001, whereasthe incidence risk of motorcycle accidents increased 1.47 per decade and fall $\leqslant 1$ m 1.66 per decade. Men had a statistically significant increased risk of TSCI from all causes compared with women, except from pedestrian accidents, skiing accidents and other sports accidents (Table 3).

Level and extent of TSCI
The lesion level was cervical in 52.4%, thoracic in 29.5% and lumbar/sacral in 18.2% of TSCI. The lesion was clinically incomplete in 58.6% and complete in 41.4% of cases. The mean incidence of cervical incomplete lesions increased from 2.1 per million per year in the first decade to 8.4 per in the last. The proportion with cervical incomplete lesions was

Table 2 Mean annual age and gender-specific incidence of different causes of TSCI according to decade 1952–2001, in Hordaland and Sogn og Fjordane Counties, Norway, per million inhabitants

	1952–1961		*1962–1971*		*1972–1981*		*1982–1991*		*1992–2001*	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
MVA[a]										
0–29 years	1.08	2.05	0.00	7.39	2.72	11.18	5.63	14.31	2.84	19.87
30–59 years	1.15	3.51	0.00	5.91	1.20	1.18	1.12	2.15	3.87	9.30
60+ years	0.00	0.00	0.00	2.77	0.00	9.52	0.00	2.15	1.65	13.13
Falls										
0–29 years	0.00	2.05	0.00	4.62	1.89	7.74	1.65	3.58	0.00	2.71
30–59 years	1.15	7.01	1.19	9.46	1.20	12.97	1.12	14.00	5.80	13.02
60+ years	0.00	17.03	4.58	8.31	7.57	26.18	8.26	19.36	11.57	43.77
Sports										
0–29 years	1.08	0.00	0.00	1.85	0.00	3.44	1.88	3.58	0.95	5.42
30–59 years	0.00	0.00	1.19	0.00	2.40	0.00	0.00	0.00	0.00	3.72
60+ years	0.00	0.00	0.00	0.00	0.00	2.38	1.65	0.00	0.00	0.00
Other[b]										
0–29 years	0.00	0.00	0.00	0.92	0.00	1.72	0.00	1.79	0.00	0.90
30–59 years	0.00	3.51	0.00	9.46	0.00	4.72	0.00	5.39	0.00	3.72
60+ years	0.00	0.00	0.00	5.54	0.00	2.38	0.00	10.76	0.00	2.19
Total	1.87	9.88	1.73	18.79	4.87	25.10	6.62	24.29	8.16	34.48

[a]MVA, motor vehicle accident.
[b]Other injuries include violence and work-related accidents.

Table 3 Multiple poisson regression analyses[a] of cause-specific traumatic spinal cord injuries (TSCI) with respect to age at injury in decades, decade of injury and gender in Hordaland and Sogn og Fjordane Counties, Norway 1952–2001

Cause	*Age in decade at injury*			*Decade of injury*			*Gender*[b]			*Goodness of fit test*[c]	
	IR	*95% CI*	P-*value*	*IR*	*95% CI*	P-*value*	*IR*	*95% CI*	P-*value*	Deviance	P-*value*
MVA car	0.99	(0.98, 1.00)	0.396	1.69	(1.38, 2.10)	<0.001	4.12	(2.22, 8.24)	<0.001	103.46	0.283
MVA motorcycle	0.98	(0.96, 1.00)	0.027	1.47	(1.06, 2.10)	0.018	6.51	(1.93, 34.19)	<0.001	64.68	0.994
MVA bicycle	1.02	(1.00, 1.04)	0.122	1.16	(0.78, 1.77)	0.499	6.41	(1.42, 59.07)	0.009	47.12	0.999
MVA pedestrian	0.98	(0.95, 1.01)	0.265	0.92	(0.58, 1.43)	0.766	2.62	(0.63, 15.33)	0.239	42.67	0.999
Falls ⩽1 m	1.08	(1.06, 1.10)	<0.001	1.66	(1.25, 2.28)	<0.001	3.18	(1.51, 7.17)	0.001	55.27	0.999
Falls 1–5 m	1.02	(1.01, 1.03)	<0.001	1.20	(1.01, 1.42)	0.035	2.02[d]	(1.27, 3.24)	0.003	118.39	0.060
Falls >5 m	1.00	(0.99, 1.02)	0.605	1.11	(0.88, 1.40)	0.418	5.64	(2.33, 16.46)	<0.001	63.40	0.996
Swimming injuries	0.97	(0.93, 1.00)	0.078	1.59	(0.93, 2.99)	0.099	7.72	(1.04, 342.64)	0.044	31.09	1.000
Skiing injuries	1.00	(0.97, 1.02)	0.911	1.39	(0.92, 2.19)	0.126	1.35	(0.41, 4.71)	0.777	49.72	0.999
Other sports injuries	1.00	(0.91, 1.01)	0.123	1.72	(0.87, 4.07)	0.136	4.80	(0.54, 227.22)	0.238	19.48	1.000
Violence	1.00	(0.95, 1.04)	0.923	0.95	(0.48, 1.90)	0.995	6.70	(0.91, +INF)	0.063	Not computable	
Other injuries	1.02	(1.01, 1.04)	0.004	1.04	(0.81, 1.33)	0.829	52.40	(9.41, +INF)	<0.001	Not computable	
Total	1.01[c]	(1.01, 1.02)	<0.001	1.31[d]	(1.21, 1.42)	<0.001	3.77[d]	(2.91, 4.89)	<0.001	154.34	<0.001

Abbreviations: CI, confidence interval; INF, infinity; IR, incidence ratio; MVA, motor vehicle accident.
[a]Exact estimates from Cytel LogXact.
[b]Gender: female = 0, male = 1.
[c]From χ^2 test with 96 degrees of freedom.
[d]Asymptotic estimates because of lack of convergence for exact method.

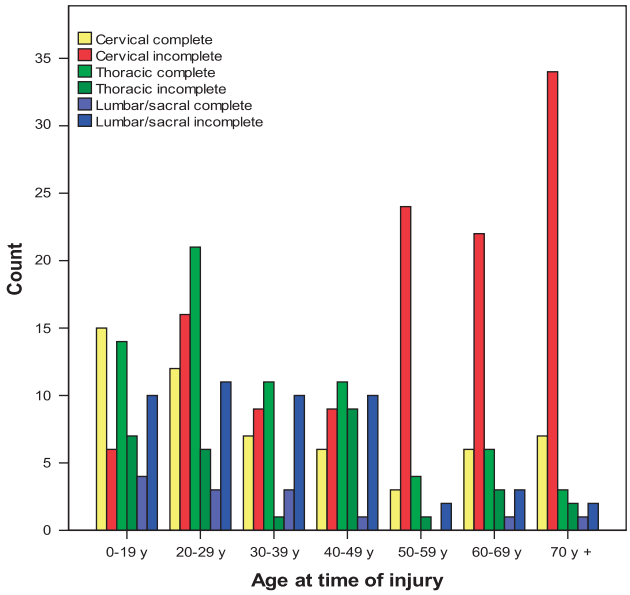

Figure 1 Level and completeness of TSCI according to age at time of injury in Hordaland and Sogn og Fjordane Counties, Norway 1952–2001 ($n = 336$).

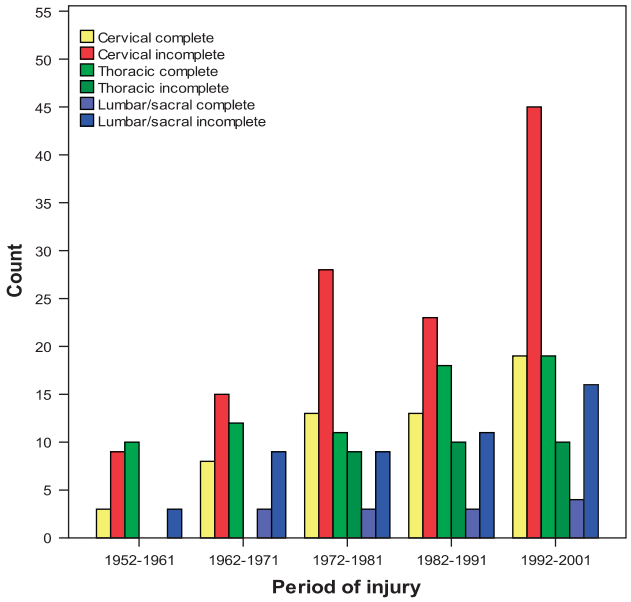

Figure 2 Level and completeness of TSCI 1952–2001 in Hordaland and Sogn og Fjordane Counties, Norway ($n = 336$).

highest among patients older than 50 years (Figure 1), and highest in the last time period (Figure 2).

Table 4 shows the distribution of TSCI by level and completeness of injury according to different causes of injury. Fall ⩽1 m is particularly associated with incomplete cervical injury.

Discussion

The increased incidence of TSCI in our population was 26.3 per million in the period 1997–2001, higher than reported from Finland 13.8,[5] and Denmark 9.2.[11] Our study is population based and included all age groups, whereas the study from Finland was limited to patients aged 16 years or more,[5] and the study from Denmark was hospital based.[11]

The incidence of TSCI in our population showed an increasing trend during the study period, and was most pronounced for the elderly, similar to findings from Canada[12] and Australia.[13] Reviews have recalculated the incidence of TSCI in Europe to be 13.9 per million per year (1975–1995),[14] increasing to 19.4 (1995–2005),[3] comparable to our data.

Table 4 Causes of trauma according to level and completeness of traumatic spinal cord injuries

Causes	n	*Cervical*		*Thoracic*		*Lumbar–sacral*	
		Complete %	*Incomplete* %	*Complete* %	*Incomplete* %	*Complete* %	*Incomplete* %
MVA car	67	23.9	25.4	20.9	13.4	4.5	11.9
MVA motorcycle	23	13.0	17.4	43.5	17.4	0.0	8.7
MVA bicycle	14	7.1	57.1	28.6	0.0	7.1	0.0
MVA pedestrian	11	27.3	45.5	18.2	0.0	0.0	9.1
Falls $\leqslant$1 m	37	10.8	78.4	2.7	5.4	0.0	2.7
Falls 1–5 m	77	15.6	41.6	15.6	9.1	2.6	15.6
Falls >5 m	39	7.7	10.3	30.8	7.7	7.7	35.9
Swimming injuries	9	44.4	44.4	11.1	0.0	0.0	0.0
Skiing injuries	14	0.0	14.3	21.4	14.3	7.1	42.9
Other sports injuries	6	16.7	33.3	16.7	0.0	16.7	16.7
Violence	5	20.0	40.0	20.0	20.0	0.0	0.0
Other injuries	34	23.5	32.4	26.5	2.9	5.9	8.8
Total	336	16.7	35.7	20.8	8.6	3.9	14.3

Abbreviation: MVA, motor vehicle accident.

We found a high TSCI crude prevalence rate of 36.5 per 100 000 inhabitants, higher than in Finland and Sweden, 28.0 and 22.3, respectively.[4,15] These studies were however hospital based, and underreporting may be a problem.[8]

The mean male to female ratio of 4.7:1, but the ratio varied through the study period probably because of the small number. This is higher than in most previous reports.[2,3] A report from Canada found an increasing percentage of women because of a decline in male rates.[12] In our population, the incidence of male TSCI increased more than female. The mean age at injury was higher for women than for men during study period, in accordance with findings from Finland.[5] There was a trend of increasing age at injury in both genders, only significant in women, whereas an increasing age at injury was found for both men and women in Finland.[5]

The main cause in our population was fall (45.5%), especially among people >60 years falling from heights <5 m. Increasing incidence of fall-induced, fracture-associated SCI among persons aged >50 years is also found in other studies,[5,12,13,16] and more than explained merely by demographic changes.[12,17,18] For unknown reasons, the age-standardized incidence (average individual risk) of fractures in general has risen in many populations during the past decades. Possible reasons include a birth cohort effect, deterioration in the average bone strength, increased risk and severity of falls.[19] Elderly people are vulnerable to TSCI because of osteoporosis, cervical spinal stenosis, sensory loss and side effects of medication causing postural instability.[20]

MVA was the second most common cause in our population, and the incidence increased primarily among young men, comparable to data from Canada[12] and Australia.[21] The number of cars in the two counties increased from 1374 per 100 000 inhabitants in 1952 to 38 556 per 100 000 inhabitants in 2001 (data from Statistics Norway). The number of MVAs in Norway increased from 73 per 100 000 inhabitants in 1952 to a peak in 1970 of 240 per 100 000 inhabitants. Although there has been a decline thereafter to 189 per 100 000 inhabitants in 2001, the incidence of TSCI caused by car accidents has increased among young men. Extensive prevention campaigns should therefore be addressed more directly to the young male population. Violence-related injuries are rare in Norway, whereas this is one of the main causes of TSCI in USA.[18]

Cervical injuries are more frequent than those at the thoracic and lumbar level, and most often associated with fall $\leqslant$1. Complete injuries are most often related to swimming injuries and motorcycle accidents. Owing to different distributions of causes around the world, the clinical picture will vary.[2] Nevertheless, our data are in accordance with the data showing a world-wide trend of increasing numbers of elderly people sustaining an incomplete cervical TSCI from falling from ground level.[5,12,13,22]

Our study is retrospective. The identification of patients was based on diagnostic codes and personal review of hospital records. Some patients may have received a diagnostic code that did not suggest a TSCI. Some patients with minor neurological deficits may not have been initially diagnosed, and some patients never reached hospital because of a lethal injury. Patients with trauma have, however, had easy access to hospitals during the whole period. Therefore, we do not expect underreporting to have had a significant influence on our data. Our study is strengthened by the population-based case ascertainment and long observation period.

The incidence of TSCI has increased during the last 50 years. Falls and MVA are potentially preventable causes. The increasing proportion of older patients with cervical lesions poses a challenge to the health system.

Conflict of interest

The authors declare no conflict of interest.

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