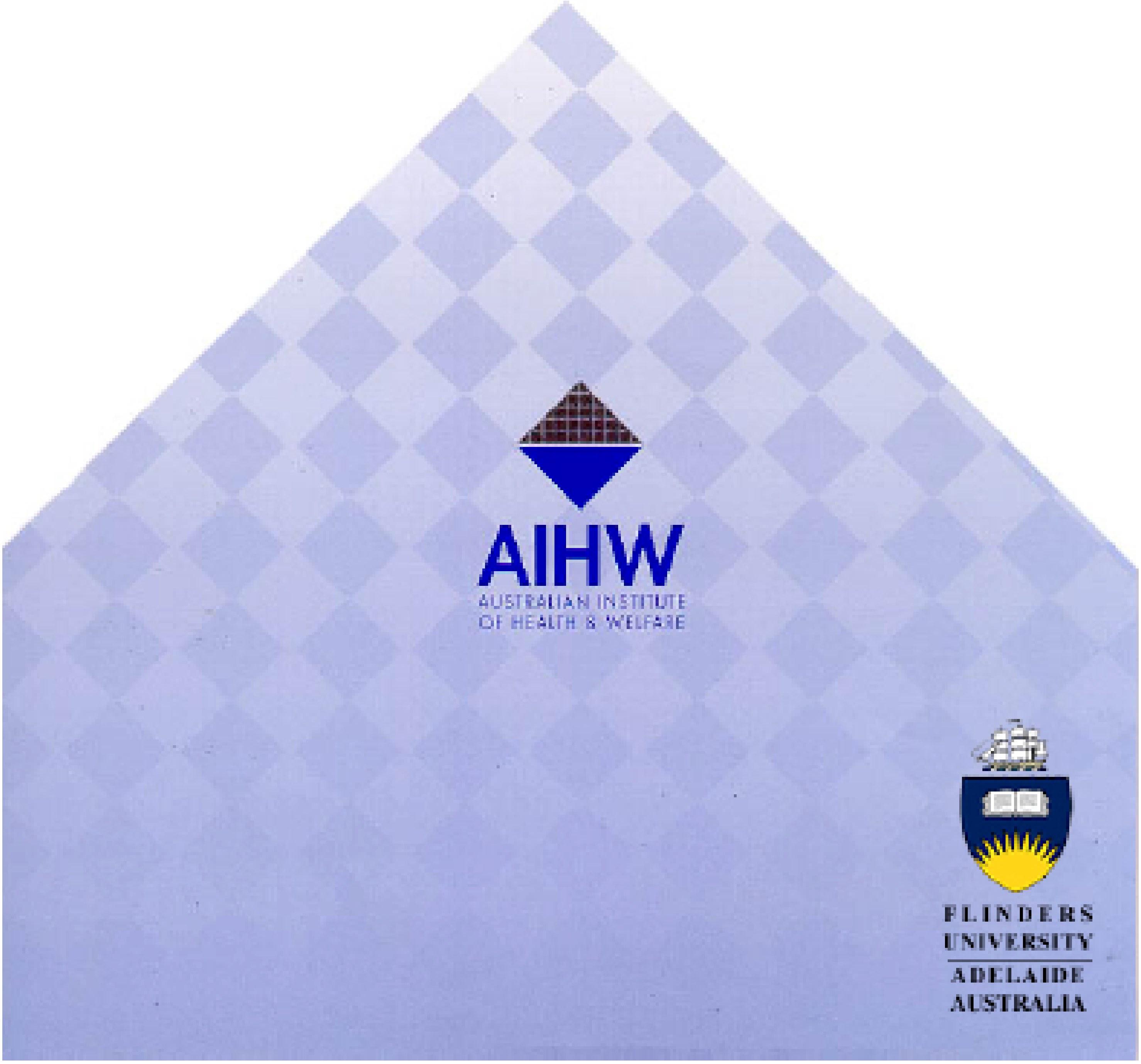
Trends in spinal cord injury, Australia 1986–1997



AIHW
AUSTRALIAN INSTITUTE
OF HEALTH & WELFARE

FLINDERS
UNIVERSITY
ADELAIDE
AUSTRALIA

Trends in spinal cord injury, Australia 1986–1997

The Australian Institute of Health and Welfare is Australia's national health and welfare statistics and information agency. The Institute's mission is to improve the health and well-being of Australians by informing community discussion and decision making through national leadership in developing and providing health and welfare statistics and information.

Injury Technical Paper Series
Number 2

Trends in spinal cord injury, Australia 1986–1997

Peter O'Connor

2002

Australian Institute of Health and Welfare
Canberra

AIHW cat. no. INJCAT 52

This publication is part of the Australian Institute of Health and Welfare's Injury Technical Paper Series. A complete list of the Institute's publications is available from the Publications Unit, Australian Institute of Health and Welfare, GPO Box 570, Canberra ACT 2601, or via the Institute's web site (http://www.aihw.gov.au). Electronic copies of publications in this series can be downloaded from the Research Centre for Injury Studies web site (http://www.nisu.flinders.edu.au)

ISSN 1446-778X

ISBN 1 74024 262 9

Suggested citation

O'Connor P, 2002. Trends in spinal cord injury, Australia 1986–1997. Injury Technical Paper Series Number 2. Adelaide: AIHW (AIHW cat no. INJCAT 52).

Any enquiries about or comments on this publication should be directed to:

Director, AIHW National Injury Surveillance Unit
Research Centre for Injury Studies
Flinders University
GPO Box 2100,
Adelaide 5001, South Australia

Phone: (08) 8374 0970
email: nisu@flinders.edu.au

Published by Australian Institute of Health and Welfare

Printed by Snap Printing

Text proofread by Stacey Avefua

Layout by Stacey Avefua

Contents

Acknowledgments

The ASCIR is a cooperative arrangement of the 6 Australian spinal units and the National Injury Surveillance Unit of the Flinders University Research Centre for Injury Studies (RCIS), funded by the Australian Institute of Health and Welfare.

The assistance of the Directors and staff of the spinal units is gratefully acknowledged.

Thanks to Clare Bradley and Stacey Avefua for their contributions in finalising the manuscript for publication.

Summary

There was no change in the age-standardised rate of spinal cord injury (SCI) from 1986–1997 in Australia. There were some opposing trends in the rates of SCI by age and sex group, cause and neurological group. In males aged 15–24 years there was an approximate 3% per annum (p.a.) decrease in the annual rate of SCI whereas in males aged 65 years and over there was an approximate 6% p.a. increase in the rate of SCI. The rate of transport-related SCI declined (–4% p.a.) whereas the rate of fall-related SCI increased (+2% p.a.). The rate of transport-related SCI decreased in young males and females (–4% p.a. and –7% p.a. respectively), and also in some older male age groups (–3% p.a. in 25–34 year age group and –6% p.a. in 45–54 year age group). In contrast, the rate of fall-related SCI increased in elderly males (+9% p.a.), but not among elderly females. The report suggests that there have been successes and relative failures in public health to address the SCI problem.

1 Overview

Spinal cord injury (SCI) is a significant public health problem in Australia. Although SCI is relatively rare, it is important due to the severity of the outcome in individual, social and economic terms. The Australian Spinal Cord Injury Register (ASCIR), established in 1995, enables the patterns and trends in SCI to be monitored.

The specific objective of this report is to present information on trends in SCI in Australia. It provides time-series information about the demographic features, causal factors and outcomes of SCI. It also illustrates how information on these parameters can provide new insights into the prevention and control of SCI and future research needs.

Injury mortality rates in Australia have declined substantially over the last 20 years (Australian Institute of Health and Welfare: AIHW, 2000). The largest contributor to this decline has been a substantial reduction in transport-related deaths, notably in young males and females (AIHW, 2000; Bordeaux and Harrison, 1998; Federal Office of Road Safety: FORS, 1998). The rate of fall-related mortality has also declined among persons over the age of 65 years, both male and female (Bordeaux and Harrison, 1998), although it has been reported using more recent data that the rate may have increased slightly since 1993 (Cripps and Carman, 2001). As transport and fall-related events are the most common causes of SCI, the mortality trends signal the potential for important changes in the incidence of SCI. Indeed, on the basis of those trends it might be expected that the overall rate of SCI would be declining, especially for transport-related causes in young males and females. It might also be expected that the rate of fall-related SCI in the elderly would have decreased among elderly males and females, although perhaps with a slight recent increase.

Of course, there are a number of reasons why the improved injury mortality experience of the population may not translate into a reduced incidence of SCI as reflected in the number of patients, or rate per head of population, that survive initial retrieval and transfer to hospital.

There may be a contrast in the specific causal factors important for SCI compared with deaths generally. In addition, it is possible that some of the 'fatalities saved' by improved medical retrieval, transfer and emergency care become survivors with SCI (e.g. ventilator dependent tetraplegics). If that were so, there might be a lower decrease (or, indeed an increase) in the SCI trend that when compared with observed for fatalities. This hypothesis has received no specific attention in the literature.

For these and other reasons it cannot be assumed that SCI would decrease to the same extent as fatalities.

2 Methods

2.1 Data source

Over the period 1986–1997, 3,027 new incident cases of persisting SCI were identified from the ASCIR. Empirical and circumstantial evidence support the view that the coverage of the ASCIR over this period was virtually complete for cases aged 15 years and over (n=2,959). Trends based on this group should therefore be reliable. However, they would not be reliable for paediatric cases because the coverage was known to be incomplete. Therefore, the analysis of trends excluded the paediatric group.

Tables 2.1 and 2.2 provide a breakdown of the case numbers and population by age and sex category and year of SCI. Table 2.3 provides a breakdown of case numbers by year of SCI, according to cause of SCI and neurological group. More detailed breakdowns are provided in Appendix 1. Case numbers for some strata are quite small, with strong year-to-year variability and this presents a challenge for the analysis and interpretation of trends.

2.2 Incidence measures

This chapter presents four types of incidence measure: case numbers, age-specific incidence rates, crude incidence rates and age-standardised incidence rates. All rates were expressed as cases per million of population. Population data were the estimated resident population at 30 June in each year, published by the Australian Bureau of Statistics (2001).

Age-specific incidence rates were calculated according to the following formula:

$r_i = d_i / p_i$

where ri is the age-specific incidence rate for age group i, di is the number of incidences for age group i, and pi is the mid-year estimated resident population for age group i.

The annual crude incidence rate was calculated according to the following formula:

$CR = \Sigma d_i / \Sigma p_i$

where CR is the crude incidence rate, di is the number of incidences for age group i, and pi is the mid-year estimated resident population for age group i. The crude incidence rate does not reflect changes in the age structure of the population over time.

Age-standardisation is a method of adjustment to allow for the effect of variation in the population age structure when comparing incidence rates for different years. The ‘direct’ standardisation method was used, which applied the age-specific incidence rates for a particular year to a standard population (Armitage and Berry, 1987).

This produced an estimate of the incidence rate that would have prevailed in the standard population if it had experienced the age-specific incidence rates in the year under study. The following formula was used:

$ASR = \Sigma r_i P_i / \Sigma P_i$

where ASR is the age-standardised incidence rate, ri is the age-specific incidence rate for age group i, and Pi is the standard population in age group i. The standard population used was the total estimated 1991 mid-year Australian population, as this is the accepted national standard population for health information reporting (AIHW, 2000).

Table 2.1: SCI case number by age and sex category and year of SCI; Australia 1986–1997

	Age group (yrs)						
Sex/year	**15–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65 plus**	**Total**
Male							
1986	79	49	29	17	9	14	197
1987	68	52	32	14	12	10	188
1988	84	48	28	22	13	16	211
1989	59	48	31	19	20	16	193
1990	82	56	28	19	7	7	199
1991	57	58	31	21	8	15	190
1992	62	45	24	18	12	23	184
1993	63	48	37	20	14	22	204
1994	64	55	20	19	11	22	191
1995	57	46	30	28	15	25	201
1996	59	46	31	25	13	32	206
1997	56	48	44	14	12	26	200
Female							
1986	23	16	7	8	1	3	58
1987	24	8	5	1	0	4	42
1988	22	4	4	7	4	7	48
1989	16	14	8	3	2	7	50
1990	10	12	3	4	2	8	39
1991	18	7	7	9	5	8	54
1992	13	12	4	3	2	11	45
1993	17	7	8	2	2	6	42
1994	19	7	11	6	1	12	56
1995	13	17	5	4	4	12	55
1996	12	11	12	4	5	9	53
1997	20	12	4	5	6	6	53

Table 2.2: Population by age and sex category; Australia 1986–1997

	Age group						
Sex/year	**15–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65 plus**	**Total**
Male							
1986	1,368,973	1,317,452	1161863	810,180	736,433	709,186	6,104,087
1987	1,382,212	1,344,758	1,197,621	831,306	735,767	736,097	6,227,761
1988	1,391,527	1,372,201	1,237,121	854,872	736,431	759,811	6,351,963
1989	1,399,357	1,399,016	1,268,740	888,220	735,885	786,012	6,477,230
1990	1,405,949	1,414,983	1,296,753	923,740	734,744	808,556	6,584,725
1991	1,405,897	1,416,512	1,319,366	960,260	734,081	836,262	6,672,378
1992	1,402,578	1,419,535	1,329,122	1,008,015	736,860	861,974	6,758,084
1993	1,394,315	1,415,819	1,338,869	1,051,640	741,581	887,292	6,829,516
1994	1,384,914	1,417,439	1,354,295	1,091,404	749,136	911,353	6,908,541
1995	1,375,984	1,421,951	1,376,440	1,131,517	760,229	934,099	7,000,220
1996	1,364,251	1,431,179	1,402,797	1,171,754	773,686	959,299	7,102,966
1997	1,361,556	1,439,422	1,426,530	1,207,416	792,712	980,628	7,208,264
Female							
1986	1,314,958	1,300,222	1,119,161	768,943	738,536	972,925	6,214,745
1987	1,331,258	1,328,866	1,160,141	789,788	735,526	1,003,190	6,348,769
1988	1,341,966	1,356,914	1,204,491	812,633	733,594	1,031,572	6,481,170
1989	1,349,711	1,383,752	1,241,632	845,097	731,593	1,060,483	6,612,268
1990	1,354,814	1,401,226	1,275,233	879,521	729,790	1,084,825	6,725,409
1991	1,354,941	1,408,886	1,303,292	915,819	728,737	1,114,453	6,826,128
1992	1,350,589	1,414,424	1,319,097	962,802	731,664	1,141,667	6,920,243
1993	1,342,131	1,411,308	1,335,272	1,006,927	735,347	1,169,066	7,000,051
1994	1,331,557	1,413,843	1,354,937	1,048,986	742,590	1,194,247	7,086,160
1995	1,322,777	1,418,418	1,380,058	1,092,553	752,300	1,217,314	7,183,420
1996	1,311,734	1,431,357	1,408,273	1,137,116	764,196	1,243,757	7,296,433
1997	1,305,694	1,440,428	1,433,716	1,176,759	782,610	1,264,440	7,403,647

Table 2.3: SCI case number by cause and neurological group by year of SCI; Australia 1986–1997

	Cause			Neurological group				
Year	Transport	Fall	Other	Complete tetraplegia	Incomplete tetraplegia	Complete paraplegia	Incomplete paraplegia	Unknown
1986	160	60	35	51	82	57	54	11
1987	117	59	54	54	66	59	48	3
1988	147	66	46	59	75	53	66	6
1989	122	72	49	51	66	55	60	11
1990	120	48	70	43	83	48	61	3
1991	129	63	52	28	104	39	70	3
1992	109	61	59	37	88	40	63	1
1993	107	75	64	34	99	49	64	0
1994	119	75	53	36	88	50	72	1
1995	127	71	58	42	87	54	71	2
1996	104	98	57	44	86	57	70	2
1997	109	84	60	49	88	61	54	1

2.3 Modelling the data

The underlying annual rate of change from 1986–1997 was estimated for age-specific, crude and age-standardised incidence rates. An appropriate model for this type of data was the Poisson regression model, with a Poisson error distribution, a log link function and the natural log of population treated as an 'offset' (McCullagh and Nelder, 1989; Valkonen, 1989; Breslow and Day, 1987; Brillinger, 1986). The trends in the case number and age-standardised rate were assessed without the offset term.

For a particular incidence measure, the model may be expressed as:

$\log_e(D_t) = \log_e(N_t) + \text{constant} + \alpha t$

where t is the year of registration of incidence, Dt is the expected number of incidences registered in year t, Nt is the mid-year population in year t, and α is the estimated annual rate of increase or decrease in mortality. This model was used to estimate the underlying trend and its statistical significance.

The trend was calculated from the estimated value of α from the Poisson regression model fitted to the data for all 12 years. It indicated whether the incidence rate was increasing or decreasing over the period and, if so, to what extent. Based on α, an average annual rate of change has been derived as follows:

$\text{percentage change} = [e^{\alpha} - 1] \times 100\%$

The test of statistical significance for the annual percentage change was two-tailed. That is, there was no prior assumption that the mortality rate would be increasing or decreasing, and the alternative hypothesis was that the change in mortality rate was different from zero. The decision to accept or reject the null hypothesis was based on an alpha level of 0.05 (p-values are reported in the tables). Where the bounds of the

95% confidence interval indicate that a trend may be less than ±1% p.a., a note will be included in the text.

A multi-variate assessment of age and sex specific rates confirmed the appropriateness of the Poisson regression model for the trend analysis (Table 2.4). The assessment could not be extended to include cause and neurological group in the multi-variate model due to a high proportion of zero cell counts in many strata, which caused over-dispersion relative to the Poisson distribution. In consideration of this, the decision was made to undertake the study, and report results, on the basis of a stratified analysis.

Table 2.4: Goodness-of-fit statistics for Poisson regression multi-variate model applied to age and sex specific rates; Australia 1986–1997

Number of observations*	Goodness-of-fit Chi^2	Significance level**
144	135.93	0.2377

* Observations are defined by age (six categories), sex (two categories) and year (12 categories).

** This indicates that we cannot reject the hypothesis that these data are Poisson distributed at 0.05 level.

2.3.1 Approach to the stratified analysis

There were 144 strata defined by the combination of age, sex, cause and neurological group. Many of these had zero or very low cell counts for some or all years over the period 1986–1997. In order to guard against the problem of over-dispersion relative to the Poisson distribution, Poisson modelling was undertaken only for strata fitting the following criteria: the series contained non-zero counts for at least 4 years, and the average number of cases across the 12 years was at least 2. Strata not meeting these criteria were excluded from the tables presented in the results section. Even where the criteria were met, care was needed in the assessment of trends with demonstrated irregularity causing instability with respect to the Poisson modelling. This was most apparent where the case number and therefore the rate was very small for most years, and a relatively large number/rate occurred for a single year or a couple of years (which can happen by chance), but also where there was strong year-to-year variation in the number/rate.

A stepwise approach was taken to the stratified analysis, which gave consideration to the exploratory nature of the study. Overall trends were assessed first, followed by age and sex specific, cause specific and neurological group specific trends. The strata defined jointly by age, sex and neurological group were then assessed, followed by the strata defined by cause and neurological group, then the strata defined by age, sex and cause. Finally, the strata defined jointly by all 4 variables (age, sex, cause, and neurological group) were assessed.

Many of the strata trends had a wide 95% confidence interval, demonstrating imprecision arising from small case numbers and other factors.

2.4 Multiple comparisons

Many significance tests were performed and it was therefore likely that some test results were reported as 'statistically significant' by chance. There are various methods for adjusting for ad-hoc comparisons (e.g. Bonferoni). However, given the exploratory nature of the analysis, and the advice of Rothman and Greenland (1998) and others (Perneger, 1998; Sankoh et al., 1997) cautioning against adjustment, these were not applied.

Of course, the possibility of a chance effect should be carefully considered when making judgement about whether statistically significant trends have sufficient medical or epidemiological importance to warrant further attention.

3 Results

3.1 Overall trends[1]

The changes in the overall case numbers and rates (crude and age-standardised) were very small (Table 3.1). There was no statistically significant change in the number of SCI cases. The crude rate for persons decreased by 1.13% per annum (p.a.) and this was statistically significant, although the upper bound of the confidence interval indicates that the trend could be very close to zero. When changes in the age structure were removed from the trend by standardisation, there was no overall change in the rate (Table 3.1 and Figure 3.1).

Table 3.1: Trends in case number, crude and age-standardised rates of SCI; Australia 1986–1997

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
SCI case number for persons	+0.0035	–0.0069 to +0.0139	0.511	+0.35
Crude rate for persons	–0.0114	–0.0218 to –0.0009	0.033	–1.13
Age-standardised rate	–0.0079	–0.0513 to +0.0354	0.720	–0.79

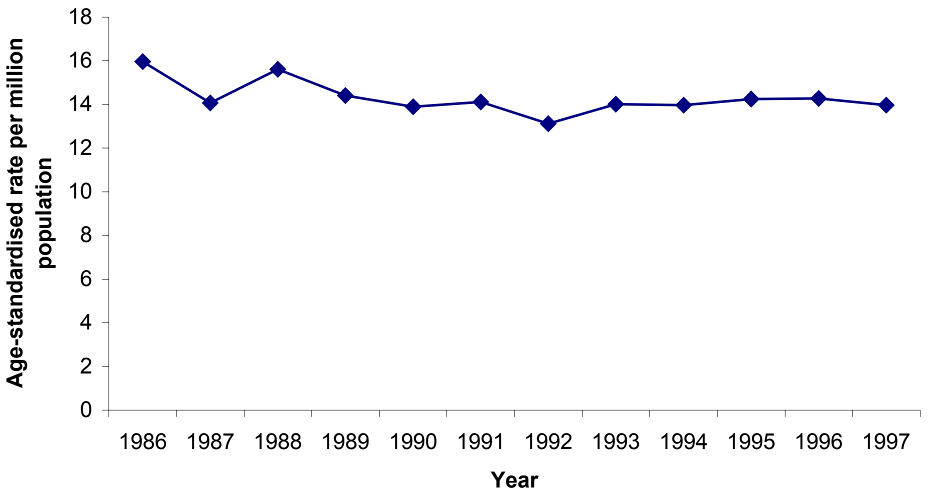


Figure 3.1: Trend in the age-standardised rate of SCI; Australia 1986–1997 (excludes cases aged 0–14 years)

---

[1] Trends described in this report are more accurate than those reported in earlier NISU publications on SCI as a result of quality assurance checks and improvements in coverage not finalised at the time of publication of the other reports.

3.2 Trends by age and sex

The analysis of overall trends masked opposing trends in the age- and sex-specific rates (Table 3.2 and Figure 3.2).

In males aged 15–24 years there was an approximate 3% p.a. decrease in the annual rate of SCI. While this trend was statistically significant, the upper bound of the confidence interval indicates that the trend may be less than –1% p.a. The trend for young males mainly reflected the trend in transport-related SCI in this group (Figure 3.16). There was some strong year-to-year variability in the rate prior to 1991, overall and for transport-related SCI in this group. During this period, the transport-related death rate in young males was declining (Figure 4.1). Since 1992 there has been little change in both the SCI rate and the death rate in young males. While the variability in the rates prior to 1991 could reflect the coding or classification of transport-related causes of SCI, this is unlikely because: (1) transport-related injury is so readily defined and measured; and (2) the same variability was not observed for young females over the same period (Figure 3.19). There are no known system changes that could account for such patterns in the data.

In males aged 65 years and over there was an approximate 6% p.a. increase in the rate of SCI, which was statistically significant. In females aged 55–64 years, there was an approximate 12% p.a. increase in the rate of SCI. While this trend was statistically significant, the lower bound of the confidence interval indicates that the trend may be less than 1% p.a.

Table 3.2: Trends in age and sex specific rates of SCI; Australia 1986–1997

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Male 15–24 yrs	–0.0283	–0.0487 to –0.0080	0.006	–2.80*
Male 25–35 yrs	–0.0122	–0.0355 to +0.0111	0.305	–1.21
Male 35–44 yrs	–0.0013	–0.0312 to +0.0286	0.931	–0.13
Male 45–54 yrs	–0.0189	–0.0559 to +0.0180	0.315	–1.88
Male 55–64 yrs	+0.0046	–0.0421 to +0.0513	0.847	+0.46
Male 65+ yrs	+0.0602	+0.0214 to +0.0990	0.002	+6.21*
Female 15–24 yrs	–0.0341	–0.0739 to +0.0058	0.094	–3.35
Female 25–35 yrs	+0.0019	–0.0488 to +0.0525	0.943	+0.19
Female 35–44 yrs	+0.0139	–0.0510 to +0.0788	0.675	+1.40
Female 45–54 yrs	–0.0584	–0.1342 to +0.0174	0.131	–5.67
Female 55–64 yrs	+0.1114	+0.0098 to +0.2129	0.032	+11.78*
Female 65+ yrs	+0.0379	–0.0219 to +0.0978	0.214	+3.87

* Annual per cent change is significantly different from zero, $p<0.05$.

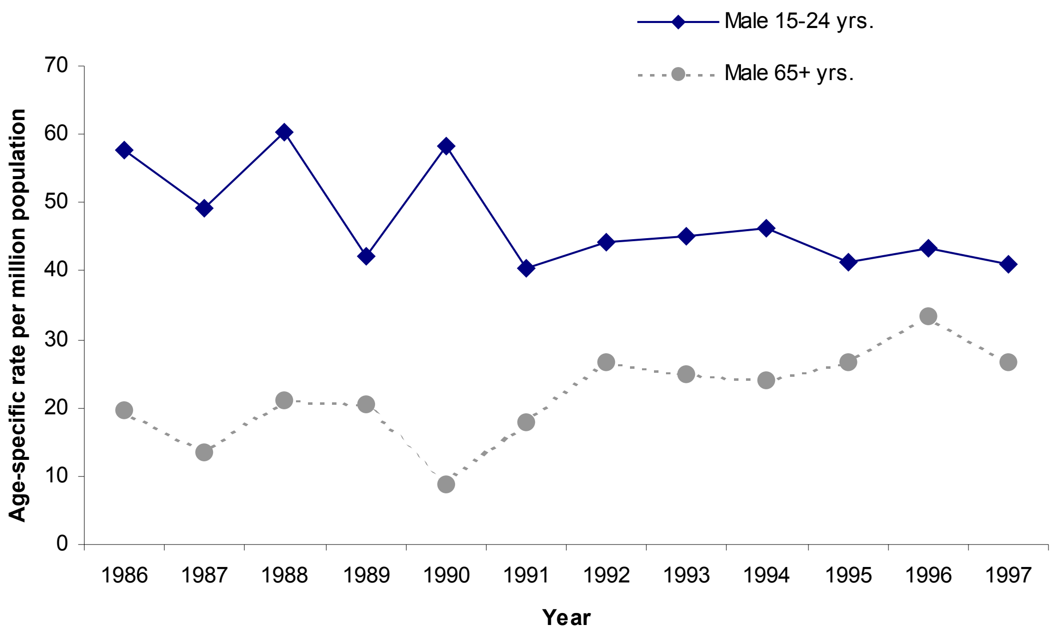


Figure 3.2: Trend in age specific rate, males aged 15–24 years and 65 years and over; Australia 1986–1997

3.3 Trends by cause

The analysis of overall trends also masked opposing trends in the rates of SCI by cause (Table 3.3 and Figure 3.3). There was an approximate 4% p.a. decrease in the annual rate of transport-related SCI but an approximate 2% p.a. increase in the annual rate of fall-related SCI. While both of these trends were statistically significant, the lower bound of the confidence interval for fall-related SCI indicates that this trend may be less than 1% p.a.

Table 3.3: Trends in cause specific rates(a) of SCI; Australia 1986–1997

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Transport	-0.0405	-0.0554 to –0.0256	<0.001	-3.97
Fall	+0.0229	+0.0031 to +0.0427	0.024	+2.32
Other cause	+0.0105	-0.0118 to +0.0327	0.356	+1.05

(a) These rates are not age standardised.

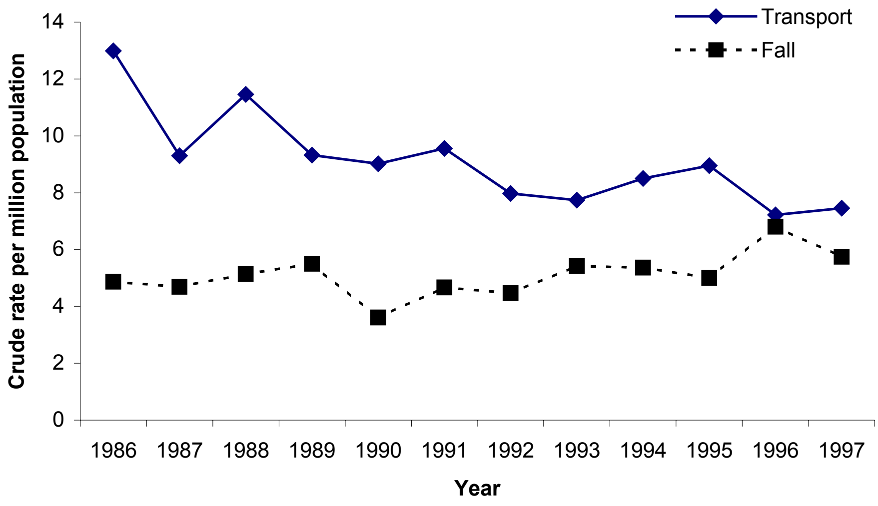


Figure 3.3: Trends in crude rate by cause of SCI; Australia 1986–1997

3.4 Trends by neurological group

Although there was a statistically significant 4% p.a. decrease in the annual rate of complete tetraplegia overall (Table 3.4), it appears from Figure 3.4 that the declining trend in 1986–1991 actually reversed from 1991–1997. No statistically, or practically, significant trends were observed for other neurological groups (Table 3.4).

Table 3.4: Trends in rates(a) of SCI by neurological group; Australia 1986–1997(b)

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Complete tetraplegia	–0.0408	–0.0656 to –0.0160	<0.001	–4.00
Incomplete tetraplegia	+0.0047	–0.0131 to +0.0227	0.601	+0.48
Complete paraplegia	–0.0141	–0.0369 to +0.0087	0.226	–1.40
Incomplete paraplegia	+0.0016	–0.0191 to +0.0224	0.878	+0.16

(a) These rates are not age standardised.

(b) Neurological group was missing for 44 cases.

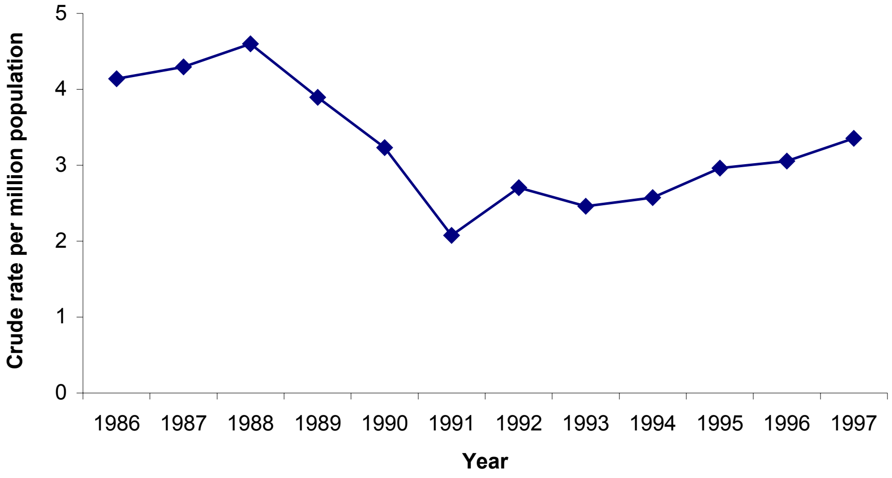


Figure 3.4: Trend in crude rate of complete tetraplegia; Australia 1986–1997

3.5 Trends by neurological group, age and sex

Statistically significant decreasing trends occurred for complete tetraplegia and complete paraplegia in males aged 15–24 years (–5% p.a.), for incomplete tetraplegia in males aged 45–54 years (–7% p.a.), and for complete paraplegia in females aged 15–24 years (–11% p.a.; Table 3.5).

Statistically significant increasing trends occurred for complete paraplegia in females aged 25–34 years (+16% p.a.) and for incomplete paraplegia in males aged 65 years and over (+20% p.a.).

Figures 2.5–2.10 show that some of the statistically significant trends noted above may have reflected influential data points in the time series, particularly Figure 3.9. The low rates and the strong variability in the rates raise doubts about the shape and reliability of some of these trends.

Table 3.5: Trends in rates by neurological group, age and sex; Australia 1986–1997(a)

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Complete tetraplegia				
Male, 15–24 yrs	–0.0528	–0.0948 to –0.0108	0.014	–5.14*
Male, 25–34 yrs	–0.0225	–0.0756 to +0.0305	0.405	–2.23
Male, 35–44 yrs	–0.0610	–0.1371 to +0.0151	0.116	–5.92
Male, 65+ yrs	+0.0355	–0.0582 to +0.1293	0.458	+3.61
Female, 15–24 yrs	+0.0163	–0.0775 to +0.1102	0.733	+1.65
Incomplete tetraplegia				
Male, 15–24 yrs	+0.0136	–0.0236 to +0.0508	0.474	+1.37
Male, 25–34 yrs	–0.0185	–0.0633 to +0.0264	0.419	–1.83
Male, 35–44 yrs	+0.0329	–0.0234 to +0.0893	0.252	+3.35
Male, 45–54 yrs	–0.0727	–0.1291 to –0.0163	0.011	–7.01*
Male, 55–64 yrs	–0.0016	–0.0677 to +0.0644	0.961	–0.16
Male, 65+ yrs	+0.0405	–0.0101 to +0.0911	0.117	+4.13
Female, 15–24 yrs	+0.0258	–0.0576 to +0.1092	0.544	+2.62
Female, 25–34 yrs	–0.0761	–0.1715 to +0.0193	0.118	–7.33
Female, 35–44 yrs	+0.0045	–0.1099 to +0.1189	0.939	+0.45
Female, 65+ yrs	+0.0791	–0.0005 to +0.1588	0.052	+8.23
Complete paraplegia				
Male, 15–24 yrs	–0.0559	–0.1007 to –0.0111	0.014	–5.43*
Male 25–34 yrs	+0.0045	–0.0414 to +0.0505	0.847	+0.45
Male 35–44 yrs	–0.0300	–0.0867 to +0.0268	0.301	–2.95
Male 45–54 yrs	+0.0826	–0.0055 to +0.1708	0.066	+8.61
Male 55–64 yrs	+0.0548	–0.0553 to +0.1649	0.329	+5.63
Female, 15–24 yrs	–0.1129	–0.2000 to –0.0258	0.011	–10.67*
Female, 25–34 yrs	+0.1487	+0.0392 to +0.2581	0.008	+16.03*
Incomplete paraplegia				
Male, 15–24 yrs	–0.0163	–0.0577 to +0.0250	0.438	–1.62
Male, 25–34 yrs	–0.0088	–0.0535 to +0.0359	0.699	–0.88
Male, 35–44 yrs	+0.0398	–0.0190 to +0.0987	0.184	+4.07
Male, 45–54 yrs	+0.0378	–0.0364 to +0.1120	0.318	+3.85
Male, 55–64 yrs	–0.0184	–0.1292 to +0.0924	0.745	–1.82
Male, 65+ yrs	+0.1793	+0.0631 to +0.2955	0.002	+19.64*
Female, 15–24 yrs	–0.0340	–0.1015 to +0.0336	0.324	–3.34
Female, 25–34 yrs	–0.0108	–0.0978 to +0.0762	0.808	–1.07
Female, 35–44 yrs	+0.0670	–0.0502 to +0.1842	0.262	+6.93

(a) Neurological group was missing for 44 cases.

* Annual per cent change is significantly different from zero, p<0.05.

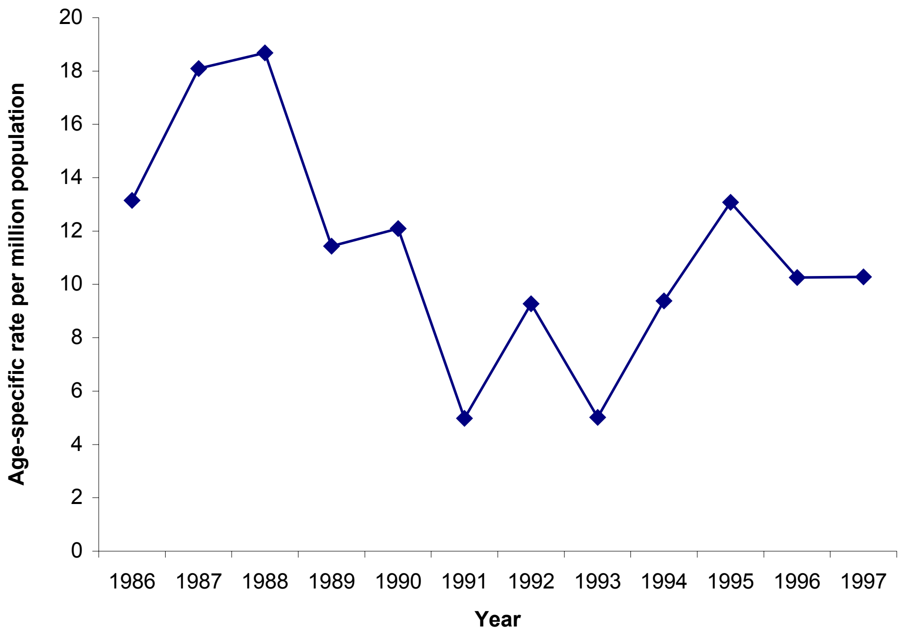


Figure 3.5: Trend in the rate of complete tetraplegia in males aged 15–24 years; Australia 1986–1997

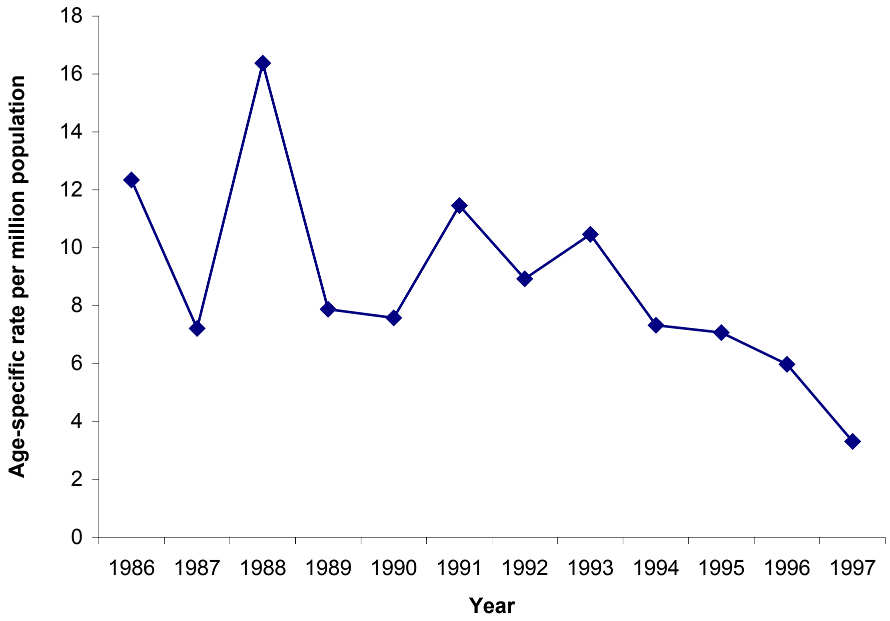


Figure 3.6: Trend in the rate of incomplete tetraplegia in males aged 45–54 years; Australia 1986–1997

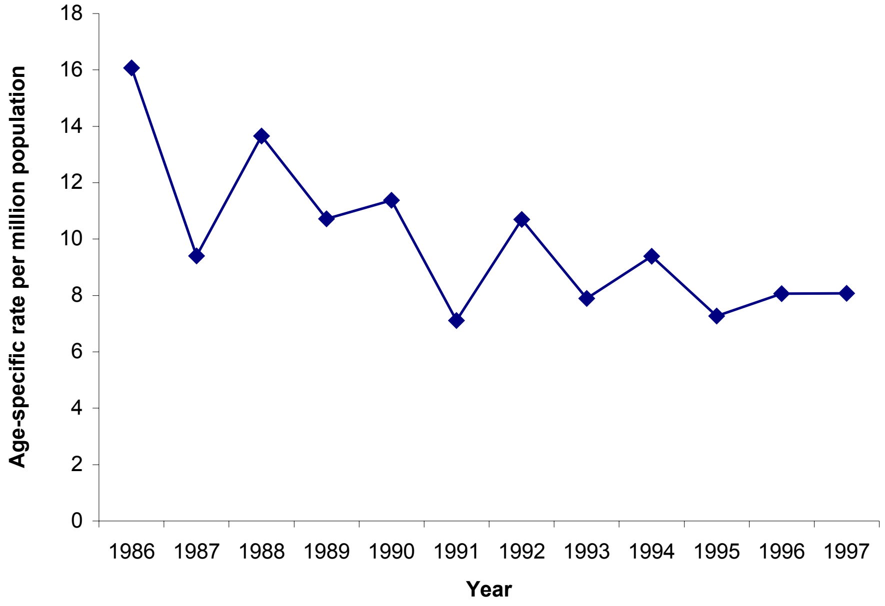


Figure 3.7: Trend in the rate of complete paraplegia in males aged 15–24 years; Australia 1986–1997

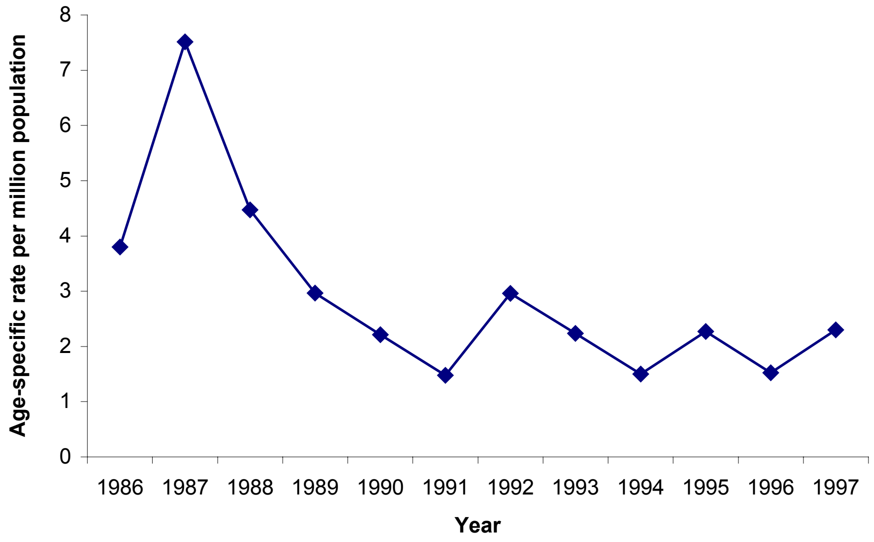


Figure 3.8: Trend in the rate of complete paraplegia in females aged 15–24 years; Australia 1986–1997

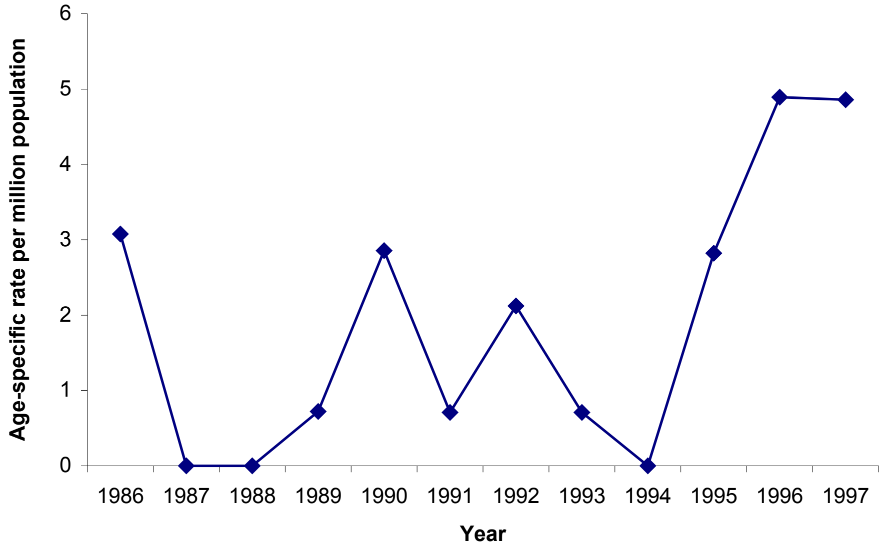


Figure 3.9: Trend in the rate of complete paraplegia in females aged 25–34 years; Australia 1986–1997

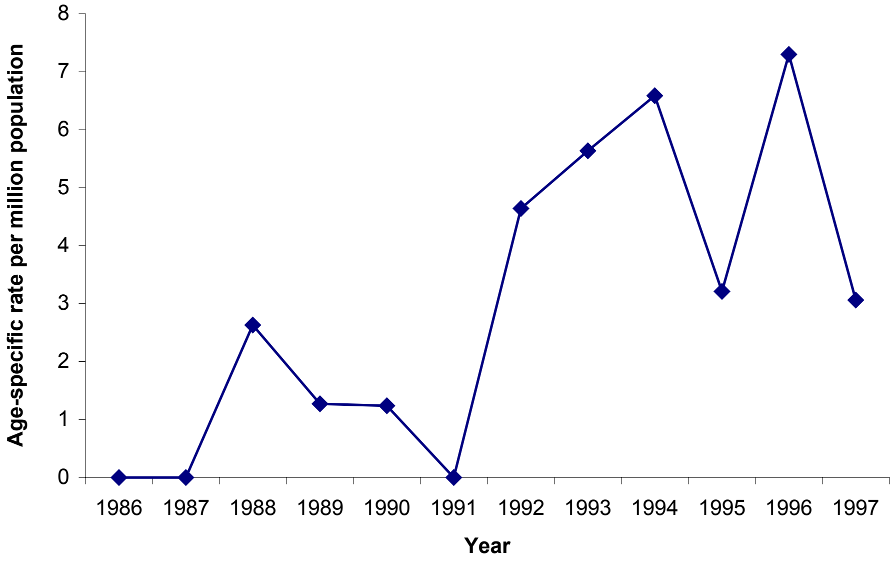


Figure 3.10: Trend in the rate of incomplete paraplegia in males aged 65 years and over; Australia 1986–1997

3.6 Trends by neurological group and cause

There were statistically significant declines in the rates of complete tetraplegia, complete paraplegia and incomplete paraplegia arising from transport-related causes (6% p.a., 5% p.a., and 4% p.a. respectively; Table 3.6). It needs to be considered however, that the lower bound of the confidence interval for transport-related incomplete paraplegia indicates that this trend may be less than 1% p.a. As noted in Figure 3.4 for complete tetraplegia overall, Figure 3.11 suggests that for transport-related complete tetraplegia there may have been an increase in the rate from 1991.

There was a statistically significant increase in the rate of incomplete tetraplegia and complete paraplegia from falls (approximately 4% p.a. for both strata). However, the lower bound of the confidence interval indicates that these trends may be less than 1% p.a. The low rate of fall-related complete paraplegia and the strong variability in the rates from year-to-year raise doubts about the shape and reliability of the trend for fall-related complete paraplegia (Figure 3.14).

Table 3.6: Trends in rates(a) of SCI by neurological group and cause; Australia 1986–1997(b)

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Complete tetraplegia				
Transport	–0.0584	–0.0927 to –0.0242	0.001	–5.67*
Fall	–0.0516	–0.1112 to +0.0080	0.089	–5.03
Other cause	–0.0030	–0.0486 to +0.0426	0.897	–0.30
Incomplete tetraplegia				
Transport	–0.0162	–0.0420 to +0.0096	0.219	–1.61
Fall	+0.0352	+0.0005 to +0.0699	0.047	+3.58*
Other cause	+0.0123	–0.0236 to +0.0482	0.502	+1.24
Complete paraplegia				
Transport	–0.0464	–0.0771 to –0.0158	0.003	–4.53*
Fall	+0.0432	+0.0002 to +0.0862	0.049	+4.42
Other cause	–0.0035	–0.0616 to +0.0546	0.907	–0.35
Incomplete paraplegia				
Transport	–0.0399	–0.0709 to –0.0089	0.012	–3.92*
Fall	+0.0321	–0.0026 to +0.0669	0.070	+3.26
Other cause	+0.0431	–0.0052 to +0.0914	0.080	+4.41

(a) These rates are not age standardised.

(b) Neurological group was missing for 44 cases.

* Annual per cent change is significantly different from zero, $p<0.05$.

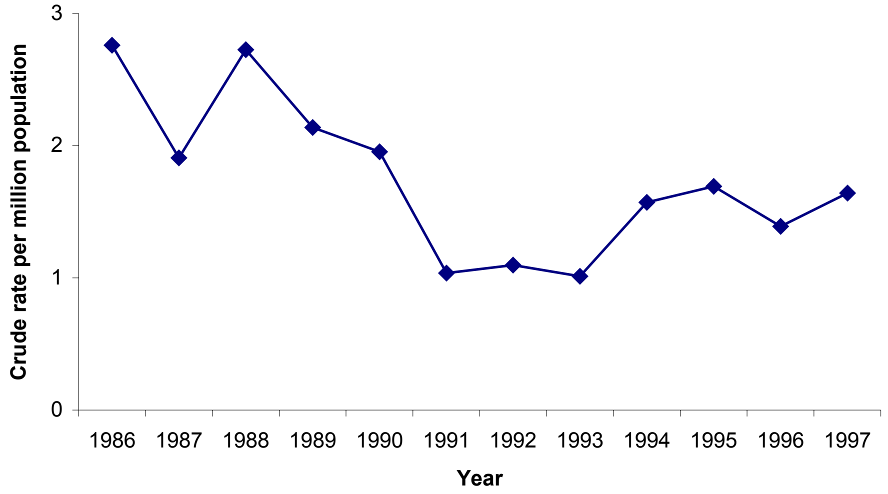


Figure 3.11: Trend in the rate of transport-related complete tetraplegia; Australia 1986–1997

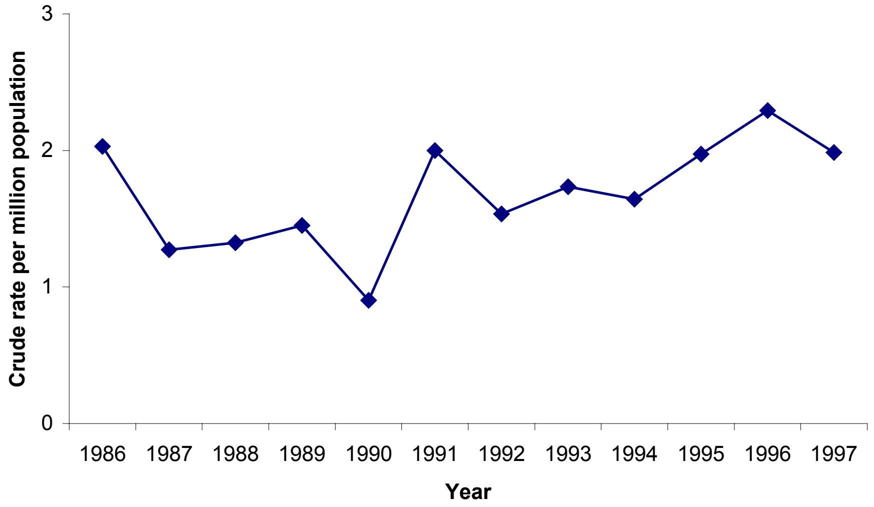


Figure 3.12: Trend in the rate of fall-related incomplete tetraplegia; Australia 1986–1997

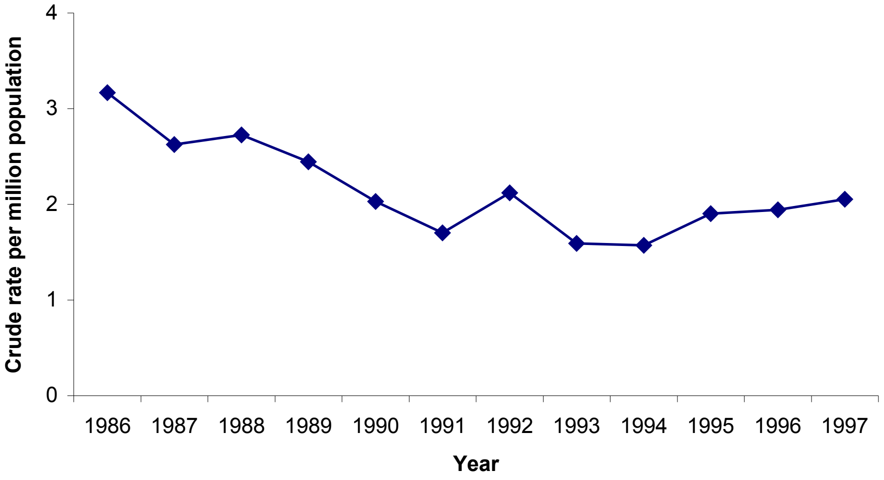


Figure 3.13: Trend in the rate of transport-related complete paraplegia; Australia 1986–1997

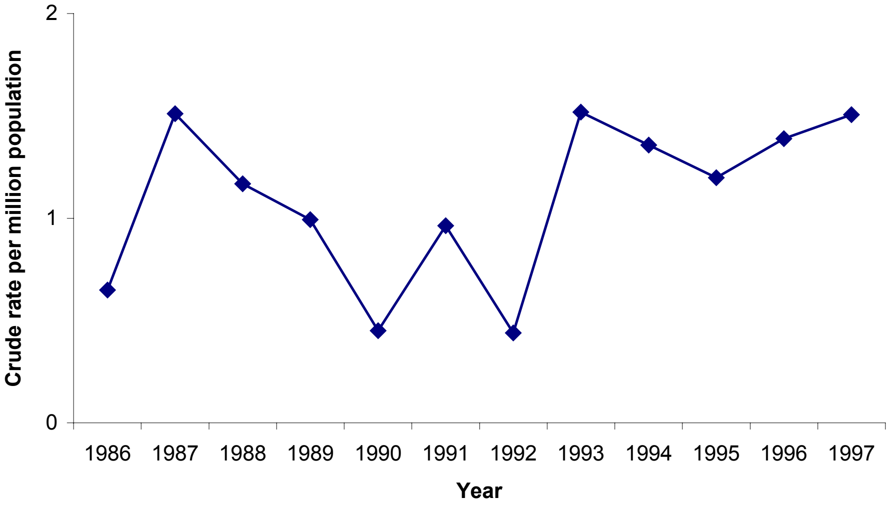


Figure 3.14: Trend in the rate of fall-related complete paraplegia; Australia 1986–1997

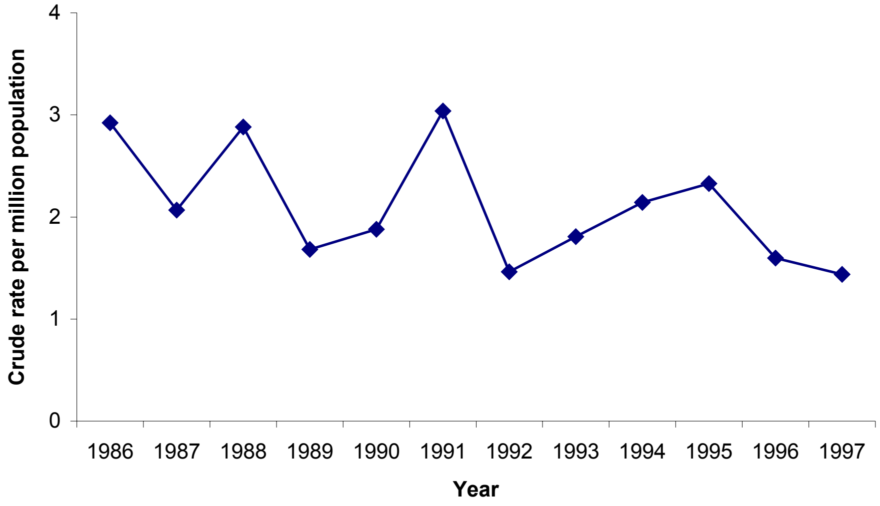


Figure 3.15: Trend in the rate of transport-related incomplete paraplegia; Australia 1986–1997

3.7 Trends by age, sex and cause

There were statistically significant decreasing trends in the rates of transport-related SCI in males aged 15–24 years (–4% p.a.), 25–34 years (–3% p.a.), and 45–54 years (–6% p.a.), and also in females aged 15–24 years (–7% p.a.; Table 3.7). It needs to be considered however, that the lower bound of the confidence interval indicates that the trends for males aged 25–34 years and 45–54 years may be small (<1% p.a.). In addition, strong year-to-year variability in the rates for these groups raises doubts about the shape and reliability of a number of the reported trends (e.g. Figures 3.17–3.19). Although the trend for males aged 15–24 years also showed some unusual year-to-year variation prior to 1991, it is considered unlikely that this reflects coding or classification issues or system changes because the same variability was not shown for young females (Figure 3.19), as discussed under *Trends by Age and Sex*.

A statistically significant increasing trend in the rate of fall-related SCI was observed in males aged 65 years and over (+9% p.a.), but not in females in the same age group. Figure 3.20 shows quite a steady increase in the rate of fall-related SCI in males aged 65 years and over.

Table 3.7: Trends in age, sex and cause specific categories; Australia 1986–1997

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Transport, male 15–24 yrs	–0.0442	–0.0720 to –0.0163	0.002	–4.32*
Transport, male 25–34 yrs	–0.0320	–0.0639 to –0.0001	0.050	–3.15*
Transport, male 35–44 yrs	–0.0435	–0.0879 to +0.0008	0.055	–4.26
Transport, male 45–54 yrs	–0.0620	–0.1226 to –0.0014	0.045	–6.01*
Transport, male 55–64 yrs	–0.0264	–0.1048 to +0.0520	0.510	–2.60
Transport, male 65+ yrs	+0.0211	–0.0462 to +0.0883	0.539	+2.13
Transport, female 15–24 yrs	–0.0724	–0.1223 to –0.0225	0.004	–6.99*
Transport, female 25–34 yrs	–0.0089	–0.0735 to +0.0557	0.787	–0.89
Transport, female 35–44 yrs	–0.0030	–0.0823 to +0.0762	0.940	–0.30
Transport, female 45–54 yrs	–0.0651	–0.1624 to +0.1624	0.190	–6.30
Transport, female 65+ yrs	+0.0692	–0.0362 to +0.1746	0.198	+7.16
Fall, male 15–24 yrs	–0.0219	–0.0754 to +0.0316	0.423	–2.16
Fall, male 25–34 yrs	–0.0097	–0.0574 to +0.0380	0.690	–0.97
Fall, male 35–44 yrs	+0.0233	–0.0292 to +0.0759	0.384	+2.36
Fall, male 45–54 yrs	+0.0424	–0.0214 to +0.1062	0.193	+4.33
Fall, male 55–64 yrs	–0.0108	–0.0814 to +0.0598	0.764	–1.08
Fall, male 65+ yrs	+0.0853	+0.0326 to +0.1380	0.002	+8.91*
Fall, female 15–24 yrs	–0.0167	–0.0983 to +0.0649	0.688	–1.66
Fall, female 25–34 yrs	+0.0377	–0.0690 to +0.1444	0.489	+3.84
Fall, female 65+ yrs	+0.0267	–0.0529 to +0.1064	0.510	+2.71
Other, male 15–24 yrs	–0.0046	–0.0407 to +0.0315	0.803	–0.46
Other, male 25–34 yrs	+0.0322	–0.0171 to +0.0816	0.200	+3.28
Other, male 35–44 yrs	+0.0503	–0.0144 to +0.1151	0.127	+5.16
Other, male 45–54 yrs	–0.0375	–0.1079 to +0.0329	0.296	–3.68
Other, male 55–64 yrs	+0.0934	–0.0133 to +0.2002	0.086	+9.79
Other, male 65+ yrs	+0.0514	–0.0607 to +0.1635	0.369	+5.27

* Annual per cent change is significantly different from zero, $p<0.05$.

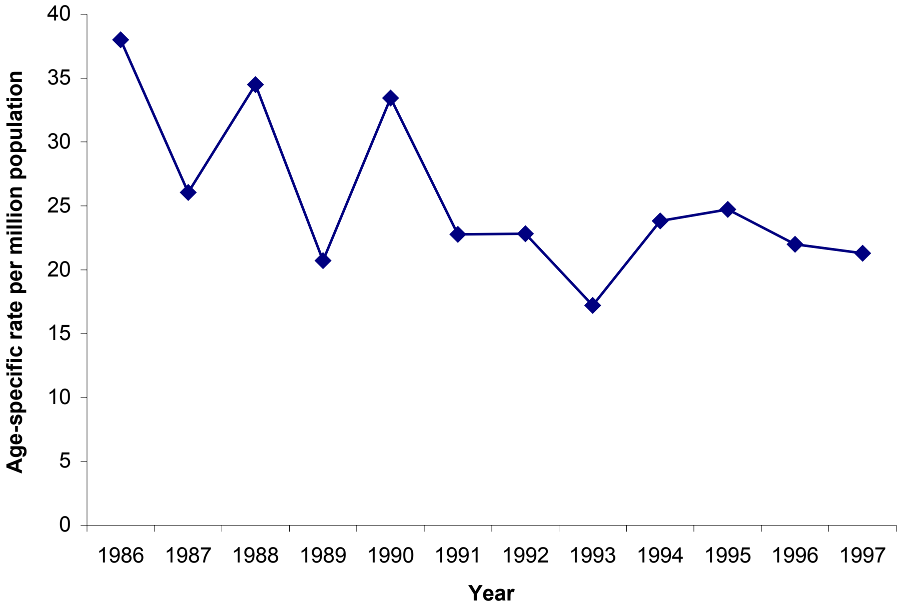


Figure 3.16: Trend in the rate of transport-related SCI in males aged 15–24 years; Australia 1986–1997

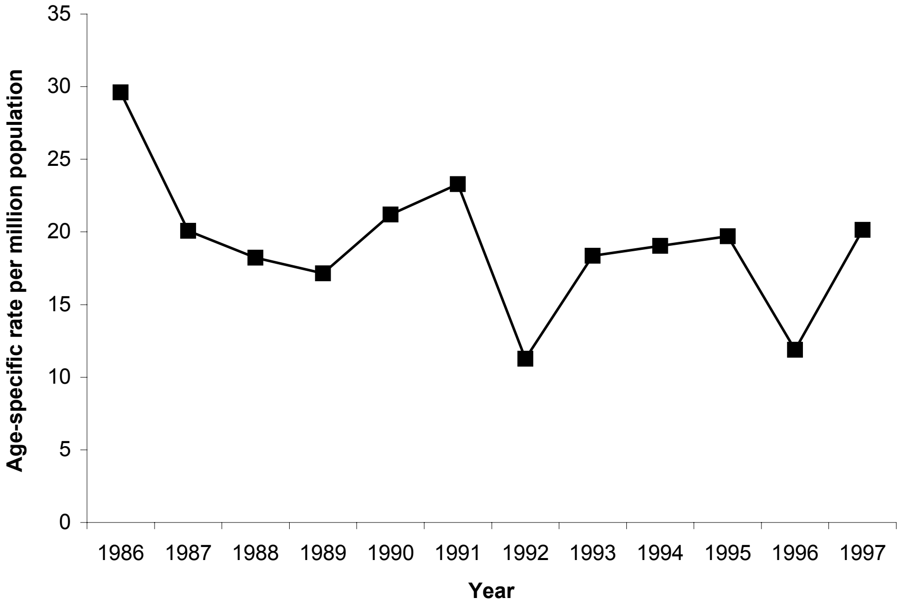


Figure 3.17: Trend in the rate of transport-related SCI in males aged 25–34 years; Australia 1986–1997

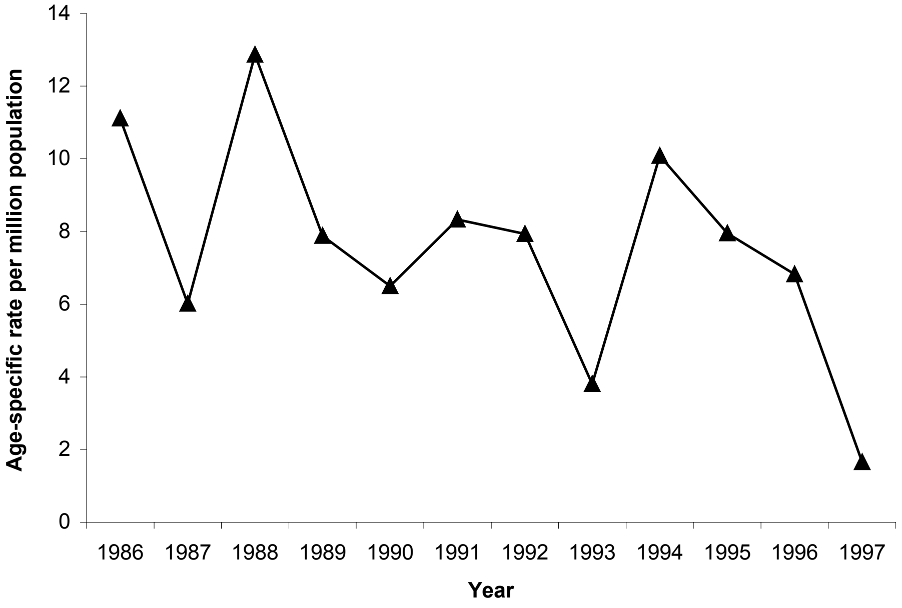


Figure 3.18: Trend in the rate of transport-related SCI in males aged 45–54 years; Australia 1986–1997

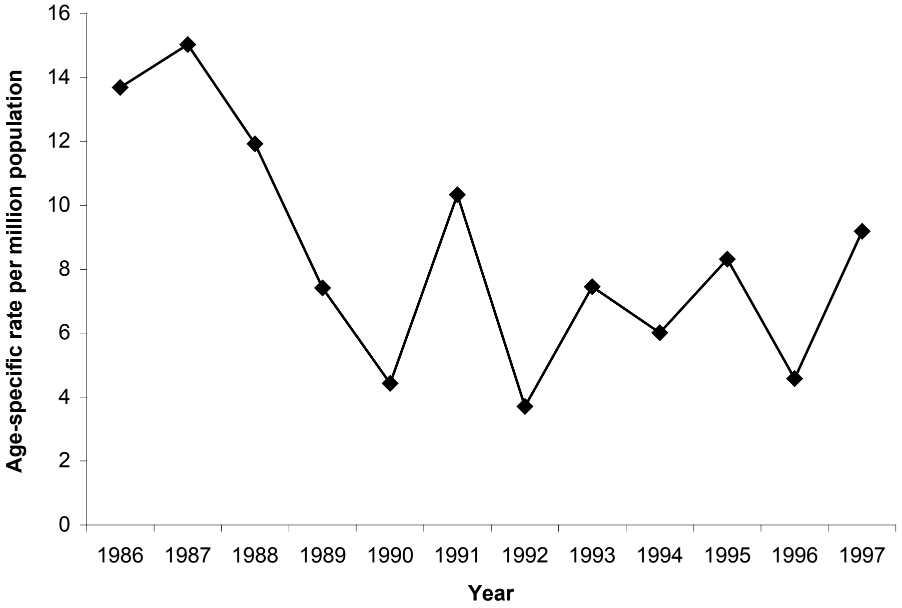


Figure 3.19: Trend in the rate of transport-related SCI in females aged 15–24 years; Australia 1986–1997

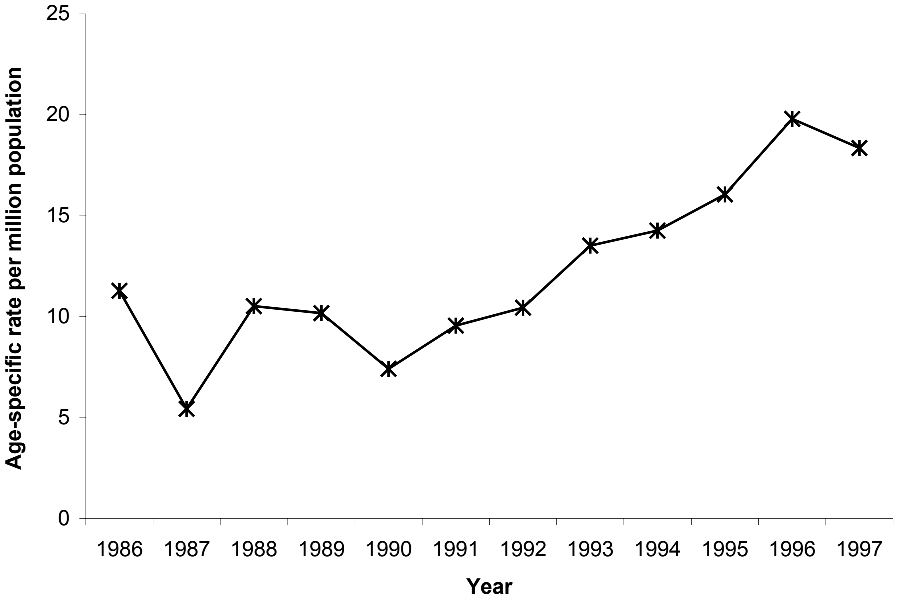


Figure 3.20: Trend in the rate of fall-related SCI in males aged 65 years and over; Australia 1986–1997

3.8 Trends by age, sex, cause and neurological group

Of the 144 strata defined jointly by age, sex, cause and neurological group, only 43 fitted the criteria specified in the Methods section to guard against over-dispersion relative to the Poisson distribution, and many of these even had sparse data.

There was a statistically significant decreasing trend in the rate of complete tetraplegia from transport-related causes in males aged 35–44 years (–12% p.a.; Table 3.8). However, Figure 3.21 shows that there was substantial year-to-year variability in the rate, raising doubt about the shape and reliability of the reported trend.

There were statistically significant decreasing trends in the rate of complete paraplegia from transport-related causes in males and females aged 15–24 years (–5% p.a. and –12% p.a. respectively). However, these trends appear to have been substantially influenced by relatively large rates in a single year (Figures 3.23 and 3.24).

There was also a statistically significant increasing trend in the rate of complete paraplegia from 'other causes' in males aged 25–34 years (+15% p.a.). However, this trend appears to have been substantially influenced by a relatively large rate in a single year (Figure 3.23).

Table 3.8: Trends in age, sex, cause and neurological group(a) specific categories; Australia 1986–1997(b)

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Transport, male 15–24 yrs, CT	–0.0539	–0.1176 to +0.0097	0.097	–5.25
Transport, male 25–34 yrs, CT	–0.0266	–0.0998 to +0.0465	0.476	–2.63
Transport, male 35–44 yrs, CT	–0.1271	–0.2292 to +0.0251	0.015	–11.94*
Transport, male 15–24 yrs, IT	–0.0076	–0.0644 to +0.0491	0.792	–0.76
Transport, male 25–34 yrs, IT	–0.0371	–0.0964 to +0.0223	0.221	–3.64
Transport, male 35–44 yrs, IT	–0.0381	–0.1206 to +0.0443	0.364	–3.74
Transport, male 45–54 yrs, IT	–0.0629	–0.1486 to +0.0228	0.150	–6.10
Transport, male 55–64 yrs, IT	–0.0042	–0.1090 to +0.1006	0.937	–0.42
Transport, male 65+ yrs, IT	+0.0458	–0.0438 to +0.1354	0.317	+4.69
Transport, male 15–24 yrs, CP	–0.0538	–0.1056 to –0.0021	0.042	–5.24*
Transport, male 25–34 yrs, CP	–0.0291	–0.0893 to +0.0312	0.344	–2.87
Transport, male 35–44 yrs, CP	–0.0341	–0.1174 to +0.0492	0.422	–3.35
Transport, male 15–24 yrs, IP	–0.0467	–0.1008 to +0.0074	0.091	–4.56
Transport, male 25–34 yrs, IP	–0.0277	–0.0932 to +0.0379	0.408	–2.73
Transport, male 35–44 yrs, IP	+0.0329	–0.0643 to +0.1300	0.507	+3.34
Fall, male 25–34 yrs, IT	+0.0202	–0.0898 to +0.1303	0.718	+2.04
Fall, male 35–44 yrs, IT	+0.1024	–0.0068 to +0.2117	0.066	+10.78
Fall, male 45–54 yrs, IT	–0.0627	–0.1683 to +0.0428	0.244	–6.08
Fall, male 55–64 yrs, IT	–0.0399	–0.1371 to +0.0574	0.421	–3.91
Fall, male 65+ yrs, IT	+0.0546	–0.0119 to +0.1211	0.108	+5.61
Fall, male 15–24 yrs, CP	–0.0053	–0.1172 to +0.1065	0.926	–0.53
Fall, male 25–34 yrs, CP	–0.0010	–0.0923 to +0.0903	0.982	–0.10
Fall, male 35–44 yrs, CP	–0.0145	–0.1123 to +0.0833	0.772	–1.43
Fall, male 15–24 yrs, IP	+0.0057	–0.0775 to +0.0889	0.894	+0.57
Fall, male 25–34 yrs, IP	+0.0102	–0.0661 to +0.0865	0.794	+1.02
Fall, male 35–44 yrs, IP	+0.0449	–0.0464 to +0.1362	0.335	+4.59
Fall, male 45–54 yrs, IP	+0.0928	–0.0232 to +0.2089	0.117	+9.73
Other, male 15–24 yrs, CT	–0.0289	–0.0895 to +0.0318	0.351	–2.84
Other, male 25–34 yrs, CT	+0.0385	–0.0586 to +0.1356	0.437	+3.93

(continued)

Table 3.8 (continued): Trends in age, sex, cause and neurological group(a) specific categories; Australia 1986–1997(b)

Trend	Coefficient (α)	95% confidence interval	p-value	Annual % change
Other, male 15–24 yrs, IT	+0.0291	–0.0252 to +0.0833	0.294	+2.95
Other, male 25–34 yrs, IT	–0.0024	–0.0905 to +0.0856	0.957	–0.24
Other, male 35–44 yrs, IT	+0.0899	–0.0264 to +0.2061	0.130	+9.40
Other, male 45–54 yrs, IT	–0.0979	–0.2045 to +0.0088	0.072	–9.32
Other, male 25–34 yrs, CP	+0.1411	+0.0184 to +0.2638	0.024	+15.15*
Other, male 15–24 yrs, IP	+0.0603	–0.0433 to +0.1641	0.254	+6.22
Other, male 25–34 yrs, IP	+0.0031	–0.0993 to +0.1056	0.953	+0.31
Transport, female 15–24 yrs, CT	–0.0328	–0.1357 to +0.0701	0.532	–3.23
Transport, female 15–24 yrs, IT	–0.0968	–0.2046 to +0.0110	0.078	–9.23
Transport, female 25–34 yrs, IT	–0.0599	–0.1708 to +0.0510	0.289	–5.82
Transport, female 15–24 yrs, CP	–0.1309	–0.2365 to –0.0254	0.015	–12.27*
Transport, female 15–24 yrs, IP	–0.0261	–0.1166 to +0.0643	0.571	–2.58
Fall, female 65+ yrs, IT	+0.0604	–0.0479 to +0.1688	0.274	+6.23
Fall, female 15–24 yrs, IP	–0.0379	–0.1484 to +0.0725	0.501	–3.72

(a) Legend: CT = Complete Tetraplegia; IT = Incomplete Tetraplegia; CP = Complete Paraplegia; IP = Incomplete Paraplegia.

(b) Neurological group was missing for 44 cases.

* Annual per cent change is significantly different from zero, p<0.05.

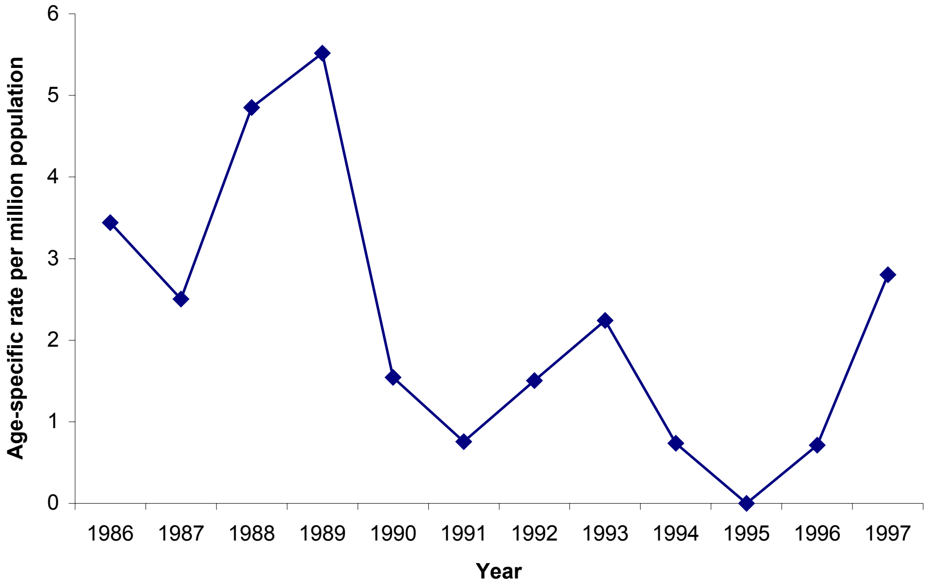


Figure 3.21: Trend in the rate of transport-related complete tetraplegia in males aged 35–44 years; Australia 1986–1997

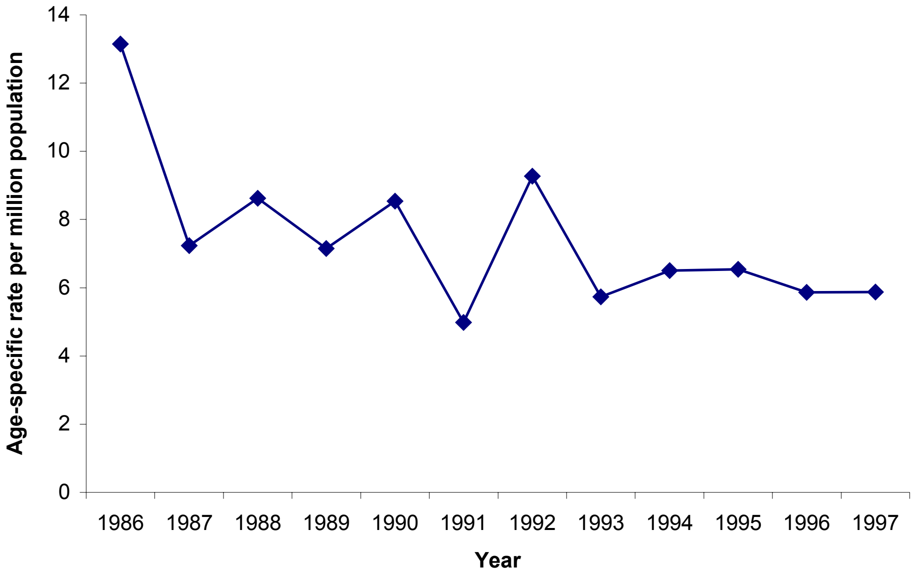


Figure 3.22: Trend in the rate of transport-related complete paraplegia in males aged 15–24 years; Australia 1986–1997

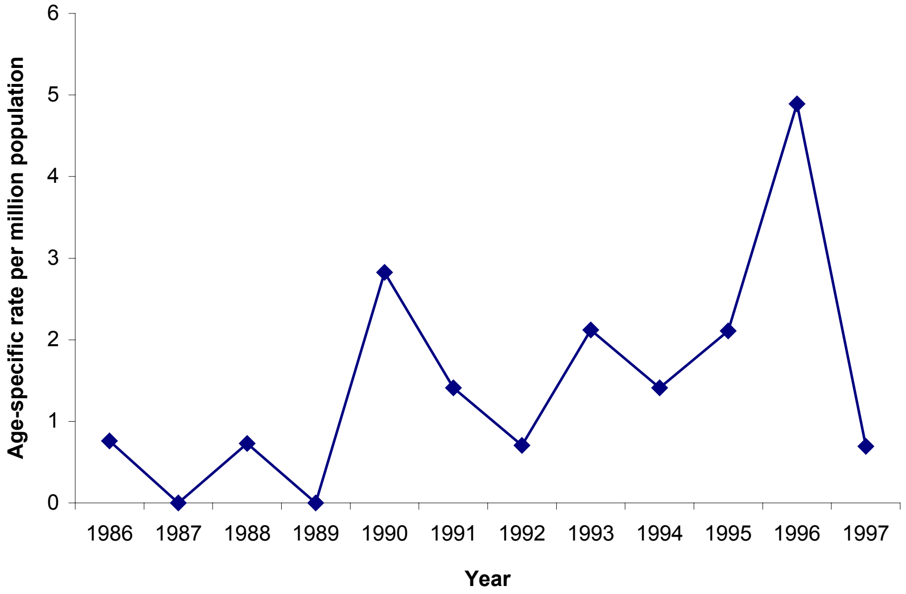


Figure 3.23: Trend in the rate of complete paraplegia from other causes in males aged 25–34 years; Australia 1986–1997

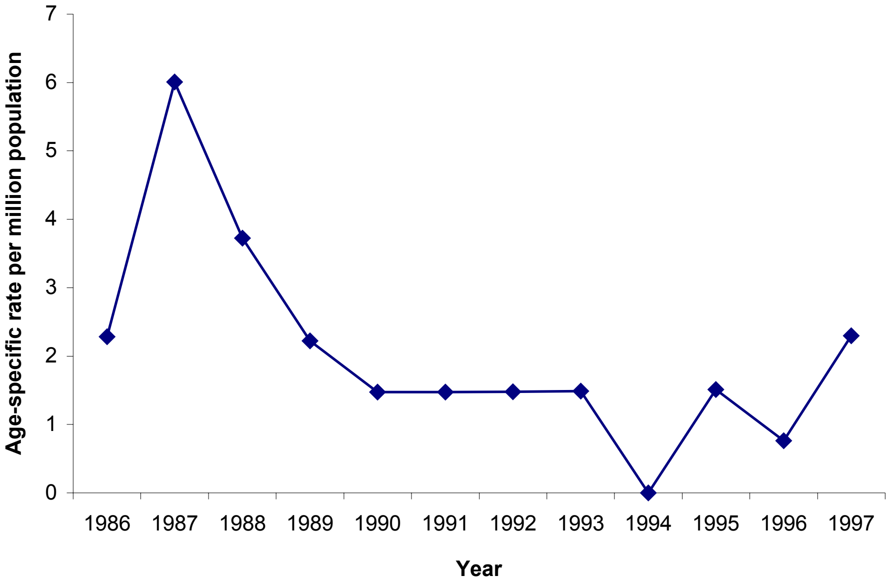


Figure 3.24: Trend in the rate of complete paraplegia from transport in females aged 15–24 years; Australia 1986–1997

4 Discussion

This exploration of SCI trends was limited in coverage due to small cell counts in many strata. In addition, there was uncertainty about some of the trends presented in the results; arising from small rates, strong variability in the year-to-year rates and the effect of influential data points in the time series for some strata. There have been methods developed over recent years to handle over-dispersion relative to the Poisson distribution, e.g. zero-inflated models (Ridout et al., 1998; Faddy, 1997; Gupta et al., 1996; Demetrio and Ridout, 1994; Lambert, 1992), and these warrant investigation to determine whether they provide the means for a more complete assessment of SCI trends.

Despite the limitations, the analysis provided some practically important information. From the perspective of a rehabilitation manager, interest often centres on the trend in the number of new cases of SCI (whatever is happening to the rate of SCI) because this effects workloads and the planning of rehabilitation services. From a public health perspective there is more interest in the trend in the incidence rate per head of population, the aim being to reduce the rate. The overall number and rate of new incident cases of SCI did not change substantially between 1986 and 1997, and there is evidence that trends are increasing for some groups. Therefore, rehabilitation managers and public health practitioners both have reason to be concerned.

A problem with an overall measure such as the age-standardised rate is that it may mask opposing trends in population sub-groups (Mausner and Bahn, 1974). Indeed, for SCI in Australia this appeared to be the case. There were some opposing trends in the rates of SCI by age and sex group, cause and neurological group. The rate of transport-related SCI declined (–4% p.a.) whereas the rate of fall-related SCI increased (+2% p.a.). Similar trends have been found in the USA and Finland. Nobunaga et al., (1999) showed that in the USA there was a decrease in the proportion of SCI from automobile crashes, but an increase in the proportion of fall-related SCI, from 1973–1977 compared with 1994–1998. Also, Kannus et al., (2000) reported an increase in fall-related SCI in Finnish persons over the age of 50 years. Further comparative and collaborative research is required to determine how fall-related SCI can be reduced.

Some contrasting trends were evident in the rates of SCI in those aged 15–24 years (referred to as 'young') and those aged 65 years and over (referred to as 'elderly'). In young males, the overall rate of SCI declined but a more substantial increase was observed among elderly males. The rate of transport-related SCI decreased in young males and females (–4% p.a. and –7% p.a. respectively), and also in some older male age groups (–3% p.a. in 25–34 year olds and –6% p.a. in 45–54 year olds). In contrast, the rate of fall-related SCI increased in elderly males (+9% p.a.), but not among elderly females. These contrasts suggest that there may have been public health successes and relative failures in addressing the SCI problem.

It appears that the public health measures directed at transport-related injury have had an important impact on the incidence of transport-related SCI. There has been a substantial investment from the early 1970s in effective public health measures, such as random breath testing, seat belt and helmet laws, improved vehicle and road design and graduated licensing, to control transport-related injury in Australia (Australian Transport Safety Bureau, 2001; Bureau of Transport Economics: BTE, 2001; BTE, 2000; O'Connor, 2000; Vulcan, 1999). The success of these measures is shown in a 6% p.a. decline in the transport-related death rate over the period 1986–1997 for all ages and 7% p.a. in young males and females (Figure 4.1); statistically significant based on the Poisson regression modelling approach utilised in the present study. These trends are in the same direction but are somewhat higher than observed for transport-related SCI over the same period for all ages and young males.

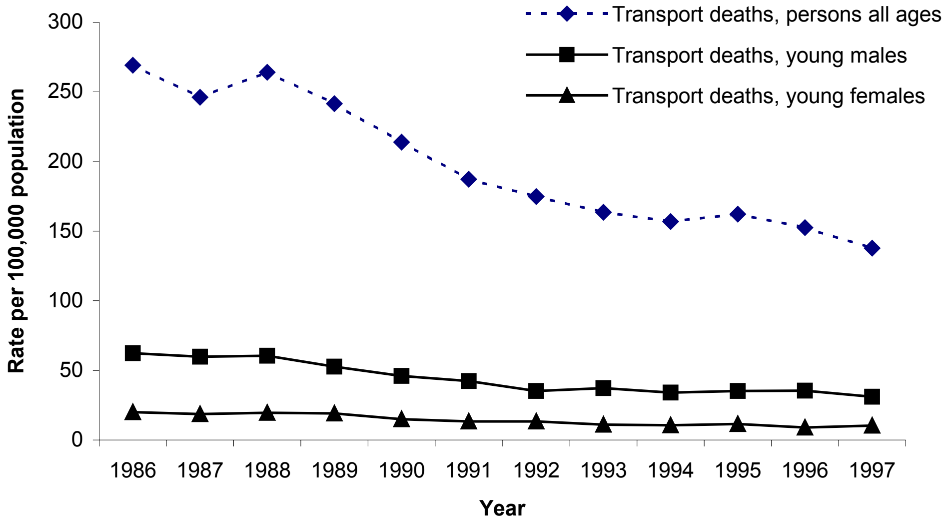


Figure 4.1: Trend in the rate of transport-related deaths; Australia 1986–1997

In contrast, public health measures directed at the primary prevention of fall-related injury do not appear to have had an impact on the incidence of fall-related SCI. It also appears that those measures may have stalled in terms of an impact on fall-related deaths. While it has been reported that the rate of fall-related mortality in Australia declined substantially over the last 20 years among persons over the age of 65 years, both male and female (Bordeaux and Harrison, 1998), it has also been reported that the rate may have increased slightly since 1993 (Cripps and Carman, 2001). Re-analysis of the data utilised in those studies, using the Poisson regression modelling approach used in this chapter, showed that while there was an overall 1% p.a. reduction in fall-related deaths 1986–1997 among elderly males and females, there was a statistically significant increase since 1993; 4% p.a. for elderly males and 7% p.a. for elderly females (Figure 4.2).

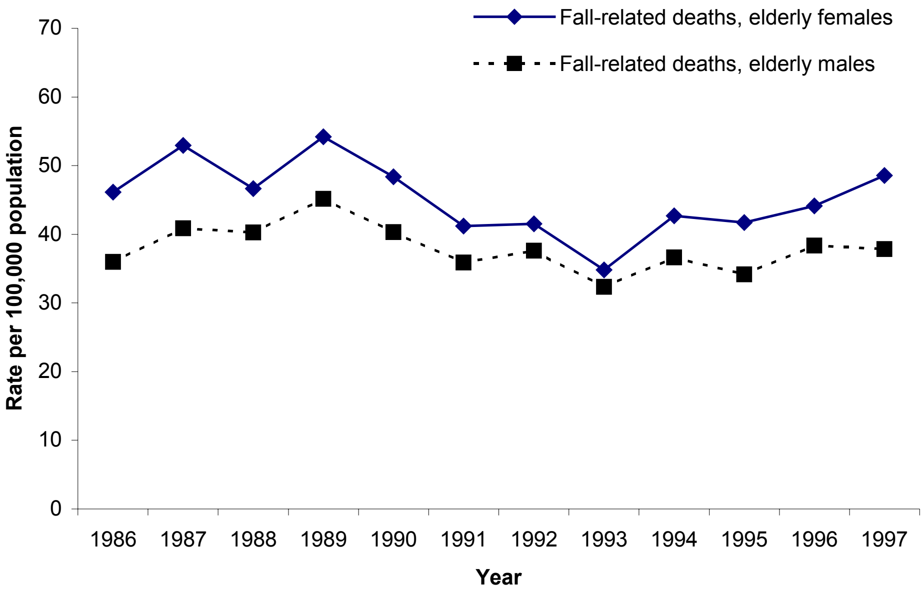


Figure 4.2: Trend in the rate of fall-related deaths in the elderly; Australia 1986–1997

The trends for fall-related SCI in the elderly have been quite different from those observed for deaths; there was no reduction in the rate of SCI. Indeed, over the full period 1986–1997, there was a 9% p.a. increase in the rate of fall-related SCI in elderly males; 12% p.a. from 1991, when the upward trend seems to have commenced. It is not clear why there has been such an increase, and this warrants investigation. The specific risk factors have not been studied before and it appears that there have been no specific measures directed at the primary prevention of this problem relative to other fall-related problems (Hill et al., 2000a, 2000b). In the report of a recent review of fall and fall injury prevention programs and research (Hill et al., 2000a, 2000b), there was no mention of specific strategies, programs or research focussed on the prevention of SCI specifically, nor indeed head and neck injury generally (Hill et al., 2000b). Falls in the elderly, including falls resulting in SCI, is an issue that warrants greater attention in Australia.

The lack of congruence between the death and SCI trends for fall-related causes suggests that there may be a contrast in the specific causal factors important for SCI compared with death. In order to assess the issue further, information on the incidence of SCI among those killed is required. That information was not available for the present time series. The potential to obtain information on the presence of SCI among persons killed was created in Australia with the introduction of multiple cause coding of death certificates, implemented in 1997 by the Australian Bureau of Statistics (ABS, 1999). A future assessment of trends in SCI, particularly from fall-related causes, should incorporate an analysis of trends among acute survivors, based on ASCIR cases, and acute deaths, based on the ABS data.

The trend that stands out when assessed in terms of practical significance, is the trend in the rate of complete tetraplegia. While there was an overall decline in the rate over the period 1986–1997 (–4% p.a.), this reflected a decline from 1986 to 1991. The rate actually increased by 7% p.a. from 1991 to 1997. This may be a cause for concern.

Complete tetraplegia is one of the most serious and costly types of injury that any person can suffer (Walsh and DeRavin, 1995) and even a small change in the rate of occurrence over a short period is practically important from a public health perspective. The rate increase equates to an increase in the case number of 3–4 per year, since 1991. An increase in the likelihood of tetraplegia has been reported in the USA from 1973–1977 to 1994–1998 (Nobunaga, 1999). It has also been reported that a trend toward an increased likelihood of incomplete injury up until 1989, began to reverse in 1994–1998 (Nobunaga, 1999). It is not clear whether the apparently similar trends in Australia and the USA reflect common causes. The increased likelihood of tetraplegia in the USA was not explained by Nobunaga et al., (1999), but does not appear to be due to the reported increase in violence-related SCI because these mostly result in paraplegia (Nobunaga et al., 1999). Becker and DeLisa (1999) suggest that it may be due to the ageing of the population and the consequent increased representation of the elderly among whom falls and tetraplegia are more common. The recent increase in complete injuries in the USA could reflect, in part, the increase in violence-related SCIs which are nearly 1.5 times more likely to be complete injuries (Becker and DeLisa, 1999). In Australia, the recent increase in complete tetraplegia could reflect the possibility raised in the Overview section, that improved medical retrieval, transfer and emergency care is maintaining lives that were previously lost (e.g. ventilator dependent tetraplegics). It is probably not due to increased SCI due to falls in the elderly because, as seen in Table A1.2, these mostly involved incomplete tetraplegia. The causes of the trends should be further investigated and compared.

Although the importance of SCI has been recognised in Australia through its selection as one of the health sector performance indicators for injury prevention and control (National Health Performance Committee, 2000), no target has yet been set for its reduction. This is an important omission that needs to be addressed. The trend information presented in this report should be used as an input to the national target-setting processes. On the basis of the impact achieved in the reduction of transport-related deaths and SCI, and using this experience as a best practice guide, it might be argued that an 'ideal' target for the reduction of the crude rate of SCI is –4 to –6% p.a. However, the more conservative target of a 3% reduction in the rate is recommended, in consideration of the current trends in non-transport-related deaths and SCI. In order to achieve this level of reduction it would require a targeted investment in SCI research and preventive activity.

5 Conclusions

The general objective of this report was to present information on trends in SCI in Australia. It provided time-series information about the demographic features, causal factors and outcomes of SCI. It illustrates how information on these parameters can provide new insights into the prevention and control of SCI and future research needs.

The assessment of trends in SCI was limited in its coverage but still provided some practically useful information, relevant both to clinicians and public health practitioners. The report suggests that there have been successes and relative failures of public health to address the SCI problem and provides a guide to target setting for primary prevention. The recent increase in fall-related SCI in elderly males and complete tetraplegia are 2 problems that require investigation and, if possible, control.

6 References

Armitage, P., Berry, G. (1987) Statistical methods in medical research. Blackwell Scientific Publications, Melbourne, pp. 399–403.

Australian Bureau of Statistics. (2001) Population by age and sex, Australian states and territories. Cat. No. 3201.0. ABS, Canberra.

Australian Bureau of Statistics. (1999) Causes of death, Australia. ABS, Canberra.

Australian Institute of Health and Welfare. (2000) Australia's health 2000: the seventh biennial health report of the Australian Institute of Health and Welfare. AIHW, Canberra.

Australian Transport Safety Bureau. (2001) The national road safety strategy, 2001–2010. ATSB, Canberra.

Becker, B.E., DeLisa, J.A. (1999) Model Spinal Cord Injury System trends, and implications for the future. Arch Phys Med Rehabil 80, 11, 1514–1521.

Bordeaux, S., Harrison, J. (1998) Injury mortality, Australia 1995. Australian Injury Prevention Bulletin, Issue 17. Australian Institute of Health and Welfare, Canberra.

Breslow, N.E., Day, N.E. (1987) Statistical methods in cancer research. II: The design and analysis of cohort studies. IARC Scientific Publications No. 82, Chapter 4. International Agency for Research on Cancer, Lyon.

Brillinger, D.R. (1986) The natural variability of vital rates and associated statistics. Biometrics 42, 693–734.

Bureau of Transport Economics. (2001) The black spot program, 1996–2002. Report 104. BTE, Canberra.

Bureau of Transport Economics. (2000) Road crash costs in Australia. Report 102. BTE, Canberra.

Cripps, R., Carman, J. (2001) Falls by the elderly in Australia: trends and data for 1998. Injury Research and Statistics Series. Australian Institute of Health and Welfare, Canberra.

Demetrio, C., Ridout, M. (1994) Coping with extra Poisson variability in the analysis of factors influencing vaginal ring expulsions. Stat Med 13, 873–874.

Faddy, M. (1997) Extended Poisson process modelling and analysis of count data. Biometrical Journal 39, 431–440.

Federal Office of Road Safety. (1998) The history of road fatalities in Australia. FORS, Canberra.

Gupta, P., Gupta, R., Tripathi, R. (1996) Analysis of zero-adjusted count data. Computational Statistics and Data Analysis 23, 207–218.

Hill, K., Smith, R., Murray, K., Sims, J., Gough, J., Darzins, P., Vrantsidis, F., Clark, R. (2000a) An analysis of research on preventing falls and falls injury in older people: community, residential aged care and acute care settings. National Ageing Research Institute, Centre for Applied Gerontology, Melbourne.

Hill, K., Smith, R., Vrantsidis, F., Nankervis, J., Gilsenang, B., Clark, R., Pettitt, A. (2000b) Report of the national stocktake of major organisations that conduct falls prevention activities for older people including a description of those activities. National Ageing Research Institute, Centre of Applied Gerontology, Melbourne.

Kannus, P., Niemi, S., Palvanen, M., Parkkari, J. (2000) Continuously increasing number and incidence of fall-induced, fracture-associated, spinal cord injuries in elderly persons. Arch Intern Med 160, 14, 2145–2149.

Lambert, D. (1992) Zero-inflated Poisson regression, with application to defects in manufacturing. Technometrics 34, 1–14.

Mausner, J.S., Bahn, A.K. (1974) Epidemiology—an introductory text. W.B. Saunders Company, Philadelphia.

McCullagh, P., Nelder, J.A. (1989). Generalized linear models. Chapman and Hall, London.

National Health Performance Committee. (2000) Fourth national report on health sector performance indicators—a report to the Australian health ministers' conference. NSW Health Department, Sydney.

Nobunaga, I., Go, B.K., Karunas, R.B. (1999) Recent demographic and injury trends in people served by the model spinal cord injury systems. Arch Phys Med Rehabil 80, 11, 1372–1382.

O'Connor, P.J. (2000) Evaluation of the South Australian Graduated Driver Licensing Scheme. In: Bailey, T., ed. Graduated driver licensing in South Australia. Transport SA, Adelaide.

Perneger, T.V. (1998) What is wrong with Bonferroni adjustments. BMJ 136, 1236–1238.

Ridout, M., Demetrio, C., Hinde, J. (1998) Models for count data with many zeros. International Biometric Conference, Cape Town.

Rothman, K.J., Greenland, S. (1998) Modern epidemiology. Lippincott–Raven, Philadelphia.

Sankoh, A.J., Huque, M.F., Dubey, S.D. (1997) Some comments on frequently used multiple endpoint adjustments methods in clinical trials. Stat Med 16, 2529–2542.

Valkonen, T. (1989) The calculation of the values of inequality coefficients and their changes. In: Fox, J., ed. Health inequalities in European countries. Gower Publishing Company, Aldershot, pp. 161–162.

Vulcan, P. (1999) What works in injury prevention. Injury Issues Monitor No. 15. Flinders University Research Centre for Injury Studies, Adelaide.

Walsh, J., DeRavin, J.W. (1995) Long term care—disability and ageing. The Institute of Actuaries of Australia, Sydney.

Appendix 1: Data tables

Table A 1.1: New spinal cord injury, Australia 1986–1997; case counts by neurological group, sex and single year

		Year											
Neurological group	**Sex**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Complete tetraplegia	Males	40	46	53	42	38	23	35	27	24	35	35	42
	Females	11	8	6	9	5	5	2	7	12	7	9	7
Incomplete tetraplegia	Males	67	55	58	55	70	79	69	81	72	67	65	69
	Females	15	11	17	11	13	25	19	18	16	20	21	19
Complete paraplegia	Males	45	46	46	48	40	34	31	43	44	44	46	48
	Females	12	13	7	7	8	5	9	6	6	10	11	13
Incomplete paraplegia	Males	38	39	50	39	49	51	48	53	50	54	58	40
	Females	16	9	16	21	12	19	15	11	22	17	12	14
Neurological group not specified	Males	7	2	4	9	2	3	1	0	1	1	2	1
	Females	4	1	2	2	1	0	0	0	0	1	0	0

Table A 1.2: New spinal cord injury by neurological group, age group and single year

Neurological group	Age	Year											
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Complete tetraplegia	15–24	23	30	27	18	19	7	15	12	17	22	17	18
	25–34	12	12	13	10	10	11	8	11	8	10	11	11
	35–44	7	7	10	13	6	1	4	5	5	0	4	12
	45–54	3	3	4	2	4	4	1	2	4	3	2	1
	55–64	2	0	3	3	2	1	3	3	1	1	1	4
	65+	4	2	2	5	2	4	6	1	1	6	9	3
Incomplete tetraplegia	15–24	25	19	17	13	34	30	26	26	25	17	20	30
	25–34	19	19	13	13	17	25	19	17	18	14	13	12
	35–44	10	7	8	7	11	12	9	20	8	11	13	13
	45–54	11	6	17	8	10	14	12	13	10	9	8	7
	55–64	5	7	7	14	2	8	6	5	8	11	11	7
	65+	12	8	13	11	9	15	16	18	19	25	21	19
Complete paraplegia	15–24	27	23	25	19	19	12	19	14	15	13	13	14
	25–34	15	14	14	17	14	13	8	14	16	18	24	19
	35–44	9	15	6	10	9	9	7	10	7	8	9	13
	45–54	4	1	3	4	3	3	1	5	5	10	6	6
	55–64	2	2	2	2	3	0	2	4	2	3	3	4
	65+	0	4	3	3	0	2	3	2	5	2	2	5

(continued)

Table A 1.2 (continued): New spinal cord injury by neurological group, age group and single year

		Year											
Neurological group	**Age**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Incomplete paraplegia	15–24	23	17	34	22	19	26	15	28	26	18	21	14
	25–34	17	15	12	19	25	16	22	13	20	20	9	18
	35–44	8	8	7	7	5	16	8	10	10	16	16	10
	45–54	4	5	5	6	6	7	7	2	6	9	13	5
	55–64	1	3	5	3	2	4	3	4	1	4	3	3
	65+	1	0	3	3	4	1	8	7	9	4	8	4
Neurological group not specified	15–24	4	3	3	3	1	0	0	0	0	0	0	0
	25–34	2	0	0	3	2	0	0	0	0	1	0	0
	35–44	2	0	1	2	0	0	0	0	1	0	1	0
	45–54	3	0	0	2	0	2	0	0	0	1	0	0
	55–64	0	0	0	0	0	0	0	0	0	0	0	0
	65+	0	0	2	1	0	1	1	0	0	0	1	1

Table A 1.3: New spinal cord injury, Australia 1986–1997; case counts by external cause, neurological group, sex and single year

Cause	Neurological group	Sex	Year											
			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Transport-related SCI	Complete tetraplegia	Males	25	18	30	21	24	11	14	9	10	20	14	20
		Females	9	6	5	7	2	3	1	5	12	4	6	4
	Incomplete tetraplegia	Males	34	27	27	24	34	35	31	33	34	28	23	27
		Females	11	6	10	8	8	16	14	13	11	14	10	7
	Complete paraplegia	Males	32	25	29	27	23	20	23	20	22	21	23	22
		Females	7	8	6	5	4	3	6	2	0	6	5	8
	Incomplete paraplegia	Males	28	19	26	13	19	30	16	22	23	25	19	14
		Females	8	7	11	9	6	11	4	3	7	8	4	7
	Neurological group not specified	Males	4	0	2	6	0	0	0	0	0	0	0	0
		Females	2	1	1	2	0	0	0	0	0	1	0	0
Falls-related SCI	Complete tetraplegia	Males	8	10	7	9	6	3	7	7	1	6	9	4
		Females	1	1	1	1	2	2	0	1	0	3	2	1
	Incomplete tetraplegia	Males	21	12	13	17	10	20	19	20	20	23	24	21
		Females	4	4	4	2	2	7	2	4	3	5	9	8
	Complete paraplegia	Males	6	15	14	12	4	11	4	17	14	14	14	19
		Females	2	4	1	1	2	2	2	4	5	3	6	3
	Incomplete paraplegia	Males	8	12	18	17	16	12	18	18	19	12	25	22
		Females	7	1	5	11	5	4	8	4	12	4	8	6
	Neurological group not	Males	2	0	2	2	1	2	1	0	1	1	1	0
		Females	1	0	1	0	0	0	0	0	0	0	0	0

(continued)

Table A 1.3 (continued): New spinal cord injury, Australia 1986–1997; case counts by external cause, neurological group, sex and single year

Cause	Neurological group	Sex	Year											
			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Other SCI	Complete tetraplegia	Males	7	18	16	12	8	9	14	11	13	9	12	18
		Females	1	1	0	1	1	0	1	1	0	0	1	2
	Incomplete tetraplegia	Males	12	16	18	14	26	24	19	28	18	16	18	21
		Females	0	1	3	1	3	2	3	1	2	1	2	4
	Complete paraplegia	Males	7	6	3	9	13	3	4	6	8	9	9	7
		Females	3	1	0	1	2	0	1	0	1	1	0	2
	Incomplete paraplegia	Males	2	8	6	9	14	9	14	13	8	17	14	4
		Females	1	1	0	1	1	4	3	4	3	5	0	1
	Neurological group not specified	Males	1	2	0	1	1	1	0	0	0	0	1	1
		Females	1	0	0	0	1	0	0	0	0	0	0	0

Table A 1.4: New spinal cord injury, Australia 1986–1997; case counts by external cause, sex, age group and single year

Cause	Age	Sex	Year											
			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Transport-related SCI	15–24	Males	52	36	48	29	47	32	32	24	33	34	30	29
		Females	18	20	16	10	6	14	5	10	8	11	6	12
	25–34	Males	39	27	25	24	30	33	16	26	27	28	17	29
		Females	8	6	3	9	7	5	8	6	4	12	4	6
	35–44	Males	16	12	18	14	15	15	14	18	7	12	13	12
		Females	5	2	4	6	2	6	3	4	8	2	7	3
	45–54	Males	9	5	11	7	6	8	8	4	11	9	8	2
		Females	5	0	4	2	2	6	3	1	5	2	2	2
	55–64	Males	2	4	7	11	2	2	3	5	5	4	2	5
		Females	1	0	3	1	0	1	1	0	0	2	3	1
	65+	Males	5	5	5	6	0	6	11	7	6	7	9	6
		Females	0	0	3	3	3	1	5	2	5	4	3	2
Falls-related SCI	15–24	Males	12	8	16	14	4	5	6	14	7	6	13	9
		Females	5	3	5	5	2	3	6	4	8	2	4	2
	25–34	Males	5	15	15	14	11	11	15	10	18	9	10	10
		Females	5	1	1	3	2	2	0	1	2	2	6	4
	35–44	Males	10	14	5	10	3	11	7	13	7	7	14	18
		Females	1	3	0	1	1	0	1	3	3	1	5	1
	45–54	Males	4	2	5	3	11	9	8	6	5	13	9	8
		Females	1	0	2	1	0	1	0	1	1	2	2	3
	55–64	Males	6	6	5	8	2	4	4	7	5	6	8	3
		Females	0	0	1	1	2	3	1	1	1	0	2	5
	65+	Males	8	4	8	8	6	8	9	12	13	15	19	18
		Females	3	3	3	4	4	6	4	3	5	8	6	3

(continued)

Table A 1.4 (continued): New spinal cord injury, Australia 1986–1997; case counts by external cause, sex, age group and single year

Cause	Age	Sex	Year											
			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Other SCI	15–24	Males	15	24	20	16	31	20	24	25	24	17	16	18
		Females	0	1	1	1	2	1	2	3	3	0	2	6
	25–34	Males	5	10	8	10	15	14	14	12	10	9	19	9
		Females	3	1	0	2	3	0	4	0	1	3	1	2
	35–44	Males	3	6	5	7	10	5	3	6	6	11	4	14
		Females	1	0	0	1	0	1	0	1	0	2	0	0
	45–54	Males	4	7	6	9	2	4	2	10	3	6	8	4
		Females	2	1	1	0	2	2	0	0	0	0	0	0
	55–64	Males	1	2	1	1	3	2	5	2	1	5	3	4
		Females	0	0	0	0	0	1	0	1	0	2	0	0
	65+	Males	1	1	3	2	1	1	3	3	3	3	4	2
		Females	0	1	1	0	1	1	2	1	2	0	0	1