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Injury experience of Australia's unprotected road-users

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Introduction

Unprotected road-users is a term commonly used to refer to motorcyclists, bicyclists and pedestrians; these groups have little or nothing as a barrier between themselves and other striking vehicles or objects, unlike car occupants who are enclosed within and derive considerable protection from their vehicles. The lack of a protective barrier makes unprotected road-users more vulnerable to injury in the event of a collision with another vehicle. Moreover, collisions involving unprotected road-users give rise to energy dispersion patterns which result in distinctive bodily distributions of injury.[1-3]

The majority of road fatalities in Australia and in other developed western countries, where the most common mode of private transport is the motor car, are motor vehicle occupants.[4] Protecting occupants of motor vehicles is thus accorded a high priority by road safety, transport and health authorities in developed countries. In contrast, the majority of road fatalities in lesser developed countries are unprotected road-users and their predominance impels a greater concern and priority for their safety.[5]

Occupants of motor vehicles have benefited from a range of engineering measures designed to improve the safety performance of a car in a crash. Additionally, high profile road safety campaigns concerned with behavioural factors such as seat-belt wearing, drink-driving and speeding have largely focused on drivers and passengers of motor cars. It could be argued that there has been a preoccupation with protecting the vehicle occupant, possibly at the expense of unprotected road-users.

This Bulletin provides an overview of the extent and nature of injury experienced by unprotected road-users in 1991, the most recent year for which hospital separations data are available at national level. For comparative purposes, similar information is provided on vehicle occupants. Long term trends in fatalities are also examined.

Overview of mortality and morbidity

There were 656 unprotected road-user deaths registered in Australia in 1991. Pedestrians accounted for 53% of the cases, motorcyclists 37% and bicyclists 10% (Table 1). These deaths represent not only a significant road safety issue but are also important when considered in the context of other classes of injury: for example, unprotected road-user deaths were 2.4 times more common than deaths due to accidental drowning; 3.1 times more common than unintentional poisoning deaths; and 4.6 times more common than fatal burns and scalds. The number of vehicle occupant deaths in 1991 was 1,448—they outnumbered deaths of pedestrians by a factor of four, motorcyclists by a factor of six, and bicyclists by a factor of 23.

The total number of hospital separations for unprotected road-users in the same year was 15,199 which is about 23 times the number of deaths. Bicyclists figured more prominently among hospital separations than for deaths, making up 37% of unprotected road-user separations but only 10% of unprotected road-user deaths. The number of hospital separations for vehicle occupants was 15,303 (Table 2).

Examining the numbers of cases that were hospitalised or killed gives an appreciation of the size of the road injury problem according to road-user type, from which it is possible to gauge the impact on hospital, community and other health resources. Differences in the numbers of persons hospitalised or killed among road-user categories arise from different levels of exposure to injury hazards (e.g., number of licensed drivers, distance travelled) and from the nature of the hazards themselves (e.g., likelihood of high velocity blunt impact to the head). Consideration should be given to these and other dimensions of the problem, in addition to absolute numbers of cases, when strategies and priorities for prevention are being determined.

Road Injury in Australia, 1991

More detailed information about road injury in 1991, and short term trends, is available from the NISU report: Road Injury in Australia, 1991 by O'Connor PJ & Trembath RF, completed under the Road Injury Information Program, funded by the Department of Human Services and Health. Interested readers should contact NISU: see back page for details.

Table 1: ***Road fatalities, age group by road-user type, Australia, 1991***

Age group	Motorcyclist (driver / pillion)		Bicyclist		Pedestrian		Vehicle occupant	
Years	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
0 - 4	0	0.0	2	3.2	13	3.7	26	1.8
5 - 14	6	2.5	16	25.4	31	8.9	48	3.3
15 - 19	53	21.8	16	25.4	29	8.3	211	14.6
20 - 24	67	27.6	3	4.8	20	5.7	242	16.7
25 - 29	42	17.3	9	14.3	23	6.6	175	12.1
30 - 49	64	26.3	8	12.7	61	17.4	340	23.5
50 - 69	8	3.3	6	9.5	82	23.4	249	17.2
70 or more	3	1.2	3	4.8	91	26.0	157	10.8
Total	243	100	63	100	350	100	1448	100

Table 2: ***Road injury hospital separations,* age group by road-user type, Australia, 1991***

Age group	Motorcyclist (driver / pillion)		Bicyclist		Pedestrian		Vehicle occupant	
Years	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
0 - 4	18	0.3	331	6.0	283	7.1	324	2.1
5 - 14	250	4.4	2755	49.5	760	19.1	848	5.5
15 - 19	1234	21.9	883	15.9	458	11.5	2548	16.7
20 - 24	1486	26.3	371	6.7	352	8.8	2482	16.2
25 - 29	1012	17.9	284	5.1	253	6.3	1695	11.1
30 - 49	1393	24.7	617	11.1	715	17.9	3868	25.3
50 - 69	213	3.8	233	4.2	582	14.6	2284	14.9
70 or more	40	0.7	89	1.6	586	14.7	1255	8.2
Total	5646	100	5564	100	3989	100	15303	100

* Cell counts are subject to rounding; see Data Issues panel

Age distribution

Fatalities

Frequency distributions of age by type of road-user are markedly different. Compared to vehicle occupants, motorcycle drivers and pillion passengers are more frequently aged between 15 and 29 years, bicyclists are more frequently aged less than 20 years, and pedestrians are more likely to be aged less than 15 or more than 50 years (Table 1).

Age-specific fatality rates are a more meaningful way to depict age variation in risk of death than a simple frequency distribution of the number of deaths in each age-group, because rates take into account the size of the population in each age-group. The age-specific rates for each class of road-user are shown in Figure 1. For both motorcycle riders and vehicle occupants there is a steep increase in the likelihood of fatality after childhood, with the highest risk age-groups being 15 to 24 years. Rates for bicyclists and pedestrians also increase throughout childhood, although not as steeply, and reach a peak during the teenage years.

Fatality rates for all road-users decline with increasing age after the initial peak levels of late childhood and early adulthood. Motorcyclist and bicyclist rates continue to decline or remain relatively stable into old age. In contrast, pedestrian and vehicle occupant rates increase quite markedly after the age of 50 years. The fatality risk for pedestrians is highest in the oldest age-group.

Hospital separations

When hospital separations are considered, the age distributions for each road-user type display features that are broadly similar to those present in the corresponding distributions for fatalities. Compared to vehicle occupants, motorcyclists are more frequently aged between 15 and 29 years, a greater proportion of bicyclists are less than 15 years old, while pedestrians are more commonly aged less than 15 or more than 70 years of age (Table 2).

Likewise, the patterns seen in age-specific hospital separation rates for each road-user type (Figure 2) correspond quite well with those already noted for fatality rates. Peak rates for bicyclists occur at the ages of 5 to 14 years, for motorcyclists at 20 to 24 years and for pedestrians at ages 70 or more years.

Figure 1: Road injury fatality rates, road-user type by age-group, Australia, 1991

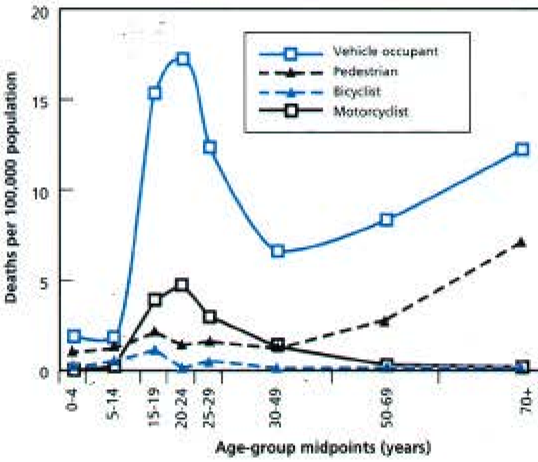
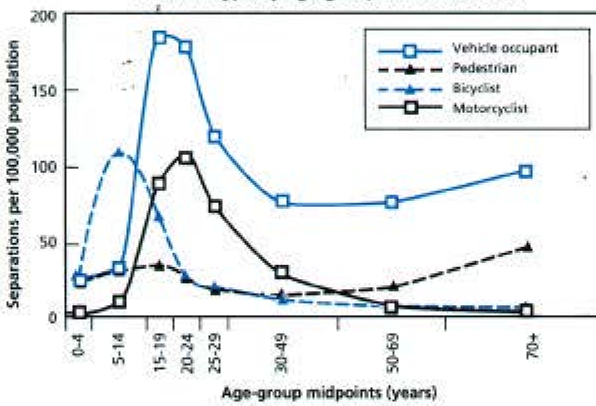


Figure 2: Road injury hospital separation rates, road-user type by age-group, Australia, 1991



Sex distribution

Fatalities

When the ratio of male to female fatality rates is examined on the basis of age-group, it is evident that males are at greater risk than females across all ages, for each road-user category (Figure 3). The greatest differences in fatality risk between the sexes occur over the ages 15 to 29 years. The most extreme divergence is for motorcyclists where the male fatality rate is about 20 times the female rate in the 25 to 29 year age-group. Other large differences in risk are manifest in the younger age-groups for bicyclists and pedestrians. The smallest sex differentials are exhibited in vehicle occupant fatality rates, although there is still a considerable excess risk for males.

Hospital separations

The ratios of male to female hospital separation rates vary across age-groups in a broadly similar manner to fatality rate ratios. A large excess male risk is evident across all ages for all road-user types, with the exception of vehicle occupants where the elevated risk is confined to the 15-29 age-group. The greatest rate ratios are those for motorcyclists and bicyclists (Figure 4).

Nature of injuries (for persons admitted to hospital)

Information about the nature of injuries sustained by road-users is only available for hospital separations. Australian deaths data provide no such information. The material which follows is therefore based upon the experience of injured road-users admitted to hospital.

Severity

The Abbreviated Injury Scale (AIS) has been used to rate the severity of the injuries for each road-user on a scale from minor to critical (Table 3). AIS scores were computed from the hospital separations data using mapping software—see Data Issues panel. (The AIS is a standardised instrument that is widely used in epidemiological studies and in the evaluation of health outcomes and costs.) There are a number of points to note when examining the distribution of injury severity among road-users. Firstly, the majority of persons who are hospitalised have sustained a minor or moderate level of injury; this applies to all types of road-users. Bicyclists are the least severely injured, with 83% of them having a minor or moderate injury. The proportion of minor or moderate injuries in the other three groups of road-users is around two-thirds.

In increasing order, the proportions of serious to critical injuries are: bicyclists 13%; vehicle occupants 24%; motorcyclists 29%; and pedestrians 33%. Only 0.5% of bicyclist injuries are critical, compared with 2.8% of pedestrian injuries, the group with the highest critical incidence.

Figure 3: Road injury fatalities, Ratio of male : female rates by road-user type and age-group, Australia, 1991

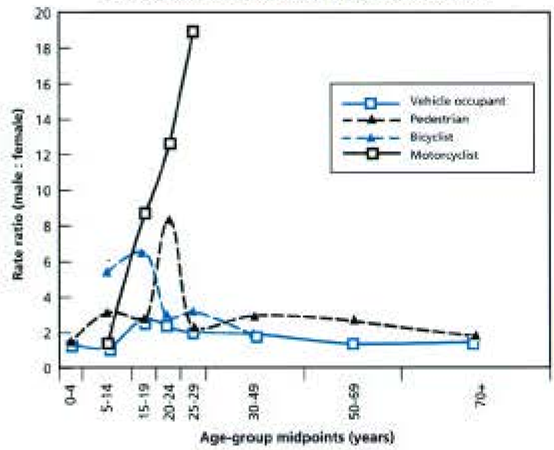


Figure 4: Road injury hospital separations, Ratio of male : female rates by road-user type and age-group, Australia, 1991

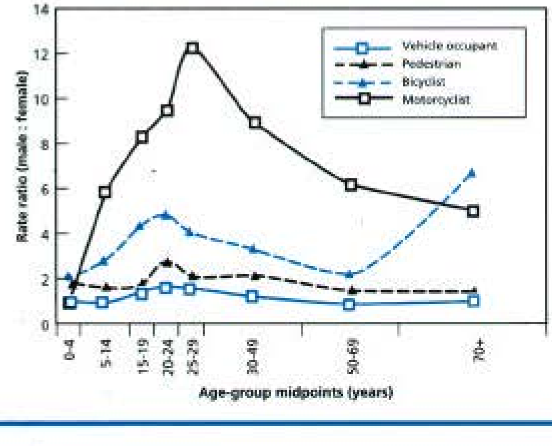


Table 3: ***Road injury hospital separations,* injury severity (max. AIS) by road-user type, All States and Territories excluding Queensland, 1991'***

Injury severity	Motorcyclist (driver / pillion)		Bicyclist		Pedestrian		Vehicle occupant	
	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
Minor	451	10.5	682	16.5	377	11.2	2447	18.6
Moderate	2403	56.0	2740	66.2	1700	50.5	6254	47.6
Serious	1067	24.8	418	10.1	800	23.7	2388	18.2
Severe	132	3.1	90	2.2	230	6.8	594	4.5
Critical	47	1.1	20	0.5	94	2.8	163	1.2
Not known	194	4.5	186	4.5	168	5.0	1302	9.9
Total	4294	100	4136	100	3368	100	13148	100

* Cell counts are subject to rounding; see Data Issues panel
' Injury severity could not be determined for Qld. separations; see Data Issues panel

Body region

The body region suffering the most severe injury is shown in Table 4. Considering the most common locations of injury for each of the road-user categories in turn: motorcyclists sustain their most severe injury to the lower extremities (i.e., the legs and feet); bicyclists are more likely to receive their most severe injury to the upper extremities and to a lesser extent the head; pedestrians receive their most severe injury to the lower extremities and to a lesser extent the head; and vehicle occupants are more likely to severely injure the head.

Also of interest, the relative frequency of the head as the most severely injured region is lowest for motorcyclists (10%) and highest for bicyclists (22%) and pedestrians (22%). The relative frequencies of the chest and spine as the most severely injured body regions are greatest for vehicle occupants (10% and 7% respectively). The upper extremity is more likely to be the site of the severest injury in bicyclists while the lower extremity is more likely to be the site of the severest injury in pedestrians and motorcyclists.

Length of hospital stay

Length of hospital stay provides a measure of the cost of injury to the community and is also an indicator of injury severity. Comparison of average length of stay on the basis of road-user type shows bicyclists stay in hospital for a considerably shorter period, on average, than other categories of road-user (Table 5). This finding is consistent with bicyclists being the least severely injured group of road-users. The longest average length of stay was associated with pedestrian injuries (12 days) followed by motorcyclists (8 days). Age of road-user is one factor which will influence length of stay. A higher percentage of elderly individuals among injured pedestrians may explain their longer length of stay. High incidence of lower extremity

Table 4: ***Road injury hospital separations,* body region of most severe injury by road-user type, All States and Territories excluding Queensland, 1991'***

Body region	Motorcyclist (driver / pillion)		Bicyclist		Pedestrian		Vehicle occupant	
	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
External	474	11.0	539	13.0	270	8.0	1717	13.1
Head	432	10.1	931	22.5	750	22.3	2272	17.3
Face	52	1.2	137	3.3	55	1.6	383	2.9
Chest	130	3.0	41	1.0	60	1.8	1332	10.1
Abdomen	70	1.6	88	2.1	42	1.2	262	2.0
Spine	150	3.5	60	1.5	58	1.7	961	7.3
Upper extremity	710	16.5	1131	27.3	230	6.8	817	6.2
Lower extremity	1159	27.0	532	12.9	1009	30.0	1400	10.6
Multiple	914	21.3	487	11.8	725	21.5	2689	20.4
Unspec./ other	202	4.7	190	4.6	169	5.0	1318	10.0
Total	4294	100	4136	100	3368	100	13148	100

* Cell counts are subject to rounding; see Data Issues panel
' Injury severity could not be determined for Qld. separations; see Data Issues panel

Table 5: *Road injury hospital separations,* length of hospital stay by road-user type, Australia, 1991†*

Length of stay	Motorcyclist (driver / pillion)		Bicyclist		Pedestrian		Vehicle occupant	
	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
1 to 2 days	2283	40.7	3877	69.7	1498	37.8	7481	49.1
3 to 6 days	1457	25.9	990	17.8	796	20.1	3456	22.7
7 or more days	1875	33.4	692	12.4	1665	42.1	4294	28.2
Total	5615	100	5559	100	3959	100	15231	100
Mean stay (days)	8.4		3.7		12.0		7.7	

* Cell counts are subject to rounding; see Data Issues panel
† Excludes cases for which 'length of stay' was not known.

injury may also be a factor in the long length of stay of pedestrians and motorcyclists as this injury often entails a long convalescence.

Trends

Trends in Australian road traffic fatality rates over the period 1968-93 according to road-user type are presented in Figures 5 & 6. (Note that the vertical axes use different scales and the rates have been age-standardised using the 1991 Australian population as the reference.) Vehicle occupant and pedestrian death rates have declined steadily from about 1970. Although the rates of decline have been different for these two groups of road-users there has been a very strong correlation (Pearson's correlation coefficient $r = 0.99$, $p < 0.001$) between vehicle occupant and pedestrian death rates over the period 1968-93, reflected in the overall similarity of the shape of the two graphs (Figure 5). In contrast, there has been little real change in bicyclist death rates throughout the 1970s and the first half of the 1980s. A considerable decline is evident post 1988. Motorcyclist rates displayed a strikingly different pattern to the other road-user groups, with a pronounced rise in rates plateauing in the mid 1970s followed by an equally pronounced decline from about the mid 1980s. The correlations between vehicle occupant rates and bicyclist and motorcyclist rates over the period 1968-93 were relatively weak, in contrast to that between vehicle occupants and pedestrians.

Long term trend data in national hospital separations are not available. There was a decline in the number of separations between 1990 and 1991 of 11% for bicyclists and 16% for pedestrians, although a slight increase was observed for motorcyclists (0.3%).

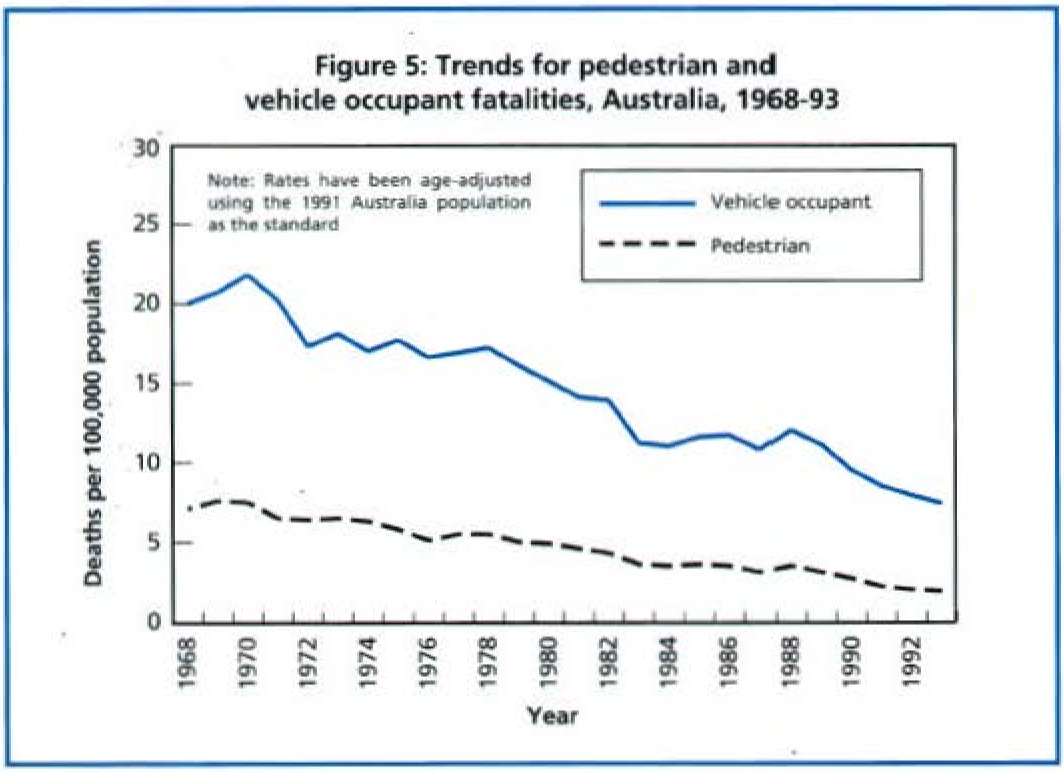
Discussion

It has been suggested that the attention paid to the safety of specific road-users reflects the relative contribution of those groups to the road toll, that is, the number of fatalities they represent.[6] Rather than relying on a single measure such as mortality, examining a wider range of injury experience indicators should give a better impression of the nature and significance of injury problems facing road-users, and provide an improved basis for public health policy and action. The information presented in this paper goes some way towards providing a more complete picture by describing important characteristics of non-fatally as well as fatally injured road-users. It shows that injury experience depends on road-user type, and this has implications for both prevention and treatment.

Certainly, vehicle occupants dominate in terms of numbers of persons hospitalised or killed. When fatality rates are examined by age-group, vehicle occupants have higher rates than any other road-user group across all ages. The same is true for hospitalisation rates except at ages 0-14 years, where bicyclist rates exceed those of vehicle occupants. The comparative rates which we have presented are based on population denominators, in which the population at risk is assumed to be all persons in a given age-group in the Australian population. These rates may not express differences in risk as well as rate calculations that are based on alternative exposure denominators such as distance travelled or number of licensed drivers. For example, the death rate of motorcyclists (in 1988) was 4.4 times greater than that of vehicle occupants when measured as deaths per 10,000 registered vehicles.[6] (For a discussion of the issues involved in selecting appropriate exposure denominators the reader is referred to a recent National Injury Surveillance Unit (NISU) report prepared by Cameron & Oxley.[7])

Gender differences in injury rates are striking. Divergence of male and female rates is greatest in late childhood and early adulthood. The reasons underlying the differences are not well understood. Explanatory factors may include differential levels and patterns of usage of the various forms of transport: for example, there are fewer female motorcycle riders; males also tend to be over-represented in some high risk activities such as drink-driving.[8]

It is not possible to present finer detailed analyses of age and sex differences across road-user types in this Bulletin because of space restrictions; however, such material is detailed in the NISU report: Road Injury in Australia, 1991.[9] The report shows, for example, that in the 15-29 age-group the number of separations for male motorcyclists exceeded by a third the number of separations for the known high risk group of



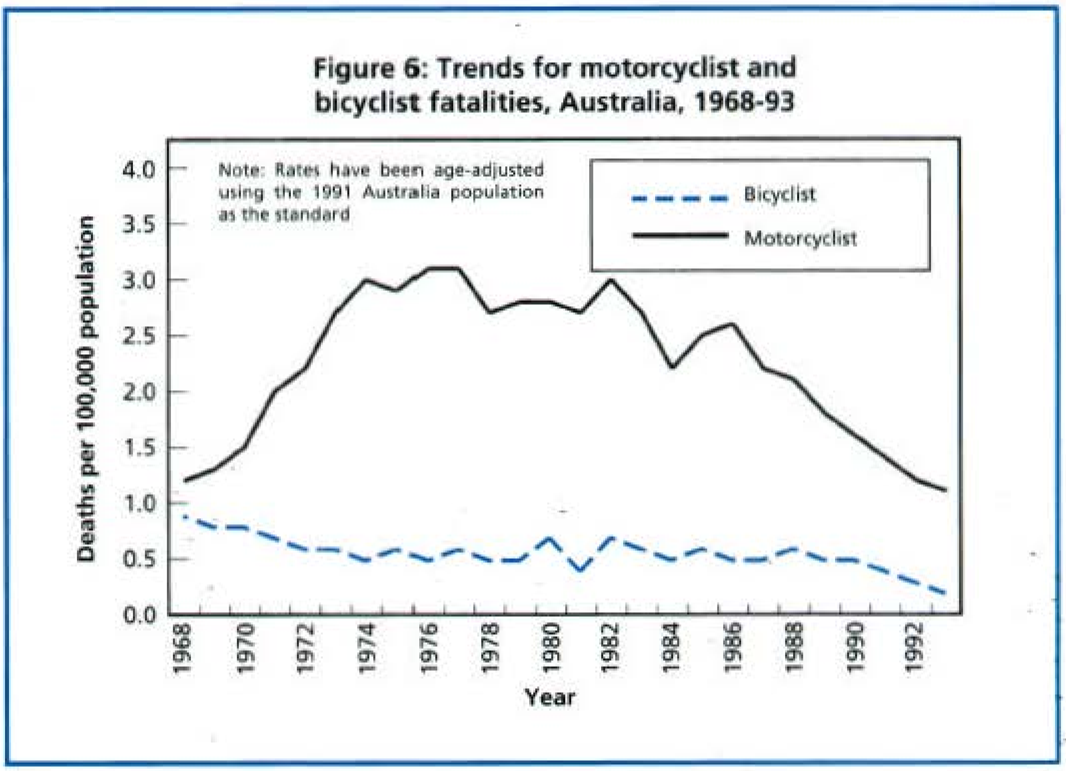
motorcyclist.[14] Indeed, distinct emphasis on motorcyclists may be called for given that in the important target group of young males, the number of motorcyclists admitted to Australian hospitals now exceeds the number of vehicle drivers admitted.

Pedestrians have the highest proportion of severe to critical injuries. This probably results from a combination of factors acting to increase their vulnerability. Physiological tolerance to impact is lowest at the extremes of ages, and it is at those ages that injury rates are highest. Additionally, nearly all pedestrian injuries result from a collision with a faster and heavier vehicle, whereas motorcyclist and bicyclist injuries often do not involve another vehicle. The severity of pedestrian injuries (often involving the lower limbs) is clearly embodied in the mean length of hospital stay of 12 days, the highest of all road-user groups. Severe leg injuries are usually caused by the front bumper or leading edge of the striking vehicle. Modification of the front and upper surfaces of cars has the potential to reduce the severity of pedestrian impacts. Further gains in pedestrian safety may be had by reducing vehicle speeds: a recent study of fatal pedestrian accidents in Adelaide concluded that a reduction of just 5 km/h in vehicle travelling speeds could reduce the incidence of fatal pedestrian crashes by up to 30%.[15]

Non-fatal bicycle injuries are distinct in that half occur in children aged 5-14 years, and they are the least severe

young male drivers—demonstrating a problem which was not evident in the fatality data. This finding has implications for the prioritisation and targeting of national and state motorcycle safety programs.

The commonest severe injury among non-fatally injured motorcyclists is leg trauma. The injury can result in extended and costly hospital procedures such as surgery, skin and bone grafts, joint reconstruction and limb amputation.[10] The average length of hospital stay for motorcyclists was 8.4 days, the second highest after pedestrians (12 days), reflecting the severity of lower extremity injuries. Given the young age of most motorcyclists, severe leg trauma can amount to many years of reduced quality of life. Modifications in motorcycle design such as provision of leg protectors and development of protective rider apparel may help to reduce the severity of leg injuries.[11] Compared with other non-fatally injured road-users in Australia, it is less likely that the head will be the most severely injured body region on a motorcyclist (Table 4); this is likely to be due to the protection achieved by wearing a crash helmet. Further safety gains could be made in the area of helmet performance in very severe crashes, for front and side impacts, and in helmet retention systems.[12] With regard to crash prevention, speeding and alcohol are known motorcycle crash risk factors.[13] Measures aimed at reducing these factors in the motoring community should not overlook the



compared with other road-users. The majority of hospital admissions from bicycle injuries do not stem from a collision with another vehicle—in many cases they occur as a result of younger bicyclists falling off their bikes.[16] The relatively minor nature of such traffic incidents is consistent with the low severity and short average length of stay in hospital for bicyclists. In-depth accident investigation has shown that around two-thirds of severe bicycle injuries are caused by a striking vehicle (usually the front bumper or leading edge) and the speed of the vehicle contributes to both crash occurrence and injury severity.[17] Reducing urban speed limits is likely to reduce the number and severity of bicycle injuries. Other possible safety measures include provision of separate bicycle paths and legalising riding on footpaths.

Mandatory bicycle helmet wearing in Australia was introduced gradually over the period July 1990 to late in 1992. (Prior to this, there was an increase in helmet wearing rates on a voluntary basis.) The introduction of mandatory helmet wearing has reportedly coincided with a sizeable reduction in the number of bicyclists with head injuries in Victoria.[18] Assessment of the extent to which helmet wearing has caused the recent downward trend in bicycle fatalities is difficult because routine deaths data don't provide any information on the nature of fatal injuries (e.g., whether a death was due to head injury and whether a helmet was worn) and is further complicated by the fact that deaths for all road-user types have been decreasing over recent years. The 1991 hospital admissions data cover the transition period from voluntary to mandatory wearing and are therefore limited in being able to demonstrate an association between helmet wearing and incidence of head injury in bicyclists.

Over the period 1968-1993 vehicle occupant fatality rates have fallen from a high of 21.9 deaths per 100,000 in 1970 to a low of 7.5 deaths per 100,000 in 1993; i.e., the current rate has reduced to one-third of the 1970 figure. Pedestrian rates have also shown a substantial decline reducing from a high of 7.6 deaths per 100,000 in 1969 to a low of 1.9 deaths per 100,000 in 1993 (one-quarter of the 1969 figure). The degree of correlation between vehicle occupant and pedestrian fatality rates over the period was unexpectedly high. Some level of correlation is to be expected given that most pedestrian fatalities involve a collision with a motor vehicle. However, certain factors responsible for declines in vehicle occupant fatality rates such as seat-belt use and improved crashworthiness of vehicle passenger compartments cannot be expected to influence pedestrian death rates. Therefore the very strong observed correlation is surprising. It suggests that factors tending to reduce motor vehicle crashes in general, may also directly or indirectly reduce pedestrian-vehicle crashes. Plausible factors include lower levels of speeding, drink-driving and exposure to motor vehicles during periods of depressed economic activity. Further research is needed to understand the influence of these factors.

In recent years, Australia has achieved impressive reductions in road fatality levels for both protected and unprotected road-users. This paper identifies several areas in which the experience of unprotected road-users is distinct from that of vehicle occupants. It should be possible to achieve even greater reductions in injury levels by paying specific attention to the characteristics and special road safety needs of motorcyclists, pedestrians and bicyclists.

Data issues

1. Data sources

The fatality data presented in this paper are derived from the Australian Bureau of Statistics mortality unit records. The hospital separations data are derived from the in-patient morbidity collections maintained by the State and Territory health authorities. It should be noted that data supplied from NSW were subject to sampling of cases in a small number of hospitals. As a result the cell counts reported in tables on hospital separations are based on estimates, some of which are not whole numbers, having a very small standard error. Cell counts have been rounded to the nearest whole number where necessary, meaning that cell counts will not always sum to column totals.

The population used as the denominator for rate calculations was the estimated resident population of Australia for 1991, based on the Australian Bureau of Statistics 1991 Census of Population and Housing.

2. E-code range

The data are restricted to ICD9 'external cause' codes in the range E810.0 to E819.9 (motor vehicle traffic accidents) inclusive or E826.0 to E826.9 (pedal cycle accidents). The fourth digit defines the road-user type. The table below shows the E-code ranges which define the four road-user types used in this Bulletin.

Road-user type	Three digit E-code range	Fourth digit
Motorcyclist	E810-E819	.2 or .3
Bicyclist	E810-E819 E826	.6 .1
Pedestrian	E810-E819 E826	.7 .0
Vehicle occupant	E810-E819	.0 or .1

3. Data transformations

To provide information about the severity of injuries (level of severity and body region of most severe injury) received by persons admitted to hospital, the 1991 separations data were mapped by NISU, using MacKenzie's ICDMAP software,[19] to impute an Abbreviated Injury Score on the basis of the ICD9-CM diagnosis codes. Cases for which injuries of equal severity were received to two or more body regions were classified as 'multiple'. The diagnosis codes provided by Queensland for 1991 were ICD9 codes and therefore could not be mapped for injury severity using ICDMAP which requires ICD9-CM codes.

4. Further information

For further information relating to any of the above data issues, or interpretation of statistics, interested readers are referred to the publication Road Injury in Australia, 1991.[9]

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