Safety in numbers in Australia: more walkers and bicyclists, safer walking and bicycling

Dorothy L. Robinson

Introduction

The concept of 'safety in numbers' is well known in transport circles. In 1949, using data from 62 countries, R.J. Smeed showed that road fatalities per vehicle were lower in countries where more people drove.[1] The relationship – a negative exponential curve – fitted the data remarkably well, suggesting that an important underlying principle of road safety may be involved. This work was reviewed in 1985 by Adams,[2] who was impressed by how well predictions from 1938 data (when the highest rate of vehicles per person was 0.23) fitted data for 1980 with rates of up to 0.7 vehicles per person. In New South Wales, an almost identical relationship was observed when Smeed's Law was used to examine 110 years of road fatality data.[3]

Adams suggested that, to represent real advances in road safety, interventions must be shown to provide benefits over and above what would be predicted by Smeed's Law.[2] In New South Wales (NSW), speed limits (introduced and abolished at various times), random breath testing (introduced in December 1982) and increased public awareness of road safety issues in 1990-91 were among the few measures to stand out as real improvements above what would be expected from changes in vehicle numbers.[3]

Safety in numbers for cyclists

For many years, anecdotal evidence suggested that the principle of 'safety in numbers' also applied to vulnerable road users such

Abstract

Issue addressed: Overseas research shows that fatality and injury risks per cyclist and pedestrian are lower when there are more cyclists and pedestrians. Do Australian data follow the same exponential 'growth rule' where (Injuries)/(Amount of cycling) is proportional to ((Amount of cycling)$^{-0.6}$)?

Method: Fatality and injury risks were compared using three datasets: 1) fatalities and amounts of cycling in Australian States in the 1980s; 2) fatality and injury rates over time in Western Australia as cycling levels increased; and 3) deaths, serious head injuries and other serious injuries to cyclists and pedestrians in Victoria, before and after the fall in cycling with the helmet law.

Results: In Australia, the risks of fatality and injury per cyclist are lower when cycling is more prevalent. Cycling was safest and most popular in the Australian Capital Territory (ACT), Queensland and Western Australia (WA). New South Wales residents cycled only 47% as much as residents of Queensland and WA, but had 53% more fatalities per kilometre, consistent with the growth rule prediction of 52% more for half as much cycling. Cycling also became safer in WA as more people cycled. Hospitalisation rates per 10,000 regular cyclists fell from 29 to 15, and reported deaths and serious injuries from 5.6 to 3.8 as numbers of regular cyclists increased. In Victoria, after the introduction of compulsory helmets, there was a 30% reduction in cycling and it was associated with a higher risk of death or serious injury per cyclist, outweighing any benefits of increased helmet wearing.

Conclusions: As with overseas data, the exponential growth rule fits Australian data well. If cycling doubles, the risk per kilometre falls by about 34%; conversely, if cycling halves, the risk per kilometre will be about 52% higher. Policies that adversely influence the amount of cycling (for example, compulsory helmet legislation) should be reviewed.

Key words: Bicycle, safety, risk, fatality, injury, helmet.

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So what?

Physical inactivity is a major cause of poor health in Australia. Encouraging cycling will not only improve health, but also make cycling safer, creating a 'win-win' situation.

as cyclists. For example, Hudson wrote in 1978: "the fact that cyclists' rights are more respected in towns where cycling is prevalent suggests than an increase in the number of cyclists on all roads would condition car drivers to expect and allow for them".[4] Peter Jacobsen recently published the first formal analysis showing safety in numbers is a reality for both cyclists and pedestrians.[5]

Jacobsen compared risks of injury per cyclist and pedestrian with Census data on the percentages of people cycling and walking to work in 68 Californian cities.[5] Risks (per cyclist and pedestrian) were estimated by dividing per-capita injury rates by the percentage of people cycling (walking) to work (used as a proxy for the total amount of cycling/walking). A strong relationship (remarkably similar to Smeed's Law for motor vehicles) was evident. Injury risks per cyclist or pedestrian were substantially lower in cities where a higher proportion of the population cycled or walked to work.[5]

Safety in numbers was also demonstrated in Europe.[5] Cycling in Denmark is generally popular and very safe; fatalities per million kilometres cycled are about one-third of the United Kingdom (UK) rate. Yet when mean distances cycled per person were plotted against injuries per million kilometres, as in the United States (US), cities where people cycle more had lower injury rates per kilometre.[5] The principle was found to hold not just for cities within a country, but also across countries. Mean per-capita distance cycled and fatalities per 100 million kilometre cycled in 14 different European countries followed an almost identical relationship.[5]

Cycling also became safer as cycling increased in the Netherlands. From 1980-98, fatalities per billion kilometres fell by more than 65% with increasing kilometres cycled per year.[5] Jacobsen concluded: "Multiple independent datasets show that the total number of pedestrians or bicyclists struck by motorists varies with the 0.4 power of the amount of walking or bicycling".

Box 1: Jacobsen's growth rule explained.

If cycling doubles, the risk per km falls by 34%

If cycling halves, the risk per km increases by 52%

Total injuries $\propto$ (Amount of cycling)$^{0.4}$

Relative risk = Total injuries/(Amount of cycling)

$\Rightarrow$ Relative Risk (RR) $\propto$ (Amount of cycling)$^{-0.6}$

So, **if cycling doubles**, total accidents increase by $2^{0.4}$

new RR = $2^{-0.6}$ (old RR) = 0.66 (old RR)

If cycling halves, total injuries fall by $(1/2)^{0.4}$

new RR = $(1/2)^{-0.6}$ (old RR) = 1.52 (old RR)

If new cycling = C times (old cycling)

new total injuries = $C^{0.4}$ x (old total injuries)

new RR = $C^{-0.6}$ x (old RR)

The fitted relationship, which he called the 'growth rule', "is consistent across geographic areas from specific intersections to cities and countries".[5] Jacobsen's growth rule predicts that if cycling doubles, the risk per cyclist will be about 34% less. Conversely, if cycling halves, the risk per cyclist is likely to increase by 52% (see Box 1).

This paper seeks to determine if Jacobsen's growth rule (the 'safety in numbers' principle) applies to cyclists in Australia, and to examine the effect of interventions such as compulsory helmet legislation in the light of the growth rule.

Methods and data

There are no recent Australia-wide data on bicycle use; the latest comprehensive survey with estimated distances cycled was 1985-86.[6] Average daily distance cycled in different Australian States in 1985-86 was therefore compared with fatality rates (six-year averages for 1983-88[7]) per 100 million kilometres cycled.

To investigate changes over time, Australian Bureau of Statistics estimates of the numbers of regular cyclists in WA in 1982, 1986 and 1989 were compared with numbers of cyclists admitted to hospitals, and numbers of reported deaths and serious injuries to cyclists in WA.

A third dataset was provided by the Transport Accident Commission (TAC) in Victoria and used TAC's definition of serious head injury, including skull fractures (ICD-9 codes 800, 801, 803, 804) and brain injuries (ICD-9 codes 851-854), but not concussion without other signs of brain injury. Conventionally, serious injuries are those requiring admission to hospital. To avoid confusing the effect of compulsory helmet legislation with other artifacts in the data (admissions policies, effects of road safety campaigns), cyclist injuries were compared with pedestrian injuries, the latter being used as a control. Pedestrian and cyclist injuries follow very similar trends.[8] So, by comparing data for pedestrians and cyclists, the effects of the law can be separated from factors affecting both cyclists and pedestrians, such as overall road safety.

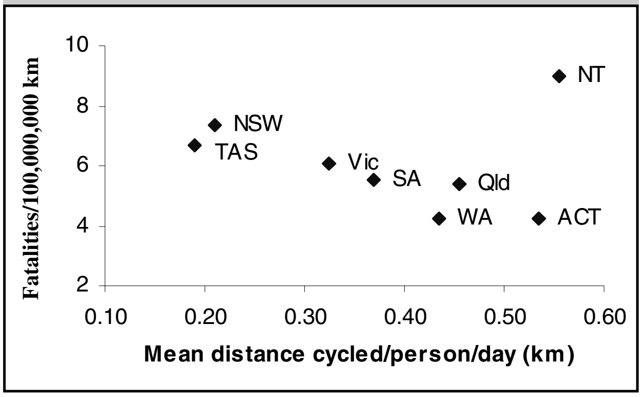
Results

Fatality rates vs. amount of cycling in Australian States

Figure 1 compares fatality rates and average daily distance cycled in different Australian States. Mean distances cycled per person per day in Western Australia (WA, 0.44 km) were slightly more than double those in New South Wales (NSW, 0.21 km). WA had 4.2 deaths/10^8 km, 42% less than NSW (7.4 deaths/10^8 km). Compared with NSW, the average improvement in safety for WA and Queensland combined – 35% – is close to the 36% predicted by the growth rule.

Smaller jurisdictions such as the Northern Territory (NT, included

Figure 1: Australian fatalities (1983-88) per 100 million km vs. mean daily distance cycled.



in Figure 1 for completeness) are too variable to be meaningful. The data used for Figure 1 (fatalities for 1983-88) included 11 cyclist deaths in the NT (population about 160,000). However, other periods of six years (e.g. 1980-82 and 1989-91) had less than half that number.

Changes over time in WA

In Western Australia, numbers of regular cyclists (those who cycle at least once a week) almost doubled from 1982 to 1989 (see Table 1). Cycling also became safer. Numbers of cyclists admitted to hospital and reported deaths and serious injuries (DSI) per 10,000 regular cyclists fell by 48% and 33% respectively (see Table 1). This observed reduction in injuries is consistent with Jacobsen's growth rule, which predicts a 34% fall in injuries per cyclist for twice as much cycling.

Injury rates following helmet laws in 1990s

Cycling in Australia became increasingly popular in the 1980s, not just in WA (see Table 1), but many other locations. For example, in the Sydney metropolitan area "cycling increased significantly (+250%) in the 1980s".[9] Australia-wide, there was a 47% increase in the proportion of journeys to work by bike

Table 2: Number of cyclists counted (n) and wearing helmets (nh) in Melbourne, Victoria, pre-law (May 1990) and in years 1 and 2 of the helmet laws (May 1991 and 1992; from Finch et al. 1993[10]).

Year	Pre-law		1st law year		2nd law year	
	n	nh	n	nh	n[a]	nh
Child cyclists	1,554	442	905	485	994	637
Change from 1990			-649	+43	-560	+195
Adult cyclists	1,567	564	1,106	818	1,484	1,247
Change from 1990			-461	+254	-83	+683
All cyclists	3,121	1,006	2,011	1,303	2,478	1,884
Change from 1990			-1,110	+297	-643	+878

(a) Counts in May 1992 were inflated by a bicycle rally passing through one site (451 cyclists counted at this site in 1992; 72 in 1991). Excluding the site with the rally, a total of 27% fewer cyclists were counted in 1992 than 1990.

Table 1: Deaths and serious injuries (DSI) in Western Australia (WA) relative to numbers of regular cyclists (from Somerford[19] and Robinson[8]).

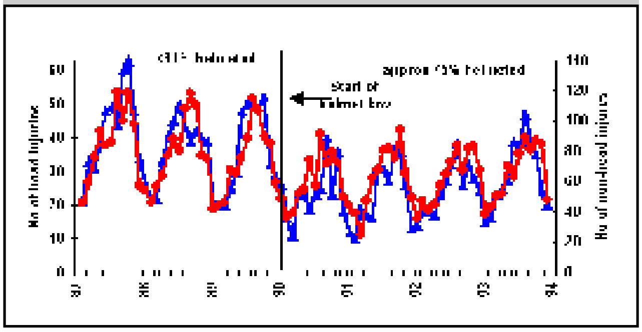
	1982	1986	1989
No. of regular cyclists, WA (thousands)	220	300	400
Cyclist hospital admissions (HOSP), WA	636	660	602
Reported cyclist DSI, WA	123	172	150
HOSP/10,000 regular cyclists, WA	29	22	15
DSI/10,000 regular cyclists, WA	5.6	5.7	3.8

on Census day, from 1.11% (1976) to 1.63% (1986). In contrast to the increases in the 1980s, surveys showed that cycling decreased with the introduction of mandatory helmet legislation. In the 1996 Census, only 1.19% of journeys to work were by bike. In Melbourne, Victoria, identical surveys at the same time of year, in similar weather, at the same 64 sites and observation periods[10] counted 36% fewer cyclists in 1991 (29% fewer adults and 42% fewer children) and 27% fewer in 1992, than before the 1990 helmet law. Increases in numbers wearing helmets were generally less than decreases in numbers counted (see Table 2). This suggests that non-helmeted cyclists, especially children, were more likely to be discouraged from cycling than encouraged to wear helmets and continue cycling.

Figure 2 shows that the number of cyclists admitted to hospital with both head and other injuries fell markedly following the introduction of the helmet legislation.[11] If the fall in head injuries had been much larger than the fall in non-head injuries, we could conclude that the increased helmet use was effective in preventing serious head injury. However, this was not the case (see Figure 2). It suggests that the falls in both head and non-head injuries were mainly because fewer people were riding (as shown by the surveys), so there were fewer serious crashes, rather than because helmets prevented serious injury when crashes occurred.

Another important factor is that Victoria launched an intensive road safety campaign to discourage speeding and drink-driving at almost the same time as the helmet law. Pedestrian fatalities

Figure 2: Cyclists admitted to hospital in Victoria with/without head injuries (from Carr et al. 1995[11]).



fell by 42% (from 159 in 1989 to 93 in 1990). To allow for the effects of this campaign, it is necessary to compare cyclist injuries with equivalent data for pedestrians.

In the two years before the introduction of mandatory helmet legislation, TAC data for cyclists in bike/motor vehicle collisions show deaths and serious head injuries (DSHI) represented 26.5% of all serious injuries (ASI). This fell by 1.6 percentage points to 24.8% in the two years after the law (see Table 3). For pedestrians, the fall in %DSHI over the same period was greater – 2.5 percentage points. Helmets are popularly believed to prevent death and serious head injury, yet the fall in the percentage of deaths and serious head injuries to pedestrians was actually greater than that achieved for cyclists with the helmet law.

Estimates of injury rate per cyclist also suggest that the 'safety in numbers' principle operated in reverse. Pedestrian DSHI fell to 74% of pre-law numbers (see Table 3), most likely because, as noted above, a substantial road safety campaign was implemented in Victoria at almost the same time as the helmet legislation. Cyclist DSHI fell to 57% of pre-law numbers, but there were fewer cyclists – about 70% as many as before the law (see Table 2). DSHI should therefore have fallen to (70% x 74%) = 52% of pre-law numbers for cyclists to enjoy the same injury reductions as pedestrians. The actual fall (to 57% of pre-law numbers) suggests cyclists did not fare as well with the helmet law as they ought to have done without it. An increase in injury rates following helmet laws was also noted for child cyclists in NSW.[8] Thus, as predicted by the growth rule, the risk of injury per cyclist increased when cycling decreased because of helmet laws in Australia.

Discussion

Consistent with overseas research confirming the 'safety in numbers' principle, Australian States with greater levels of cycling had fewer injuries per kilometre cycled. Also consistent with safety in numbers, when the amount of cycling increased in Western Australia there was a corresponding drop in injury rates.

Jacobsen discussed possible mechanisms for 'safety in numbers' and concluded the most probable cause was that motorists were driving more carefully when they expected to see, and share the road with, proportionately more cyclists and pedestrians. Indeed, as walking and cycling become increasingly popular, the average motorist is more likely to occasionally walk or bicycle and hence may give greater consideration to cyclists and pedestrians.[5]

Other factors may be involved. For example, more cyclists on the roads may lead to greater awareness and understanding of their needs, and hence more effective planning for cyclists. It is also possible that, if cycling is perceived to be safer, more people will ride their bikes. However, perceived safety, e.g. of cycle paths and lanes, may differ from objective measures of injury rates.[12] In addition, safety is only one of a number of factors potentially influencing the amount of cycling. Other cited reasons are health, enjoyment, convenience, cost, climate and terrain.[13] Several of these vary between, and within, States. It therefore seems unlikely that the strong observed relationships could be explained simply by an increase in perceived safety leading to increased cycle use.

Moreover, the introduction of mandatory helmet legislation (which might have been perceived to enhance safety) appears to have led to a drop in levels of cycling and, compared with pedestrians, increased risk of injury relative to the amount of cycling. Previously published analyses noted a significant drop in numbers of head injuries with the law (see Figure 2), without fully examining the effect of reduced cycling and safer road conditions, evident from the large reductions in non-head injuries to cyclists (see Figure 2) and the fall in %DSHI for pedestrians (see Table 3). Once these factors are taken into account, it appears that, as predicted by the growth rule, there was an increase in the risk of death or serious head injury per cyclist relative to that for pedestrians. This outweighed any benefits of increased helmet wearing.

In contrast, the campaign against speeding and drink-driving in Victoria was remarkably successful, reducing accident costs by an estimated £100 million for an outlay of £2.5 million.[14] From 1988-90 to 1990-92, deaths and serious head injuries to pedestrians fell by 26%. It seems likely that cyclists enjoyed similar benefits.

Jacobsen's work shows that, in conjunction with campaigns such as the above to reduce speeding and drink-driving, safety per cyclist can best be improved by encouraging more people to cycle. This is a 'win-win' situation because encouraging cycling

Table 3: Transport Accident Commission (TAC) data for average numbers of deaths and serious head injuries (DSHI) and all serious injuries (ASI) per year in Victoria.

Injuries due to collisions with motor vehicles (average number per year)	Cyclists DSHI[a]	Cyclists ASI	Cyclists % DSHI	Pedestrians DSHI	Pedestrians ASI	Pedestrians % DSHI
Pre-law (1988/90)	72.5	274.0	26.5	285.5	828.0	34.5
Post-law (1990/92)	41.0	165.0	24.8	211.0	660.0	32.0
Two post-law years as a percentage of two pre-law years	56.6	60.2	93.9	73.9	79.7	92.7
Adjusted for 30% fall in cycling	80.8	86.0				

(a) DSHI as defined by TAC (skull fracture or brain injury excluding concussion).

also improves health and is beneficial to the environment.[15] Policies that affect amount of cycling (including helmet laws) should be reviewed and potential increases in injuries per cyclist calculated using the growth rule. Maximum benefit will be achieved, as discussed in a recent *HPJA* editorial,[15] by policies encouraging cycling and making it a safe, healthy, enjoyable and environmentally friendly activity.

The 'safety in numbers' principle needs to be taken seriously and used by everyone involved in bicycle planning and road safety issues. Any measures that discourage cycling by 30-40% (including mandatory helmet legislation, which in both Australia and New Zealand was found to cost substantially more than the estimated benefits[16,17]) are therefore likely to produce real and significant increases in the risk of injury per cyclist.

Acknowledgement

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Appendix: Other published analyses of TAC data

The most widely cited helmet law analysis stated: "(TAC) insurance claims from bicyclists killed or admitted to hospital after sustaining a head injury decreased by 48% and 70% in the first and second years after the law, respectively. Analysis of the injury data also showed a 23% and 28% reduction in the number of bicyclists killed or admitted to hospital who did not sustain head injuries in the first and second post-law years, respectively."[18] As well as cyclists with skull fractures and brain injuries (classified as serious head injuries in the data provided by TAC for Table 3), the 48% and 70% reductions above included cyclists with any injury in ICD-9 classifications 850 (concussion), 872 (open wound of ear), or 873.0, 873.1, 873.8, 873.9 (open wounds to head). These cases were included in the total number of "bicyclists killed or admitted to hospital after sustaining a head injury", even if the reason for admission to hospital was a serious injury to another part of the body.[18]

Table 3, based on TAC's classification of the most serious injury, shows that changes in the proportion of cyclists admitted to hospital for serious head injury were no different from those for pedestrians. This implies that the widely quoted claims of 48% and 70% reduction in cyclist head injuries were mainly due either to the changes in admission procedures or road safety conditions (resulting in 29% and 75% reductions in numbers of *pedestrians* with concussion in years one and two of the helmet law), or reductions in head wounds to cyclists who may have been admitted to hospital for treatment of serious injuries to other parts of the body.

The discrepancies between results presented here and previously published analyses highlight the importance of making adequate use of injuries to pedestrians, or other road users, as a control.

Author

Dr Dorothy L. Robinson, University of New England, New South Wales

Correspondence

Dr Dorothy L Robinson, c/o AGBU, University of New England, Armidale, New South Wales 2004. Tel: (02) 6773 3209; fax: (02) 6773 3266; e-mail: drobinso@pobox.une.edu.au