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Relative injury severity among vulnerable non-motorised road users: Comparative analysis of injury arising from bicycle–motor vehicle and bicycle–pedestrian collisions

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ABSTRACT

With the expansion of bicycle usage and limited funding and/or space for segregated pedestrian and bicycle paths, there is a need for traffic, road design and local government engineers to decide if it is more appropriate for space to be shared between either cyclists and pedestrians, or between cars and cyclists, and what restrictions need to be applied in such circumstances. To provide knowledge to aid engineers and policy makers in making these decisions, this study explored death and morbidity data for the state of New South Wales, Australia to examine rates and severity of injury arising from collisions between pedestrians and cyclists, and between cyclists and motor vehicles (MVs).

An analysis of the severity of hospitalised injuries was conducted using International Classification of Diseases, Version 10, Australian Modification (ICD-10-AM) diagnosis-based Injury Severity Score (ICISS) and the Disability Adjusted Life Year (DALY) was used to measure burden of injury arising from collisions resulting in death or hospitalisation. The greatest burden of injury in NSW, for the studied collision mechanisms, is for cyclists who are injured in collisions with motor vehicles. Collisions between cyclists and pedestrians also result in significant injuries. For all collision mechanisms, the odds of serious injury on admission are greater for the elderly than for those in other age groups. The significant burden of injury arising from collisions of cyclists and MVs needs to be addressed. However in the absence of appropriate controls, increasing the opportunity for conflict between cyclists and pedestrians (through an increase in shared spaces for these users) may shift the burden of injury from cyclists to pedestrians, in particular, older pedestrians.

1. Introduction

Vulnerable non-motorised road users are those who travel unprotected, at slow speeds and have a small mass relative to other road users (SWOV, 2007). Pedestrians and cyclists are two large groups of vulnerable road users, who account for a significant number of transport-related injuries in Australia. Walking and cycling are activities undertaken by people of all ages, both as a means of transport and for recreation, and they are important health promoting activities that are being actively encouraged (Carnall, 2000).

Indeed, there is good evidence that these activities are increasing in Australia. For example, walking appears to have replaced some car trips in Sydney, with the number of walk trips reportedly increasing for years 1999–2005 (TDC, 2007). The number of bicycles being imported has shown a steady increase over the period 2000–2005, with over 9 million bicycles being sold since 2000, significantly exceeding the sale of motor vehicles in Australia (Austroads, 2005). There has also been a recent upward trend in cycling by Australians aged 15 years and over; and almost two-thirds of Australian children aged between 5 and 14 years participate regularly in cycling (Austroads, 2005).

However, as in other western countries, motorised forms of transport remain predominant. Therefore, governments and road authorities are challenged to provide infrastructure of adequate capacity for all users without compromising safety, amenity and enjoyment. With the expansion of bicycle usage and limited funding and/or space for segregated pedestrian and bicycle paths, there is a need for traffic, road design and local government engineers to decide if it is more appropriate for space to be shared between either cyclists and pedestrians, or between cars and cyclists and

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what restrictions need to be applied in such circumstances. To provide knowledge to aid engineers and policy makers in making these decisions, the authors explored death and morbidity data for the state of New South Wales, Australia to examine rates and severity of injury arising from collisions between pedestrians and cyclists, and cyclists and motor vehicles.

2. Materials and methods

Mortality data, classified using the International Classification of Diseases, Version 10, Australian Modification (ICD-10-AM), were obtained from the Australian Bureau of Statistics (ABS) Death Unit Record File database. Injury-related mortality of NSW residents was identified using the following criteria:

- the deceased was a resident of NSW and the death occurred in NSW, Australia;
- the date of death occurred between 1 July 2000 and 30 June 2005; and
- an ICD-10 external cause code was assigned as a pedestrian injured in collision with pedal cycle (V01), a cyclist injured in collision with pedestrian/animal (V10) or a cyclist injured in collision with motor vehicle (V12–V14, V19.0–V19.2, V19.4–V19.6).

To explore hospitalised injuries, data were obtained on all NSW public and private hospital separations for NSW residents using the NSW Admitted Patients Data Collection (APDC). A separation occurs when a patient is discharged, dies, is transferred to another hospital or changes status (e.g. from acute to rehabilitation). To minimise multiple counting, separations relating to transfers, type changes and deaths were excluded. This data include interstate hospitalisations of NSW residents.

Injury-related hospitalisations were identified using the following criteria:

- a principal diagnosis was in the ICD-10-AM range S00-T98, and the principal ICD-10-AM external cause of injury was assigned as a pedestrian injured in collision with pedal cycle (V01), a cyclist injured in collision with pedestrian (V10) or a cyclist injured in collision with motor vehicle (V12–V14, V19.0–V19.2, V19.4–V19.6) and
- the hospital separation occurred between 1 July 2000 and 30 June 2005.

The severity of each hospitalised non-fatal injury separation was estimated using the ICD-10-AM diagnosis-based Injury Severity Score (ICISS) (Osler et al., 1996). ICISS is an estimate of the probability of a patient surviving a given set of injuries and is the product of the Survival Risk Ratios (SRRs; the probability of a patient surviving a single injury) of each of the patient's injuries (Stephenson et al., 2003). Australian SRRs[1] were developed for each ICD-10-AM injury diagnosis code by Stephenson et al. (2003). ICISS scores range from 0 (death) to 1 (complete recovery). Patients with an ICISS score $\leq$0.941 are defined as having a serious injury, that is, they have a probability of death (at admission) of at least 5.9% (Cryer and Langley, 2006).

Given that ICISS is a severity measure based on "threat-to-life", an alternative method was sought to assign a measure of "threat-of-disability" to non-fatal hospitalisations and to quantify the burden of injury arising from death and disability in pedestrians and cyclists. Despite its limitations (Anand and Hanson, 1997; Arneson and Nord, 1999; Elbasha, 2000; Reidpath et al., 2003), the only measure of this type, in common use, which can be applied directly to ICD-10 injury diagnoses codes, is the Years Lost to Disability (YLD) component of the Disability Adjusted Life Year (DALY). The DALY is a commonly used measure of the burden of disease and injury which came to prominence following the 1996 Global Burden of Disease Study (Murray and Lopez, 1996). It is a health gap measure which represents the loss of health due to injury (or disease) compared to an ideal or reference state. One DALY unit corresponds to a year of healthy life lost to an injury. The calculation of total DALYs is the sum of the time lost due to disability (YLD) and time lost due to premature death (years of life lost, YLL). The methods described in the Australian and Victorian burden of injury studies (Mathers et al., 1999; Vos and Begg, 1999a,b) were used to calculate YLDs and YLLs in this study. In particular, Australian cohort life expectancies for 1996 were used to calculate the years of life lost and discounting (but not age weighting) was applied.

2.1. Statistical analysis

Statistical analyses were performed using SAS version 9.1.3 (SAS Institute, Inc., Cary, NC). Age-adjusted hospitalisation rates were calculated using direct age-standardisation employing the estimated Australian residential population as of 30 June 2001 as the standard population. The association between the outcome variable serious injury (ICISS $\leq$ 0.941) with explanatory variables type of collision, gender and age group (<10, 10–19, 20–64, $\geq$65) was assessed through multiple logistic regression. Adjusted odds ratios, derived from the multiple logistic regression, were used for pairwise comparisons between age groups and between collision types. In the presence of numerous post hoc comparisons, Bonferroni adjusted p-values, used to control for the experiment wise error rate (EWER), are overly conservative. For this study, the level of significance after a Bonferroni adjustment would be $0.05/9 \approx 0.0056$. As a compromise between controlling for EWER and conservatism, p-values from post hoc comparisons less than $\alpha = 0.01$ are deemed statistically significant.

The distribution of quality of life measures, which includes YLD, is often positively skewed (Fayers and Machin, 2000). Data of this type make significance tests based on a normal assumption questionable. The data from the current study follows this trend and a log transformation, routinely used in the presence of positively skewed data, did not ameliorate this issue with skewness estimates of 12.1 and 5.7 respectively for the raw and transformed data. As a result, the non-parametric Kruskal–Wallis test was used for testing the medians of YLD among collision types.

3. Results

The frequency of hospital separations by gender and age group (<10, 10–19, 20–64, $\geq$65) is given in Table 1 for collision types. While there was a similar proportion of male and female pedestrians injured in collisions with cyclists, the majority of cyclist injuries occurred in males with younger men more likely to be injured in collisions between cyclists and motor vehicles. This pattern, however, did not hold for females 65 and older in which most injuries were for pedestrians injured in a collision with a cyclist.

Table 2 shows the number of deaths and hospital separations for injury in NSW by injury mechanism, by age group and by transport accident. A transport accident is classifed as either a traffic accident or a non-traffic accident. A traffic accident is defined as any vehicle accident that occurs on a public highway, while all other vehicle accidents are considered non-traffic accidents (NCCH, 2002).

[1] ICISS scores are most reliable when the SRRs used are derived from the same population. New South Wales injury hospitalisations account for about one-third of all Australian injury hospitalisations and therefore SRRs developed from the Australian hospitalisation data are representative of those for NSW.