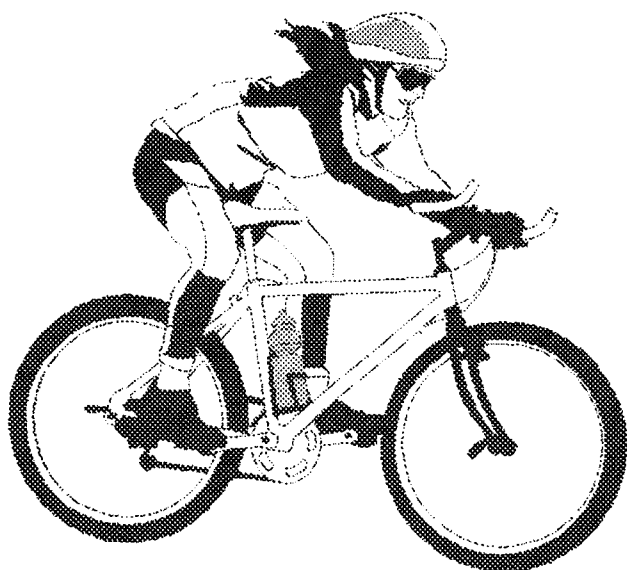




MONASH University

Accident Research Centre

HEAD INJURY REDUCTIONS IN VICTORIA TWO YEARS AFTER INTRODUCTION OF MANDATORY BICYCLE HELMET USE



by

Caroline F. Finch
Stuart V. Newstead
Max H. Cameron
A. Peter Vulcan

July 1993

Report No. 51

ISBN 0 7326 00448

Printed by the Australian Road Research Board as part of an agreement with
Monash University Accident Research Centre.

**MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
REPORT DOCUMENTATION PAGE**

| Report No. | Report Date | ISBN | Pages |
|-------------------|--------------------|--------------|--------------|
| 51 | July 1993 | 0 7326 00448 | 18 |

Title and sub-title:

Head Injury Reductions in Victoria Two Years After Introduction of Mandatory Bicycle Helmet Use

Author(s):

Finch, C.F.
Newstead, S.V.
Cameron, M.H.
Vulcan, A.P.

Type of Report & Period Covered:

General, 1983-1992

Sponsoring Organisation:

This project was funded through the Centre's baseline research program for which grants have been received from:

| | |
|--|---------------------------------------|
| Australian Road Research Board | Royal Automobile Club of Victoria Ltd |
| Ministry for Police and Emergency Services | Transport Accident Commission |
| Roads Corporation (VIC ROADS) | |

Abstract:

On July 1, 1990, a law requiring wearing of an approved safety helmet by all bicyclists (unless exempted) came into effect in Victoria, Australia. There was an immediate increase in average helmet wearing rates from 31% in March 1990 to 75% in March 1991, although teenagers continued to show lower rates than younger children and adults. The number of insurance claims from bicyclists killed or admitted to hospital after sustaining a head injury had decreased by 66% in Melbourne and 70% Victoria-wide two years after the law. Analysis of the injury data also showed a 16% and 23% reduction in the number of bicyclists killed or admitted to hospital who did not sustain head injuries two years after the law in metropolitan Melbourne and the whole of Victoria, respectively. The proportion of all injured cases with a head injury in 1992 was significantly less than that projected on the basis of continuing pre-law trends. The mechanisms by which this reduction was achieved seem to be twofold: a reduction in the number of bicyclists involved in crashes resulting in severe injury and a reduction in the risk of head injury for bicyclists who were severely injured.

Key Words:

(IRRD except when marked*)

bicycle, crash helmet, cyclist,
evaluation (assessment), injury,
traffic regulations, statistics,
regression analysis, safety,
collision, head

Disclaimer:

This report is disseminated in the interests of information exchange. The views expressed are those of the authors, and not necessarily those of Monash University.

Reproduction of this page is authorised.

Contents

| | | |
|-----|--|----|
| 1. | INTRODUCTION | 1 |
| 2. | OBJECTIVES | 1 |
| 3. | METHODS AND MATERIALS | 2 |
| 3.1 | Surveys of Helmet Wearing | 2 |
| 3.2 | Estimates of Overall Helmet Wearing Rates in Metropolitan Melbourne... 4 | 4 |
| 3.3 | Estimates of Victoria-wide Helmet Wearing Rates | 4 |
| 3.4 | Bicycle Use in Metropolitan Melbourne | 5 |
| 3.5 | Bicyclist Injuries | 5 |
| 3.6 | Statistical Methods | 5 |
| 4. | RESULTS | 7 |
| 4.1 | Metropolitan Melbourne | 7 |
| 4.2 | Victoria | 13 |
| 5. | DISCUSSION | 15 |
| 6. | CONCLUSIONS..... | 17 |
| 7. | REFERENCES | 17 |
| 8. | ACKNOWLEDGMENTS | 18 |

List of Tables

| | | |
|---------|--|----|
| Table 1 | Number of bicyclists (all ages) and helmet wearing rates (%) observed in the VIC ROADS surveys in metropolitan Melbourne and country Victoria: 1983-1991. | 2 |
| Table 2 | Number of bicyclists (all ages) and helmet wearing rates (%) observed in 64 sites during the MUARC series of surveys in metropolitan Melbourne: 1987/88-1992. | 3 |
| Table 3 | Age-specific helmet wearing rates (%) in regional cities of country Victoria, during March 1990 and 1991. | 9 |
| Table 4 | Estimated Victoria-wide helmet wearing rates | 13 |

List of Figures

| | | |
|-----------|--|----|
| Figure 1 | Age-specific helmet wearing rates amongst commuter bicyclists in metropolitan Melbourne: 1983-1991. | 7 |
| Figure 2 | Age-specific helmet wearing rates amongst recreational bicyclists in metropolitan Melbourne: 1987-1991. | 8 |
| Figure 3 | The influence of the law on overall helmet wearing rates in metropolitan Melbourne. | 8 |
| Figure 4 | Severe bicyclist casualties in metropolitan Melbourne registered with the Transport Accident Commission: July 1981-June 1992..... | 10 |
| Figure 5 | Relationship between the proportion of cases with a head injury and the helmet wearing rate (%) in metropolitan Melbourne: July 1981 - June 1992. | 11 |
| Figure 6 | Logistic regression of bicyclist head injuries based on pre-law data. Percentages of head injured cases vs survey year in metropolitan Melbourne.... | 11 |
| Figure 7 | Age-specific estimated bicycle use in metropolitan Melbourne: 1987/88-1992..... | 12 |
| Figure 8 | Increase in helmet wearing rates in Victoria during 1983-1991. | 14 |
| Figure 9 | Number of severe bicyclist casualties in Victoria registered with TAC: July 1981-June 1992. | 14 |
| Figure 10 | Logistic regression of bicyclist head injuries based on pre-law data. Percentages of head injured cases vs survey year in Victoria. | 15 |

EXECUTIVE SUMMARY

On July 1, 1990 a law requiring all bicyclists to wear an approved helmet (unless exempted) came into effect in Victoria, Australia. This important initiative is believed to be the first statewide legislation of its type in the world and was the result of a decade of activity.

In Victoria, there was an immediate increase in helmet wearing rates from 31% in March 1990 to 75% in March 1991, although teenagers continued to show lower rates than younger children and adults. In Melbourne, helmet wearing rates increased from 36% pre-law to 73% post-law. Logistic regression analyses showed that, for Melbourne, there was a significant increase in helmet wearing rates, over and above that predicted from pre-law trends.

Based on claims to the Transport Accident Commission for bicyclist casualties who were involved in collisions with a motor vehicle, the number of Victorian bicyclists killed or admitted to hospital after sustaining head injuries decreased by 48% in the first year after the law and by a total of 70% by the second year. Analysis of the injury data also showed a 23% reduction in the number of bicyclists killed or admitted to hospital who did not sustain head injuries during the first post-law year and 28% in the second year.

In metropolitan Melbourne, the number of bicyclists admitted to hospital with a head injury as a result of a collision with a motor vehicle decreased by 66% and the number admitted without a head injury by 17%, two years after the law. For Melbourne, where regular annual surveys of helmet wearing have been conducted, it was possible to fit a logistic regression model that related the reduction in head injuries to helmet wearing rates. This analysis indicated a statistically significant reduction in the proportion of head injured cases two years after the law.

The large reduction in the proportion of bicyclists with head injuries appears to have been achieved by a combination of two factors:

- I. a reduction in the number of bicyclists involved in crashes resulting in severe injury (at least partly through a decrease in bicycle use by children and teenagers and a reduction in overall road trauma); and
- II. a reduction in the risk of a head injury for bicyclists involved in crashes.

1. INTRODUCTION

Since 1 July 1990, bicyclists in Victoria have been required to wear an approved helmet whilst bicycling. This legal requirement is specified in the Road Safety (Bicycle Helmets) Regulations 1990, under the Road Safety Act 1986. It provides exemptions for participants in authorised bicycle races and people who would find it extremely difficult to comply with the regulation. An exemption has also been granted to Postal Delivery Officers riding bicycles whilst delivering mail (Leicester et al, 1991). It is understood that fewer than 60 exemptions on the grounds of "extreme difficulty" have been granted to date.

Victoria was the first State in the world to introduce compulsory bicycle helmet wearing. The more important activities which paved the way for this initiative during the preceding decade have been described elsewhere by Vulcan et al (1992).

The law was introduced as a means of increasing helmet wearing practices in all groups of bicyclists in the State. Observational surveys of bicyclists in the Melbourne metropolitan area have confirmed that the mandatory helmet wearing law has achieved its goal of increasing bicycle helmet wearing rates amongst bicyclists of all ages (Finch et al, 1993). Two years after its introduction, high levels of helmet wearing have been maintained in adults and children. Both adult and teenage rates, in particular, are continuing to increase.

Anecdotal reports have suggested that an unintended effect of the compulsory bicycle helmet wearing law may have been a reduction in the amount of bicycling. The series of observational surveys of bicyclists in Melbourne has also suggested that the introduction of the helmet wearing law coincided with a reduction in the number of people under the age of 18 years riding their bicycles, particularly during the first post-law year (Finch et al, 1993). However, by 1992, two years after the law, the number of bicyclists aged 5-11 years was approaching pre-law levels but was still greatly reduced in teenagers.

The direct result of increased helmet wearing rates was expected to be a significant reduction in the number and severity of head injuries in bicyclists involved in road crashes. The results of a pre- and one year post- law evaluation of bicyclist head injuries have been published (Cameron et al, 1992). With regards to injury reduction, this study found an immediate large decrease in the number of bicyclists with head injuries during the first year after the law's introduction. However, the results suggested that increased helmet wearing in the first post-law year had not been as effective in reducing the risk of head injury in crash-involved bicyclists as would have been predicted based on pre-law trends. Furthermore, there were indications that this had been achieved through a decline in the number of bicyclists involved in crashes (at least partly through a decrease in bicycle use by children and teenagers) and a reduction in the risk of head injury of bicyclists involved in crashes.

2. OBJECTIVES

The aim of the present report is to evaluate the continuing influence of increased helmet wearing rates on bicyclist head injuries two years after the introduction of mandatory wearing. This evaluation is presented for both metropolitan Melbourne and the whole of Victoria. However, it should be noted that 1992 helmet wearing rates are only available for metropolitan Melbourne because of the absence of country surveys conducted during that year.

3. METHODS AND MATERIALS

3.1 SURVEYS OF HELMET WEARING

VIC ROADS has conducted a series of observational surveys of bicyclists at specific sites in February/March each year during the 1980's to measure progress in helmet wearing due to various educational and promotional activities. The surveys were initially conducted in the Melbourne metropolitan area and several country/regional cities were added later (Sullivan and Wise, 1990; Morgan et al, 1991). Separate surveys were conducted for both commuter and recreational bicycling activities. In general, bicyclists were considered to be riding for recreational purposes if they were observed in residential streets between 4pm and 6pm on weekdays, and in places and during periods which varied from survey to survey on weekends. Full details of the survey methodology used in the annual surveys conducted during 1983-1991 are given by Wise (1989) and Morgan et al (1991).

The Melbourne metropolitan surveys were of adult commuter bicyclists on arterial roads near the Central Business District and of primary (aged 5-11) and secondary (aged 12-17) school students on the approaches to a sample of schools. It is possible that the student surveys could be biased towards higher wearing rates (Heiman, 1987) as it is known that some students only wear their helmets when leaving home and on approaching school. Since 1987, recreational bicyclist surveys were also included in both the Melbourne and country annual surveys (Sullivan and Wise, 1990; Morgan et al, 1991). Table 1 summarises the full series of annual VIC ROADS surveys and indicates the observed overall helmet wearing rates.

Table 1 Number of bicyclists (all ages) and helmet wearing rates (%) observed in the VIC ROADS' surveys in metropolitan Melbourne and country Victoria: 1983-1991.

| Year | Metropolitan Melbourne | | | | Country Victoria | | | |
|-----------------|------------------------|-----------------------|--------------|-----------------------|------------------|-----------------------|--------------|-----------------------|
| | Commuter | | Recreational | | Commuter | | Recreational | |
| | n | helmet wearing rate % | n | helmet wearing rate % | n | helmet wearing rate % | n | helmet wearing rate % |
| Pre-law | | | | | | | | |
| 1983 | 2957 | 3 | | | | | | |
| 1984 | 1728 | 14 | | | | | | |
| 1985 | 1698 | 28 | | | 4498 | 16 | | |
| 1986 | 2926 | 30 | | | 4408 | 25 | | |
| 1987 | 2865 | 34 | 537 | 13 | 4242 | 32 | 977 | 15 |
| 1988 | 5925 | 35 | 5406 | 16 | 7849 | 21 | 2723 | 15 |
| 1989 | 5444 | 39 | 7274 | 20 | 7504 | 23 | 4279 | 17 |
| 1990 | 6855 | 43 | 8777 | 31 | 11598 | 23 | 7453 | 13 |
| Post-law | | | | | | | | |
| 1991 | 5781 | 79 | 7604 | 70 | 11464 | 81 | 9068 | 74 |

It should be noted that because these surveys were generally conducted in March of each year, the 1991 results reflect the situation some eight months after the helmet wearing law was introduced. Some additional surveys in July and November 1990 reported even higher post-law wearing rates, particularly for secondary school students, but these surveys have not been included here because of their limited size.

A series of observational surveys of bicycle usage and helmet wearing was also conducted by the Monash University Accident Research Centre (MUARC) before and after the introduction of the law. Each survey collected data on bicycle use and helmet wearing from a representative sample of bicyclists observed in metropolitan Melbourne during a two-week, non-holiday period over 8am-6pm, seven days a week. Both commuter and recreational bicycling were included, although data was not collected in country Victoria. Identical survey methodology was adopted during each of the surveys and full details are available in Finch et al (1993).

The May 1991 MUARC survey was conducted to assess whether the law had an unintended effect of reducing the amount of bicycling in metropolitan Melbourne. It was based on the same methodology used in two earlier surveys undertaken by MUARC. During November-January 1987/88, a survey of 105 sites in Melbourne had been conducted to study the relative safety of footpath bicycling and measurements of bicycling exposure and helmet wearing rates were collected (Drummond and Jee 1988). In May 1990, a survey of 80 sites selected from the 1987/88 survey was undertaken to examine child traffic behaviour in terms of exposure and accident risk (Drummond and Ozanne-Smith 1991). The 1990 survey focussed on child behaviour, however results on bicycle helmet wearing rates were reported for both children and adults. The timing of this observational survey was very relevant as it was conducted about 5 weeks prior to the introduction of the bicycle helmet wearing law. This survey was repeated twice after the introduction of the law in May 1991 and May 1992 at 64 of the sites used during the 1990 survey, so that comparisons between bicycle use and helmet wearing prior to the law and after the law could be made (Finch et al 1993). Table 2 summarises the MUARC series of surveys.

Table 2 Number of bicyclists (all ages) and helmet wearing rates (%) observed in 64 sites during the MUARC series of surveys in metropolitan Melbourne: 1987/88-1992.

| Survey | No. of bicyclists | Helmet wearing rate (%) |
|-----------------|-------------------|-------------------------|
| <i>Pre-law</i> | | |
| Nov-Jan 1987/88 | 2745 | 16 |
| May 1990 | 3119 | 32 |
| <i>Post-law</i> | | |
| May 1991 | 2011 | 65 |
| May 1992 | 2477 | 76 |

3.2 ESTIMATES OF OVERALL HELMET WEARING RATES IN METROPOLITAN MELBOURNE

Estimates of overall helmet wearing rates in metropolitan Melbourne for the years prior to, and after, the introduction of the law were calculated from the separate VIC ROADS survey results in Melbourne by combining the commuter and recreational rates. The VIC ROADS helmet wearing rates were used because they had been collected annually from 1983-1991 and covered a longer period of time than the MUARC surveys. The combining of rates was achieved by calculating weighted averages of helmet wearing rates amongst commuter and recreational bicyclists based on the relative proportions of commuter and recreational bicyclists derived from the 1987/88 (Drummond and Jee, 1988) and 1991 (Finch et al, 1993) MUARC exposure surveys. The proportions in the 1987/88 survey were applied to each of the pre-law years, whereas the 1991 survey proportions were used to combine the 1991 wearing rates. Recreational wearing rates prior to 1987 were estimated from the commuter bicyclist rates by assuming that the ratio of recreational to commuting wearing rates during 1983-86 was the same as that observed during 1987 (Cameron et al 1992).

3.2.1 Estimation of helmet wearing rates in 1992

The latest survey in the VIC ROADS series was completed in 1991. An estimate of helmet wearing rates in 1992 was therefore only available from the MUARC data. However, for consistency, an estimate of the "likely" VIC ROADS helmet wearing rate needed to be obtained.

Comparison of the VIC ROADS and MUARC estimates for the years 1988, 1990 and 1991 consistently found higher rates for the VIC ROADS surveys. This may be explained partly by the fact that the VIC ROADS surveys of adult commuter bicycling were conducted on arterial roads near the Central Business District generally in March. The MUARC surveys, on the other hand, were conducted at randomly selected sites throughout metropolitan Melbourne, generally in May. An estimate of the 1992 VIC ROADS helmet wearing rate was obtained by adjusting the MUARC 1992 rate by a factor representing the average difference between the two survey's rates in earlier years.

3.3 ESTIMATES OF VICTORIA-WIDE HELMET WEARING RATES

Commuter and recreational surveys for country Victoria were combined in the same way as those for Melbourne to obtain an overall estimate of helmet wearing rates in country Victoria (see Section 3.2). Country rates prior to 1985 were estimated from the Melbourne rates by assuming that the ratio of country to Melbourne rates during 1983 and 1984 was the same as that calculated during 1985 (Cameron et al, 1992).

The estimated VIC ROADS wearing rates for Melbourne and country Victoria were combined in the ratio 70:30 to produce overall wearing rate estimates for Victoria from 1983 to 1991. The ratio corresponds to the population distribution of the State during 1986-90 and also to the distribution of bicycle use estimated from a telephone survey in 1989 (State Bicycle Committee 1991).

A Victoria-wide estimate of helmet wearing was not able to be obtained for 1992, however, because no survey of country bicyclists was conducted in that year.

3.4 BICYCLE USE IN METROPOLITAN MELBOURNE

Observational surveys of bicycle use conducted by MUARC have provided estimates of bicycle use in metropolitan Melbourne (Finch et al, 1993). The 1991 survey was used to determine whether bicycling had decreased following introduction of the helmet wearing law, compared to the situation before the law's introduction. The 1992 survey was performed to establish whether the post-legislation changes observed in 1991 (Cameron et al, 1992) had been maintained.

Bicycle use was assessed by timed measurements of bicyclist exposure. Individual measures of timed bicyclist exposures were scaled up to provide an estimate of total bicycle use in metropolitan Melbourne (in seconds of bicycling) (Drummond and Jee, 1988; Finch et al, 1993).

Estimates of bicycle use are not available for country Victoria because no survey of bicycle exposure has been conducted in these areas.

3.5 BICYCLIST INJURIES

The initial effects of the law on bicyclist head (excluding face) injuries were measured by examining claims for "no fault" injury compensation from bicyclists who were killed or hospitalised (ie. severely injured) after a collision with a motor vehicle in Victoria. Details of these claims were obtained directly from the Transport Accident Commission (TAC), the sole insurer for such claims in Victoria. Details of the location of the collision (metropolitan Melbourne or country Victoria) were also obtained.

The claims records for killed or hospitalised bicyclists in Victoria were classified by TAC according to injury type on the basis of up to five recorded injuries using the ICD-9 system. Bicyclists were broadly classified as those who sustained a head injury (whether or not there were other injuries as well), those who did not sustain a head injury (referred to as "other injury") and those with unknown injury information. Head injuries were those assigned N-codes 800, 801, 803, 850-854, 872, 873.0, 873.1, 873.8 and 873.9, following Healy (1986).

A limitation of the available annual injury data is that the corresponding number of bicyclists in Victoria each year during the 1980's is not available. This means that injury rates per bicyclist population are not able to be computed. Furthermore, given that about 65% of bicycle accidents are bicycle/vehicle collisions, it is to be expected that bicycle injury rates would reduce with reduced overall road trauma, but not necessarily proportionately. Assessment of changes over time was therefore based on an examination of the proportion of all injured cases with a head injury.

3.6 STATISTICAL METHODS

All data was analysed by the BMDP data analysis package (BMDP 1988). The LR procedure was used for the logistic regression analyses. Logistic regression is a specialised type of multiple regression analysis used when the outcome of interest is a binary variable (eg wearing helmet vs not wearing a helmet; head injury vs no head injury).

3.6.1 Wearing Rates

The effect of the introduction of mandatory helmet use in 1990 on helmet wearing rates and the risk of head injury were assessed by logistic regression techniques (Kleinbaum et al, 1982). One property of the logistic model is that it constrains the dependent variable (in this first case,

helmet wearing rate or injury rate) to be between 0% and 100%. For this reason, it is the most appropriate technique to apply to data of the type analysed here.

When assessing the influence of the law on helmet wearing rates, the logistic model included two independent variables: a dummy variable indicating the pre- and post-law periods and the other representing the year of the survey. The logistic regression procedure also considered the interaction between these two variables to assess whether the rate of change in helmet wearing rates had been influenced by the introduction of mandatory helmet use in 1990. Thus a model of the form:

$$\log\left(\frac{P}{1-P}\right) = b_0 + b_1 \times year + b_2 \times lawflag + b_3 \times year \times lawflag$$

was fitted to the data, where P represents the helmet wearing rate.

A logistic model fitted to pre-law data only was also obtained. The resultant curve ($\log\left(\frac{P}{1-P}\right) = b_0 + b_1 \times year$) was then extrapolated to provide an estimate of the helmet wearing rates that might have been expected in 1991 and 1992 had mandatory wearing not been introduced. By comparing these projected estimates with the actual helmet wearing rates in 1991 and 1992, an estimate of the additional benefit of the law on top of the background helmet promotion activity was able to be obtained.

3.6.2 Head Injuries

Cameron et al (1992) found an indication that increased helmet wearing in the first 12 months following the introduction of the law had not been as effective in reducing the risk of head injury to crash-involved bicyclists as would have been predicted by extrapolation of pre-law trends. One possible partial explanation for this finding might be the greater proportion of lighter, soft-shell (foam-only or microshell) helmets being worn as a result of the amendment to the Australian Standard for bicycle helmets in 1990 (Cameron et al 1992, Finch et al, 1993).

In order to assess whether this was still the case two years after the law, a logistic regression model was used to assess the relationship between head injury risk and helmet wearing rates. The variable being modelled, in this case, was the proportion of all severely injured crash-involved bicyclists with a head injury. That is $P = \frac{H}{O+H}$, where H is the number of head injured cases and O is the number of cases without head injuries. All cases with unknown injury information have been excluded from the following analyses.

In a separate analysis, a dummy variable indicating the post-law period was considered in the model as well as the estimated helmet wearing rates as an explanatory variable. The purpose of this was to provide an assessment of whether the relationship between head injuries and helmet wearing was different before and after the law, independently of the magnitude of helmet wearing in the community or whether other factors associated with the law might be related to head injury trends. An interaction term between these two explanatory variables was also considered. However, neither the dummy variable nor its interaction with the helmet wearing rate were found to be statistically significant. Neither term was included in the final model.

The logistic model describing the relationship between the head injury and helmet wearing rates was therefore of the form:

$$\log\text{it}\left(\frac{H}{H+O}\right) = \log\left(\frac{H}{O}\right) = b_0 + b_1 \times \text{helmet wearing rate}$$

To assist the interpretation of the logistic regression findings, and to assess whether the actual head injury rates in 1991 and 1992 were associated with the observed increased helmet wearing rates, a logistic regression was also applied to the pre-law data only. The estimates of helmet wearing rates that would have occurred in 1991 and 1992 if the law had not been introduced were then substituted into the fitted model to obtain projected head injury rates that would have been expected in the absence of the law in these two years. A basic assumption of this approach is that the pre-law head injury versus wearing rate trend would have continued in the same way without the law in 1991 and 1992.

Observed head injury rates were then compared with the projected rates obtained by this procedure to assess whether head injury reductions were greater than might have been expected if the law had not be implemented. Confidence intervals for the logistic model were obtained (Kleinbaum et al, 1982) and interval estimates of the projected head injury rates in the absence of the law for 1991 and 1992 were obtained after de-transforming the corresponding interval estimates of the logistic function. This part of the analysis assumed that the projected helmet wearing rates for 1991 and 1992 are, themselves, without error.

4. RESULTS

4.1 METROPOLITAN MELBOURNE

4.1.1 Helmet wearing rates

Figures 1 and 2 show the age-group specific helmet wearing rates observed in the VIC ROADS surveys in Melbourne, during 1983-1991, for commuter (including to/from school) and recreational bicyclists, respectively. The substantial increase in helmet wearing over this period by all age groups on both types of trips is clearly shown.

Figure 1 Age-specific helmet wearing rates amongst commuter bicyclists in metropolitan Melbourne: 1983-1991.

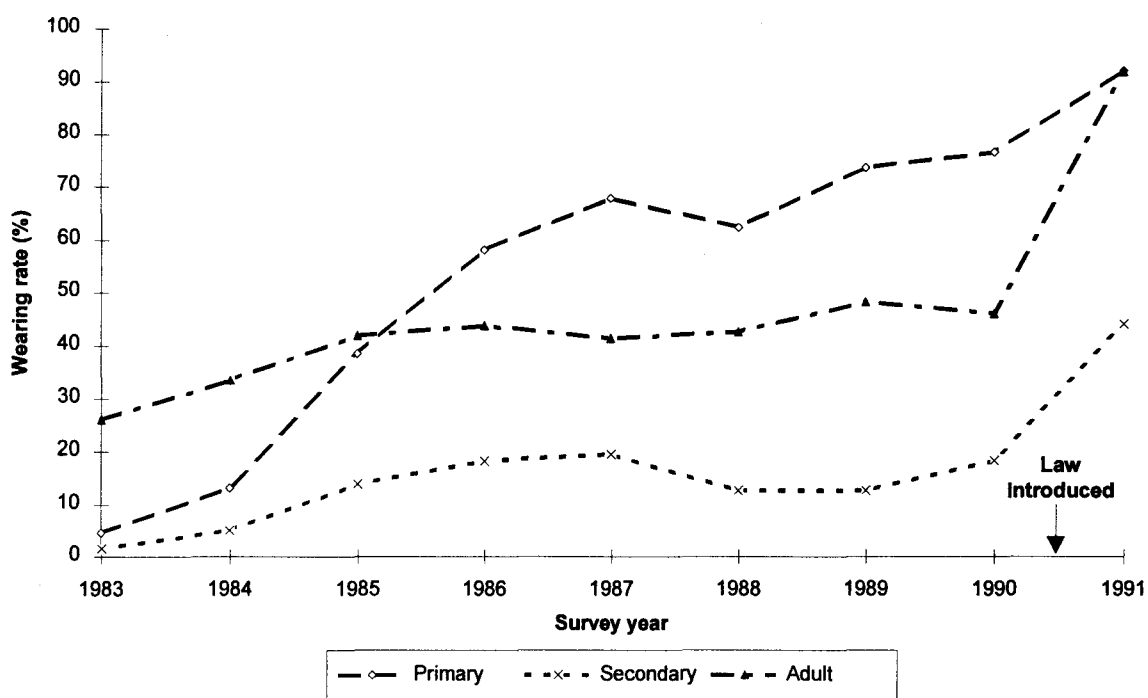


Figure 2 Age-specific helmet wearing rates amongst recreational bicyclists in metropolitan Melbourne: 1987-1991.

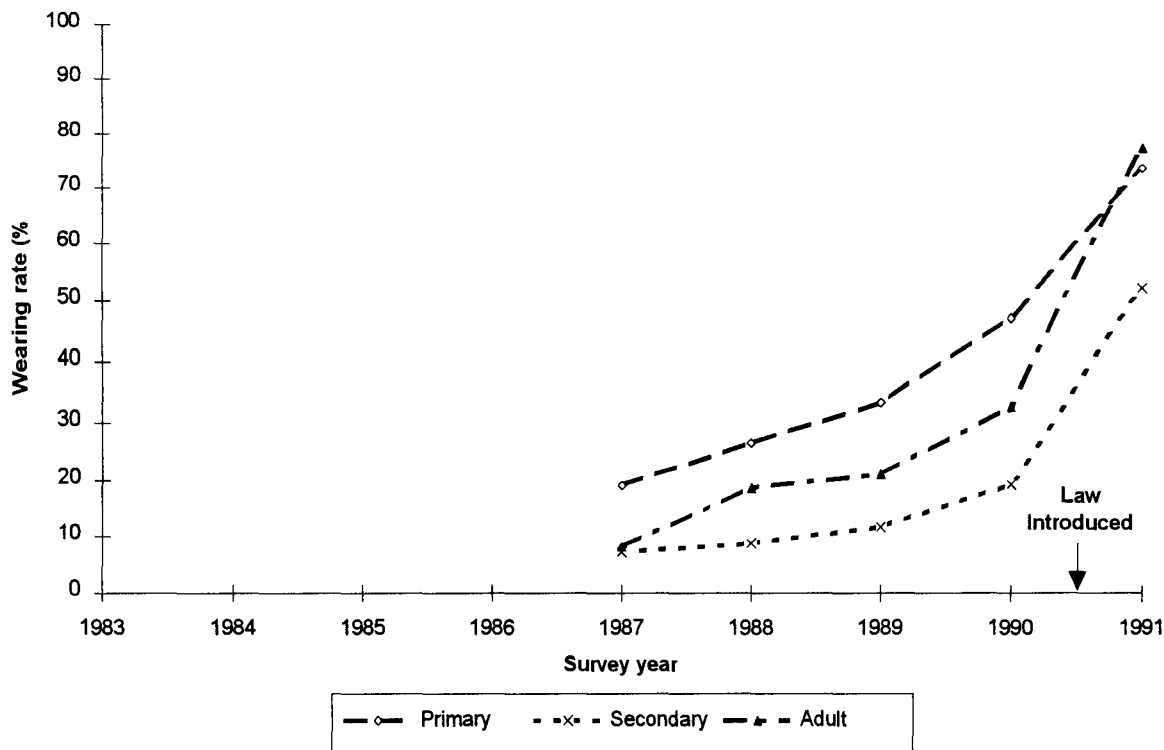
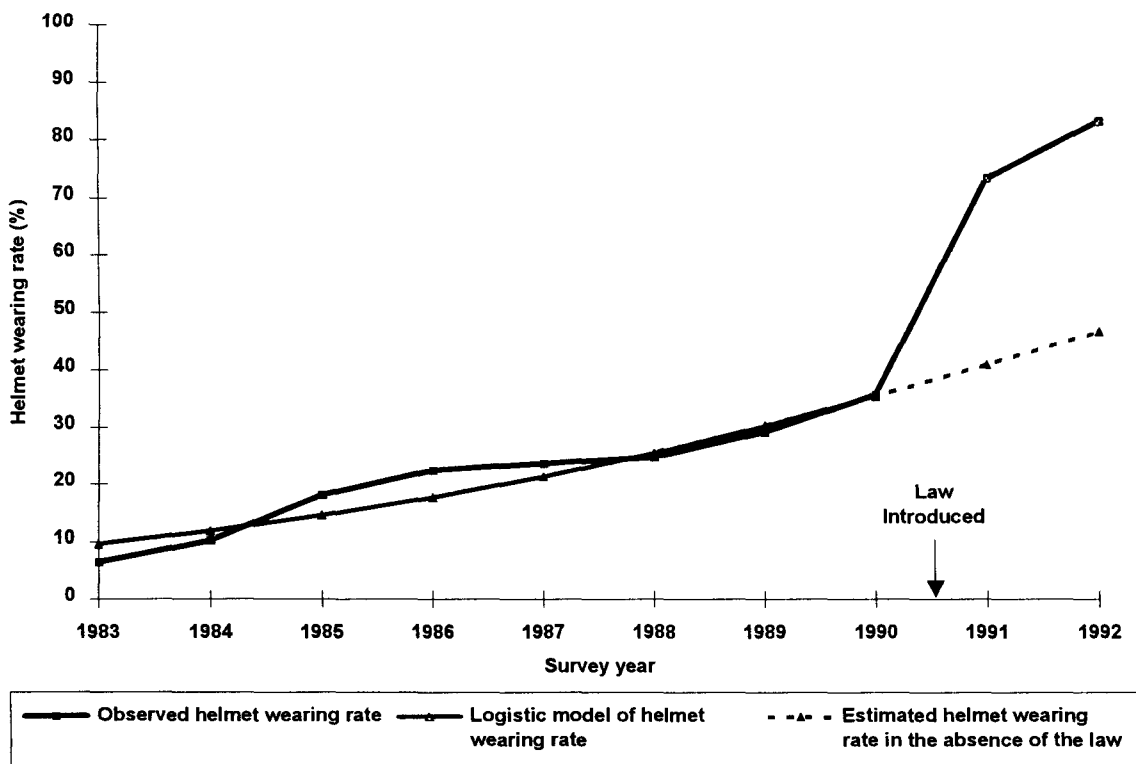


Figure 3 The influence of the law on overall helmet wearing rates in metropolitan Melbourne. (All age groups and commuter and recreational bicyclists combined.)



Estimates of overall helmet use by bicyclists in Melbourne, during 1983-1992 are indicated in figure 3 (heavy solid line). Overall helmet wearing rates rose gradually from 6% in March 1983 to 36% in March 1990. After introduction of the law they had increased to 73% by March 1991 and are estimated to have risen further to 83% by May/June 1992. These trends in overall wearing rates are used in the interpretation of the changes in bicyclist head injuries described in the following section.

Figure 3 also displays the logistic regression model fitted to the observed data (solid line). The level of agreement between the two solid lines indicates how well the logistic model describes the observed data. The logistic model included a term representing the survey year ($p < 0.001$), as well as a term representing the law's introduction in July 1990 ($p < 0.001$). An interaction term between these variables was also fitted and found to be statistically significant ($p < 0.001$) suggesting that the rate of increase in helmet wearing rates was different (in fact, greater) after the law than before its introduction.

The dashed line in figure 3 indicates the increasing trend in helmet wearing that would have been expected if the law had not been introduced and if the logistic model relating helmet wearing to survey year prior to that time represented the true trend. Clearly, the actual helmet wearing rates far exceed those that would have been expected if the 1990 mandatory use law was not introduced - actual helmet wearing rates in 1991 and 1992 were 1.8 times those projected on the basis of pre-law trends.

The VIC ROADS country surveys began in 1985 in 10 regional cities in country Victoria and showed considerable variation between cities (Sullivan and Wise, 1990). However, the general pattern of wearing rates was similar to that in metropolitan Melbourne, with large increases in wearing rates for all age groups following introduction of the law (Table 3).

Table 3 Age-specific helmet wearing rates (%) in regional cities of country Victoria, during March 1990 and 1991 (from Morgan et al 1991).

| Year | Commuter Bicyclists | | | Recreational Bicyclists | | |
|-----------------|---------------------|-----------|---------|-------------------------|-----------|---------|
| | 5-11 yrs | 12-17 yrs | 18+ yrs | 5-11 yrs | 12-17 yrs | 18+ yrs |
| <i>Pre-law</i> | | | | | | |
| 1990 | 58 | 20 | 13 | 26 | 9 | 10 |
| <i>Post-law</i> | | | | | | |
| 1991 | 95 | 75 | 82 | 80 | 70 | 76 |

4.1.2 Bicyclist injuries

Figure 4 shows that, based on TAC injury claims for bicyclists involved in collisions with motor vehicles, the number of bicyclists killed or admitted to hospital with a head injury in Melbourne fell progressively between July 1981 and June 1990 as the use of helmets increased. In the 1990/91 financial year (July 1990 to June 1991), following the introduction of the mandatory wearing law, the number of cases with head injuries decreased by 36% relative to the corresponding period during 1989/90. By 1991/92, there were 66% fewer head injuries than in the year before the law. This decrease suggests that, other things being unchanged, the substantially increased level of helmet use due to the law has reduced the risk of head injury to bicyclists.

The trend in the number of Melbourne bicyclists sustaining severe injuries other than to the head increased during the early 1980's, then declined slowly, particularly after 1988 (Figure 4). During 1990/91, the number of injured bicyclists without head injuries decreased by 6% relative to 1989/90. By 1991/92, non-head injured cases had further declined to 17% fewer than pre-law.

These decreases were somewhat unexpected, because a reduction in head injuries through helmet use would have led to some bicyclists with multiple body region injuries now being classified as "other than head injuries". They suggest that the number of bicyclists involved in crashes with motor vehicles has decreased during the post-law period, either due to a reduction in bicycle use or a reduction in the risk of crash involvement. The first of these possible explanations will be examined in Section 4.1.3. The second possibility is consistent with the general reduction in all police-reported road deaths and serious injuries in Victoria, which fell by 18% between 1989/90 and 1990/91 and by 26% between 1989/90 and 1991/92.

Because of the fall in non-head injuries as well as head injuries, the effect of helmet use on bicyclists involved in crashes was addressed by examining TAC injury claims for the percentage of killed and admitted bicyclists who sustained a head injury (figure 5). As expected there was a clear inverse relationship between the proportion of head injured cases and helmet wearing rate. The logistic regression model (solid line) describes the relationship with increasing helmet wearing rates (p-value <0.001).

Figure 4 Severe bicyclist casualties in metropolitan Melbourne registered with the Transport Accident Commission: July 1981-June 1992

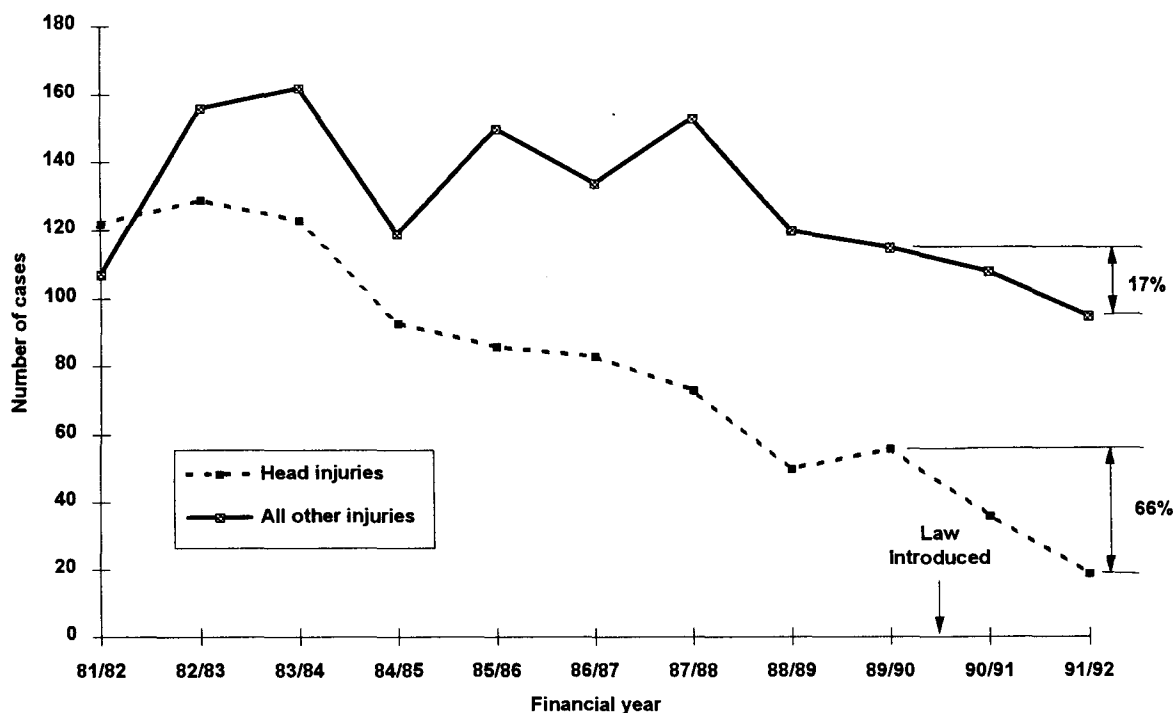


Figure 5 Relationship between the proportion of cases with a head injury and the helmet wearing rate (%) in metropolitan Melbourne: July 1981 - June 1992.

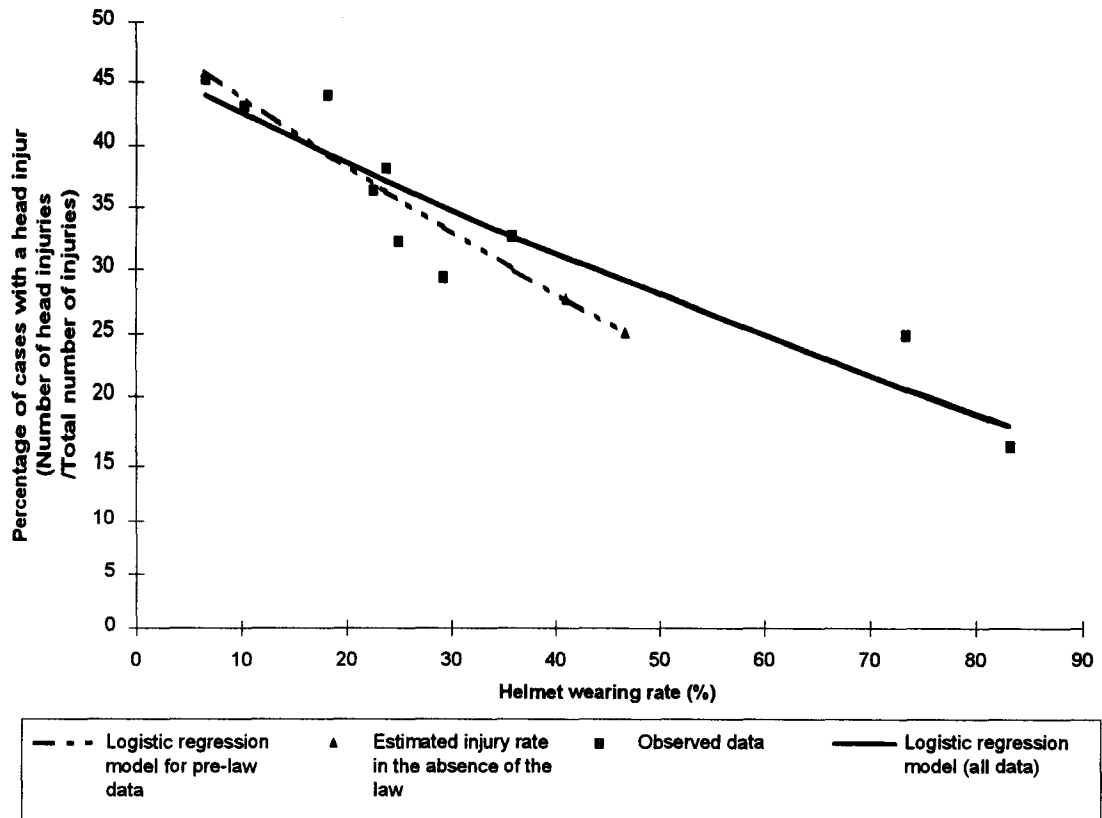
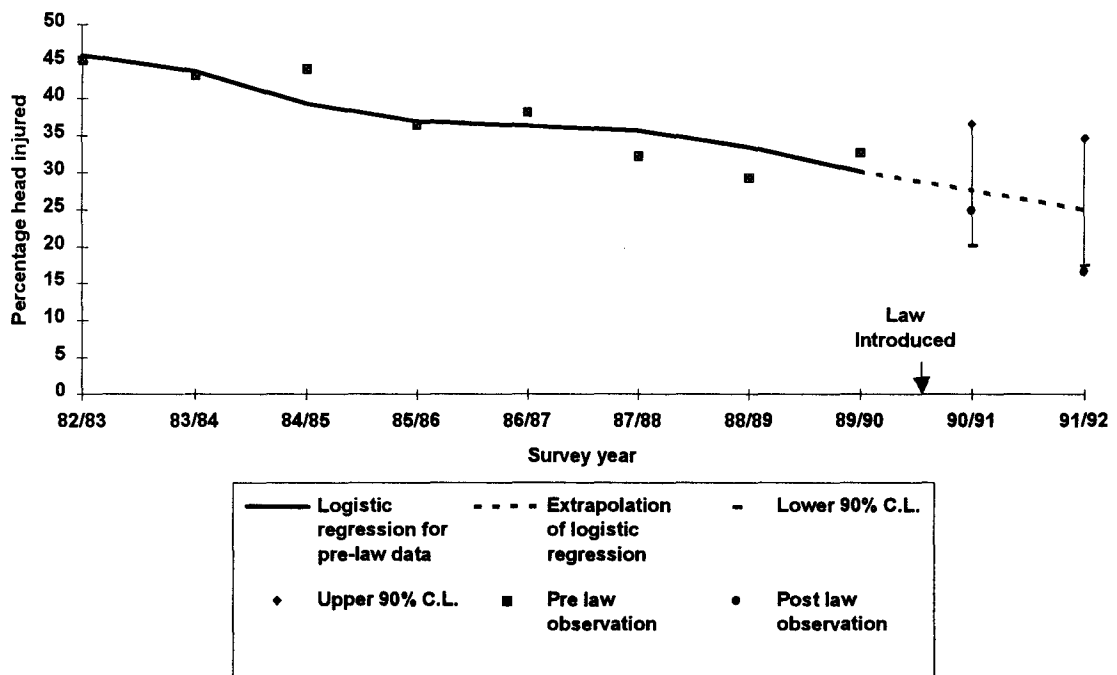


Figure 6 Logistic regression of bicyclist head injuries based on pre-law data. Percentages of head injured cases vs survey year in metropolitan Melbourne. (90% confidence intervals for the post-law estimates also indicated.)



The proportion of head injured cases that would have been expected if the law had no effect on helmet wearing rates (figure 3), and if the pre-law head injury versus wearing rate trend continued, is also shown in figure 5 (dashed line). For 1991, this proportion was estimated to be 28%, compared to the observed head injured proportion of 25%; this difference was not statistically significant. In 1992, on the other hand, the observed proportion of cases with a head injury (17%) was significantly less (one-sided test, $p=0.03$) than the estimate based on no effect of the law on wearing rates (25%). This comparison is shown in figure 6. Figure 6 also suggests that increased helmet wearing during the first post-law year may not have been as effective in reducing head injuries as it appeared to be during the second post-law year.

4.1.3 Bicycle use

The reduction in the number of severely injured bicyclists with injuries other than to the head (and some of the reduction in those with head injuries) during the post-law period may have been due to a reduction in bicycle use as well as due to other factors affecting the risk of accident involvement.

In May of 1991 and 1992, observational surveys were conducted at a representative sample of 64 sites in Melbourne to determine whether bicycle use (on roads and footpaths) had decreased since the introduction of the new law. In analysing the effects, comparisons were made with the results of a very similar survey of child bicycling conducted in May/June 1990 just prior to the mandatory wearing law (Finch et al, 1993).

Figure 7 Age-specific estimated bicycle use in metropolitan Melbourne: 1987/88 - 1992. (The symbols indicate where data is available.)

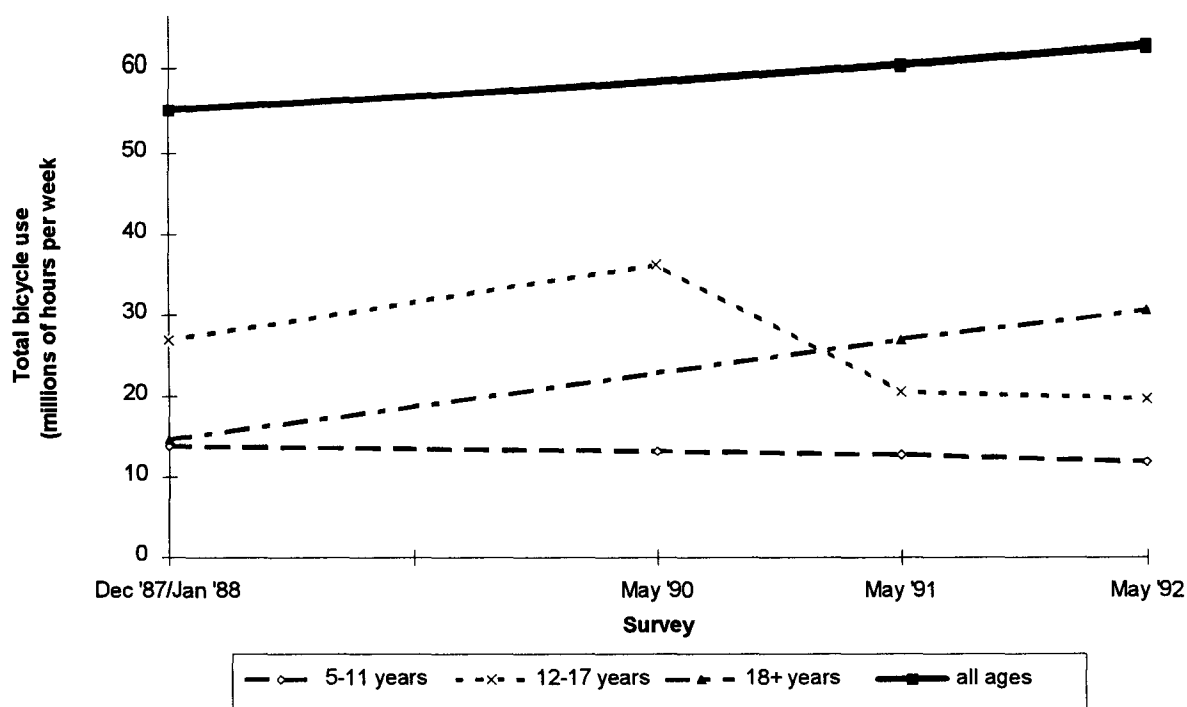


Figure 7 shows that bicycle usage in teenagers had decreased by 43% by 1991 and 45% by 1992, relative to 1990. Bicycle use in children aged 5-11 years also decreased over the same period - by 3% in 1991 and 11% in 1992, compared to 1990. Because the 1990 survey did not cover adult bicyclists, it was not possible to fully examine the change in their bicycle use. However, there was an increase in adult bicycling of 86% by 1991 and a doubling of bicycle use

in 1992 when compared with a survey in November 1987 - January 1988 (Finch et al, 1993). When data for all age groups are combined, the total bicycle use in 1991 was 9% greater than in 1987/88 and by 1992 it had increased a further 3%. A more direct measure of the effect of the law on bicycle use can not be made because adults were not included in the 1990 survey.

4.2 VICTORIA

4.2.1 Helmet wearing rates

Table 4 gives the helmet wearing rates that were estimated for the whole of Victoria as outlined in Section 3.2.2. Victoria-wide helmet wearing rates rose from 31% in 1989/90 to 75% in 1990/91 following introduction of the helmet wearing law. Helmet wearing throughout Victoria was not able to be estimated for 1992 because of the lack of country surveys in that year.

Table 4 Estimated Victoria-wide helmet wearing rates

| Year | Helmet wearing rate (%) |
|-----------------|-------------------------|
| <i>Pre-law</i> | |
| 1983 | 5.2 |
| 1984 | 8.5 |
| 1985 | 15.5 |
| 1986 | 19.8 |
| 1987 | 22.9 |
| 1988 | 22.6 |
| 1989 | 26.5 |
| 1990 | 30.9 |
| <i>Post-law</i> | |
| 1991 | 75.2 |

Figure 8 shows the logistic regression model fitted to the data in Table 4. The observed post-law helmet wearing rate is almost twice that projected from the pre-law trends.

4.4.2 Bicyclist head injuries

Figure 9 shows that the number of bicyclists killed or admitted to hospital with head injuries in Victoria fell progressively between July 1981 and June 1990 as the usage of helmets increased. In the two post-law years (1990/91 and 1991/92) the number with head injuries decreased by 48% and 70%, respectively, relative to the last pre-law year (1989/90).

The number of Victorian bicyclists sustaining severe injuries other than to the head fluctuated about a constant value during the 1980s (figure 8). However, in 1990/91, the number decreased by 23% relative to 1989/90 and in 1991/92 the corresponding drop was 28%.

Figure 8 Increase in helmet wearing rates in Victoria during 1983-1991.

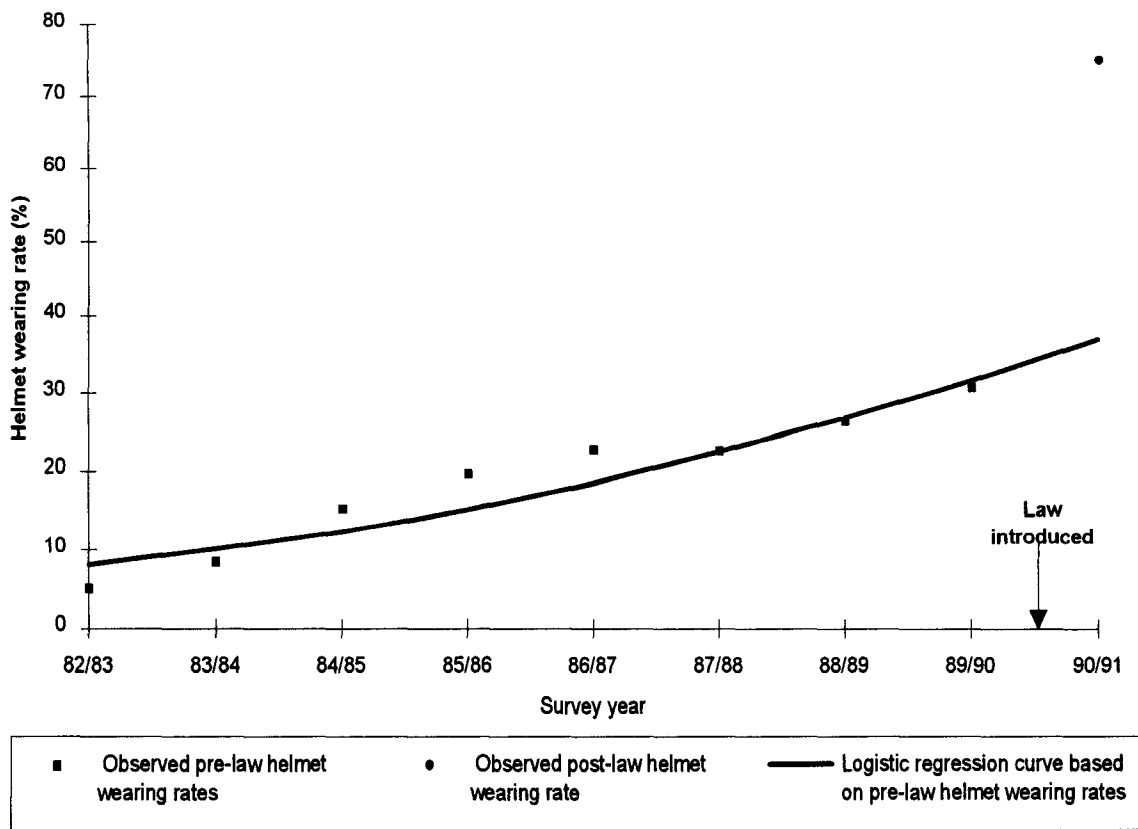
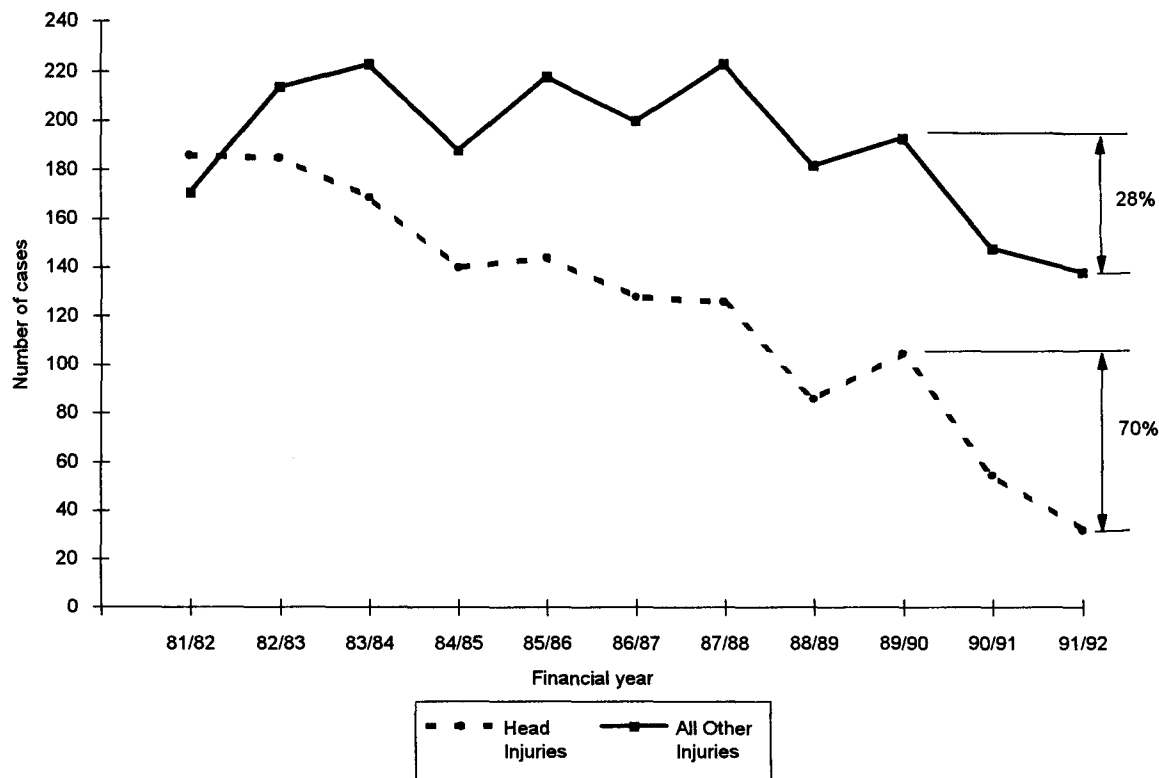
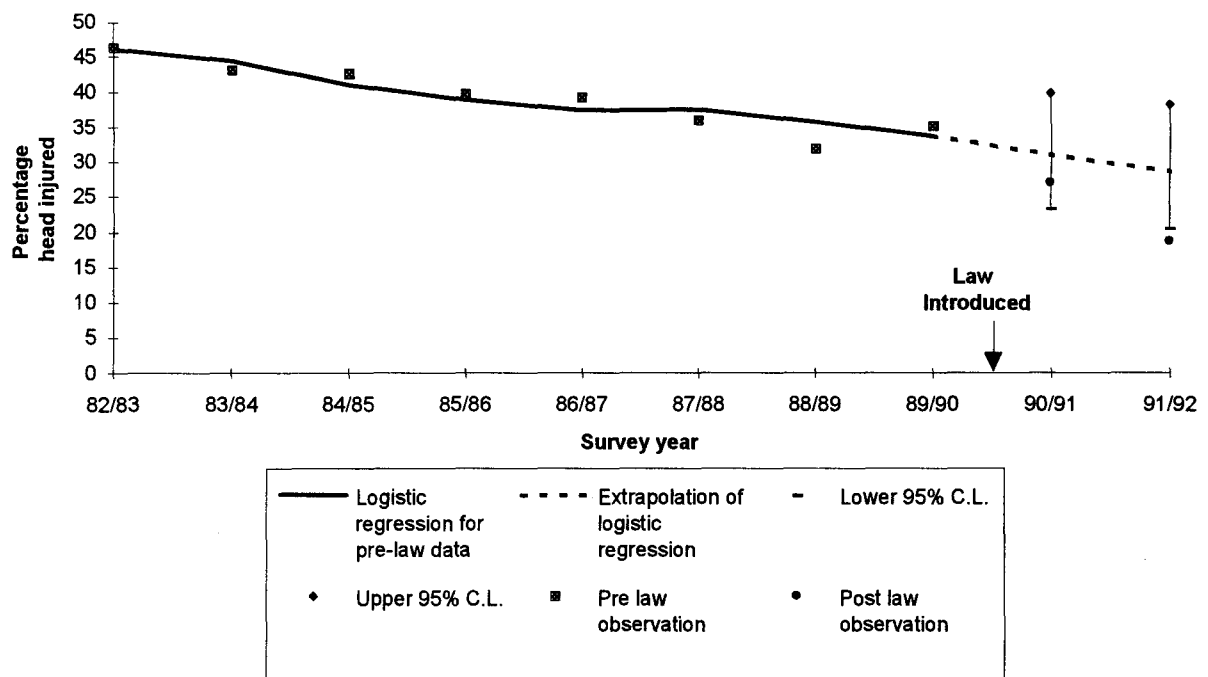


Figure 9 Number of severe bicyclist casualties in Victoria registered with TAC: July 1981-June 1992.



No detailed analysis of the relationship between the Victorian-wide risk of head injury and helmet wearing rates post-law was able to be conducted due to the lack of country surveys of helmet wearing in 1992. However, figure 10 shows that the proportion of cases with a head injury in 1992 was significantly less than that projected on the basis of continuing pre-law trends. The general trend relating the proportion of head injured cases to the survey year for the whole of Victoria is very similar to that for metropolitan Melbourne alone. Furthermore, as was also the case for metropolitan Melbourne, there is a suggestion that increased helmet wearing during the first post-law year may not have been as effective in reducing head injuries as it appeared to be a year later.

Figure 10 Logistic regression of bicyclist head injuries based on pre-law data. Percentages of head injured cases vs survey year in Victoria. (90% confidence limits for the post-law projections also indicated.)



5. DISCUSSION

There has been a progressive increase in helmet wearing rates amongst commuter and recreational bicyclists of all ages during the pre-law period. Country and metropolitan Melbourne surveys indicate that these increases have occurred throughout Victoria. In the two post-law years, the wearing rates were significantly higher than would have been predicted if the previous decade's combined efforts towards increasing helmet wearing had continued their effect in the absence of the law.

The results show a large reduction (48%) in the number of bicyclists with head injuries during the first year after the introduction of the mandatory helmet wearing law in Victoria on 1 July 1990. During the second year after the law's introduction, there were 70% fewer head injuries

in Victoria, compared to the 1989/90 period. However, the mechanisms by which this reduction was achieved seem to be twofold:

- I. a reduction in the number of bicyclists involved in crashes resulting in severe injury (ie. killed or admitted to hospital), and
- II. a reduction in the risk of head injury for bicyclists who were severely injured.

The extent of the reduction in bicyclist claims to TAC for severe injuries other than to the head (23% by 1990/91 compared to 1989/90; 28% in 1991/92) supports the first mechanism. In addition, there is evidence that bicycle use by persons under 18 years fell by an average of 36% during the first two post-law years although use by adults increased markedly. Hence reduction in bicycle use appears to be an important contributor to the reduction in crash involvement, though it is also possible that the wearing of helmets has made bicyclists more conspicuous, or that the helmets and associated publicity have made bicyclists ride more carefully. Alternatively, the overall reduction in road trauma over the same period could have influenced the risk of bicyclist involvement in road crashes.

In addition, major initiatives directed at drink/driving and speeding were introduced in Victoria in December 1989 and March 1990, respectively. The total number of persons killed and admitted to hospital resulting from all road trauma during the year commencing July 1990 was 12% below the number for the previous year. This could account for some of the reductions in bicyclist trauma during this period. However, the relationship between reductions in overall road trauma and bicycle injury rates are not necessarily proportionate.

There is also evidence that the risk of head injury to bicyclists involved in crashes has been reduced (the second mechanism). The percentage of severely injured bicyclist claimants to TAC who suffered a head injury during the post-law period was considerably less than pre-law levels. This result was found both for Melbourne alone and for the whole State of Victoria.

On the basis of the logistic regression model describing the relationship between the percentage of severely injured bicyclists who sustained a head injury, and the helmet wearing rates established in the pre-law period, there is an indication that increased helmet wearing in the first post-law period was not as effective in reducing the risk of head injury to crash-involved bicyclists during the first post-law year compared with the second year.

Finch et al (1993) found that the proportion of helmet owners wearing their helmets, rather than carrying them, had increased between 1991 and 1992, particularly amongst teenagers. In addition, fewer hard-shell helmets were being worn in 1991, compared to 1992, particularly in adults. This may reflect initial enthusiasm following the amendment to the Australian Standard for bicycle helmets in 1990 which allowed lighter, soft-shell (ie. foam-only or micro-shell) helmets.

There was no evidence that bicyclists were less likely to secure their helmets in 1991 than in 1992, although it is possible that they were less securely adjusted or fastened by those bicyclists who did not previously wear them. Helmeted bicyclists may also have been engaging in more behaviours resulting in more severe impacts in 1991 than in 1992.

These observations may help to explain the differences in the apparent effectiveness of helmets in 1991 and 1992. Alternatively, they may also be a result of the assumptions which had to be made in combining a range of helmet wearing data.

6. CONCLUSIONS

The mandatory bicycle helmet wearing law implemented in Victoria on 1 July 1990 has been successful in building on past efforts to promote helmet use by bringing helmet wearing rates to new high levels for all bicyclist age groups, both in Melbourne and country Victoria.

The introduction of the law has been accompanied by an immediate large reduction in the number of bicyclists with head injuries. Apparently this has been achieved through a reduction in the number of bicyclists involved in crashes (at least partly through a decrease in bicycle use by children and teenagers) and a reduction in the risk of head injury of bicyclists involved in crashes. Increases in helmet wearing rates and decreases in head injury risk have continued for two years after the introduction of the law.

7. REFERENCES

BMDP Inc. 1988, *BMDP statistical software manual*, Chief Ed: WJ Dixon, University of California Press, Berkeley.

Cameron, M., Heiman, L. & Neiger, D. July 1992, *Evaluation of the bicycle helmet wearing law in Victoria during its first 12 months*, Monash University Accident Research Centre, Report No. 32.

Dorsch, M.M., Woodward, A.J. & Somers, R.L. 1984, 'Do bicycle safety helmets reduce severity of head injury in real crashes?', Road Accident Research Unit, University of Adelaide.

Drummond, A.E. & Jee, F.M. October 1988, *The risks of bicyclist accident involvement*, Monash University Accident Research Centre, Report No. 2.

Drummond, A.E. & Ozanne-Smith, E.J. July 1991, *The behaviour and crash involvement risk of child pedestrians and bicyclists: a traffic exposure study*, Monash University Accident Research Centre, Report No. 17.

Finch, C.F., Heiman, L. & Neiger, D. February 1993, *Bicycle use and helmet wearing rates in Melbourne, 1987 to 1992: the influence of the helmet wearing law*, Monash University Accident Research Centre, Report No. 45.

Healy, D.J. August 1986, *Trends in helmet usage rates and bicyclist numbers sustaining head injury - July 1981 to December 1985 - Victoria*, Road Traffic Authority, Report No. GR/86/11.

Heiman, L. 1987, *Bicycle helmet usage surveys of primary and secondary school children, adult commuter and recreational cyclists 1983-1987*, Road Traffic Authority, Report No. GR/87/14.

Kleinbaum, D.G., Kupper, L.L. & Morgenstern, H. 1982, *Epidemiologic research. Principles and quantitative methods*, Van Nostrand Reinhold Company. New York.

Leicester, P., Nassau, F. & Wise, A. 1991, *The introduction of compulsory bicycle helmet wearing in Victoria*, VIC ROADS Report No. GR/91-4.

Morgan, M., Peberdy, J. & Rogerson, P. July 1991, *Bicycle helmet usage rates in Victoria: 1990 - 1991, and other bicycle safety factors*, VIC ROADS, Report No. GR91-9.

State Bicycle Committee November 1991, *Victorian bicycle strategy*, VICROADS.

Sullivan, G. & Wise, A. 1990, *Bicycle helmet usage rates in Victoria 1983 - 1990*, VIC ROADS, Report No. GR 90-9.

Vulcan, P., Cameron, M.H. & Watson, W.L. 1992, 'Mandatory bicycle helmet use: experience in Victoria, Australia', *World Journal of Surgery*, Vol. 16, pp 389-397.

Wise, A. 1989, *Bicycle helmet usage rates in Victoria 1983-1989*, VIC ROADS, Report No. GR 89-1.

8. ACKNOWLEDGMENTS

This study was funded through MUARC's baseline research program for which grants have been received from the Australian Road Research Board, Ministry for Police and Emergency Services, Roads Corporation (VIC ROADS), Royal Automobile Club of Victoria Ltd and Transport Accident Commission.

Mr David Attwood, Transport Accident Commission, is acknowledged for providing the injury data presented in this report. All other sources of data are referred to directly in the text.

Dr John Lane (MUARC), John Lambert (VIC ROADS) and Andrea Anderson (VIC ROADS) are thanked for their useful comments on the report.

Tri Le is thanked for his assistance with preparing some of the figures and Glenda Cairns for preparing the final manuscript.

Part of the material in this report has been accepted for publication in the journal 'Accident Analysis and Prevention'.