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BICYCLIST HEAD INJURIES IN VICTORIA THREE YEARS AFTER THE INTRODUCTION OF MANDATORY HELMET USE

by

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Abstract:

The continuing influence of bicycle helmet wearing on bicyclist head injuries in Victoria three years after the introduction of mandatory wearing on 1st July 1990 is evaluated here by building on the results of the two previous evaluations of the bicycle helmet wearing law conducted by the Monash University Accident Research Centre. Results are presented for both metropolitan Melbourne and the whole of Victoria and the study uses data sourced from motor vehicle involved bicyclist injury claims from the Transport Accident Commission as well as Victorian hospital admissions records of injured cyclists.

Analysis of hospital admissions records was not able to find a relationship between helmet wearing and head injury rates in the immediate pre-law years for bicyclists injured in accidents not involving a motor vehicle. Despite this, head injury rates for bicyclists injured in these crashes was significantly lower than the pre-law level in each of the three post-law years. A significant inverse relationship between helmet wearing and head injury rate was found for cyclists involved in accidents with motor vehicles. This relationship was found in analysis of both insurance claims data and hospital admissions records.

The effect of the bicycle helmet law in reducing head injury rates below pre-law trend predictions for bicyclists injured in motor vehicle involved crashes was not clear. Analysis of the insurance claims data showed bicyclist head injury rates significantly below pre-law trend predictions in the second post-law year although this benefit appeared to have been lost in the third post-law year, with an increase in head injury rate from the second post-law year. Analysis of the hospital admission records however, failed to show any additional benefit of the law over pre-law trends in reducing head injury rates in the three post-law years. A subsequent MUARC report, which should be read in conjunction with this report, investigates bicycle injury data and the effect of the bicycle helmet law four years after its introduction. This report has revealed biases in the bicyclist injury data, certainly affecting the analysis and results presented here, with different conclusions reached in the subsequent analysis after adjusting for bias.

Key Words:
(IRRD except where marked*)
bicycle, crash helmet, cyclist, injury, evaluation (assessment), statistics, traffic regulations, regression analysis, safety.

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EXECUTIVE SUMMARY

The mandatory bicycle helmet wearing law implemented in Victoria on 1 July, 1990 was successful in building on past efforts to promote helmet use by bringing helmet wearing rates to new high levels for all cyclist age groups in the first post-law year, both in Melbourne and Victoria as a whole. Estimates of trends in helmet wearing over all three post-law years were, however, not available for this report.

The continuing influence of bicycle helmet wearing on bicyclist head injuries three years after the introduction of mandatory wearing is evaluated here by building on the results of the two previous evaluations of the bicycle helmet wearing law conducted by the Monash University Accident Research Centre (Cameron et al 1992, Finch et al 1993b). Results are presented for both metropolitan Melbourne and the whole of Victoria and the study uses data sourced from motor vehicle involved bicyclist injury claims from the Transport Accident Commission (TAC) as well as Victorian hospital admissions records of injured cyclists.

Analysis of hospital admissions records using logistic regression was not able to find a relationship between helmet wearing and head injury rates in the immediate pre-law years for bicyclists injured in accidents not involving a motor vehicle. Despite this, head injury rates for bicyclists injured in these crashes was significantly lower than the pre-law level in each of the three post-law years. A significant inverse relationship between helmet wearing and head injury rate was found for cyclists involved in accidents with motor vehicles. This relationship was found in analysis of both TAC insurance claims data and hospital admissions records.

The effect of the bicycle helmet law in reducing head injury rates below pre-law trend predictions for bicyclists injured in motor vehicle involved crashes was not clear. Analysis of the TAC claims data showed bicyclist head injury rates significantly below pre-law trend predictions in the second post-law year although this benefit appeared to have been lost in the third post-law year, with an increase in head injury rate from the second post-law year. Analysis of the hospital admission records however, failed to show any additional benefit of the law over pre-law trends in reducing head injury rates in the three post-law years (an increase in head injury rate in the third post-law year was also observed here). Comparison of the TAC claims data and hospital admission records for non-fatal motor vehicle involved bicyclist injuries revealed possible differences in injury coding between the two.

A subsequent MUARC report (Carr et al 1995), which should be read in conjunction with this report, investigates bicycle injury data and the effect of the bicycle helmet law four years after its introduction. This report has revealed biases in the bicyclist injury data, certainly affecting the analysis and results presented here. This is shown by the analysis of Carr et al (1995) which adjusts for the bias in the bicyclist injury data and reaches different conclusions to those drawn here.

1. INTRODUCTION

Since 1 July 1990, bicyclists in Victoria have been required to wear an approved helmet. The introduction of the bicycle helmet wearing law in Victoria was preceded by ten years of helmet promotion, involving education, mass media publicity, support by professional associations and community groups, consultation with bicycle groups, and financial incentives. These activities are discussed in greater detail in Wood and Milne 1988 and Vulcan et al 1992.

The law requires all persons cycling on the road, footpath, separate bicycle path or in a public park to wear a securely fitted approved bicycle helmet. It also applies to bicycle passengers. The legal requirement is specified in the Road Safety Bicycle Helmets Regulations 1990, under the Road Safety Act 1986, and provides exemptions for participants in authorised bicycle races, people with medical conditions, members of an organised religion and people with a physical condition or characteristic which makes it impracticable to wear a helmet. An exemption has also been granted to Postal Delivery Officers riding bicycles whilst delivering mail (Leicester et al, 1991). In practice, exemptions have been difficult to obtain and it is understood that fewer than 50 were granted in the two years following introduction of the law. The maximum penalty for non-compliance with the bicycle helmet wearing law of $100 is rarely applied as offenders are not normally taken to Court, but rather a Bicycle Offence Penalty Notice for $15 is issued. For children, a Bicycle Offence Report (no monetary penalty) may be sent to the parents. During the first post-law year 19,229 Bicycle Offence Penalty Notices (BOPNs) and 5,028 Bicycle Offence Reports (BORs) were issued. The comparable figures for the 1991-92 and 1992-93 financial years are 24762 BOPNs, 5197 BORs and 19391 BOPNs, 5749 BORs respectively.

Victoria was the first State in the world to introduce compulsory bicycle helmet wearing. 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 for all age groups of bicyclists (Finch et al, 1993a).

The direct result of increased helmet wearing rates was expected to be a significant reduction in the number and severity of head injuries to bicyclists involved in road crashes. The results of two evaluations of the impact of helmet wearing on bicyclist head injuries have been previously published by MUARC, the first covering data up to one year post-law (Cameron et al, 1992), the second extending this to two years post law (Finch et al 1993b). Both studies examined bicyclist injury trends in insurance claim data to assess the impact of the helmet wearing law on bicyclist head injuries. With regards to injury reduction, both studies 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 of both 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. The second study, covering data in the second year post-law, showed the risk of head injury to bicyclists in the second post-law year to be significantly below that predicted on pre-law trends. This significant reduction in the risk of bicyclist head injuries observed in the second year post-law was attributed directly to implementation of the bicycle helmet wearing law.

2. OBJECTIVES

The aim of this report is to evaluate the continuing influence of bicycle helmet wearing on bicyclist head injuries three years after the introduction of mandatory wearing. This report builds on the results of the two previous evaluations of the bicycle helmet wearing law conducted by MUARC (Cameron et al 1992, Finch et al 1993b). This evaluation is presented for both metropolitan Melbourne and the whole of Victoria and uses data sourced from motor vehicle involved bicycle accident claims from the TAC as well as Victorian hospital admissions records of injured cyclists.

3. METHODS AND MATERIALS

3.1 SURVEYS AND ESTIMATES OF HELMET WEARING RATES

Both VicRoads and MUARC have carried out observational surveys of bicycle usage and bicycle helmet wearing. Finch et al. (1993a) describe these surveys and develops a method by which the results of each can be aggregated to estimate cyclist helmet wearing rates by year of survey for both Victoria as a whole and Melbourne separately. Table 1 summarises the calculated aggregate helmet wearing rates for Melbourne and Victoria for all ages combined and for age groups 5 to 11 years, 12 to 17 years and over 18 years. These age groupings represent respectively primary school, secondary school and adult aged cyclists. The head injury analysis presented in this report uses the estimated helmet wearing rates of Table 1.

TABLE 1
ESTIMATED BICYCLIST HELMET WEARING RATES

	Helmet Wearing Rate (%)							
Year	***Melbourne***				***Victoria***			
	All	*5-11yrs*	*12-17yrs*	*18+ yrs*	*All*	*5-11yrs*	*12-17yrs*	*18+ yrs*
Pre law								
1983	6.5	2.4	1.0	18.9	5.2	2.4	0.9	14.8
1984	10.2	7.0	3.3	24.3	8.5	6.9	2.8	19.0
1985	18.1	20.4	9.0	30.4	15.5	19.9	7.6	23.8
1986	22.5	30.6	11.9	31.7	19.8	30.0	11.5	23.4
1987	23.7	35.8	12.6	30.0	22.9	35.0	13.4	26.4
1988	24.9	38.8	10.6	34.5	22.6	38.4	10.4	27.1
1989	29.2	47.1	12.2	39.3	26.5	43.7	12.9	31.6
1990	35.8	57.2	18.9	42.1	30.9	51.1	17.8	33.0
Post law								
1991	73.4	82.6	48.8	88.0	75.2	84.0	55.7	85.8
1992	83.2	*NE*	*NE*	*NE*	*NA*	*NA*	*NA*	*NA*

NE = Not estimated from survey data
NA = Not available from survey data

3.2 BICYCLIST INJURIES

The effects of the helmet wearing law on bicyclist injuries has been measured by examining data from two sources:

1. Transport Accident Commission (TAC) claims for "no fault" injury compensation from bicyclists killed or hospitalised after collision with a motor vehicle in Victoria.

2. Health Department records of acute presentations by bicyclists to Victorian public hospitals resulting in admission, after collisions either involving or not involving a motor vehicle.

3.2.1 TAC Data

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 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 nosologists 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 defined as those with N-codes 800, 801, 803, 850-854, 872, 873.0, 873.1, 873.8 and 873.9, following the procedure described by Healy (1986).

A limitation of the injury data was that the number of bicyclists in Victoria each year during the 1980's was not available. This meant that injury rates per bicyclist population were not able to be computed. Assessment of changes over time were therefore based on an examination of the proportion of all injured cases with a head injury.

3.2.2 Victorian Hospital Admissions Data

A second source of data on bicyclist injuries was the Victorian Hospital Morbidity File. This database records broad details of public hospital admissions in Victoria from July 1986 to June 1993. Bicyclist admissions were selected from the database using the ICD-9-CM E-codes assigned to each record. Bicyclist admissions identified using E-codes fall into four broad categories. Table 2 lists these categories and the E-codes associated with each.

TABLE 2
E-CODES IDENTIFYING BICYCLIST INJURIES

Category	Injury Cause	E-Codes
A	Railway accident (impact with railway equipment)	800.3 801.3 802.3 803.3 804.3 805.3 806.3 807.3
B	Motor vehicle traffic accidents (impacts with motorised vehicles on public roads)	810.6 811.6 812.6 813.6 814.6 815.6 816.6 817.6 818.6 819.6
C	Motor vehicle non-traffic accidents (impact with motorised vehicles not on public roads)	820.6 821.6 822.6 823.6 824.6 825.6
D	Other road vehicle accidents (non motor, including single bicycle on road accidents)	826.1 827.1 828.1 829.1

For analysis, only two of these four categories were used; (I) - on road impacts of bicyclists with vehicles (category B in Table 2) and (II) - non-motor vehicle involved bicycle accidents (category D in Table 2). Categories A and C from Table 2 were excluded from the analysis as these cases were very rare, with these categories representing only 0.8% of all bicycle crashes in the database. The data analysis also allowed direct comparison with the TAC data described above. TAC insurance covers all accidents involving registered motorised vehicles on public roads, so TAC recorded bicyclist claims should be comparable with category B.

Each record in the Victorian hospitals admissions database contains injury coding by hospital staff according to injury type for up to five injuries using the ICD-9-CM system. The ICD-9-CM system of coding is an extension of the ICD-9 system, adding sub-codes to many of the base ICD-9 codes hence allowing more precise description of injury. It was possible to re-collapse the extra sub-codes in the ICD-9-CM system back to ICD-9 detail hence making the two systems fully compatible. This compatibility meant injury data from the hospital admissions records could be classified on the same basis as injuries in the TAC data. Bicyclists cases from the hospital admissions records were classified as those who sustained a head injury, and those who did not sustain a head injury, in the same way as the TAC claims data. Location of the incident (metropolitan Melbourne or country Victoria) is difficult to obtain from the Victorian hospital admissions database. The postcode of the hospital to which each case was admitted is recorded along with the home address postcode of each case. The postcode of where the incident occurred is, however, not recorded. For this reason, analysis of the hospital admissions data was confined to Victoria as a whole.

3.3 STATISTICAL METHODS

All data was analysed by the BMDP data analysis package ((BMDP 1988). The LR procedure was used for the logistic regression analyses.

3.3.1 Helmet Wearing Rates

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

For each age group in the Melbourne metropolitan area and for the Victorian wide data only one post law year's helmet wearing rate was available. Here a logistic model fitted to pre-law data only was obtained. The resultant curve

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

where P is represents the helmet wearing rate, was then extrapolated to provide an estimate of the helmet wearing rates that might have been expected in 1991, 1992 and 1993 in the absence of the law. By comparing this with the actual helmet wearing rates in 1991, an estimate of the additional benefit of the law on top of the ongoing helmet promotion activity was able to be obtained.

When assessing the influence of the law on helmet wearing rates for all ages in the Melbourne metropolitan region where two years post law data was available, the model included two independent variables: a dummy variable indicating the post-law period and the other representing the annual assessment of helmet wearing. The logistic regression procedure also considered the interaction between these two variables to assess whether the rate of change in helmet wearing rates increased or decreased after 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 again represents the helmet wearing rate. With the law flag set to zero, the helmet wearing rates for the first two post law years, 1991 and 1992, had the law not been in effect, could be predicted. This could be further extrapolated to predict the 1993 helmet wearing rate in the absence of the law

3.3.2 Head Injuries

In order to assess the relationship between helmet wearing rates and head injury risk, as well as the influence of the law on head injury rates, a logistic regression model was used. 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. The logistic model describing the relationship between the head injury and helmet wearing rates was of the form:

$$\text{logit}(P) = \log\left(\frac{H}{O}\right) = \beta_0 + \beta_1 \times \text{helmet wearing rate}$$

In order to assess whether the actual head injury rates in 1991 to 1993 were associated with the observed increased helmet wearing rates, the logistic regression was applied to the pre-law data only. The estimates of helmet wearing rates that would have occurred in 1991 to 1993 without the law (see previous section) were then applied to this model to obtain the head injury rates in these years that would have been expected in the absence of the law. This analysis assumes that the pre-law head injury versus wearing rate trend would also have continued in the same way without the law as suggested by the pre-law levels. Furthermore, it assumes that the estimated helmet wearing rates are themselves without error.

Observed head injury rates were then compared with those predicted 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, 1983) and interval estimates of the projected head injury rates in the absence of the law for 1991 to 1993 were obtained after de-transforming the corresponding interval estimates of the logistic function.

4. RESULTS

4.1 HELMET WEARING RATES

The logistic regressions described in section 3.3.1 were fitted to the helmet wearing rates of Table 1. Results are presented here for Victoria as a whole and then for Melbourne separately. Age specific analyses for Victoria and Melbourne were also carried out (Appendix A).

4.1.1 Victoria

Helmet wearing rates by year of survey along with the extrapolated logistic regression fitted to the pre-law helmet wearing rates are presented in Figure 1 for Victoria.

FIGURE 1
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE VICTORIA

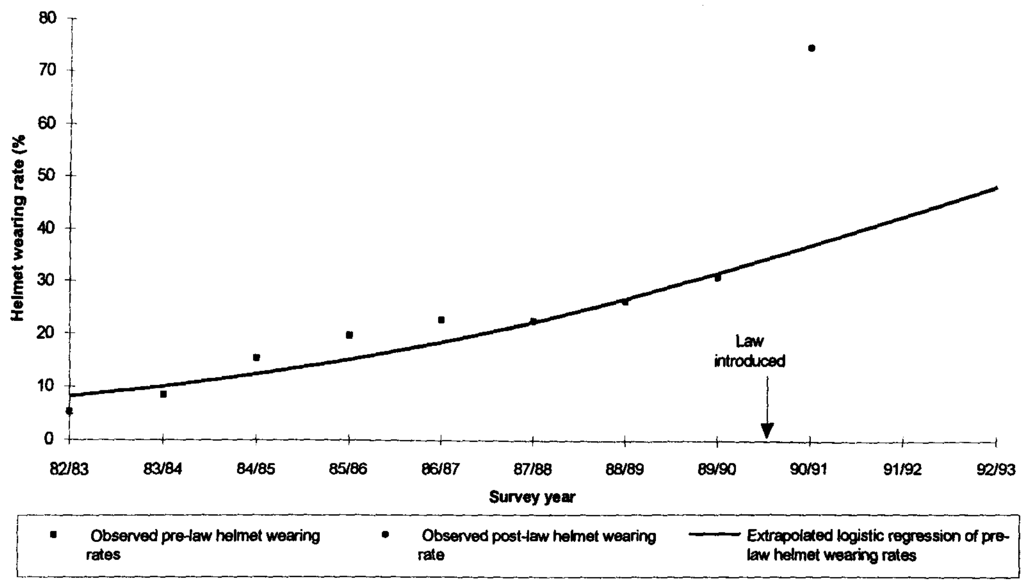
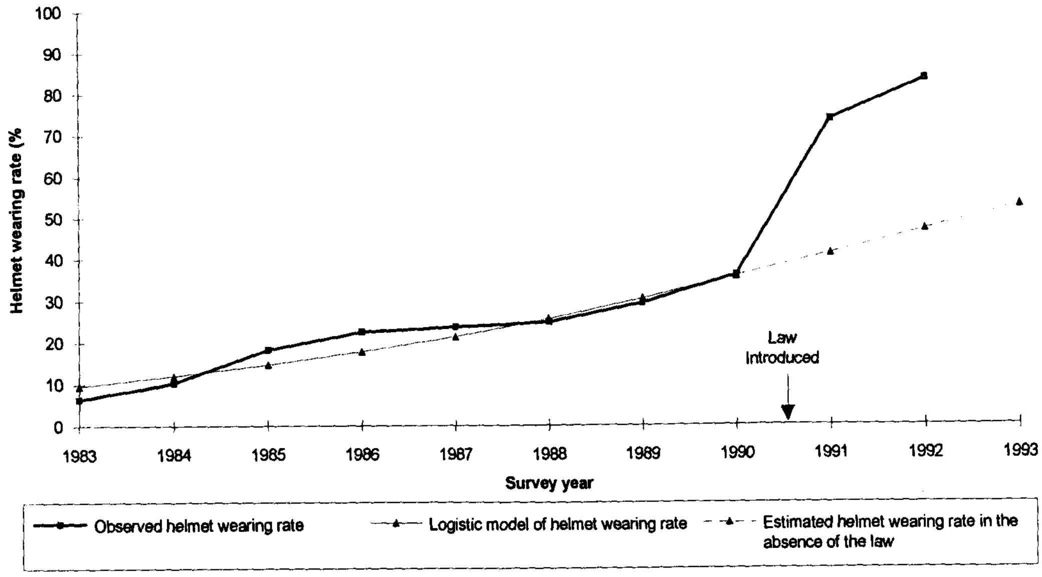


Figure 1, through the logistic regression, shows a statistically significant increase in helmet wearing rates in the pre-law years ($p<0.001$). The observed first year post-law helmet wearing rate is statistically significantly higher ($p<0.0001$) than predicted from pre law trends being almost twice that predicted. Due to the absence of bicycle helmet wearing rate estimates for the whole of Victoria in 1992 and 1993 there is no data in these years to compare with the extrapolated logistic curve.

4.1.2 Melbourne

The availability of an estimate of the bicycle helmet wearing rate in Melbourne for 1992 meant two years of post-law data were available for Melbourne. This allowed the more detailed logistic model including the test for a different rate of helmet wearing rate increase post-law to be fitted to the Melbourne helmet wearing rate data. Figure 2 shows the observed helmet wearing rates, estimated logistic curve (solid line) and estimated curve in the absence of the law (dashed line).

FIGURE 2
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE MELBOURNE



The estimated logistic curve shows a significant upwards trend in helmet wearing ($p<0.001$) and a significant increase in helmet wearing rate after introduction of the law ($p<0.001$). The law by year interaction term (see section 3.3.1) was also significant ($p<0.001$) suggesting that the rate of increase in helmet wearing was different (in fact greater) after the law than before its introduction. Significance of this interaction term must be treated with caution as it is based on only two post-law wearing rate estimates, possibly leading to spurious significance.

4.2 BICYCLIST INJURIES : TAC CLAIMS

The effects of the law on bicyclist head (excluding face) injuries have been measured firstly by analysing TAC claims for injury compensation from cyclists who were killed or admitted to hospital (ie severe casualties) following collision with a motor vehicle. The analysis has been carried out for all ages pooled in both Victoria as a whole and for metropolitan Melbourne. Age specific analyses have also been carried out for these two regions and are presented in Appendix B.

4.2.1. Victoria

Figure 3 shows that, based on TAC claims, the number of cyclists killed or admitted to hospital with head injuries in Victoria fell progressively between July 1981 and June 1990 as the usage of helmets increased. Table 3 shows the percentage reductions in head injuries for the three post law years relative to the year immediately pre-law. In the first two post-law years (1990/91 and 91/92) large reductions in the number head injured relative to the last pre-law year (1989/90) were recorded. In the third year post-law however, an increase in the number of head injured cyclists was recorded, though this was still well below the 1989/90 level. These figures suggest that, other things being unchanged, the substantially increased helmet use due to the law reduced the risk of head injury to cyclists in the first two years post-law but that some of this ground has been lost in the third post-law year.

FIGURE 3
NUMBER OF SEVERE BICYCLIST CASUALTIES
VICTORIA : TAC CLAIMS

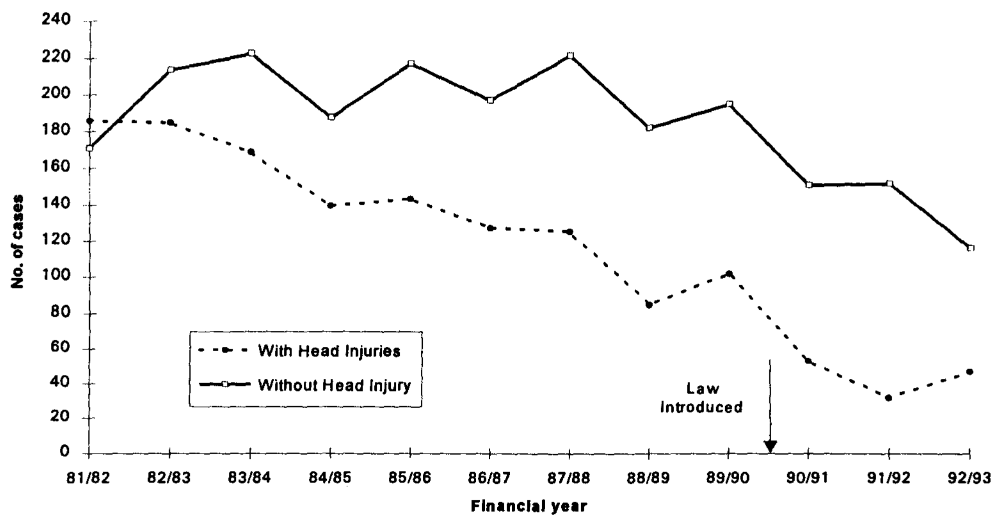


TABLE 3
PERCENTAGE REDUCTIONS IN SEVERE BICYCLIST CASUALTIES
RELATIVE TO 1989/90 FINANCIAL YEAR
VICTORIA : TAC CLAIMS

Financial Year	Bicyclists with head injuries	Bicyclists without head injuries
1990/91	49%	22%
1991/92	69%	22%
1992/93	54%	40%

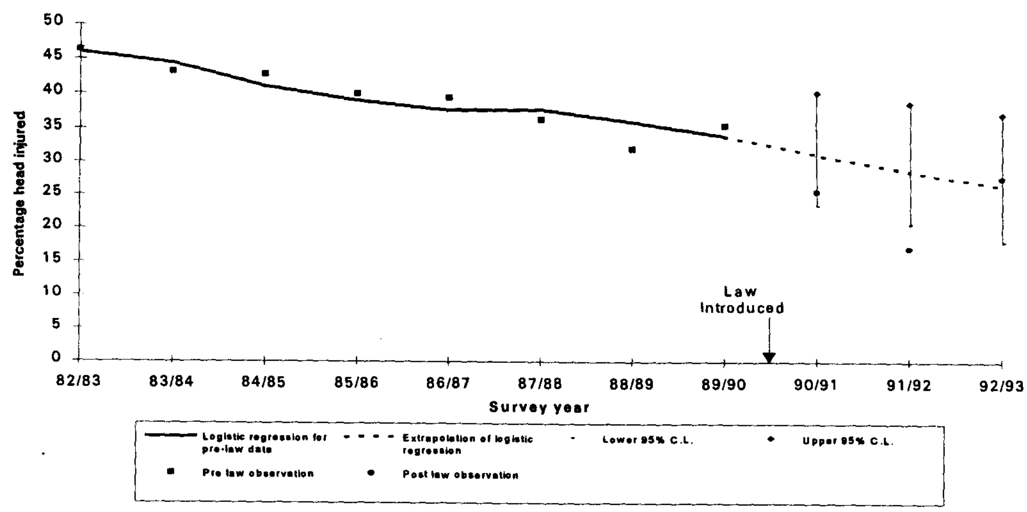
The number of Victorian cyclists sustaining severe injuries other than to the head fluctuated about a constant value during the 1980s (Figure 3). Table 3 shows the number of cyclists without head injuries dropped to a steady level for the two years immediately post-law and has shown a further drop in the third post-law year.

These reductions in the numbers of cyclists killed or admitted to hospital with other than head injuries were somewhat unexpected. They suggest that the number of cyclists involved in crashes with motor vehicles has decreased during the post-law period, due to a reduction in bicycle use and/or a reduction in the risk of crash involvement. The first of these possible explanations is discussed later. The second possibility is consistent with the general reduction in police reported total road deaths and serious injuries in Victoria, which fell by 18% in 1990/91 relative to 1989/90, by a further 8% in 1991/92, and again a further 4% in 1992/93.

Because of the fall in non-head injuries, as well as head injuries, the effect of helmet use for cyclists in a crash was assessed by examining the percentage of cyclists who were killed or admitted to hospital with a head injury. A statistically significant ($p < 0.001$) inverse relationship between this percentage and the pre-law helmet wearing rate was found fitting the logistic regression model described in section 3.3.2. This model was used to predict the proportion of head injured cases in Victoria during each of the three post-law years. The fitted regression is plotted against year rather than helmet wearing rate to show the chronological development of the series (Figure 4).

Figure 4 shows that there was a lower percentage of head injured cases in the two years immediately post-law than predicted by the model assuming that the upward helmet wearing rate trends continued as observed in the pre-law period, with no influence of mandatory wearing (dashed line in Figure 1). The percentage during the second year was statistically significantly below the prediction (one-tailed test $p < .05$ for 1991/92). For the third post-law year, however, Figure 4 shows the observed proportion of head injured cases to be no different from the downward trend predicted by the model using pre-law wearing rate trends.

FIGURE 4
LOGISTIC REGRESSION OF BICYCLIST TAC CLAIMS.
PERCENTAGE HEAD INJURED VS. YEAR
VICTORIA



It is likely that the reduction in the proportion of head injured cases in the first two years post-law was related to the introduction of the helmet wearing law and the large increase in helmet wearing rates which followed. Possible reasons for the apparent loss of effectiveness of the law in reducing head injury during the third year after its introduction will be discussed below.

4.2.2 Melbourne

Figure 5 and Table 4, based on TAC claims, show similar reduction patterns in bicyclist injuries in Melbourne for the three post-law years to those observed in Victoria. Once again a decrease in the number of head injured cyclists in the first two post law years was observed followed by an increase in the third year, parallelled with a steady decrease in the number of those without head injuries over all three years. In both Victoria as a whole and in Melbourne, the decreases in the number of severe bicyclist casualties in each of the three post law years relative to the year immediately pre-law were greater for those with head injuries than those without head injuries despite the increase in head injuries in the third post-law year.

FIGURE 5
NUMBER OF SEVERE BICYCLIST CASUALTIES
MELBOURNE : TAC CLAIMS

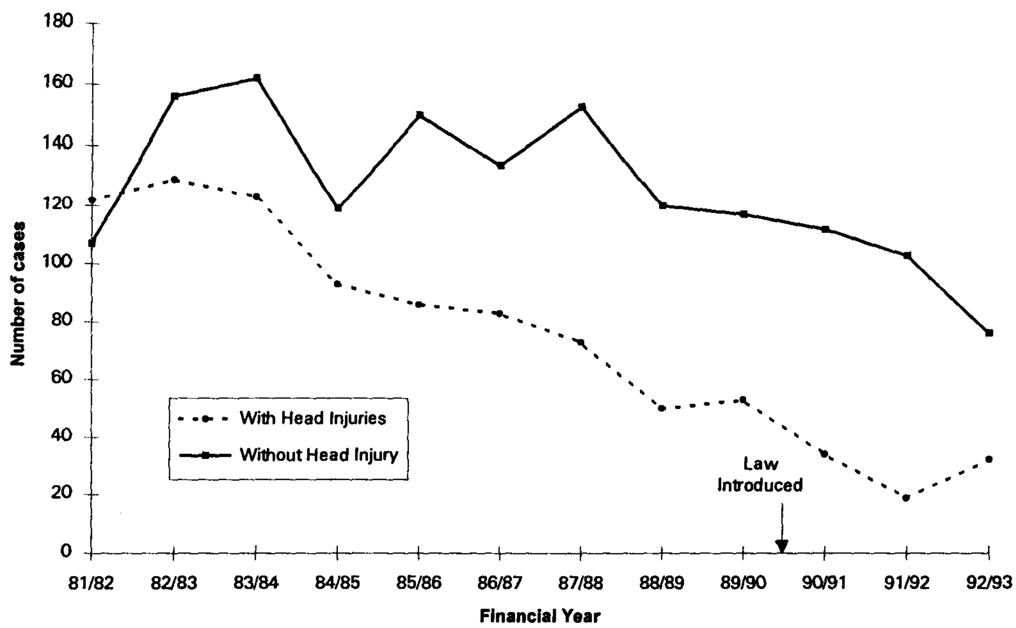
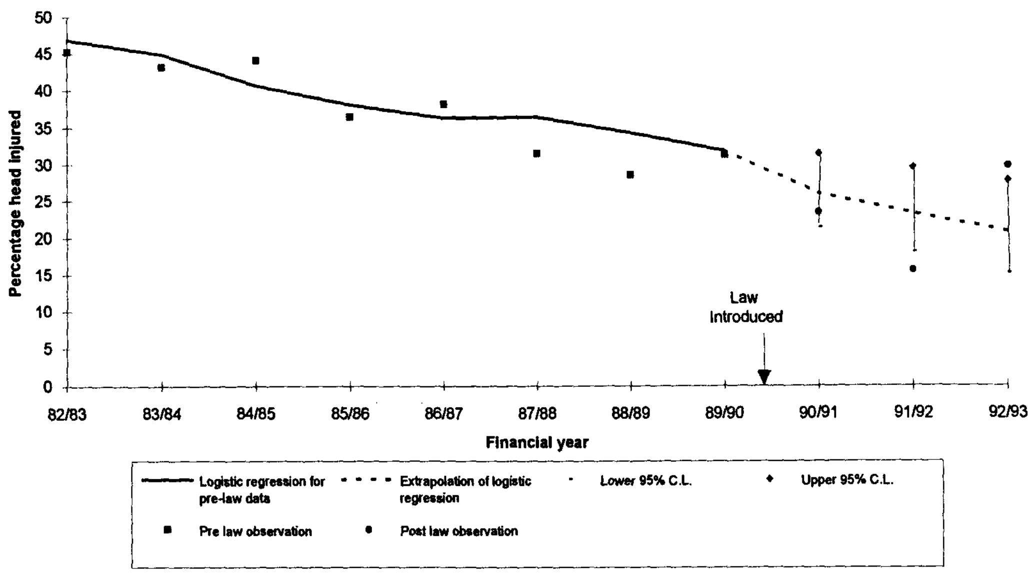


TABLE 4
PERCENTAGE REDUCTIONS IN SEVERE BICYCLIST CASUALTIES
RELATIVE TO 1989/90 FINANCIAL YEAR
MELBOURNE : TAC CLAIMS

Financial Year	Bicyclists with head injuries	Bicyclists without head injuries
1990/91	36%	4%
1991/92	64%	12%
1992/93	40%	35%

Figure 6 shows the logistic regression of percentage head injured against helmet wearing rate for Melbourne cyclists plotted against year. Reflecting the similarity in the patterns of injury reduction, the logistic regression results for Melbourne bicyclist injuries are also similar to those for Victoria as a whole. A statistically significant ($p<0.001$) inverse association was found on pre-law trends between bicycle helmet wearing rates and proportion head injured. In the first year after introduction of the law, no significant departure from pre-law trends was observed in the proportion head injured. This is shown in Figure 6 by the observed proportion head injured in the first post-law year lying within the confidence limit on the extrapolated logistic curve estimated from pre-law data. For the second year post-law, the observed proportion head injured was significantly less than that predicted from pre-law trends (one-tailed $p < 0.05$). As for Victoria however, the gains over pre law trends due to introduction of the law appear to have been lost in the third post-law year with the observed proportion head injured lying above the extrapolated pre-law trend in Figure 6.

FIGURE 6
LOGISTIC REGRESSION OF BICYCLIST TAC CLAIMS.
PERCENTAGE HEAD INJURED VS. YEAR
MELBOURNE



4.2.3 Age specific analyses

Appendix B gives the results of age specific analyses of bicyclist head injuries in the TAC claims data for Melbourne and Victoria as a whole. For Victoria as a whole, the results of analysis of the 12-17 year and over 18 year age groups reflect those of the all ages combined analysis. A significant inverse relationship was found between helmet wearing and head injury rates in the pre-law data. For these two age groups, head injury rates were significantly lower than predicted from pre-law trends in the second year after introduction of the law but not in the first or third years. For the 5-11 year age group in Victoria as a whole, no significant relationship was found in the pre-law data between helmet wearing and head injury rate. This is probably due to the small number of observations in this group.

Like the whole of Victoria, age specific analysis of the Melbourne TAC claims data was similar to the analysis for all ages combined. Again, the 12-17 and over 18 year age groups showed a significant inverse relationship between helmet wearing and head injury rate. Unlike the combined analysis, for these two age groups head injury rate was not significantly below pre-law trend predictions in any of the post law years, although the patterns of change across the three years was the same as the combined analysis. The absence of a statistically significant reduction in head injury rate in the second post-law year, as was observed in the combined analysis, is most likely due to wider confidence limits on the post-law predictions resulting from smaller quantities of data. As for Victoria as a whole, no pre-law trend was observed in the 5-11 year age group.

4.3 BICYCLIST INJURIES : VICTORIAN HOSPITAL ADMISSIONS RECORDS

All the analyses presented above has been carried out on bicyclist injury claims which have been filed with the TAC. These injuries result only from bicyclist crashes with registered motorised vehicles driving on public roads in Victoria. Analyses of a second data source, namely Victorian public hospital admission records of injured bicyclists, is presented here. Reliable data from this source is available for the period 1987/88 to 1992/93 thus only data from three financial years pre-law and three financial years post-law data are available for analysis. This relatively short pre-law period meant that the statistical analysis carried out on this data was less powerful with, estimation of pre-law head injury trends being probably less accurate.

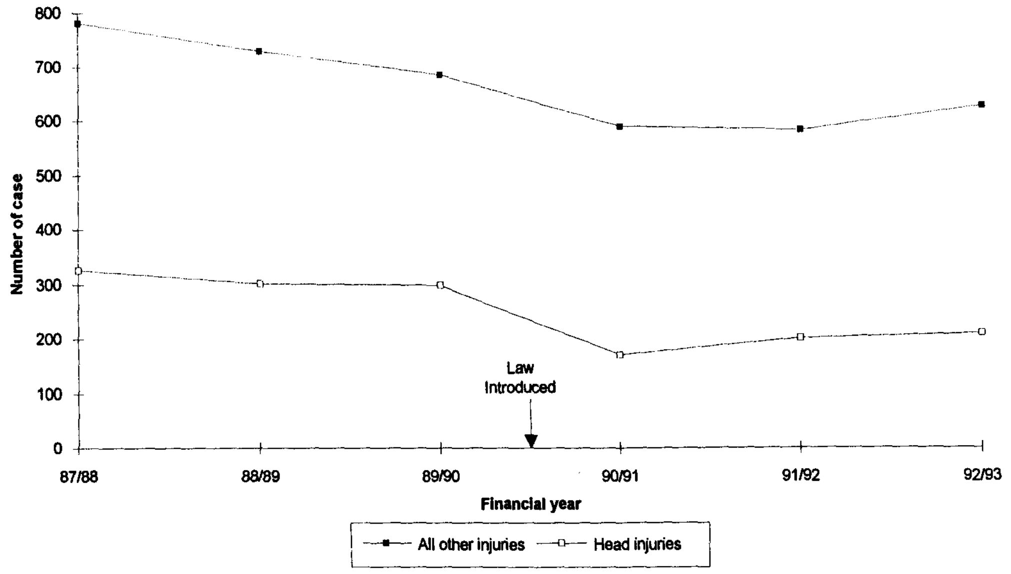
The data was analysed in two groups as described in section 3.2.2 above; bicyclist injuries from crashes involving motor vehicles (which should be comparable to the TAC claims analysis) and bicyclist injuries sustained in crashes not involving motor vehicles. Because of the problems in identifying location of accident from the hospital admission records discussed in 3.2.2 above, the results here cover only Victoria as a whole.

4.3.1 Bicycle crashes not involving a motor vehicle

Figure 7 shows the number of head injuries and number of all other injuries for bicyclists in crashes not involving registered motor vehicle on public roads. Cyclists injuries in this category include those sustained in off road activity, in places such as bicycle tracks, and those sustained on the road but not involving a motor vehicle, for example simply falling from the bicycle.

The trends in head and non-head injuries shown in Figure 7 are more parallel than those observed in the TAC claims data for Victoria. A drop in the number of bicyclists admitted to hospital both with a head injury and without a head injury was observed across the years immediately prior to and immediately after introduction of the law. Injury rates in the three year periods before after introduction of the appear law relatively constant. A logistic regression of percentage head injured against helmet wearing rate was again carried out to quantify the effects of helmet wearing and the law on head injury rates (Figure 8).

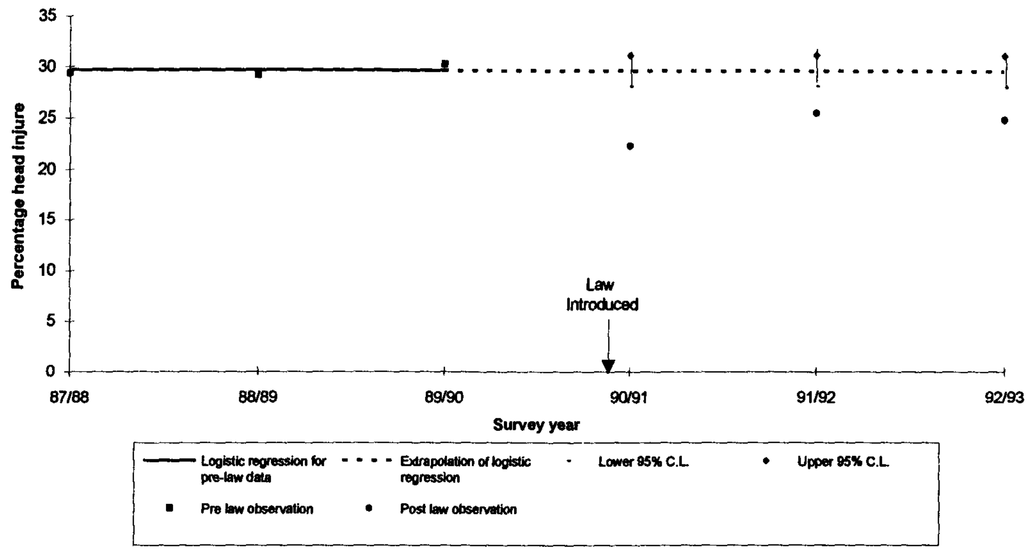
FIGURE 7
BICYCLIST HOSPITAL ADMISSIONS FROM CRASHES NOT INVOLVING MOTOR VEHICLES VICTORIA



The logistic regression fitted to the pre law data was not able to find a significant relationship between helmet wearing rate and the observed percentage of head injuries ($p > 0.10$). This may have been because only 3 data points were available and because the increase in helmet wearing rate during that period was not large (22.6-30.9%). Hence, only a constant term entered the logistic model indicated by the horizontal regression line in Figure 8. Despite the inability to show a relationship between helmet wearing and head injury rate from the limited pre-law data, Figure 8 shows the observed percentage head injured to be significantly below the level predicted from pre-law trends for each of the three years after introduction of the law. This suggests that introduction of the law has been successful in reducing cyclist head injuries for these accident types despite the absence of evidence of any pre-law association.
Age specific analyses of bicyclist injuries from crashes not involving motor vehicles are presented in Appendix C. As for the combined analysis, it was not possible to find an association between helmet wearing and head injury rate in the pre-law data for any of the three age groupings. Also following the combined analysis, for the 5 to 11 and 12 to 17 year age groups, head injury rates in each of the post law years was significantly below that predicted from pre-law trends. For the over 18 year age group however, the head injury rate was significantly below the pre-law trend line only the first post-law year.

The lack of association between helmet wearing and head injury from the regression results does not preclude the existence of such a relationship, even though one could not be identified from the available data. This is not surprising given that only three pre-law data points were available, especially in the age specific analysis where the quantity of data is much less than the combined analysis.

FIGURE 8
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES NOT INVOLVING MOTORISED VEHICLES. PERCENTAGE HEAD INJURED VS. YEAR VICTORIA



4.3.2 Motor vehicle involved bicycle crashes

The TAC is the sole source of compensation for injury resulting from motor vehicle involved crashes on public roads. It could be expected then that any admission of a bicyclist to a public hospital as a result of impact with a motor vehicle would usually result in a TAC claim for that bicyclist. In that case, analysis of bicyclist hospital records from on road motor vehicle involved crashes should closely parallel the analysis of TAC claims data (section 4.2) and serve to verify those results. The results from analysis of these bicyclist hospital admissions records are presented here.

Figure 9 shows the trends in head and non-head injuries for bicyclist hospital admissions after crashes with motor vehicles for three years before and after introduction of the helmet wearing law. Table 5 gives the reductions in bicyclist hospital admissions with and without head injury for each of the three post law years relative to the year immediately prior to the law. As observed in the TAC claims data, both head and non head injuries have shown downward trends in the study period. However, in the case of the hospital admissions records, the percentage reduction in head injuries exceeded the reductions in non head injuries only in the second post-law year (Table 5).

FIGURE 9
BICYCLIST HOSPITAL ADMISSIONS FROM CRASHES INVOLVING MOTOR VEHICLES VICTORIA

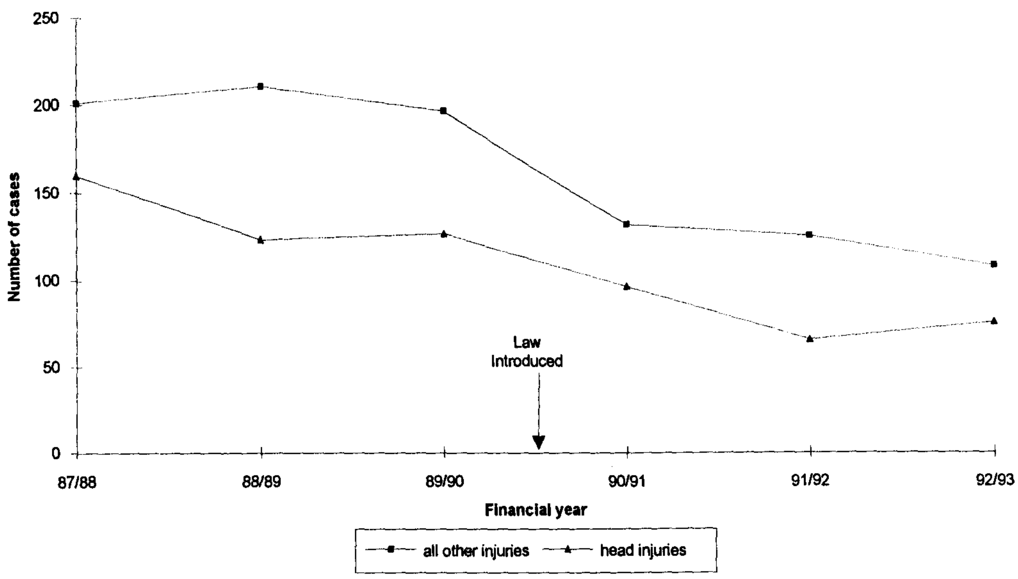
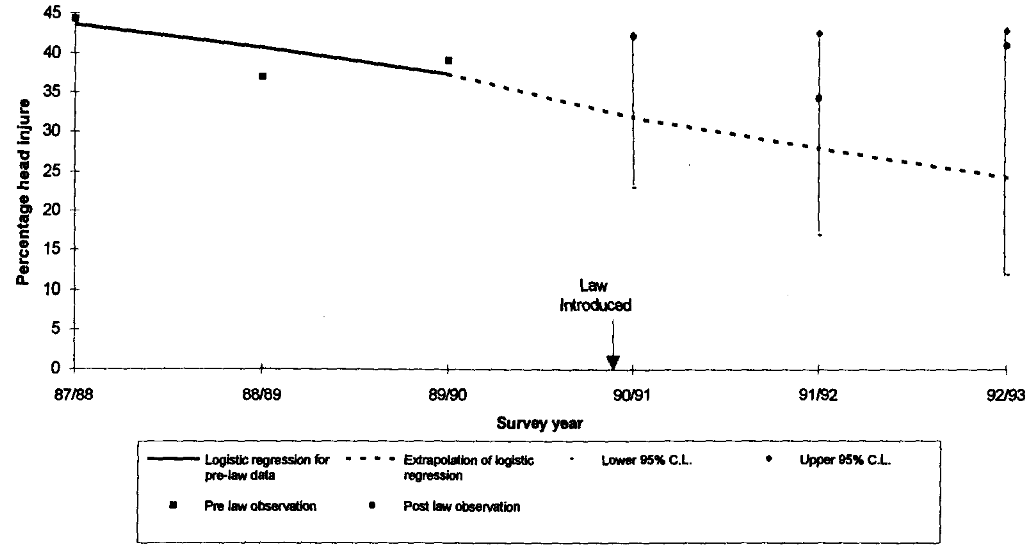


TABLE 5
PERCENTAGE REDUCTIONS IN BICYCLIST HOSPITAL ADMISSIONS RELATIVE TO 1989/90 FINANCIAL YEAR CRASHES WITH MOTOR VEHICLES

Financial Year	Bicyclists with head injuries	Bicyclists without head injuries
1990/91	24%	33%
1991/92	48%	37%
1992/93	40%	45%

Also similar to the TAC claims data analysis, the logistic regression analysis of the proportion of bicyclists with head injuries against helmet wearing rate in Figure 10 shows a statistically significant ($p < 0.05$) inverse relationship between these two measures. Unlike the TAC claims data however, Figure 10 shows no significant reduction in the percentage head injured from pre-law trends in any of the three years after introduction of the law. This suggests that the helmet wearing law has provided no additional benefit in reducing head injury rates in cyclists involved in crashes with motor vehicles.

FIGURE 10
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES INVOLVING MOTORISED VEHICLES. PERCENTAGE HEAD INJURED VS. YEAR VICTORIA



The reason for the apparent disparity in findings between analysis of the TAC claims data and the hospital admissions records is not immediately apparent. Large confidence limits on the extrapolation of the logistic regression in Figure 10 point to poor estimation of pre-law trends. The problem of only three pre-law data points to estimate the trend could explain some of the differences in the results. Comparison of Tables 3 and 5 however suggest more fundamental differences in the two data sources. These differences will be investigated in the next section.

Age specific analysis of motor vehicle involved bicyclist injuries, given in Appendix C, is inconclusive. No pre-law trends in head injury rate with helmet wearing were established and observed post-law head injury rates are highly variable. The lack of any significant pre-law trend in the age specific analyses when a strong trend was observed in the combined analysis is almost certainly due to insufficient data quantities.

4.3.3 Comparison of hospital admissions records with TAC claims data

Comparison of the total number of bicyclist hospital admissions from involvement in crashes with motor vehicles against total non-fatal TAC bicyclist claims is given in Figure 11. Apart from the 1988/89 financial year where there were substantially fewer hospital admissions recorded, the total number of cases from each data source was within 7% of the other. This suggests that both data sources are roughly consistent in inclusion of relevant cases. Figures L and M show the data stratified by head and non-head injuries respectively for the two data sources. Examination of the trends for head injuries in Figure 12 shows the TAC claims data to consistently contain fewer head injured cases than appear in the hospital admissions records. Conversely, for non-head injuries in Figure 13, the TAC claims data generally contains more cases than are recorded as hospital admissions, the magnitude of the difference being roughly equal to the difference in head injuries (Figure 12) leading to similar total injuries .

FIGURE 11
BICYCLIST CRASHES INVOLVING A MOTOR VEHICLE : VICTORIA
HOSPITAL ADMISSIONS V. TAC CLAIMS DATA

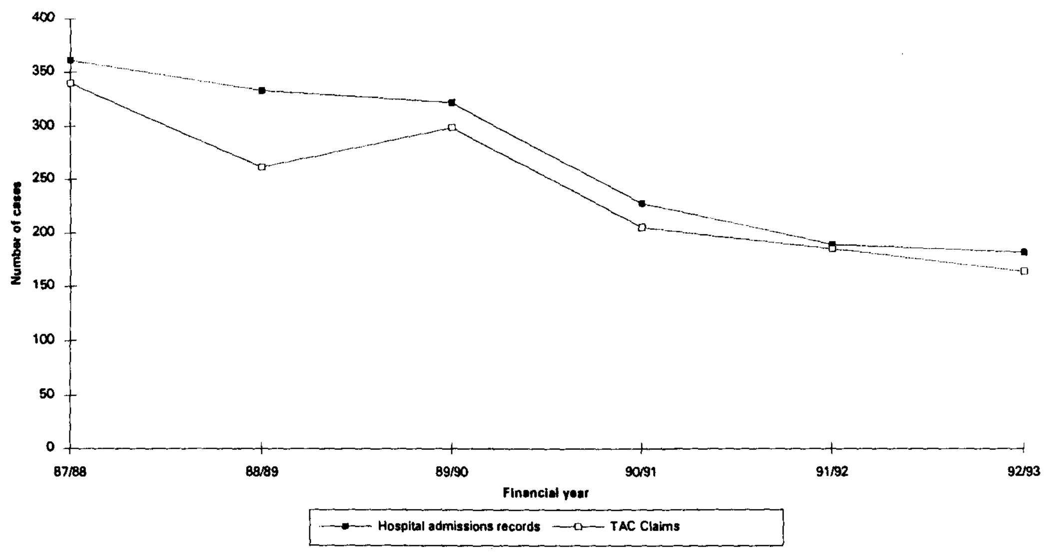


FIGURE 12
BICYCLISTS WITH A HEAD INJURY
CRASHES INVOLVING A MOTOR VEHICLE
HOSPITAL ADMISSIONS V. TAC CLAIMS DATA

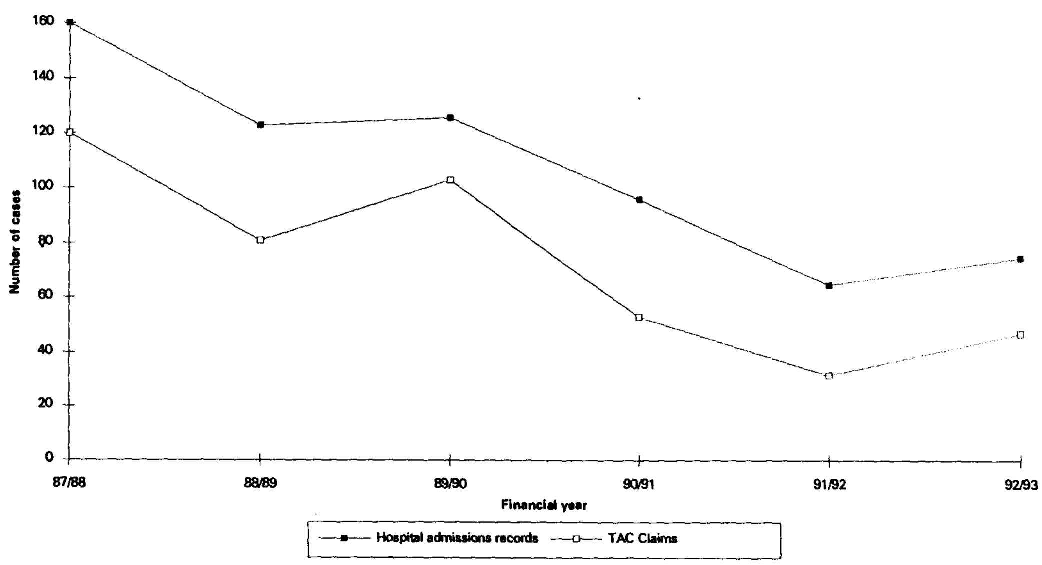
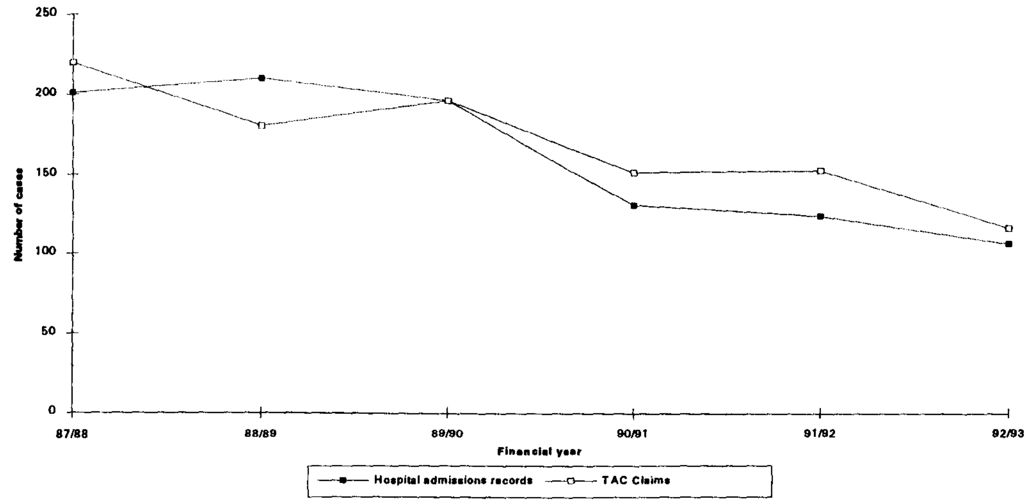
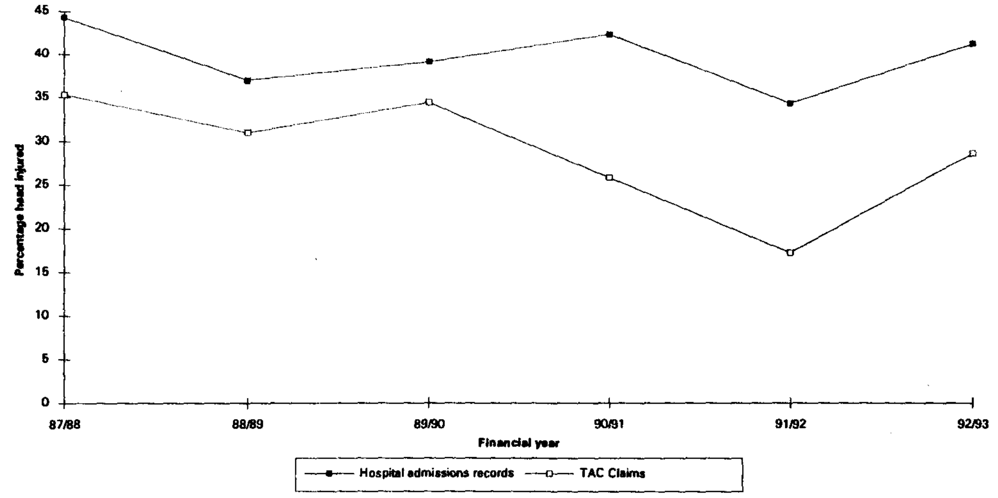


FIGURE 13
BICYCLIST WITHOUT A HEAD INJURY
CRASHES INVOLVING A MOTOR VEHICLE : VICTORIA
HOSPITAL ADMISSIONS V. TAC CLAIMS DATA



The apparent difference in the number of head injuries and other injuries between the two data sources leads to the different observations of the proportion of head injuries shown in Figure 14. This fundamental data difference consequently leads to the different conclusions from the logistic regression analyses described above. Assuming the two data sets contain identical cases, and noting the similar number of total cases in Figure 11, the results here suggest different injury coding conventions are used by the organisations supplying the data. This is plausible considering that both organisations supplying the data report to coding their data independently. There is however, no evidence that each data source contains information on the same cases, the similar number of total cases perhaps occurring entirely by chance. It is beyond the scope of this project to attempt matching of the two data sets to determine their equivalence.

FIGURE 14
PERCENTAGE BICYCLISTS WITH A HEAD INJURY
HOSPITAL ADMISSIONS V. TAC CLAIMS DATA
CRASHES INVOLVING A MOTOR VEHICLE : VICTORIA



5. DISCUSSION

There are a number of clear points which can be made from the results of this study. Firstly, from the analysis of helmet wearing rates over time, introduction of the law coincided with immediate large increases in the proportion of bicyclists wearing helmets (Figures A and B). Age specific analysis (Appendix A) shows these gains to be particularly evident in teenage and adult bicyclists, presumably because the 5-11 year age group already had much higher wearing rates prior to introduction of the law. What is not available from the analysis is an indication of long term post-law helmet wearing trends. A recently released survey of bicycle helmet usage during March 1994 (VicRoads 1994) suggests that overall helmet usage has remained high amongst most cyclists, with only small reductions observed in primary school aged children. The results of this survey will be particularly relevant for inclusion in the proposed evaluation of the effects of the helmet wearing law during its fourth year.

The logistic regression analysis of the percentage of head injured bicyclists against helmet wearing rate for both the TAC claims data and the motor vehicle involved hospital admissions data show a clear inverse relationship between these two measures during the pre-law years. This indicates that helmets are particularly effective in reducing the likelihood of head injury when bicyclists are involved in impacts with motor vehicles. This result is perhaps intuitive given the typically severe nature of impacts of this type. The relationship between helmet wearing and head injury rates for non-motor vehicle involved bicyclist injuries in not so clear. It was not possible to find a significant relationship in the pre-law years in analysis of the hospital admissions records, the only source of data for injuries of this type. As discussed above, this is possibly due to the lack of pre-law data to establish a clear trend. On the other hand, the logistic regression analysis of head injury risk against helmet wearing shows a clear benefit from the law, with the percentage head injured being significantly lower than predicted on pre-law trends.

The results show a marked and consistent reduction in the number of head injured bicyclists. Finch et al (1993b) attribute this to both a general reduction in the number of all bicyclist injuries, along with a reduction in the risk of head injury based on analysis of the TAC claims data in the second post-law year. However, the impact the introduction of compulsory helmet wearing on the risk of head injury is not clear from this analysis. The logistic regression analysis of head injury risk against helmet wearing rate compare the observed proportion of head injured post-law with that expected on pre-law trends. Observations lying below the prediction confidence limit indicate a real benefit of the law in reducing head injury beyond the pre-law trend.

Whilst the results from analysis of the TAC claims data show a significant benefit from the law in the second year after its introduction, this benefit is not reflected in analysis of the motor vehicle involved hospital admissions records. Limited statistical power from fewer data points in the hospital admissions records data goes some way to explaining the different outcomes of the two analyses however, fundamental differences in the two data sets appears to provide the bulk of the discrepancy. The nature of the differences between the two data sets has been explored in the results, but the underlying reasons for these differences are not clear. A research priority emerging from this study is a detailed matched comparison of these two data sets to explain noted discrepancies.

Another point of concern, primarily in the analysis of the TAC claims data, is the apparent loss of the additional benefits of the law in reducing head injury risk in the third year after its introduction (1992/93). In both Melbourne and Victoria as a whole, the number of head injured cyclists has risen during the third year whilst total injuries to bicyclists have continued to fall. The logistic regression analysis shows the percentage of head injured cyclists in this third year returned to a level which would have been expected had the law not been introduced, but helmet wearing continuing to increase according to the pre-law trend. There are a number of possible reasons why this may have occurred. One possibility is that actual helmet wearing rates have declined in the 1992/93 financial year. However, the latest VicRoads survey of helmet wearing use during the fourth year suggests that if this was the case it was a temporary phenomenon, as the survey showed helmet wearing rates to have remained high in all age groups (VicRoads 1994).

Another possible cause of the increased proportion of cyclists sustaining head injuries is a reduction in the protective ability of the helmets which are now being worn. Research comparing the protective performance of these new lighter helmets against the older hard shell types however, failed to find a difference in protective capabilities of these helmets (Cameron et al 1994). In any case, a large change in the types of helmets being worn would not be possible in one year.

Another possibility is that in 1992-93, more of the minor head injuries were being recorded, or at least included among the five injuries being recorded in the system. This may have resulted from a tending towards more complete recording of all injuries as part of the move towards preparation for case mix funding of hospitals.

In fact, the reversal of TAC claims would be explained if the presence of a head injury had been recorded in about 20 more of the 160 bicyclist injury claims. Similarly, if head injuries were included among the five injuries recorded for only about 20% more of the 360 bicyclists admitted to hospital after a crash involving a motor vehicle, this reversal in trends would be explained. It should be noted that every case where a head injury is recorded not only increases the number of bicyclists with a head injury, but also reduces the number of bicyclists without a head injury. There is therefore a need to examine whether coding practices in regard to head injuries or decisions on which injury types are to be included in the five recorded on the data system changed in 1992-93.

One final explanation for the apparent loss of benefit from the law in the third post law year may be a function of the analysis technique used. The expected proportion of head injuries in the post law years is obtained by using extrapolation of the pre-law helmet wearing rate trend. If in fact helmet wearing rates have reached a plateau after the large increase with the introduction of the law, any projected pre-law trend will in time also reach this plateau. Given a relationship between helmet wearing and head injury, post law observations of head injury risk will also then converge to their expected level. This problem may be overcome by having accurate estimates of post-law helmet wearing rate trends which were not available for this study. The VicRoads helmet wearing survey during 1994 will allow estimation of this post-law trend and could be used in any subsequent analysis.

6. CONCLUSIONS

The mandatory bicycle helmet wearing law implemented in Victoria on 1 July, 1990 was successful in building on past efforts to promote helmet use by bringing helmet wearing rates to new high levels for all cyclist age groups in the first post-law year, both in Melbourne and Victoria as a whole. Estimates of trends in helmet wearing over all three post-law years are however, not available.

From the analysis of hospital admissions records, no relationship could be found between helmet wearing and head injury rates in the pre-law years for bicyclists injured in accidents not involving a motor vehicle. Despite this, head injury rates for bicyclists injured in these crashes was significantly lower than the pre-law level in each of the three post-law years. A significant inverse relationship between helmet wearing and head injury rate was found for cyclists involved in accidents with motor vehicles. This relationship was found in both TAC insurance claims data and hospital admissions records.

The effect of the law in reducing head injury rates below pre-law trend predictions for bicyclists injured in motor vehicle involved crashes was not clear. Analysis of the TAC claims data showed bicyclist head injury rates significantly below pre-law trend predictions in the second post-law year although this benefit appeared to have been lost in the third post-law year. Analysis of the hospital admission records however, failed to show any additional benefit of the law over pre-law trends in reducing head injury rates in the three post-law years. Comparison of the TAC claims data and hospital admission records for motor vehicle involved bicyclist injuries revealed possible differences in injury coding between the two. Consequently, a closer matched comparison of these two data sources is recommended

A subsequent MUARC report (Carr et al 1995), which should be read in conjunction with this report, investigates bicycle injury data and the effect of the bicycle helmet law four years after its introduction. This report has revealed biases in the bicyclist injury data, certainly affecting the analysis and results presented here. This is shown by the analysis of Carr et al (1995) which adjusts for the bias in the bicyclist injury data and reaches different conclusions to those drawn here.

7. ACKNOWLEDGMENTS

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Mr David Attwood and Ms Indu Zutshi of the Transport Accident Commission are acknowledged for providing the injury data presented in this report and for their helpful discussion in interpretation of this data.

The Victorian Health Department are acknowledged for supplying the Victorian hospital admission records data file.

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APPENDIX A

Age Specific Analysis of Helmet Wearing Rates

FIGURE A
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE VICTORIA, 5 - 11 YEARS AGE GROUP

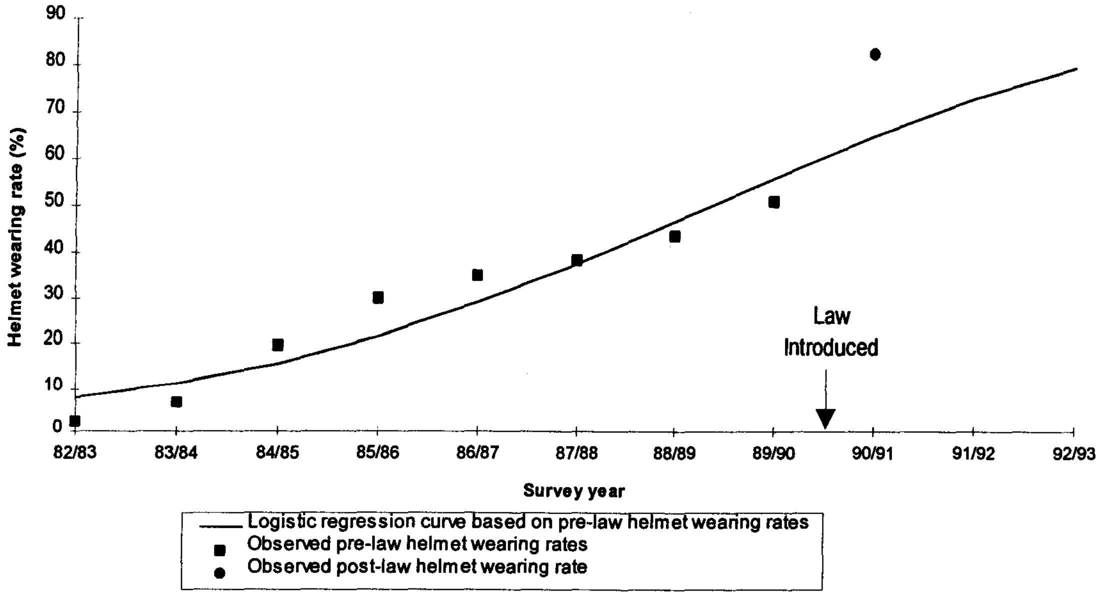


FIGURE B
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE VICTORIA, 12 - 17 YEARS AGE GROUP

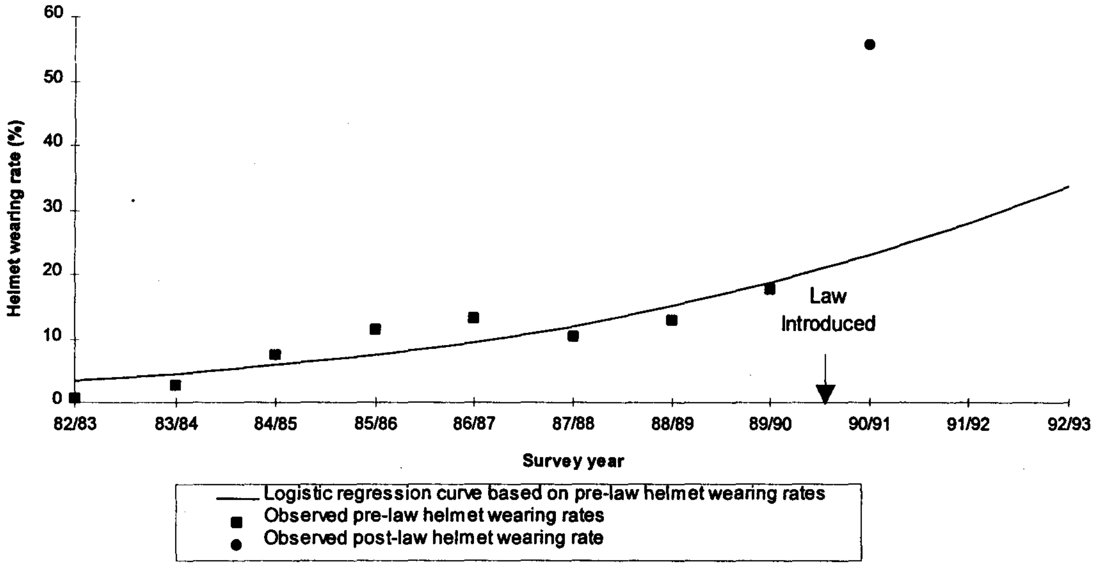


FIGURE C
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE
VICTORIA, OVER 18 YEARS AGE GROUP

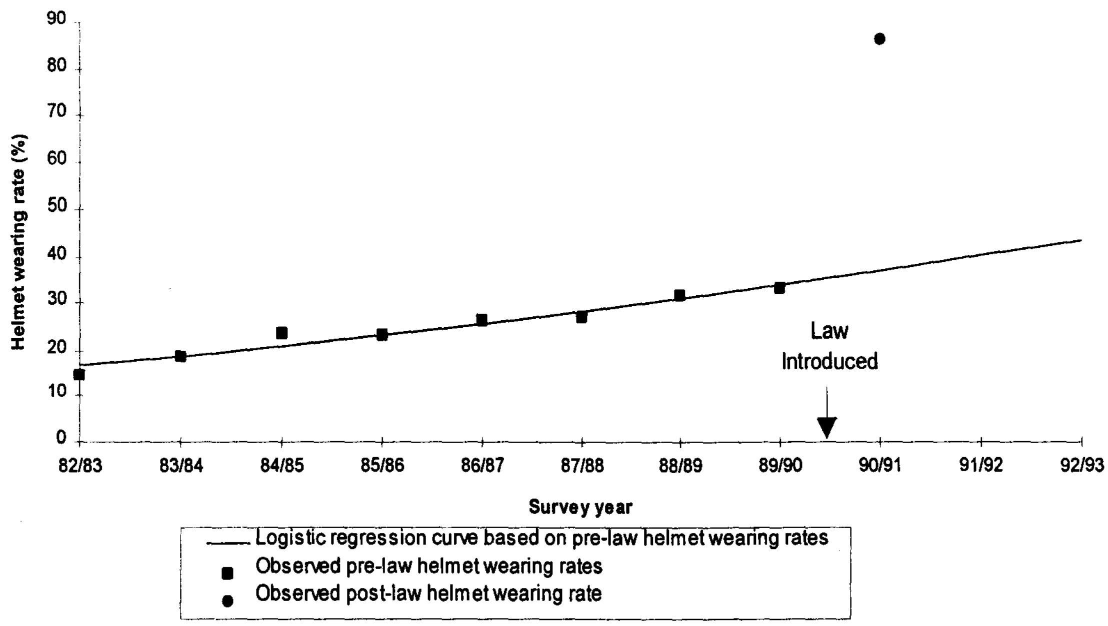


FIGURE D
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE
MELBOURNE, 5 - 11 YEARS AGE GROUP

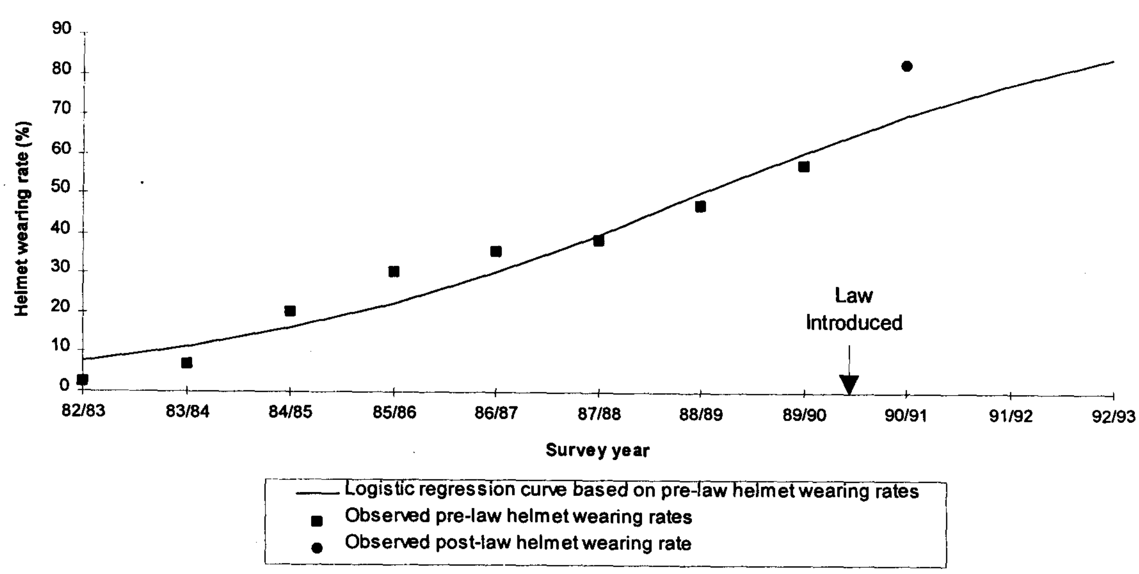


FIGURE E
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE
MELBOURNE, 12 - 17 YEARS AGE GROUP

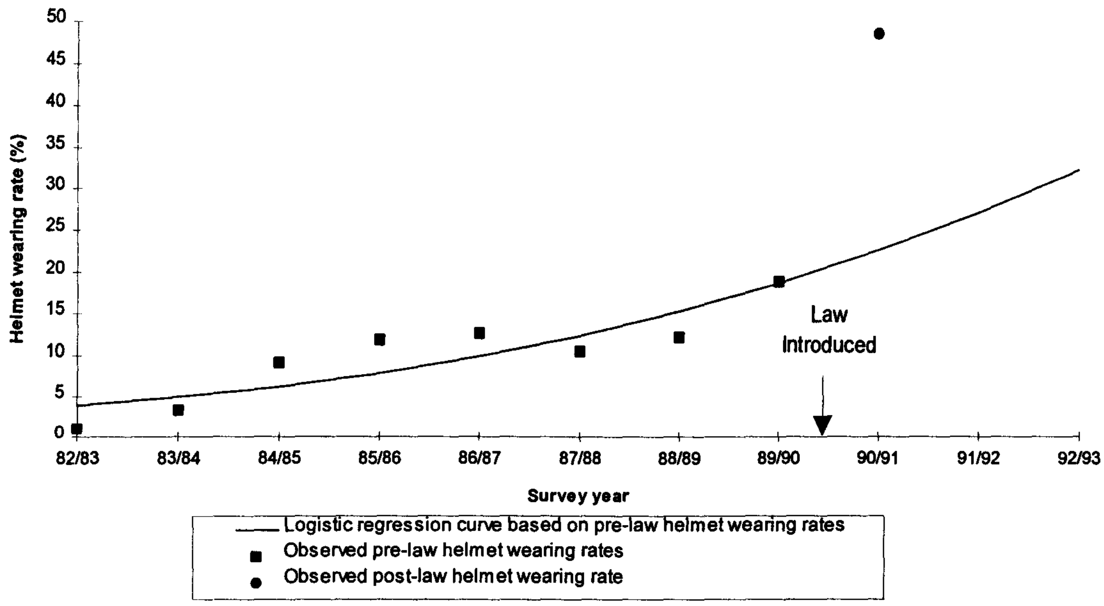
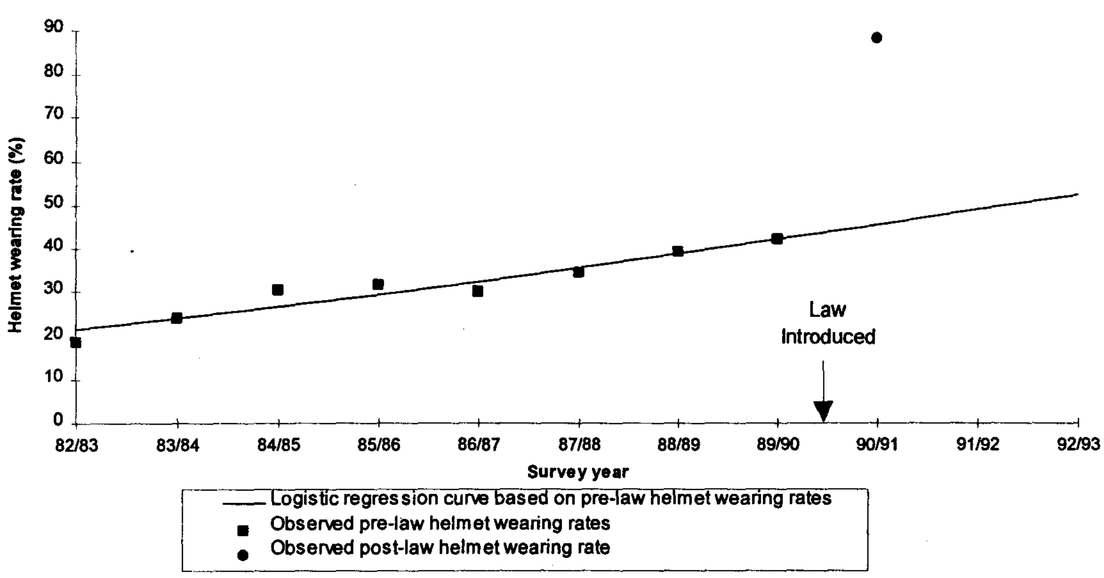


FIGURE F
LOGISTIC REGRESSION OF BICYCLE HELMET WEARING RATE
MELBOURNE, OVER 18 YEARS AGE GROUP



APPENDIX B

Age Specific Analysis of the TAC Claims Data

FIGURE A
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES
PERCENTAGE HEAD INJURED VS. YEAR
VICTORIA, 5 - 11 YEARS AGE GROUP

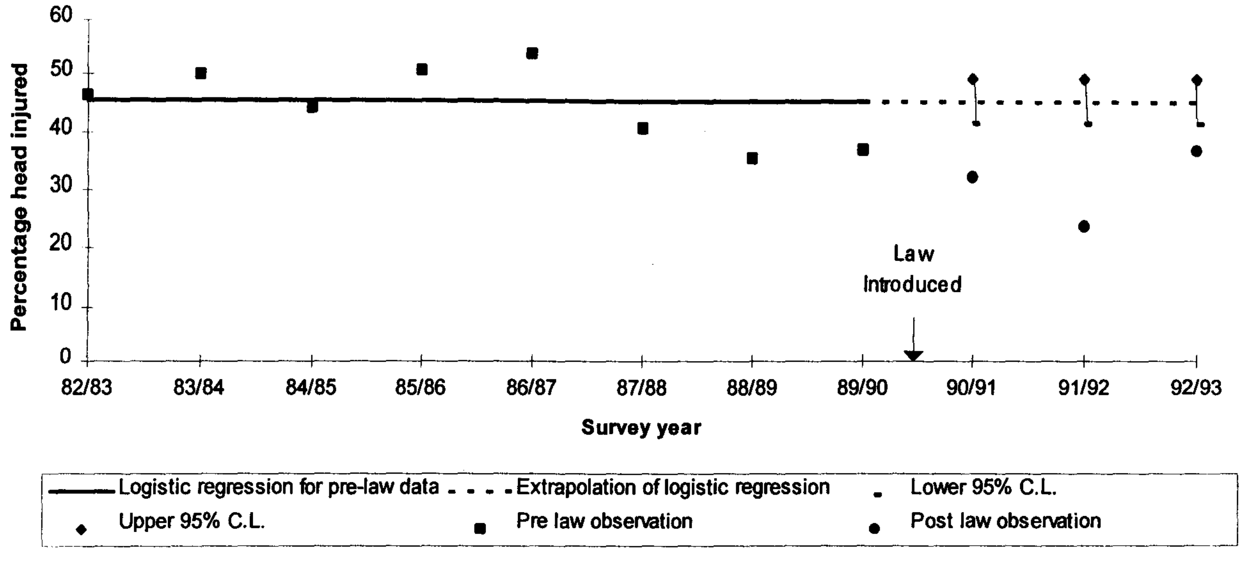


FIGURE B
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES
PERCENTAGE HEAD INJURED VS. YEAR
VICTORIA, 12 - 17 YEARS AGE GROUP

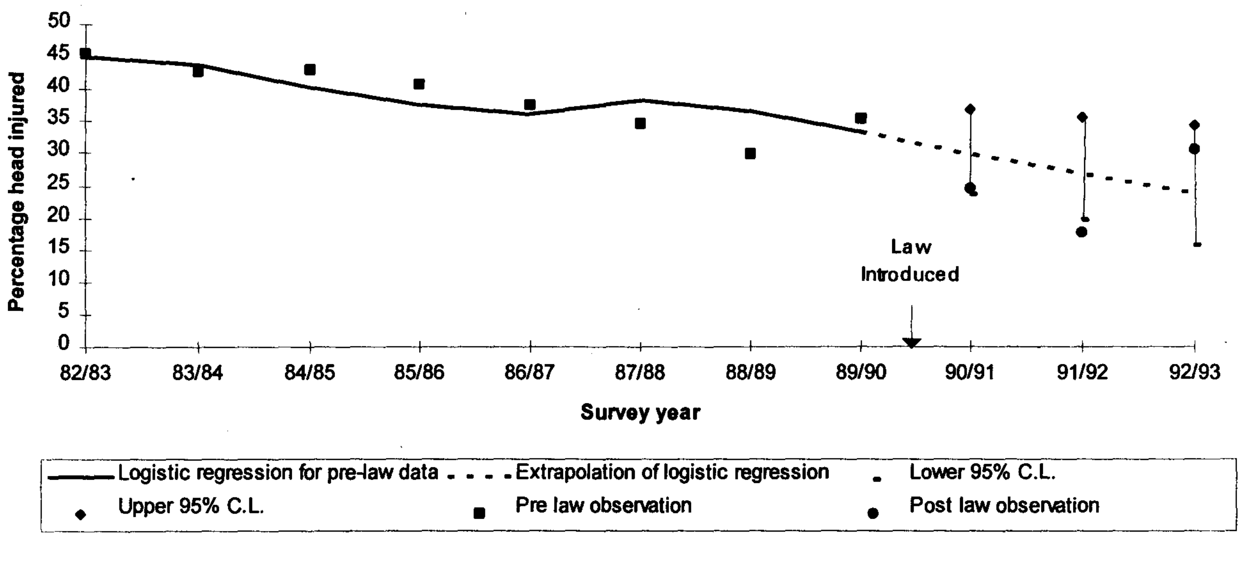


FIGURE C
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, OVER 18 YEARS AGE GROUP

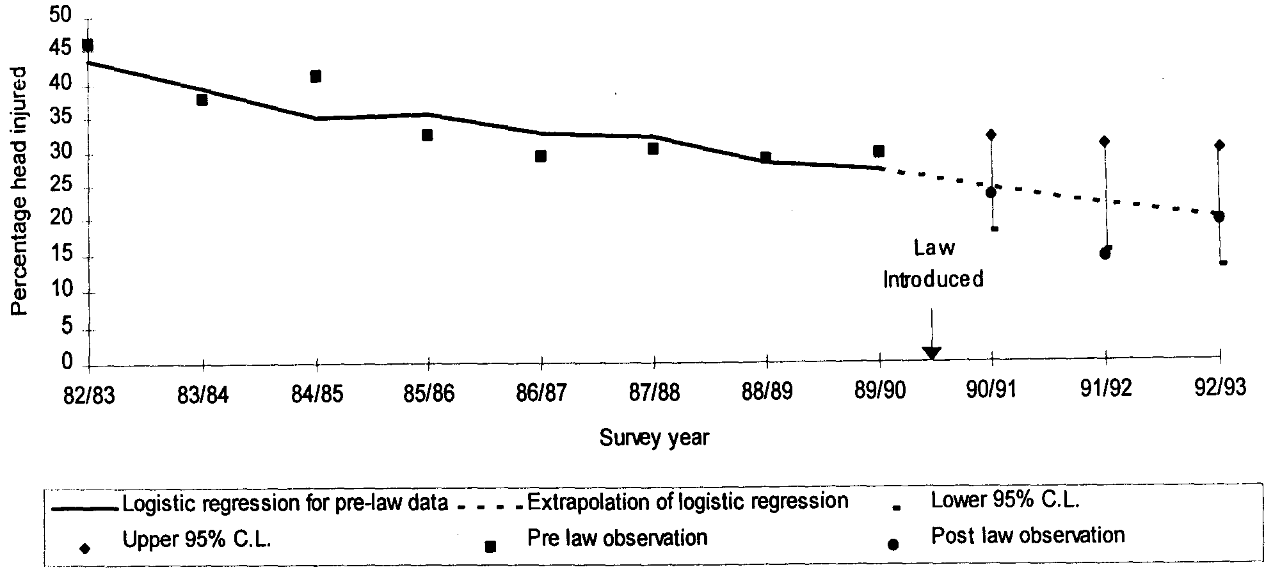


FIGURE D
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES PERCENTAGE HEAD INJURED VS. YEAR MELBOURNE, 5 - 11 YEARS AGE GROUP

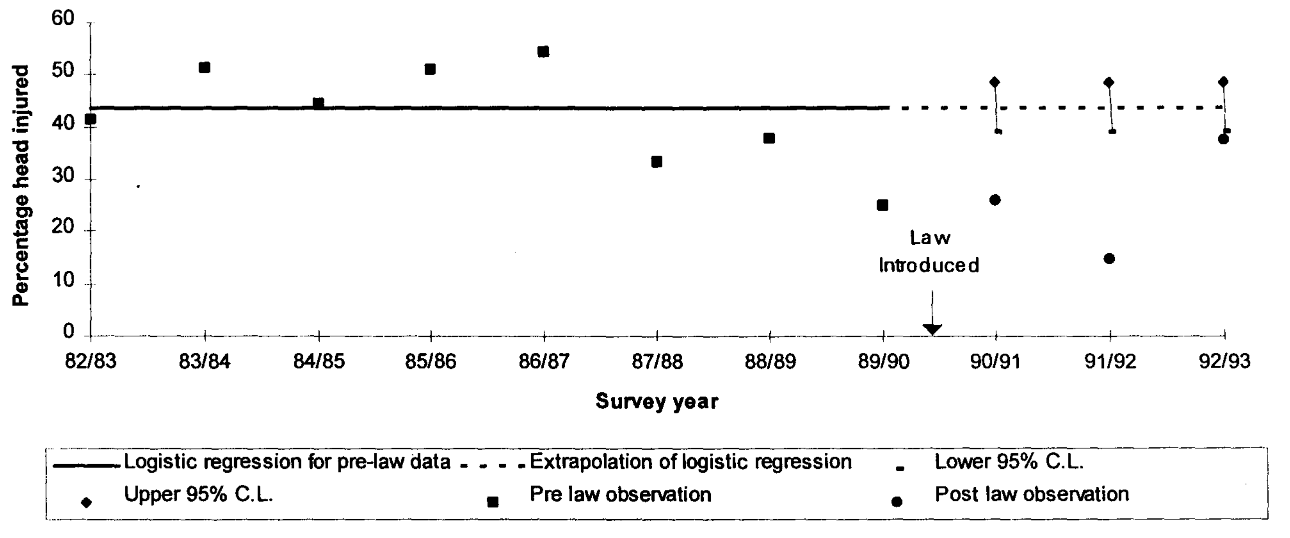


FIGURE E
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES
PERCENTAGE HEAD INJURED VS. YEAR
MELBOURNE, 12 - 17 YEARS AGE GROUP

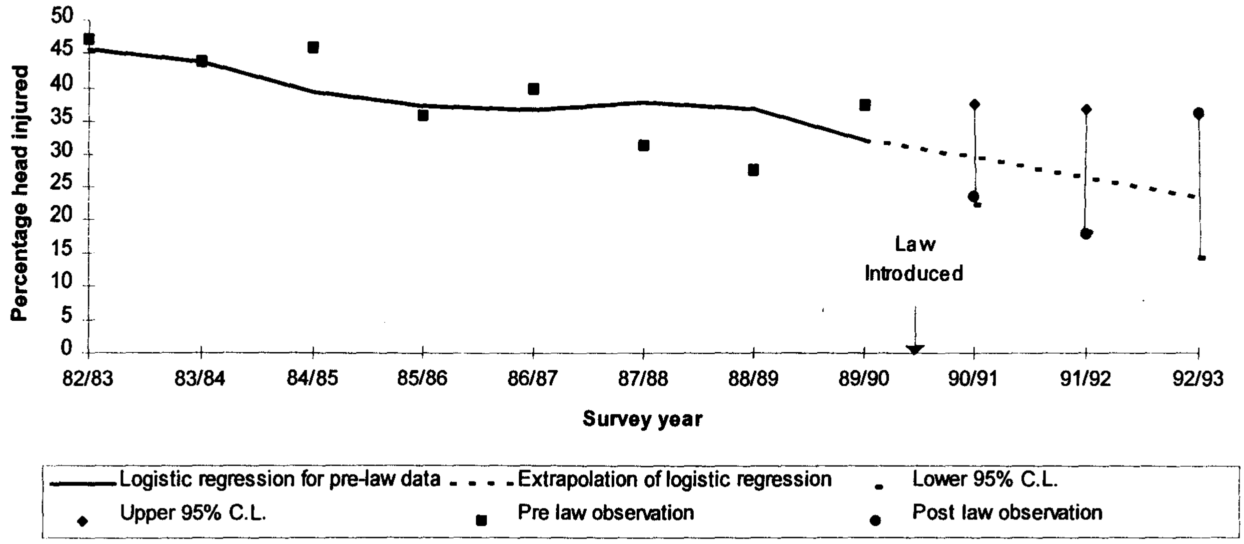
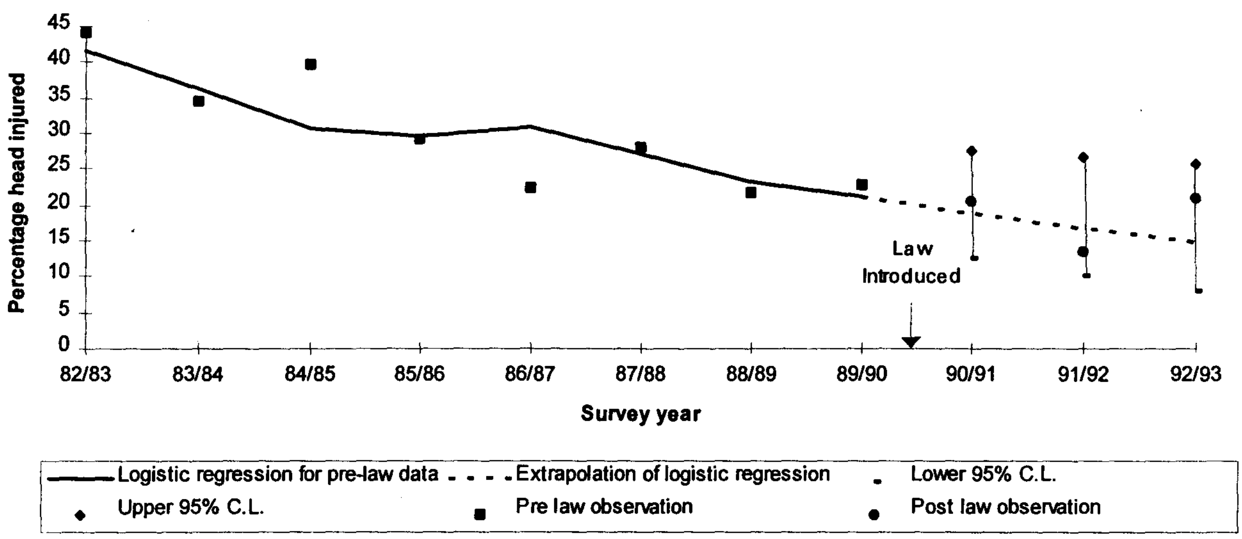


FIGURE F
LOGISTIC REGRESSION OF BICYCLIST HEAD INJURIES
PERCENTAGE HEAD INJURED VS. YEAR
MELBOURNE, OVER 18 YEARS AGE GROUP



APPENDIX C

Age Specific Analysis of the Victorian Hospital Admissions Records

FIGURE A
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES NOT INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, 5 - 11 YEARS AGE GROUP

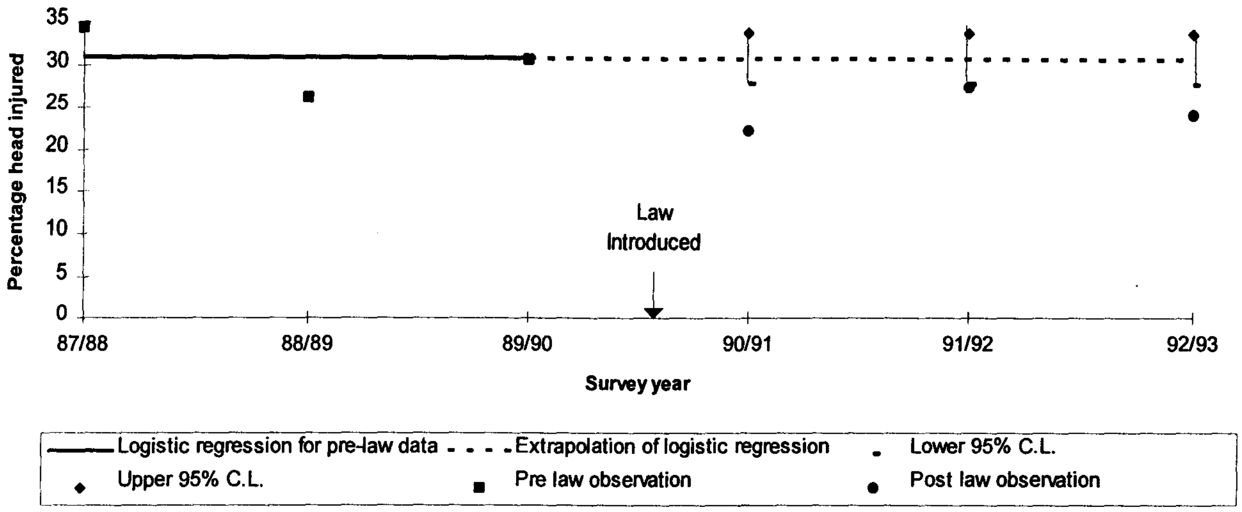


FIGURE B
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES NOT INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, 12 - 17 YEARS AGE GROUP

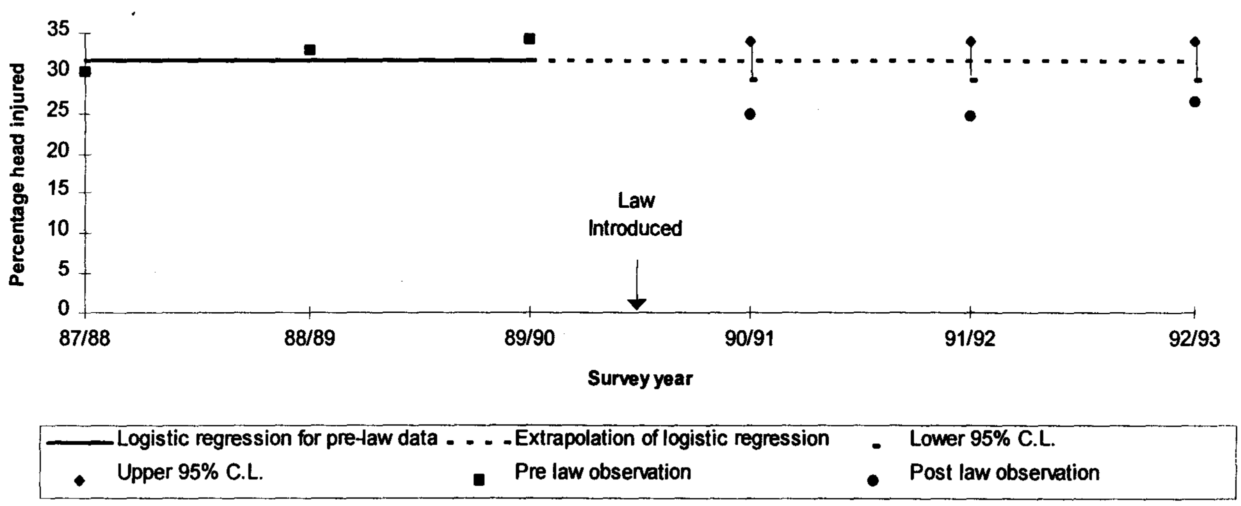


FIGURE C
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES NOT INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, OVER 18 YEARS AGE GROUP

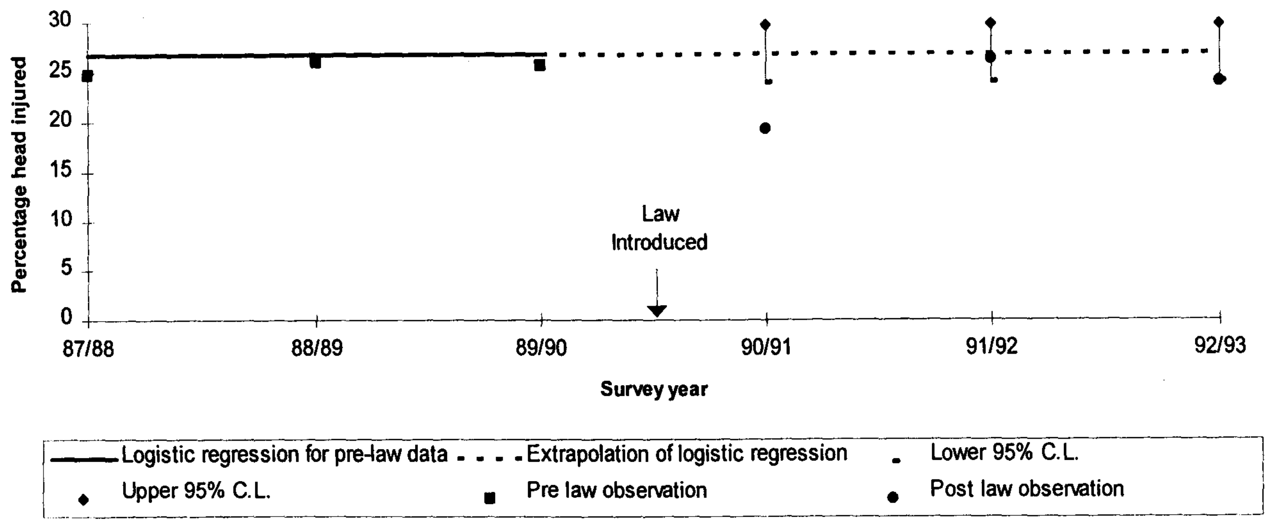


FIGURE D
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, 5 - 11 YEARS AGE GROUP

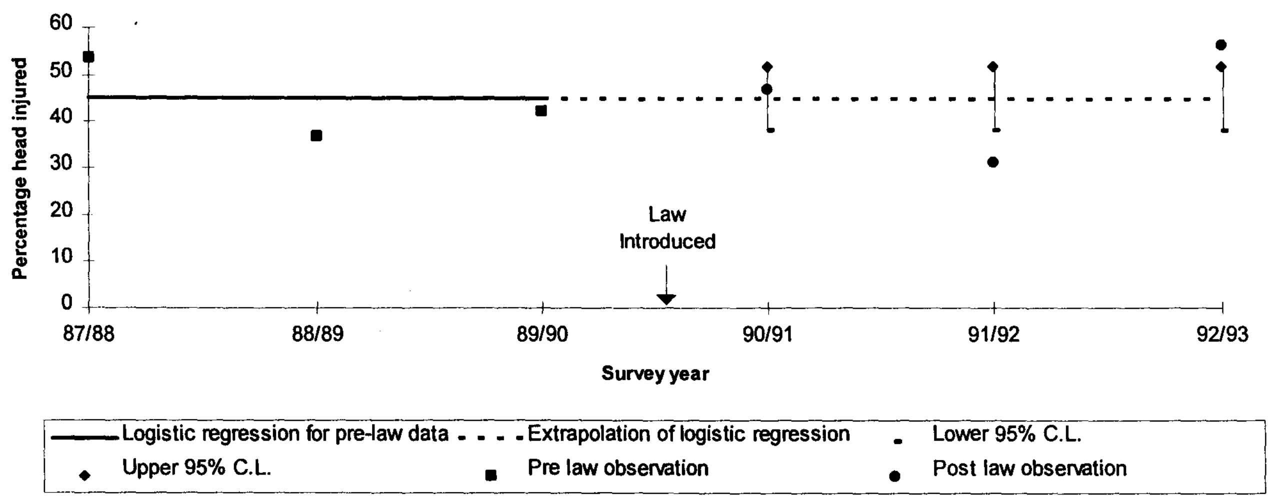


FIGURE E
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, 12 - 17 YEARS AGE GROUP

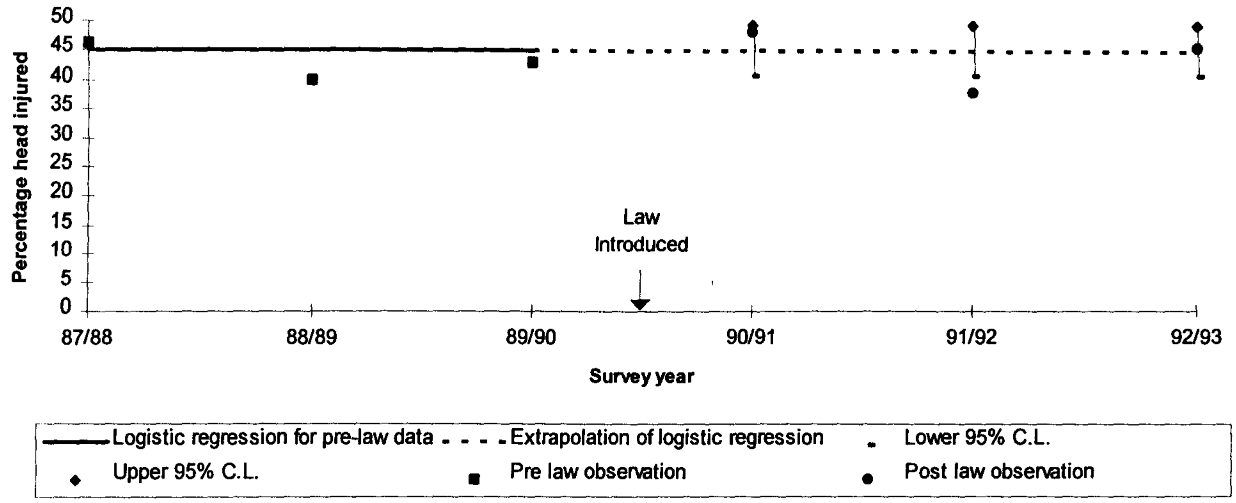


FIGURE F
LOGISTIC REGRESSION OF HEAD INJURIES FOR BICYCLISTS IN CRASHES INVOLVING MOTORISED VEHICLES PERCENTAGE HEAD INJURED VS. YEAR VICTORIA, OVER 18 YEARS AGE GROUP