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EFFECT OF SEAT BELTS AND HEAD RESTRAINTS ON NECK INJURY

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EFFECT OF SEAT BELTS AND HEAD RESTRAINTS ON NECK INJURY

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Abstract

While there is strong evidence that seat belt wearing reduces the incidence of severe injuries to vehicle occupants involved in crashes, there is also evidence that the use of lap/sash seat belts increases minor and moderate neck injuries in crashes. In recent years, head restraints have been installed in the front seats of cars with the aim of reducing minor neck injuries ("whiplash"), principally in rear impacts where their frequency of occurrence is highest. This study examined the interaction between static lap/sash belt use and the availability of head restraints installed under Australian Design Rule 22 (ADR 22), in terms of their effect on neck injury. ADR 22 allowed either fixed or fully height-adjustable head restraints, and many of the adjustable type are not set in the correct position in practice.

There was no statistically significant evidence for such an interaction. However there was some evidence that the effect of seat belt use on neck injury severity is smaller when ADR 22 head restraints are available, compared with the belt effect on occupants of pre-ADR 22 cars.

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ADR 22 head restraints appeared to decrease the risk of whiplash injury, but increase the risk of moderate-to-critical neck injury, especially among static lap/sash belt users and possibly among non-users as well. When ADR 22 head restraints and static lap/sash belts were available together, the effect of the head restraints on neck injury appeared to dominate any moderating influence that their presence may have had on the belt effect.

It was concluded that ADR 22 head restraints as used in practice are not suitable as a countermeasure to the negative effects of lap/sash seat belt use on neck injury.

The study was based on the Royal Australasian College of Surgeons' Pattern of Injury Survey of road accident victims treated at hospital or killed, and who were transported from the crash scene by ambulance. Thus only serious casualties were considered, which may have had implications for the reporting of minor neck injuries.

Since both static seat belts and ADR 22 head restraints have been superseded in the front outboard seats of new Australian cars, a study of the joint effects of inertia reel seat belts and current style (ADR 22A) head restraints (which limit improper adjustment) on neck injuries of all severities would appear worthwhile.

EFFECT OF SEAT BELTS AND HEAD RESTRAINTS ON NECK INJURY

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INTRODUCTION

A large number of studies have identified the benefits from seat belt wearing in terms of reducing severe injuries to vehicle occupants involved in crashes (see Grime 1978 for a review of this research). However, some studies have indicated that the positive benefits of three-point lap/sash seat belts are negated somewhat by an increase in minor and moderate neck injuries when these belts are worn in crashes (Bohlin 1967, Scott et al 1976, Huelke et al 1977, Langwieder 1977, Cameron and Nelson 1977, Hobbs 1978, Cameron 1979).

In recent years, head restraints have been installed in the front seats of cars with the aim of reducing minor neck injuries ("whiplash"), principally in rear impacts where their frequency of occurrence is highest. Head restraints can be either fixed or height adjustable. A number of studies have found that adjustable head restraints are often set at their lowest position (O'Neill et al 1972, Garrett and Morris 1972, Cameron and Wessels 1979), thus potentially limiting their effectiveness.

Studies of head restraints installed in American cars under Federal Motor Vehicle Safety Standard (FMVSS) 202 (which allows fixed or adjustable restraints) have indicated that they are effective in reducing whiplash injuries in rear impacts and that the effect applies particularly to female occupants (Garrett and Morris 1972, O'Neill et al 1972, States and Balcerak 1973, McLean 1973, Joksch 1973). Head restraints installed in European cars have also been shown to be effective (Volvo 1973, Langwieder 1975). Two studies of head restraints installed in Australian cars under Australian Design Rules (ADR) 22 and 22A have partially confirmed the American and European findings, except that a benefit for male occupants has not been established (Cameron and Wessels 1979, Cameron 1980). ADR 22, effective for 1972-74 models, allowed fixed or adjustable height head restraints. A survey of Australian cars late in 1972 showed that 53 per cent of the ADR 22 head restraints fitted were of the fully adjustable type (Cameron and Wessels 1979). The same survey showed that 58 per cent of the adjustable head restraints were set at their lowest position. ADR 22A, effective from 1975, specifies that head restraints cannot be adjustable below a certain minimum height. A further survey in March 1980

showed that 83 per cent of ADR 22A head restraints were integral with the seat (Cameron 1980).

None of the American nor European studies considered the interaction between seat belt use and head restraint availability in terms of the effect on whiplash and other neck injuries. Thus it is not known whether the benefits from head restraints are sufficient to off-set the disbenefits from seat belt use so far as neck injuries are concerned. Australia is in a unique position to answer this question due to its relatively long-term experience with the usage of both head restraints and seat belts in comparison with other countries. The Expert Groups on Road Safety (1977) identified this as a topic deserving further study.

Neither of the two previously cited Australian studies of head restraint effectiveness were able to consider the interaction with seat belt use due to the absence of information on belt wearing from the data analysed. Both studies were based on claims to the "no-fault" injury compensation scheme operated by the Motor Accidents Board in Victoria. Whiplash frequencies among claimants involved in rear impacts ranged from 40 to 50 per cent of those who occupied the driver or front left passenger seating positions. Attention was confined to those claimants who occupied cars and station wagons manufactured in 1969 or later, i.e. those with three-point lap/sash seat belts fitted to the above seating positions. Thus the identified benefits of head restraints installed under ADRs 22 and 22A apply to occupants with lap/sash belts available. Presumably a high proportion of these crash-involved occupants were using the available belts, in view of the high usage rates of occupants of the seating positions observed in roadside surveys (Boughton et al, in press). However the question of an interaction between head restraint use and seat belt wearing cannot be answered from these results.

Data collected during the Royal Australasian College of Surgeons' (RACS) Pattern of Injury Survey contains information on seat belt use and allows vehicles with head restraints fitted to be identified. These data were analysed to examine the effect of the interaction of these two factors on neck injury.

DATA

From 1 June 1971, legislation was in force in Victoria requiring hospitals to supply, on a Road Trauma Report (RTR) form, details of injuries for all road accident victims treated. In the RACS Survey these data were supplemented by RTRs filled out using post-mortem reports on fatally-injured road users. In addition, Road Crash Report (RCR) forms describing the crash circumstances of occupant casualties were completed by ambulance officers. As there was no legal compulsion associated with this source, RCR forms were returned for only about one-third of crashes attended by ambulances, with a bias toward rural crashes.

A matched file of trauma and crash reports for the first two years was originally created for analysis by Nelson (1974). This file was later supplemented by data for the third year (Cameron 1977). At the same time the injuries recorded on the RTR were translated to the Abbreviated Injury Scale (AIS) (Joint Committee on Injury Scaling 1976). The full matched file covers 8537 occupants of passenger cars and car derivatives. Further details of the return rates, matching rates, bias and accuracy of the data are given in Nelson (1974), Cameron and Wessels (1975), and Cameron (1977).

Because only road accident victims treated at hospital or killed were included, the RACS Survey was less likely to include occupant casualties with minor neck injuries than, say, claimants to the Motor Accidents Board. Only 11 per cent of the non-ejected casualties who occupied the driver or front left passenger seats sustained whiplash injury (AIS=1) in rear impacts, compared with 40 to 50 per cent of Motor Accidents Board claimants who occupied the same seats in the same type of crash. However, it was considered that there were sufficient neck injuries recorded to enable a meaningful study of the interaction between seat belt use and head restraint availability. In addition, it should be recalled that these same data had earlier identified the association between seat belt use and increased neck injuries (Cameron and Nelson 1977, Cameron 1979).

The RACS Survey included only occupants of vehicles manufactured up to 1974 and hence only head restraints installed under ADR 22 (fixed or adjustable type) could be considered in this study. Vehicles with ADR 22 were identified by their year of manufacture (derived from a combination of the ambulance officer's estimate and the registration number issue year; see Cameron 1977). Pre-ADR 22 vehicles were restricted to those manufactured in 1960 or later, up to 1971.

Only front outboard seat occupants aged over 15 and who were not ejected were considered, to enable comparison with the results of Cameron (1979). The restrained occupants of these seating positions were almost exclusively using static lap/sash belts. ADR 4B, which required inertia reel belts to be fitted to these same seating positions, did not come into effect until the 1975 year of manufacture.

In summary, the following results pertain to the wearing of static lap/sash belts and the head restraints available include fixed and adjustable types. The latter type of head restraints are often set at unsuitable positions.

RESULTS

Effect of seat belt use

Table I shows the association between seat belt use and neck injury severity of the occupants considered. Whiplash is the only injury included in the AIS=1 category, whereas neck injuries with AIS at least 2 include injuries ranging from transient cervical spinal cord damage to cervical spine fractures resulting in quadraplegia. While the differences were small, the incidence of neck injury (all severities) was statistically significantly higher when wearers of lap/sash seat belts were compared with unrestrained occupants ($X_1^2 = 3.904$; $p < 0.05$). A measure of the effect of belt use on neck injury severity is shown in the last column of Table 1.

Table II shows the belt effect on neck injury severity of occupants with head restraints available (i.e. front outboard seat occupants of ADR 22 cars) compared with occupants without head restraints. The increase in the proportion of occupants with neck injuries when lap/sash belts were worn, compared with unrestrained occupants, was less in the ADR 22 cars than in the pre-ADR 22 cars. The statistical significance of the difference in the two belt effects shown in Table II was judged by a 3x2x2 Chi-square test of the hypothesis of no second-order interaction between the three variables: neck AIS, seat belt use, and head restraint availability (Bishop, Fienberg and Holland 1975). The test was not statistically significant ($X_2^2 = 0.080$).

In a strict sense, this (non-significant) result represents the end of this study. There was no statistically significant evidence of an interaction between seat belt use and head restraint availability in terms of their effect on neck injury. However, the data in Table II are suggestive of such an interaction and the absence of statistical significance may have been due to the relatively small number of occupants with head restraints available. For these reasons it was decided to examine the data further.

TABLE I: Neck injury Abbreviated Injury Scale (AIS) scores of non-ejected front outboard seat occupants aged over 15, by seat belt use.

	Lap/sash Belt Use		Belt Effect (2)-(1)
	Not Worn (1)	Worn (2)	
Neck AIS	%	%	
0	96.1	94.9	-1.2
1	2.5	3.2	0.8
2+	1.5	1.9	0.4
Total Occupants	2432	2622	

TABLE II: Neck AIS scores by seat belt use and presence of head restraints (fixed or adjustable type).

	NO HEAD RESTRAINT			HEAD RESTRAINT AVAILABLE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	96.1	94.8	-1.3	95.5	95.0	-0.5
1	2.5	3.5	0.9	1.5	1.8	0.3
2+	1.4	1.7	0.3	3.0	3.2	0.2
Total Occupants	2299	2283		133	339	

Effect of head restraints

The same data were used to examine the effect of head restraint availability on neck injury severity. Since seat belt wearing rates were higher in the ADR 22 cars than in the earlier models, seat belt wearers and non-wearers were considered separately (Table III). There were insufficient data to meaningfully examine the effect of ADR 22 head restraints in various types of crash separately; in particular, in rear impacts.

Similar effects of ADR 22 were apparent for lap/sash belt wearers and for non-wearers. In each case, there was a decrease in the proportion with whiplash (AIS=1) and an increase in the proportion with moderate-to-critical neck injuries (AIS at least 2), when occupants of ADR 22 cars were compared with those occupying earlier models. The ADR 22 effect on lap/sash belt wearers was statistically significant ($X_2^2 = 6.256$; $p < 0.05$), whereas that on unrestrained occupants was not ($X_2^2 = 2.750$). The ADR 22 effect on unrestrained occupants appeared to have been of the same order of magnitude as that on the seat belt wearers. The absence of statistical significance may have been due to the relatively small number of unrestrained occupants of ADR 22 cars compared with restrained occupants of these cars.

Crash location

There was evidence that the effect of lap/sash belt use on neck injury severity was different for occupants involved in crashes in built-up areas compared with those involved in open road crashes (Table IV), perhaps reflecting the different severities of crashes in these two environments. The belt effect in crashes in built-up areas applied primarily to whiplash injuries (AIS=1), whereas in open road crashes there was evidence of a belt effect on neck injuries with AIS at least 2, but not on whiplash injuries. Because of this difference, the effect of the interaction between seat belt use and head restraint availability was considered in the two crash environments separately.

In crashes in built-up areas, there was a decrease in the proportion on occupants with neck injuries when lap/sash belts were worn, compared with unrestrained occupants, in ADR 22 cars. This compares with an increase in the proportion of the same type in pre-ADR 22 cars (Table V). However the difference in these two belt effects was not statistically

TABLE III: Neck AIS scores by presence of head restraints (fixed or adjustable type) and seat belt use.

	SEAT BELT NOT WORN			LAP/SASH BELT WORN		
	Pre-ADR 22 Cars (1)	ADR 22 Cars (2)	ADR 22 Effect (2)-(1)	Pre-ADR 22 Cars (3)	ADR 22 Cars (4)	ADR 22 Effect (4)-(3)
Neck AIS	%	%		%	%	
0	96.1	95.5	-0.6	94.8	95.0	0.2
1	2.5	1.5	-1.0	3.5	1.8	-1.7
2+	1.4	3.0	1.6	1.7	3.2	1.5
Total Occupants	2299	133		2283	339	

TABLE IV: Neck AIS scores by seat belt use and crash location.

	BUILT-UP AREAS			OPEN ROAD		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	96.7	95.4	-1.3	95.0	93.7	-1.2
1	2.2	3.4	1.2	3.2	2.8	-0.4
2+	1.1	1.2	0.1	1.8	3.5	1.7
Total Occupants	1673	1720		713	861	

TABLE V: Neck AIS scores by seat belt use and presence of head restraints (fixed or adjustable type) in crashes in built-up areas.

BUILT-UP AREAS

	NO HEAD RESTRAINT			HEAD RESTRAINT AVAILABLE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	96.8	95.3	-1.5	94.9	96.4	1.5
1	2.2	3.6	1.4	2.5	2.0	-0.5
2+	1.0	1.1	0.1	2.5	1.5	-1.0
Total Occupants	1594	1524		79	196	

significant (X_2^2 = 1.109). Among lap/sash belt wearers, the effect of ADR 22 head restraints appeared to be a decrease in whiplash injuries, but an increase in moderate-to-critical neck injuries.

In open road crashes in ADR 22 cars, there were increases in the proportion with whiplash as well as in the proportion with moderate-to-critical neck injuries, when lap/sash belt wearers were compared with non-wearers (Table VI). However there was no statistically significant evidence of a difference between the belt effect in ADR 22 cars and that in pre-ADR 22 cars (X_2^2 = 1.052). Among lap/sash belt wearers, the effect of ADR 22 was, once again, apparently a decrease in whiplash injuries, but an increase in moderate-to-critical neck injuries.

Occupant sex

Because of the known greater susceptibility of women to neck injury (Kihlberg 1969, States et al 1972, O'Neill et al 1972), male and female occupants were considered separately. The increased susceptibility of women to neck injury was confirmed, and there was evidence that the effect of lap/sash belt use on whiplash injury was greater for female occupants than for males (Table VII).

For male occupants, there was a decrease in the proportion with neck injuries when lap/sash belts were worn, compared with unrestrained occupants, in ADR 22 cars. This compares with an increase in the proportion of the same type in pre-ADR 22 cars (Table VIII). However the difference in these two belt effects was not statistically significant (X_2^2 = 0.598). Among male occupants wearing lap/sash belts, the apparent effect of ADR 22 was as for occupants of both sexes - a decrease in whiplash injuries, but an increase in moderate-to-critical neck injuries.

For female occupants, the increase in the proportion with whiplash injuries when lap/sash belts were worn, compared with unrestrained occupants, was not as great in ADR 22 cars as it was in pre-ADR 22 cars (Table IX). However the increase in the proportion with moderate-to-critical neck injuries (AIS at least 2) when belts were worn was greater in ADR 22 cars

TABLE VI: Neck AIS scores by seat belt use and presence of head restraints (fixed or adjustable type) in open road crashes.

OPEN ROAD

	NO HEAD RESTRAINT			HEAD RESTRAINT AVAILABLE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	94.7	93.9	-0.8	98.0	93.0	-5.0
1	3.5	3.1	-0.4	0.0	1.4	1.4
2+	1.8	3.1	1.2	2.0	5.6	3.6
Total Occupants	663	719		50	142	

TABLE VII: Neck AIS score by seat belt use and sex of occupant.

	MALE			FEMALE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	96.8	96.0	-0.9	94.7	93.4	-1.4
1	1.8	2.3	0.4	3.6	4.6	1.0
2+	1.4	1.8	0.4	1.7	2.1	0.4
Total Occupants	1544	1508		888	1113	

TABLE VIII: Neck AIS scores by seat belt use and presence of head restraints (fixed or adjustable type) for male occupants.

MALES

	NO HEAD RESTRAINT			HEAD RESTRAINT AVAILABLE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	96.9	95.9	-1.0	95.3	96.2	0.9
1	1.9	2.4	0.6	1.2	1.1	-0.1
2+	1.2	1.7	0.4	3.5	2.7	-0.8
Total Occupants	1458	1322		86	186	

TABLE IX: Neck AIS scores by seat belt use and presence of head restraints (fixed or adjustable) for female occupants.

FEMALES

	NO HEAD RESTRAINT			HEAD RESTRAINT AVAILABLE		
	Lap/sash Belt Use		Belt Effect (2)-(1)	Lap/sash Belt Use		Belt Effect (4)-(3)
	Not Worn (1)	Worn (2)		Not Worn (3)	Worn (4)	
Neck AIS	%	%		%	%	
0	94.6	93.3	-1.3	95.7	93.5	-2.3
1	3.7	4.9	1.2	2.1	2.6	0.5
2+	1.7	1.8	0.1	2.1	3.9	1.8
Total Occupants	841	960		47	153	

than in pre-ADR 22 cars. There was no statistically significant difference between the belt effect in ADR 22 cars and that in pre-ADR 22 cars ($X^2_2 = 0.246$). Among lap/sash wearers, the apparent effect of ADR 22 head restraints on female occupants was similar to that for male occupants.

There were insufficient data to meaningfully examine the interaction between seat belt use and head restraint availability within categories defined by crash location and occupant sex. Nor were there sufficient data to consider various types of crash separately.

DISCUSSION

This study has confirmed the effect of lap/sash seat belt use on neck injuries of the type of occupant considered (i.e. non-ejected front outboard seat occupants aged over 15 occupying cars and car derivatives manufactured in 1960 or later). While the belt effects in Table I appear small, they represent a 31 per cent increase in whiplash injuries and a 29 per cent increase in moderate-to-critical neck injuries.

The effect of lap/sash belt use on neck injury appeared smaller when ADR 22 head restraints were available, compared with the belt effect on occupants of pre-ADR 22 cars. Indeed, there was some evidence of belt effects resulting in reductions in neck injuries of all severities among male occupants and those involved in crashes in built-up areas, when ADR 22 head restraints were present. However, in none of the circumstances considered was the belt effect in the presence of ADR 22 head restraints significantly different from the belt effect in pre-ADR 22 cars.

If there is an effect of ADR 22 head restraints in terms of moderating or negating the effect of lap/sash belt use on neck injuries, then this effect should be viewed against the negative effects of these head restraints. Among wearers of lap/sash belts (and possibly among non-wearers as well), the effect of ADR 22 head restraints appeared to result in a decrease in whiplash injuries and an increase in moderate-to-critical neck injuries. This applied to occupants of each sex and to occupants involved in crashes in each type of location (built-up area or open road). When all restrained occupants were considered together, the effect of the ADR 22 head restraints was statistically significant. In general, the positive and negative effects of the ADR 22 head restraints in the injury severity categories were of equal magnitude, representing a transfer from minor neck injury (i.e. whiplash) to moderate-to-critical neck injury, but with no real change in neck injury occurrence.

Thus, while the availability of ADR 22 head restraints may lead to a situation where the effect of lap/sash belt use

on neck injury severity is moderated, their presence appears to increase the severity of neck injuries which do occur. Together, the two countermeasures (lap/sash belt use and head restraint presence) appear to result in a decrease in whiplash injuries and an increase in moderate-to-critical neck injury, with the presence of ADR 22 head restraints having the dominant effect on neck injury.

The results of this study should be viewed against other research on the effect of head restraints. All of the American and European studies previously cited were based on occupants with low rates of seat belt use and in general focussed on whiplash injuries only. While the negative effect of ADR 22 head restraints (which closely resembles the American standard FMVSS 202) was similar among seat belt non-users to that among lap/sash belt wearers, it would only be apparent when neck injuries of moderate or greater severity are considered explicitly. This study is unusual in that respect. Indeed, the two Australian studies previously cited, which were both based on occupants with lap/sash belts available for use during periods when compulsory wearing applied, did not fully consider neck injuries with greater severity than whiplash. Thus there is no inconsistency between the results of this study and other related research.

However, it should be emphasised that the results of this study apply to designs of head restraints and seat belts which have been superseded by later ADRs. ADR 22 was superseded in 1975 by ADR 22A, which requires that head restraints cannot be adjusted below a specified minimum height. This ADR may prevent head restraints from acting as a fulcrum and producing more severe neck injuries than would be the case in their absence. ADRs 4 and 4A, which allowed static lap/sash belts in the front outboard seating positions, were superseded by ADR 4B in 1975 and by ADR 4C in 1976, both of which required inertia reel seat belts. The effects of ADR 22A head restraints and inertia reel seat belts, together or alone, on moderate-to-critical neck injuries, are unknown. However, for whiplash injuries, Cameron (1980) found that ADR 22A head restraints were effective in reducing their occurrence among female

occupants with inertia reel belts available, but his study was inconclusive regarding the effect for male occupants. A study of the joint effects of ADR 22A head restraints and inertia reel seat belts on the full range of neck injury severity would appear worthwhile.

CONCLUSIONS

In examining the conclusions from this study it should be noted that Australian Design Rule 22 (ADR 22) for head restraints allowed manufacturers to install either fixed or fully height-adjustable head restraints. Some 53 per cent of the ADR 22 head restraints installed were of the adjustable type, and a roadside survey showed that 58 per cent of the adjustable head restraints were set at their lowest position. Thus, at least 31 per cent of ADR 22 head restraints were probably not set at their optimal position for protection of the occupants of the seats concerned (some head restraints, while not in their lowest position, may still have been set too low for the particular occupants).

The conclusions of this study were as follows:

1. While there is strong evidence that seat belt wearing reduces the incidence of severe injuries to vehicle occupants involved in crashes, there is also evidence that the use of lap/sash seat belts increases minor and moderate neck injuries in crashes.

2. There is no statistically significant evidence of an interaction between static lap/sash belt use and ADR 22 head restraints in terms of their effect on neck injury severity. However there is some evidence that the effect of such belts is smaller when ADR 22 head restraints are available, compared with the belt effect on occupants of pre-ADR 22 cars.

3. ADR 22 head restraints decrease the risk of whiplash injury, but increase the risk of moderate-to-critical neck injury, especially among static lap/sash belt users and possibly among non-users as well. When ADR 22 head restraints and static lap/sash belts are available together, the effect of the head restraints on neck injury dominates any moderating influence that their presence may have on the belt effect.

4. ADR 22 head restraints as used in practice are unsuitable as a countermeasure to the negative effects of lap/sash seat belt use on neck injury.

5. A study of the joint effects of ADR 22A head restraints (which limit improper adjustment) and inertia reel seat belts on neck injuries of all severities would appear worthwhile.

It is important to note that this study was based on front seat occupants injured sufficiently to be treated at hospital or killed, and who were transported from the crash scene by ambulance. Thus the persons concerned were rather special road accident victims in terms of the seriousness of their injuries. In particular, they had relatively few minor neck injuries (whiplash). In those cases where whiplash was sustained, it was likely that it was accompanied by a more serious injury, as whiplash per se would not lead to treatment at hospital in most cases. Notwithstanding these remarks, any deficiencies in the data analysed applied equally, however, to occupants of ADR 22 cars as well as to occupants of pre-ADR 22 cars.

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APPENDIX

RAW DATA USED IN ANALYSIS

TABLE A1: Frequencies of neck injury Abbreviated Injury Scale (AIS) scores of non-ejected front outboard seat occupants aged over 15.

	NO HEAD RESTRAINT		HEAD RESTRAINT AVAILABLE	
	Pre-ADR 22 cars (1960-71 models)		ADR 22 cars (1972-74 models)	
	Belt Not Worn	Lap/sash Belt Worn	Belt Not Worn	Lap/sash Belt Worn
Neck AIS				
0	2209	2165	127	322
1	58	79	2	6
2+	32	39	4	11
Total	2299	2283	133	339

TABLE A2: Frequencies of neck injury Abbreviated Injury Scale (AIS) scores of non-ejected front outboard seat occupants aged over 15, by crash location.

	NO HEAD RESTRAINT		HEAD RESTRAINT AVAILABLE	
	Pre-ADR 22 cars (1960-71 models)		ADR 22 cars (1972-74 models)	
	Belt Not Worn	Lap/sash Belt Worn	Belt Not Worn	Lap/sash Belt Worn
BUILT-UP AREAS				
Neck AIS				
0	1543	1452	75	189
1	35	55	2	4
2+	16	17	2	3
Total	1594	1524	79	196
OPEN ROAD				
Neck AIS				
0	628	675	49	132
1	23	22	0	2
2+	12	22	1	8
Total	663	719	50	142

TABLE A3: Frequencies of neck injury Abbreviated Injury Scale (AIS) scores of non-ejected front outboard seat occupants aged over 15, by sex of occupant.

	NO HEAD RESTRAINT		HEAD RESTRAINT AVAILABLE	
	Pre-ADR 22 cars (1960-71 models)		ADR 22 cars (1972-74 models)	
	Belt Not Worn	Lap/sash Belt Worn	Belt Not Worn	Lap/sash Belt Worn
MALES				
Neck AIS				
0	1413	1268	82	179
1	27	32	1	2
2+	18	22	3	5
Total	1458	1322	86	186
FEMALES				
Neck AIS				
0	796	896	45	143
1	31	47	1	4
2+	14	17	1	6
Total	841	960	47	153