# Who doesn't wear seat belts?

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**Abstract –** Using real world accident data, seat belts were estimated to be 61% effective at preventing fatalities, and 32% effective at preventing serious injuries. They were most effective for drivers with an airbag. Seat belts were estimated as having prevented 57,000 fatalities and 213,000 seriously injured casualties in the UK since 1983. Seat belt legislation was estimated to have prevented 31,000 fatalities and 118,000 seriously injured casualties. A future increase in effective seat belt wearing rate (which takes into account seating position) in the UK from 92.5% to 93% may prevent casualties valued at a societal cost of over £18 million per year.

To target a seat belt campaign, the question "who doesn't wear seat belts?" must be answered. Seat belt wearing rates and the number of unbelted casualties were analysed. It was primarily young adult males who didn't wear seat belts, and they made up the majority of unbelted fatalities and seriously injured casualties.

## INTRODUCTION

In the UK on the 31st January 1983, legislation was introduced which made seat belt wearing in the front seats of cars compulsory. This immediately led to an increase of seat belt wearing rates from approximately 40% to over 90% in the front of cars [1]. Now, 25 years on, seat belt wearing rates in the front of cars remain at over 90% according to road side wearing surveys [2], although wearing rates in the rear of cars are significantly lower.

The first objective of this paper was to analyse real world accident data to determine whether seat belts prevent casualties. The effectiveness of seat belts was determined using accident data from the Co-operative Crash Injury Study. Using this effectiveness, the number of casualties prevented by seat belts since 1983 was estimated. This was calculated using the number of car occupant casualties and the observed seat belt wearing rates.

Once it was demonstrated that seat belts are and have been effective at saving lives, an estimate of the possible future savings was made. The potential benefit of raising seat belt wearing rates was estimated, which provides justification for attempting to increase seat belt use.

Having quantified the benefit of increasing seat belt use, the question "who doesn't wear seat belts?" was answered. This will enable targeting of occupants for whom increasing seat belt use would have the greatest effect. Variables which were related to seat belt wearing rates were investigated. The *numbers* of people in different groups who were in accidents and unbelted were also considered. To have the largest effect on casualty numbers, it is these groups that should be targeted.

## METHODOLOGY

### Sources of data

#### *Co-operative Crash Injury Study (CCIS)*

CCIS is an ongoing project which has collected in-depth real world crash data since 1983. Vehicle examinations are undertaken at recovery garages several days after the collision. Car occupant injury information is collected and questionnaires are sent to survivors. Accidents are investigated according to a stratified sampling procedure, which favours cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. It also favours newer vehicles. More information about the study is available at www.ukccis.org. CCIS data collected from June 1998 to the present time has been used for this paper.

*Heavy Vehicle Crash Injury Study (HVCIS)*

HVCIS is an ongoing study which analyses Police fatal accident reports involving at least one large vehicle to identify countermeasures that would have either prevented the collision and/or reduced the severity of the injuries sustained. The project's database contains information on all the pertinent vehicles' crashworthiness performance characteristics and the human factors which were associated with the accident.

*On The Spot (OTS)*

The OTS accident data collection project started in 2000 and investigates 500 crashes per year. Expert investigators attend the scene of accidents usually within 15 minutes of the incident occurring, using dedicated response vehicles and equipment. OTS investigations allow vital perishable accident data to be gathered, including witness and physical evidence that provides information about the behaviour of the people involved prior to the accident. The project investigates crashes of all severities, involving all vehicle types.

*The Department for Transport (DfT) seat belt surveys*

The DfT seat belt survey is carried out in geographical areas centred on Crowthorne and Nottingham in England. They are undertaken in April and October each year. TRL staff observe the seat belt use of occupants of stationary vehicles, mainly at junctions controlled by traffic signals. The results allow long-term trends in seat belt wearing to be monitored, since the survey has been carried out in a consistent fashion since 1988. The geographical coverage of the survey is steadily extended by making observations during the summer in two additional survey areas, changed each year to build up a picture of seat belt wearing throughout England. Between 1983 and 1988 seat belt surveys of front seat occupants were carried out, the results of which are summarised by Broughton [1]. Between them these surveys provide the seat belt wearing rates from 1983-2006 which are used in this paper. At the time of writing, the survey results from 2007 were not available and therefore estimates were used.

## Effectiveness of seat belts

CCIS records each injury suffered by the casualty, and codes these injuries using the Abbreviated Injury Scale (AIS) [3]. AIS is a threat-to-life scale and every injury is assigned a score, ranging from 1 (minor cuts, bruises etc) to 6 (currently untreatable). The Maximum AIS injury a casualty sustains is termed MAIS.

To determine the effectiveness of seat belts, occupants were selected from CCIS who met the following criteria:

1. 15 years old or greater
2. Known gender, seating position and MAIS
3. Outboard seated occupants
4. The status of lap and diagonal seat belt use known

Children under 15 were excluded to remove any bias caused by children not using suitable child restraints. The final sample included 10,529 car occupants.

For the following analysis, the effectiveness of seat belts was defined as the percent reduction in the chance of an occupant sustaining injury at a given level, compared to the non seat belted condition. The following formula was used [4]:

$$Effectiveness = \frac{(Unbelted\ rate - Belted\ rate)}{Unbelted\ rate}\% \qquad [1]$$

This was used to determine the effectiveness of seat belts in preventing fatal and serious injuries to all car occupants in CCIS. These values were then used in the estimate of the number of casualties prevented by seat belts since 1983. The effectiveness for drivers of different injury severities with and without airbags was also investigated, as well as the difference in effectiveness for front and rear seat passengers.

## Casualties prevented by seat belts

In addition to effectiveness, the seat belt wearing rate and the number of car occupant casualties were required to estimate the casualties prevented by seat belts.

The seat belt surveys enabled an "effective seat belt wearing rate" to be calculated, which took into account the wearing rate in different seating positions, and the number of occupants who were sitting in those positions. This could then be used with the estimate of seat belt effectiveness in CCIS (calculated using occupants from all seating positions), and the number of car occupant casualties (which included casualties in all seating positions).

The number of car occupant casualties in Great Britain has been published by the DfT for every year from 1983-2006 in Road Casualties Great Britain (previously Road Accidents Great Britain) [5,6].

Equation 2 was derived which gives the difference in the number of casualties for two different seat belt wearing rates:

$$\Delta C = C_2 - C_1 = \left( \left( \frac{1-\sigma\omega_2}{1-\sigma\omega_1} \right) C_1 \right) - C_1 \qquad [2]$$

where:

- $C_1$ is the number of casualties of a given severity when the seat belt wearing rate is $\omega_1$
- $C_2$ is the number of casualties of a given severity when the seat belt wearing rate is $\omega_2$
- $\sigma$ is the effectiveness of seat belts at preventing casualties of a given severity.

This equation was used to estimate the number of lives saved by seat belts, by setting the seat belt wearing rate $\omega_2 = 0$. This gave equation 3:

$$\Delta C = \frac{C_1}{1-\sigma\omega_1} \qquad [3]$$

where $C_1$ and $\omega_1$ are the number of casualties and seat belt wearing rate for that year. This calculation was repeated for each year from 1983-2007. The results were summed to give an estimate of the number of casualties prevented by seat belts since 1983.

## Effect of increasing seat belt wearing rate

Equation 2 was used to estimate the effect of increasing seat belt use. Setting $C_1$ as the number of car occupant casualties in 2006, $\omega_1$ as the effective seat belt wearing rate in 2006, and $\omega_2$ as a hypothetical increased seat belt wearing rate, $\Delta C$ gave the number of casualties prevented if the seat belt wearing rate in 2006 had been $\omega_2$.

The estimated number of fatal and serious casualties can be expressed in terms of societal cost. The cost savings associated with reducing a fatality to a serious casualty, and a serious casualty to a slight casualty, are given by the DfT [5] and shown in Table 1.

Table 1. Monetary benefit of preventing and reducing fatal and serious casualties

| Injury severity | Benefit of preventing injury | Benefit of reducing injury |
|---|---|---|
| Fatal | £1,489,450 | £1,322,090 |
| Serious | £167,360 | £154,460 |

## Who doesn't wear a seat belt?

Survey results and real world data evidence were correlated to describe the characteristics of non-seat belt wearers. The analysis was performed by cross-tabulating seat belt use with variables related to the accident, vehicle or occupant involved in the accident. Some of the variables where there was a statistical relationship (using a chi-squared test to the $p < 0.05$ level) are presented. This begins to paint a picture of the characteristics of occupants who are involved in accidents and are not wearing a seat belt.

# RESULTS AND DISCUSSION

## Effectiveness of car seat belts

Table 2 gives the effectiveness of seat belts at preventing fatal and serious casualties, calculated using CCIS. This was calculated for all the fatal and serious casualties in CCIS, regardless of seating position or the presence of airbags etc.

Table 2. Seat belt effectiveness for fatal and serious casualties in CCIS

| Injury severity | Seat belt effectiveness, σ |
|---|---|
| Fatal | 61% |
| Serious | 32% |

Figure 1 shows the seat belt effectiveness at different injury levels for drivers in all types of impacts. It outlines the difference in seat belt effectiveness in vehicles with and without steering wheel mounted airbags.

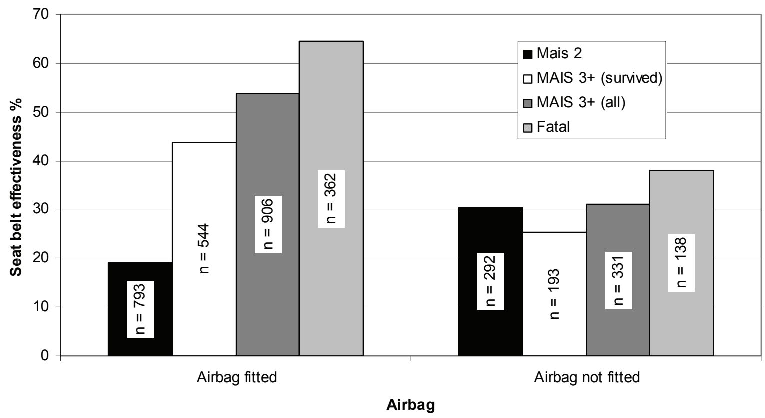


Figure 1. Seat belt effectiveness for drivers

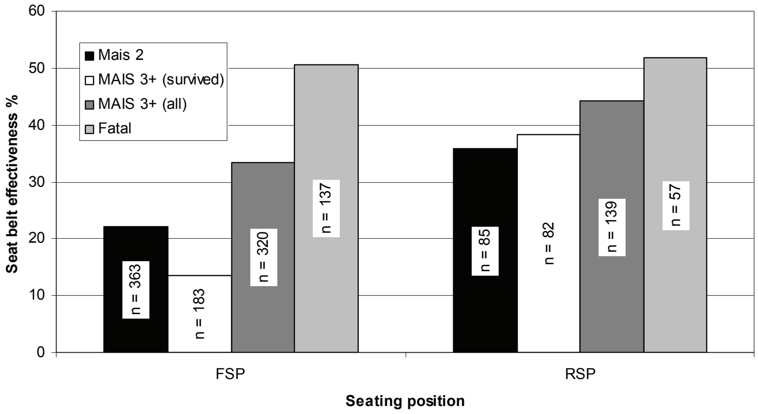


Figure 2. Seat belt effectiveness for passengers

Combining seat belts with steering wheel mounted airbags afforded greater protection to drivers than just wearing a seat belt. There are many other factors that may be associated with this relationship. For example, the drivers with no airbags were typically in older vehicles and therefore would not have benefited from newer vehicle structural improvements or advances to seat belt design. The exact nature of the crashes was not fully investigated and therefore there could be crash severity or impact type differences between older and newer cars that may also skew the results.

Figure 2 shows the differences in seat belt effectiveness for front and rear seat passengers. Seat belts were more effective for rear seat passengers than front seat passengers, although it should be noted that there were a lot more front seat passengers in the sample and their demographics were different to rear passengers. Historically, seat belts in the rear of cars have been identified as being slightly less effective than seat belts in the front. Newer cars in this sample may have improved belt geometry and design in the rear, leading to increased effectiveness.

## Casualties prevented by seat belts

Figure 3 shows how the effective seat belt wearing rate varied from 1983-2007. Most of the variation is likely to be caused by differences in the measured wearing rate of rear seat passengers, because of the smaller sample size. The data for 2007 was estimated using the seat belt survey for the previous year.

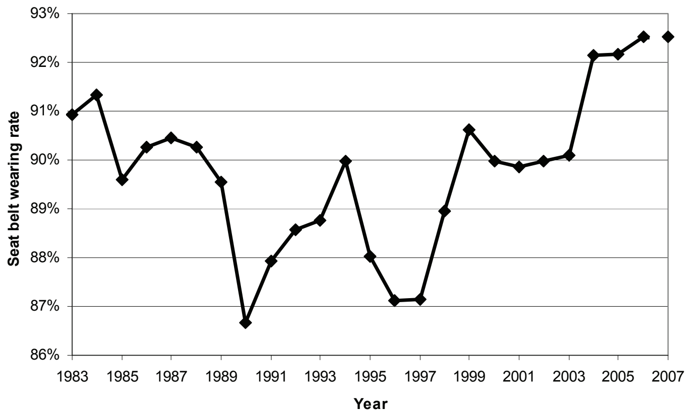


Figure 3. Effective seat belt wearing rate

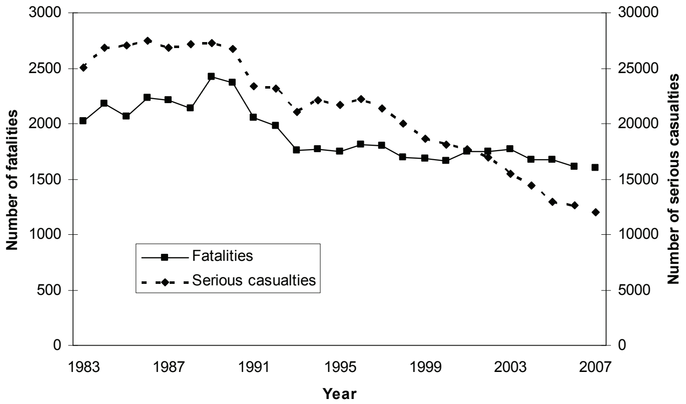


Figure 4. Fatal and serious car occupant casualties

Figure 4 shows the number of car occupant casualties in Great Britain since 1983. The number of fatalities in 2007 was estimated as 1,600, and the number of seriously injured casualties was estimated as 12,000.

The number of casualties prevented each year by seat belts is shown in Figure 5. This was calculated using equation 3, which gives the difference in casualties between a 0% seat belt wearing rate and the effective seat belt wearing rate, shown in Figure 3.

The shape of Figure 5 is very similar to Figure 4 because the seat belt effectiveness was assumed to remain constant, and seat belt wearing rates remained relatively constant over the 25 year period. The result was that the fluctuations in the number of casualties prevented each year mirror the fluctuations in the actual number of casualties. Table 3**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the sum of the fatal and serious casualties estimated to have been prevented over the 25 year period.

Table 3. Total estimate of casualties prevented by seat belts since 1983

| Injury severity | Casualties prevented by seat belts |
|---|---|
| Fatal | 57,025 |
| Serious | 213,137 |

It is likely that improvements in restraint systems over 25 years have increased their effectiveness. A typical value for the effectiveness of seat belts in 1983 was about 40% [7]. Assuming a linear rise in effectiveness from 40% in 1983 to 61% in 2007, the estimated number of fatalities prevented was about 41,000.

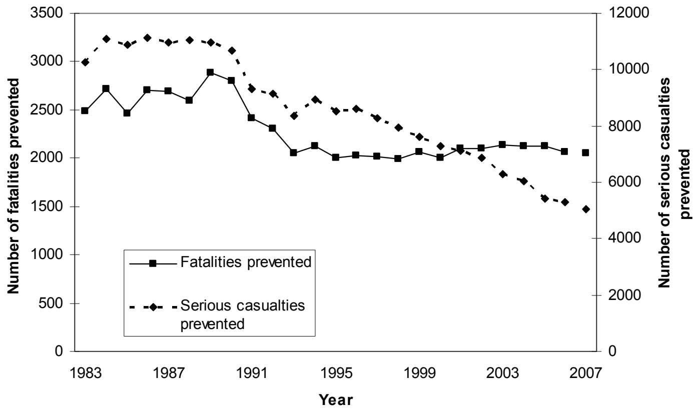


Figure 5. Number of car occupant casualties prevented by seat belts

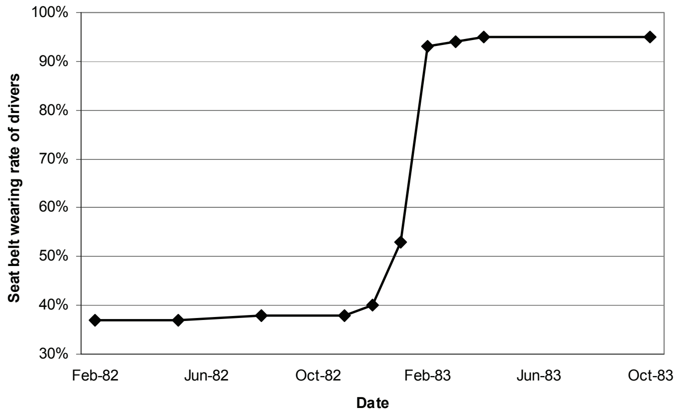


Figure 6. Effect of seat belt legislation on seat belt wearing rates for car drivers

The effect of the seat belt legislation was a rise in seat belt wearing rates from under 40% to over 90%, shown in Figure 6. Using the estimate of effectiveness from Table 2, the estimates of the total numbers of casualties prevented from 1983 to 2007 by this rise are shown in Table 4.

Table 4. Casualties prevented by rise in seat belt wearing rates following introduction of seat belt legislation

| Injury severity | Casualties prevented by rise in seat belt wearing rates |
|---|---|
| Fatal | 31,668 |
| Serious | 118,218 |

These models give a lower value for the number of serious casualties prevented than previous estimates. This is because the effectiveness of seat belts for serious casualties, calculated using CCIS, is lower than the effectiveness for preventing fatalities. If the effectiveness for serious casualties was the same as for fatalities (61%), then the number of serious casualties prevented would be estimated at about 680,000.

It should be noted that these equations estimate the casualties prevented by seat belts using only the seat belt wearing rates, seat belt effectiveness, and the number of casualties which occurred. Factors such as any change in driving behaviour for occupants who do / do not wear a seat belt were not taken into account.

The models used in this paper provide estimates of the true number of casualties prevented which, itself, will never be known. But it seems certain that seat belts have saved tens of thousands of lives, and hundreds of thousands of serious casualties since 1983 in the UK alone.

## Effect of increasing seat belt wearing rate

Table 5 shows the estimate of the number of casualties that would have been prevented in 2006 if the effective seat belt wearing rate had been higher. It also gives the associated monetary cost saving.

Even a relatively small increase in seat belt wearing rates of about 0.5% would reduce the cost of killed and seriously injured casualties by over £18 million per year. This only considers the benefit to car occupants; large commercial and passenger carrying vehicles were not considered. The purpose of this estimate was to show that there is a very large potential for benefit with relatively small increases in seat belt use.

Table 5. Effect of increasing seat belt wearing rate in 2006

| Effective seat belt wearing rate | Casualties prevented | | Valuation of casualties prevented |
|---|---|---|---|
| | Fatal | Serious | £ million |
| 92.5% | 0 | 0 | 0 |
| 93.0% | 11 | 28 | 18.5 |
| 94.0% | 33 | 85 | 56.9 |
| 95.0% | 55 | 143 | 95.3 |
| 96.0% | 78 | 200 | 133.7 |
| 97.0% | 100 | 258 | 172.1 |
| 98.0% | 122 | 315 | 210.5 |
| 99.0% | 145 | 373 | 248.8 |
| 100.0% | 167 | 430 | 287.2 |

## Who doesn't wear a seat belt?

This section details some variables which are strongly related to variations in seat belt wearing rates. The nature of the stratified sampling procedure in CCIS means that the absolute percentages cannot be compared to those from other studies without more detailed weighting, but they can be used to compare trends in the data.

Figure 7 shows a clear relationship between the age of car occupants and seat belt wearing rates. From the age of 10, seat belt use increased with age. This relationship did not hold for children aged 0-9 years, who had relatively high seat belt wearing / child restraint use rates. At this age, it is the attitude of the parents which determines whether the child is wearing a seat belt, although older children aged 10-15 had the lowest seat belt wearing rates of all ages. This is a potential concern as these teenage passengers are frequently driven by slightly older friends or siblings, and these are the young drivers with high crash liability. Non-use of seat belts has been linked to risk-taking [8], so the increase in seat belt wearing rate with age coincides with a reduction in risk-taking behaviour for most drivers.

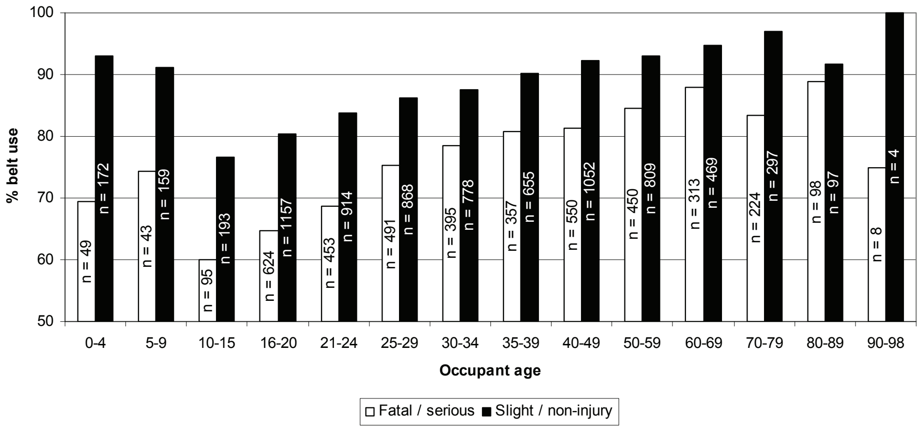


Figure 7. Belt use by occupant age


Figure 8. Belt use by gender

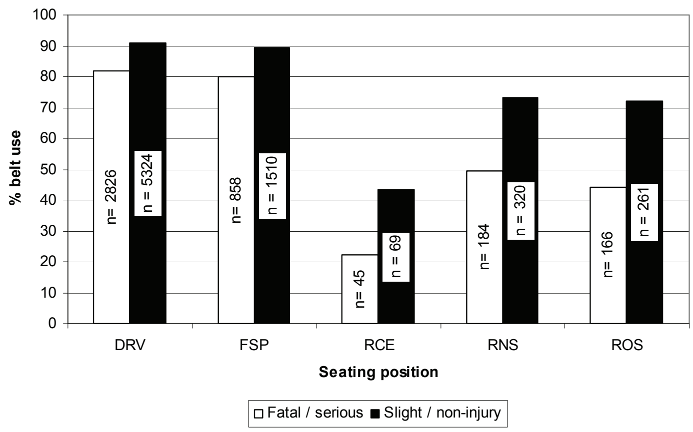


Figure 9. Belt use by seating position

Figure 8 shows that seat belt wearing rates for women were higher than for men. This relationship is seen in all previous literature and seat belt surveys.

Figure 9 shows that one of the most important factors determining seat belt use was the seating position in the car, with rear adult passengers far less likely to wear a seat belt. Other factors play a part here, for example children and young adults are most likely to be rear seat passengers. Also, there is a relationship between the number of occupants in a car and seat belt wearing rates, especially for cars containing young adult males.

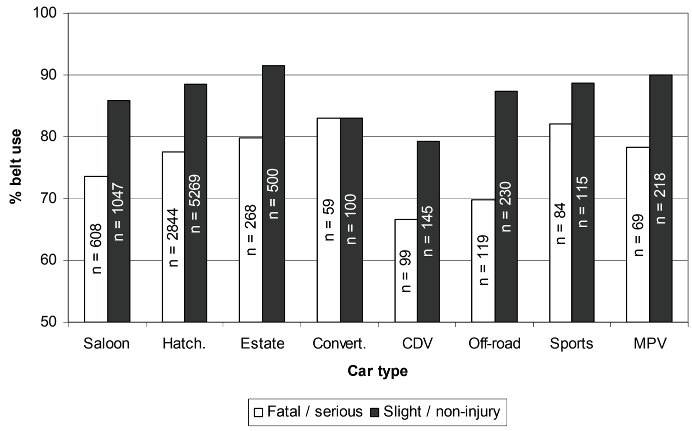


Figure 10. Belt use by vehicle type

Figure 10 shows that the lowest seat belt wearing rates occured in car-derived vans (CDVs). These are the only type of goods vehicle included in CCIS. However, the HVCIS database includes larger goods vehicles, although it only records the seat belt use of fatalities. In HVCIS, the seat belt wearing rate in heavy goods vehicles was 2%, for light goods vehicles it was 35% and for cars it was 80%. The seat belt wearing rate of fatalities would be expected to be lower than average, and seat belt wearing rates in goods vehicles have historically been extremely low.

Figure 11 shows that seat belt wearing rates were lowest in cars aged 12-13 years old. There is a relationship between young people driving older cars [9], and also between the age of vehicle and drivers' socio-economic status, which could both have had an effect here. However, the relationship between the age of the vehicle and seat belt use was not as strong as other variables.

Figure 12 shows that occupants involved in accidents in the early hours of the morning had much lower seat belt wearing rates than occupants in accidents at other times. Young adult males were over-represented at these times, which would account for some of the difference in seat belt wearing rates.

Other variables were investigated and found to have a correlation with seat belt wearing rates. For example, using OTS it was found that company car drivers had relatively low seat belt wearing rates. Wearing rates were also lower in urban areas with low speed limits.

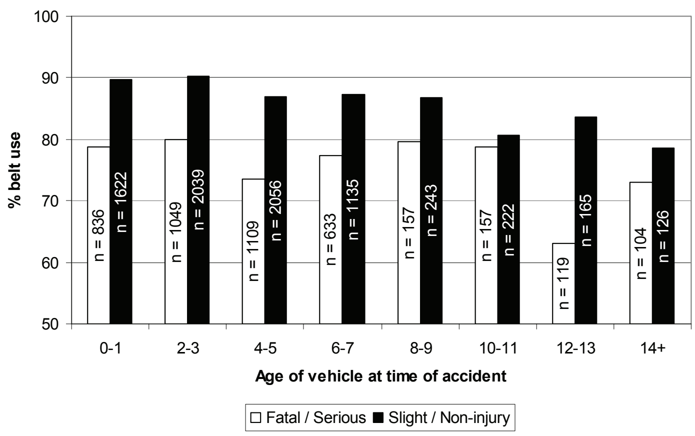


Figure 11. Belt use by age of vehicle

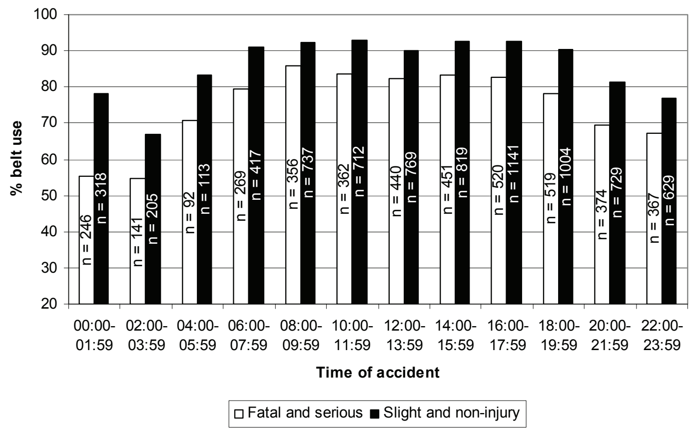


Figure 12. Belt use by time of accident

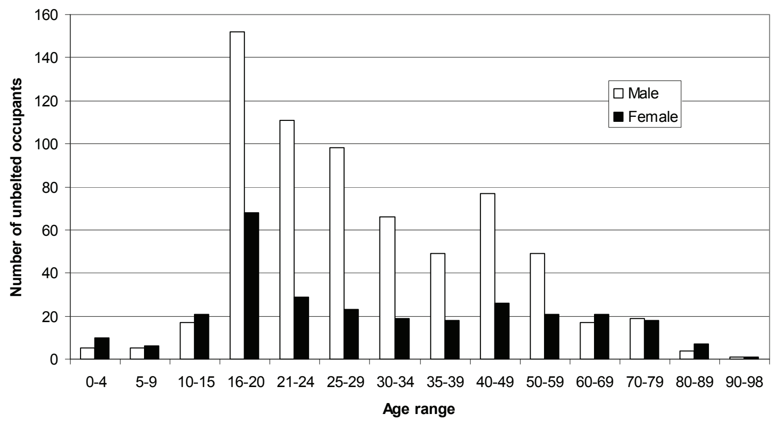


Figure 13. Unbelted killed and seriously injured occupants in CCIS by age and gender, all seating positions

In order to have the largest effect on casualty numbers, it is important to concentrate on the largest groups of occupants who are unbelted and suffer fatal or serious casualties. Figure 13 identifies the number of killed and seriously injured occupants in CCIS who did not wear a seat belt, and groups them by age and gender.

From Figure 13 it is clear that young adult males accounted for a large proportion of occupants killed or seriously injured when not wearing a seat belt. Any seat belt campaign which could improve the wearing rates of young adult males would have a relatively large effect.

Figure 14 shows the age and gender of killed and seriously injured rear seat occupants. Again, in the rear of the car it was young adult males who were the largest group. Although rear seat passengers made up a relatively small proportion (13%) of the casualties in CCIS, their low seat belt wearing rates meant they made up 28% of unbelted casualties.

Figure 13 and Figure 14 show the importance of considering the *number* of unbelted occupants, as well as the seat belt wearing rate. For example, Figure 7 showed that 10-15 year olds had the lowest seat belt wearing rates of all occupants. However, occupants aged 10-15 accounted for relatively few of the occupants not wearing a seat belt. In Figure 14 which only considers rear seat occupants, children aged 10-15 were the 3rd largest group, but this group was much smaller than the 16-20 age group.

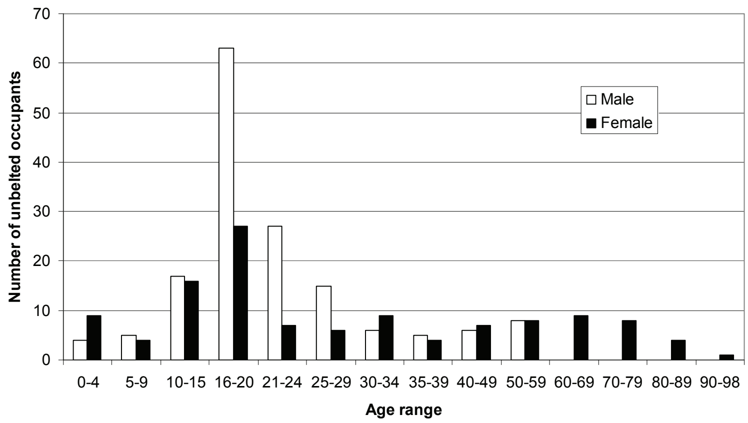


Figure 14. Unbelted killed and seriously injured occupants in CCIS by age and gender, rear seat passengers only

The most important car occupants to target appear to be young adult males, who made up the majority of killed or seriously injured unbelted occupants. Those driving in the early hours of the morning or driving older cars had particularly low seat belt wearing rates, as did those who sat in the rear of the car.

A relation between risk taking behaviour and non-belt use was noted when looking at case studies in OTS. Occupants who were not wearing a seat belt in the OTS database were often in accidents associated with speeding, drink-driving, and other risk-taking behaviour.

## CONCLUSIONS

- CCIS was used to determine the effectiveness of car seat belts. For occupants in all seating positions, seat belts were found to be 61% effective at preventing fatalities, and 32% effective at preventing serious casualties. Seat belts were most effective for drivers when used in conjunction with an airbag. Seat belts were also more effective for rear seat passengers than front seat passengers.

- An estimated 57,000 fatalities and 213,000 serious casualties have been prevented by seat belts in the UK since 1983. The rise in seat belt wearing rates due to seat belt legislation has prevented an estimated 32,000 fatalities and 118,000 serious casualties.

- In 2006, if the seat belt wearing rate had been 93% instead of 92.5%, an estimated 11 fatalities and 28 serious casualties may have been prevented. These were valued at £18.5 million.

- Age and gender had a strong relationship with seat belt use. From the age of 10, seat belt wearing rates increased with age, although wearing rates for men were lower than for women. Seat belt wearing rates were much lower for occupants in the rear of the car than for drivers or front seat passengers.

- In CCIS, seat belt wearing rates were lowest for occupants in car-derived vans. From HVCIS it was apparent that seat belt wearing rates in all types of goods vehicle were much lower than those in cars.

- When identifying groups of occupants to target with a potential future safety campaign, it is important to target those who account for a large number of casualties, not just groups with low seat belt wearing rates. It is clear that young adult males account for a very large proportion of occupants who do not wear seat belts. Any seat belt campaign would have the greatest effect on casualty numbers if it could raise seat belt wearing rates of young men.

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This report used accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected during the period 1998-2007.

Currently CCIS is managed by TRL Limited, on behalf of the DfT (Transport Technology and Standards Division) who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Previous sponsors of CCIS have included Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe(UK) Ltd.

Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency of the DfT.

Further information on CCIS can be found at http://www.ukccis.org

The OTS project is funded by the DfT and the Highways Agency. The On The Spot investigations are carried by teams at TRL in Berkshire and the Vehicle Safety Research Centre (VSRC) Loughborough University. The project would not be possible without help and ongoing support from many individuals, especially including the Chief Constables of Nottinghamshire and Thames Valley Police Forces, and their officers.

The views expressed in this report belong to the authors and are not necessarily those of the DfT.