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# MALE AND FEMALE CAR DRIVERS – DIFFERENCES IN COLLISION AND INJURY RISKS

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## ABSTRACT

Crash data from two UK resources were examined for differences between male and female passenger car drivers in collision circumstances and injury outcomes. The proportion of female car licence holders is growing, women are more likely to be the driver in a collision and are more vulnerable to injury particularly neck strain. Women drive smaller, lighter cars compared to men and are more often the driver of the smaller vehicle in a multivehicle collision. Vehicle design, crash testing programmes and regulation, currently based heavily on the average male, should give more balanced consideration to female characteristics in future activities.

Previous consideration has been given to the differences in injury outcome to male and female car occupants. Evans shows that in the US for belted drivers in identical crashes the risk of fatality is higher for women than men up to the age of 55 (Evans, 1999). Surprisingly his results show that men have a higher risk of fatality than women beyond this age, when osteoporosis is thought to affect women more severely. Evans points to differences in basic human physiology as an explanation for the effects noticed. Using CCIS data from 1992-1994 Mackay (2000) concluded that for the UK frontal collision population age is a more important variable than sex but that consistent differences between the sexes exist in their vulnerability to head, thorax and lower extremity AIS 2-6 injury. McFadden (1998) intimates that a female driver's increased vulnerability to injury is due to a closer proximity to the steering wheel, itself a function of driver height rather than gender. In a study concerning foot and ankle injury Crandall (1996) showed that the risk of injury decreases with driver height and is greater for women than for men, a possible factor being the type of footwear worn by the different sexes. All these studies lead to the conclusion that any analyses concerned with gender differences in injury outcome cannot be considered univariate but that such analyses are complex matters with many important and influential factors. In this paper however, we are primarily interested in the effect that gender, encompassing the diversity of physical and psychological attributes found in the population, has on accident involvement and injury risk. Seat belt wearing rates are high (95%) in the UK. Consequently we are interested in determining the risk of injury to a belted population unlike other works which look at unbelted occupants (e.g. Evans 2001). The initial findings reported here are explored further in a forthcoming paper (Lenard & Welsh, 2001).

## METHOD

Statistical analysis of the UK police accident records (STATS 19), the UK in-depth accident database (CCIS), the UK Focus on Personal Travel, and road user diary studies have been used to examine the factors influencing collision involvement rates and to determine any difference in injury outcome for male and female drivers of European passenger cars. The work was carried out as part of a much wider study examining the in-car safety and personal security needs of female drivers and passengers (Galer-Flyte et al, 2000). The aim of this paper is to present those findings most salient to the field of accident research. Consideration has been given to collision involvement rates, environmental circumstances surrounding the collision, size of vehicle driven, impact type, occupant characteristics, overall injury severity, and injury to specific body regions.

**DATA –** The STATS 19 data (1996-1998) comprises 950,000 passenger car drivers involved in a collision resulting in injury to a road user and provides a broad overview of the environmental circumstances at the time of the collision together with limited vehicle damage and occupant injury information. The CCIS data is a stratified sample from selected geographical regions around the UK. The data is weighted towards fatal and serious injury outcome and contains detailed vehicle and injury information for over 6000 restrained car drivers (1992-2000). The two databases complement each other and together provide a very strong basis for examining road safety issues. Exposure data is drawn from the government survey data, Focus on Personal Travel. Female perspective is provided by responses given by a broad sample of female drivers as part of a study into the in-car and personal security needs of female drivers and passengers (Galer-Flyte et al 2000).

## RESULTS

Throughout this section tests for statistical significance have been performed where appropriate. It should be noted that the STATS 19 database contains the whole UK injury accident population and as such significance testing is inapplicable. For the STATS 19 data any differences noted between the genders, even if small, are true differences and not due to sampling error.

**EXPOSURE –** The proportion of female car licence holders within the UK increased substantially during the years 1990-1996, a trend that is likely to continue. The proportion of women holding a current licence is increasing more rapidly than that for men over all age groups except in the over 70 population where the growth is equal (Table 1). Whilst men still outnumber women behind the wheel, women are increasingly more representative of the car driver population, particularly among the middle-aged.

**Table 1 - Percentage of car licence holders by age and gender 1990 – 1996**

| Age | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | 1990 | 1996 | change | 1990 | 1996 | change |
| 17-20 | 52 | 48 | -4 | 35 | 36 | 1 |
| 21-29 | 82 | 79 | -3 | 64 | 67 | 3 |
| 30-39 | 88 | 89 | 1 | 67 | 74 | 7 |
| 40-49 | 89 | 89 | 0 | 66 | 74 | 8 |
| 50-59 | 85 | 88 | 3 | 49 | 61 | 12 |
| 60-69 | 78 | 83 | 5 | 33 | 46 | 13 |
| 70+ | 58 | 65 | 7 | 15 | 22 | 7 |

It is reported that women make fewer and shorter trips as a car driver compared to their male counterparts (DETR, 1998). This is reflected in the ratio of mileage driven per annum between the genders given in Table 2. Comparing the ratio of annual mileage with that for collision involvement as a driver, female drivers account for a quarter of total mileage but a third of all injury accidents. This leads to the conclusion that women are more likely to be the driver in an injury crash per mile driven. Only in the youngest age group (17-20 years) are men more likely to be involved in a collision than their female counterpart. It should be noted that this exposure data does not apportion blame for the occurrence of a collision.

Figure 1 shows that around 60% of both male and female drivers involved in a collision on the UK roads are under the age of 35; the cumulative frequency curves for each gender are similar up to this age. Overall male drivers exhibit a higher age distribution than female drivers.

**Table 2 - Mileage per annum (1997) and collision involvement (STATS 19 1996-1998)– Male:Female ratios**

| Age | Mileage | | | Collision involvement | | |
|---|---|---|---|---|---|---|
| | Male N | Female N | M:F Ratio | Male N | Female N | M:F Ratio |
| 17-20 | 2706 | 1635 | 1.7 | 72652 | 31801 | 2.3 |
| 21-29 | 6590 | 3111 | 2.1 | 152230 | 87891 | 1.7 |
| 30-39 | 8560 | 3491 | 2.5 | 143404 | 86797 | 1.7 |
| 40-49 | 9446 | 3632 | 2.6 | 95550 | 55419 | 1.7 |
| 50-59 | 8206 | 2439 | 3.4 | 64793 | 30900 | 2.1 |
| 60-69 | 4938 | 1162 | 4.2 | 36795 | 12558 | 2.9 |
| 70+ | 2169 | 338 | 6.4 | 26309 | 8662 | 3.1 |
| All | 5086 | 1867 | 2.7 | 591133 | 314028 | 1.9 |

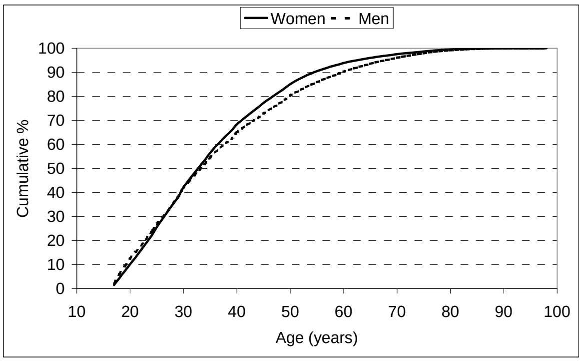


**Figure 1 - Cumulative frequency of driver age (STATS 19 N=944,638)**

**CIRCUMSTANTIAL –** The UK national accident data shows that women are the driver in a higher proportion of collisions than men where the road layout includes some form of junction (including roundabouts and slip roads) (Figure 2). Primary impacts to the front of the vehicle are most prevalent among car drivers followed by side impacts (irrespective of which side). When side impacts are separated into right side (the driver's side in the UK) and left side then rear impacts account for the second highest proportion of primary impacts. Female drivers have a higher proportion of primary impacts to the rear and right side of the vehicle (Figure 3). Women report being less confident in their driving ability than men partially due to lack of good external visibility from the vehicle (Galer-Flyte et al 2000). This may contribute to both the increased prevalence of junction collisions and the types of impact more commonly experienced by female drivers.

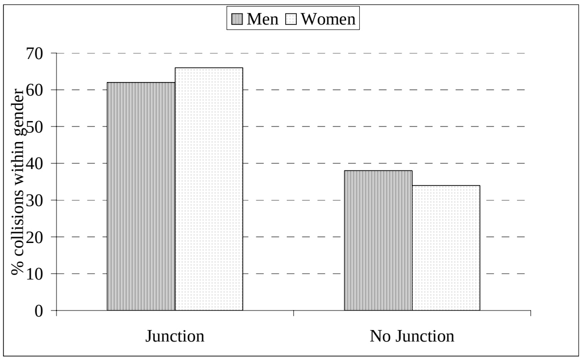


**Figure 2 - Distribution of road layout at collision site by gender (STATS19 N=944,638)**

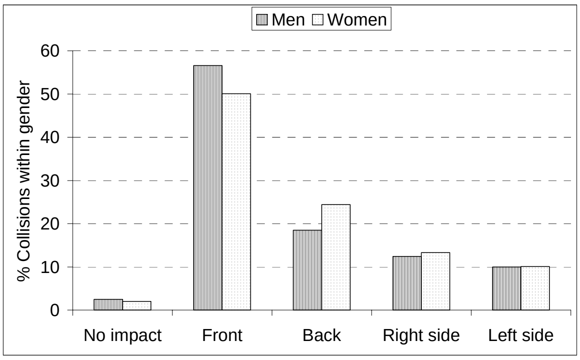


**Figure 3 - Distribution of primary impact by gender (STATS19 N=944,638)**

Figures 4 and 5 show that there is very little difference between driver gender in the weather conditions and road surface conditions at the time of the collision.

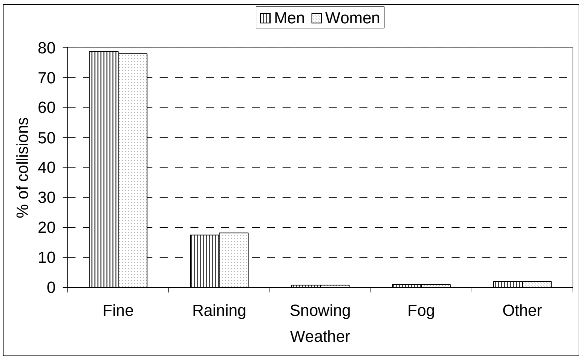


**Figure 4 - Distribution of weather conditions by gender (STATS19 N=944,638)**

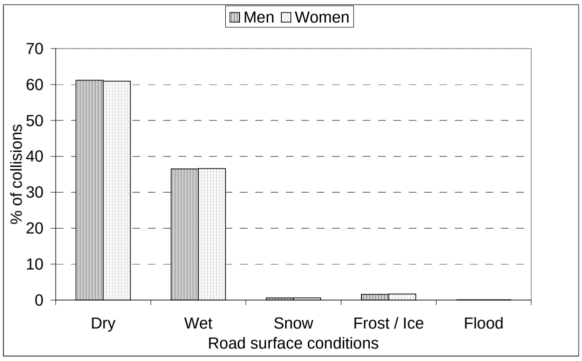


**Figure 5 - Distribution of road surface conditions by gender (STAT19 N=944,638)**

It is impossible to say from these results whether there are any underlying differences between men and women in their willingness to drive under adverse weather conditions and their risk of being involved in an accident when doing so. If women drove less miles under adverse conditions, as a result of lower confidence in their driving ability (Galer-Flyte, 2000), this would necessarily imply an increased vulnerability to collision to counterbalance their reduced exposure. This suggestion cannot be confirmed without exposure data.

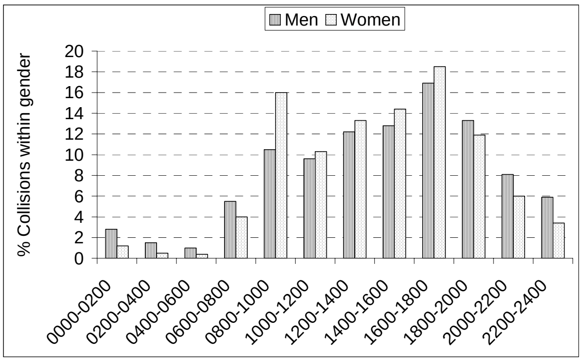


**Figure 6 - Distribution of time of collision by driver gender (STATS19 N=944,638)**

Collisions occur more frequently during the day than night for both sexes (Figure 6). Female drivers have a higher proportion of collisions during the hours of 0800-1800 than male drivers, this being especially noticeable during the period from 0800-1000. The highest proportion for both sexes is during the hours of 1600-1800, the 'rush hour', a time when there is a high density of traffic on the road. Female drivers have a higher proportion of collisions during weekdays, and consequently fewer across the weekend than male drivers, and also have proportionally more collisions during the months of October, November and February (Galer-Flyte, 2000). Changes in environmental light conditions at the beginning and end of the working day that make driving conditions more difficult may contribute to the increase in collisions during this time as well as pure volume of traffic. Owens (1995) shows that there is a marked increase in the occurrence of fatal car to pedestrian/pedal cycle collisions during the twilight hours associated with reduced visibility. The proportion of female drivers in this scenario was higher than that of men. Further detailed analysis of the UK STATS 19 data, not in the scope of this paper, could with appropriate exposure data, determine whether the twilight zone increases the risk of accident involvement and whether one gender is more at risk during this time than the other.

Whilst medium sized cars (C/CD class) are driven most frequently by both sexes, 42% of female drivers have a collision in a small car (A/B class) compared to 23% of male drivers (Figure 7).

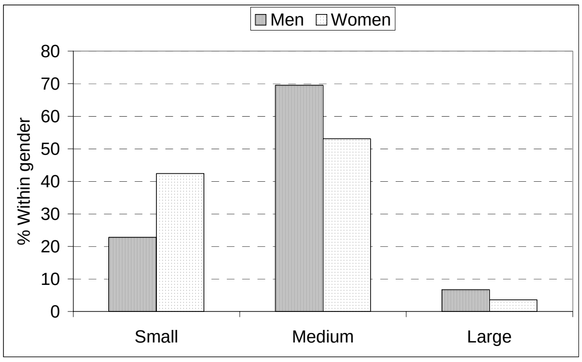


**Figure 7 - Distribution of vehicle size by driver gender (STATS19 N=944,638)**

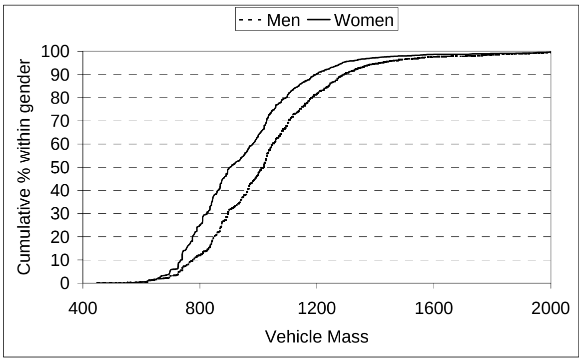


**Figure 8 - Cumulative frequency curve showing vehicle mass by gender (CCIS N=6846)**

The cumulative frequency curve in figure 8 shows that around 30% of men drove vehicles less than 900kg compared to around 50% of women. On the whole women drive significantly smaller and lighter vehicles than men (Mann-Whitney U test for difference in means, p=0.00). It is intrinsically disadvantageous to be in the lighter of two colliding vehicles, since for equal road speeds at impact the lighter vehicle necessarily has a greater change of velocity and rate of acceleration from the impact. Mass is an important component of 'vehicle compatibility' and so is of particular relevance to women. Improvements in vehicle compatibility potentially offer significant benefits to women as they tend to be in the lighter, 'disadvantaged' vehicles.

**ANTHROPOMETRY –** Naturally men are seen to be both taller and heavier than women. It is well accepted that driver height and weight is distinctly bimodal with respect to gender. In this section we consider the anthropometric differences between the genders among the crash population, the specific population for whom crash tests should be designed. The CCIS data (figures 9 and 10) show female drivers in the crash population to be significantly shorter (Mann-Whitney U test for equal means, p=0.00) and lighter (Mann-Whitney U test for equal means, p=0.00) than male drivers. Whilst over 15% of both males and females lie in the 170-174 cm height band, most men are taller than this whereas most women are shorter. The 50$^{th}$ percentile adult height in the general UK population is 176cm and 162 cm for men and women respectively (PeopleSize 2000). The cumulative frequency curve in figure 9 shows that over 95% of female drivers in the collision sample are shorter than 176cm. It is clear how poorly women are represented by the height of the 50$^{th}$ percentile male when it is used as the design or testing parameter for airbag and other safety systems.

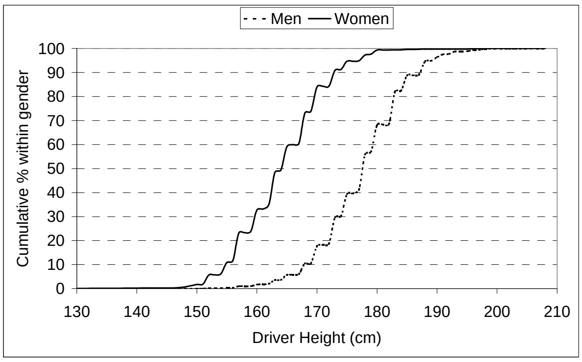


**Figure 9 - Cumulative frequency (%) of driver height (CCIS N=3267)**

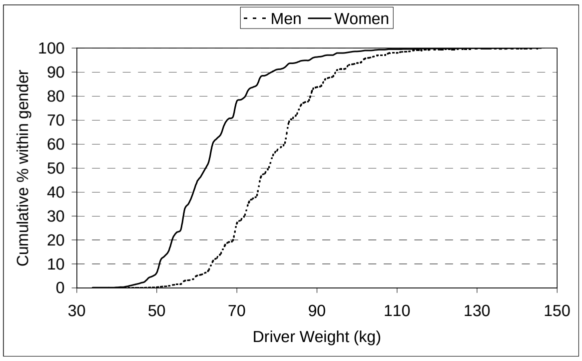


**Figure 10 - Cumulative frequency (%) of driver weight (CCIS N=3853)**

The 50$^{th}$ percentile weights for the general UK population are 78kg for men and 64kg for women (PeopleSize 2000). Over

90% of female drivers in the collision sample are lighter than 78kg (Figure 10) again showing how poorly they are represented by the weight of the 50th percentile male. Characteristics of the 50th percentile male are sometimes used in conjunction with those of the 5th percentile female. The height and weight of the 5th percentile female in the general UK population is 151.5cm and 49kg respectively (PeopleSize 2000) these figures being reflected in the collision sample. The 50th percentile male in conjunction with the 5th percentile female represents the extremes of the female driver crash population and does not cater for the average.

**INJURY –** At the national level, a difference is seen in the overall injury outcome between male and female drivers (Figure 11). Comparing the uninjured rates, women are considerably more at risk of receiving an injury than men. This difference is accounted for exclusively at the slight injury level (49% women, 31%men.) Men more frequently receive serious and fatal injuries, the respective male and female rates being 4.1% compared to 4.5% for serious injury and 0.4% compared to 0.2% for fatal injury.


**Figure 11 - Distribution of injury outcome by gender (STATS19 N=944,638)**

The remaining analysis in this section has been carried out on the UK in-depth accident data base. The reader is reminded of the weighting towards serious and fatal injury outcome that exists in this data. This is reflected in the injury severity distribution for drivers within the CCIS data (Figure 12). In this sample the proportion of drivers receiving no injury is much lower than for the national population. Significant differences exist in the injury severity between the genders (chi-squared test for equal distribution, p=0.00). Women in the sample are still more vulnerable to injury and there is an increase in the proportion of serious injury (28% men, 27% women) and fatal injury (6% men, 4% women) for both sexes, a product of the sampling criteria used for the in-depth database.


**Figure 12 - Distribution of injury outcome by gender (CCIS N-8,659)**

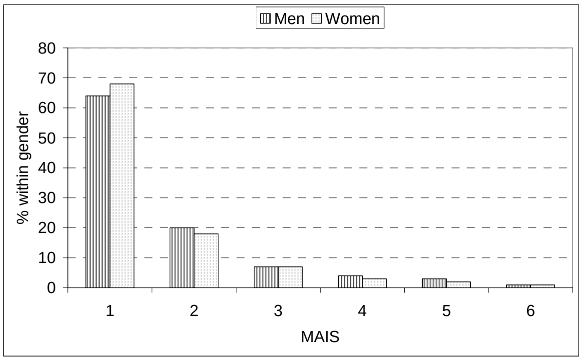


**Figure 13 - MAIS distribution for injured belted drivers (CCIS N=5149)**

Among injured restrained drivers, the difference between the sexes in injury severity as measured by MAIS is greatly reduced but still significant (Figure 13) (chi-squared test for equal distribution, p=0.005) The majority (over 60%) of injured drivers of both sexes had no injury higher than AIS level 1. 18% of women and 20% of men had an AIS 2 injury as their most severe. The proportion of men and women with an AIS level 3 injury is identical (7%). There is a slightly higher proportion of men with AIS 4+ injury than women.

**Table 3 - Summary of impact severity percentile for slight and serious injury outcome.**

| **Injury Severity** | | **Delta-V (km/h) Percentiles** | | |
|---|---|---|---|---|
| | | 25% | 50% | 75% |
| MAIS 1 | Male | 22 km/h | 29 km/h | 37 km/h |
| | Female | 21 km/h | 27 km/h | 33 km/h |
| MAIS 2+ | Male | 31 km/h | 44 km/h | 54 km/h |
| | Female | 31.5 km/h | 39 km/h | 52 km/h |

Table 3 shows the delta-V percentiles for male and female drivers at MAIS 1 and MAIS 2+ levels. Delta-V is the change of velocity during the impact. For the same change in velocity during impact, the acceleration pulse and several other factors relevant to injury are likely to be broadly comparable in smaller and larger cars. For frontal impacts however, the level of passenger compartment intrusion could tend to be greater in smaller vehicles than in larger vehicles due to the shorter crumple zone. This could to some extent generate higher injury outcomes for the drivers of small vehicles irrespective of gender. Whilst the $25^{th}$ percentile figures for delta-V are similar for men and women, the $50^{th}$ and $75^{th}$ percentile scores indicate that women are susceptible to both MAIS 1 and MAIS 2+ injury at a lower delta-V than men.

Looking broadly at overall injury severity within impact type a difference between the genders is apparent (Table 4). Here, each collision has been classified according to the most severe impact during the collision. The rollover category includes any collision during which a roll occurred.

**Table 4 - MAIS by impact type for male drivers**

| Injury Severity | Location of primary impact | | | | |
|---|---|---|---|---|---|
| | **Front** | **Right** | **Left** | **Rear** | **Roll-over** |
| MAIS 0 | 20.4% | 12.3% | 25.7% | 16.3% | 11.1% |
| MAIS 1 | 52.0% | 48.7% | 47.3% | 67.8% | 57.5% |
| MAIS 2 | 17.5% | 15.2% | 12.6% | 10.6% | 17.3% |
| MAIS 3+ | 10.1% | 23.7% | 14.5% | 5.3% | 14.0% |
| Total | 100%<br>N=2256 | 100%<br>N=519 | 100%<br>N=366 | 100%<br>N=227 | 100%<br>N=602 |

**Table 5 - MAIS by impact type for female drivers**

| Injury Severity | Location of primary impact | | | | |
|---|---|---|---|---|---|
| | **Front** | **Right** | **Left** | **Rear** | **Roll-over** |
| MAIS 0 | 7.6% | 9.5% | 14.4% | 9.5% | 5.7% |
| MAIS 1 | 61.2% | 58.9% | 60.5% | 80.4% | 70.3% |
| MAIS 2 | 19.5% | 15.8% | 10.2% | 6.1% | 13.8% |
| MAIS 3+ | 11.7% | 15.8% | 15% | 4.2% | 10.1% |
| Total | 100%<br>N=1151 | 100%<br>N=316 | 100%<br>N=167 | 100%<br>N=148 | 100%<br>N=246 |

For belted drivers, women are more vulnerable to injury across all impact types. The greatest difference in uninjured rates is seen for frontal impacts and for this impact type there is a higher proportion of women than men at all injury levels. In right side impacts, that is the driver's side, there is a higher proportion of women in all but the most severe injury category, MAIS 3+. For the remaining types of impact women are seen to be more susceptible at the MAIS 1 injury level and men more so at each of the higher levels.

Each type of impact presents its own challenge for vehicle and restraint design in terms of occupant protection. In order to adequately design a smart, adaptive restraint system an understanding of the different needs of the driver population is required. This in turn warrants exploration of the accident data for each impact type to determine more specifically the differences that exist between the genders.

It is not within the scope of this paper to report individually on each of the impacts, but we concentrate on that which occurs most frequently, frontal collisions. First we look to see if there are any obvious significant differences in the type of frontal collision suffered by men and women. Ideally there would be little difference in key descriptors of the collision so that the injury outcomes were clearly a product of gender rather than any other influencing factor.

Figure 14 shows the cumulative frequency curves of delta-V for male and female restrained drivers in frontal collisions.

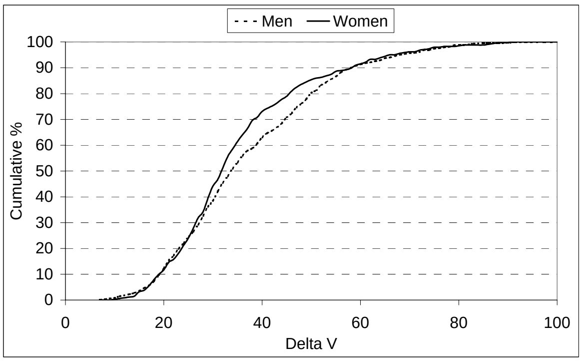


**Figure 14 - Cumulative frequency showing delta-V by gender (CCIS N=961)**

The null hypothesis that there is no difference in the mean delta-V between gender is accepted at the 95% significance level ($p=0.57$). However there is a visible difference between the 40$^{th}$ and 90$^{th}$ percentiles when the curve for female drivers rises more steeply than that of the male drivers. This indicates that a higher proportion of female drivers in frontal collision are injured at the lower end of the delta-V band corresponding to this inner percentile range, (30-60 km/h).

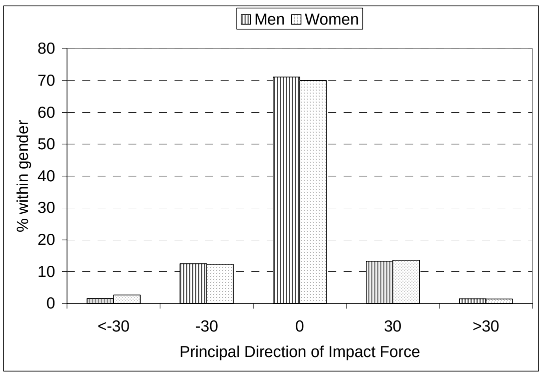


**Figure 15 - Distribution of principal direction of frontal collision force (CCIS N=2835)**

Figure 15 shows the distribution of the principal direction of the collision force. 0 degrees represents an impact force directly into the front of the vehicle.

The null hypothesis that there is no difference in the principle direction of impact force within gender is accepted at the 95% significance level (p=0.255)

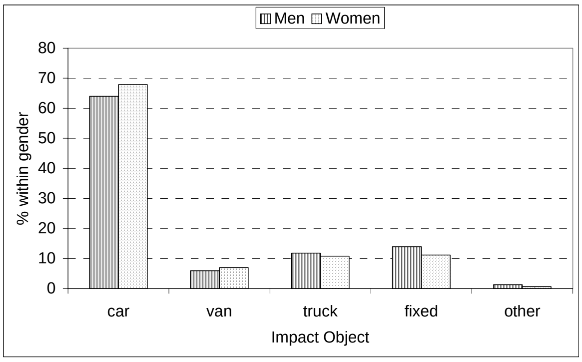


**Figure 16 - Distribution of frontal collision partner (CCIS N=2884)**

The null hypothesis that no difference exists in the collision partner between gender is accepted at the 95% significance level (p=0.06). Figure 16 shows that men have a slightly higher proportion of collisions with trucks and fixed objects whereas the proportion of car to car collisions is higher for women. As fixed objects and trucks are heavier and usually more rigid than passenger cars, these impacts can be quite aggressive.

**Table 5 - Delta-V percentiles for frontal collisions by injury severity and gender (CCIS N=2893)**

| **Injury Severity** | | **Delta-V (km/h) Percentiles** | | |
|---|---|---|---|---|
| | | 25% | 50% | 75% |
| MAIS 1 | Male | 22 km/h | 29 km/h | 38 km/h |
| | Female | 23 km/h | 29 km/h | 34 km/h |
| MAIS 2 | Male | 31 km/h | 41 km/h | 52 km/h |
| | Female | 29 km/h | 35 km/h | 44 km/h |
| MAIS 3+ | Male | 44 km/h | 53 km/h | 64 km/h |
| | Female | 41 km/h | 52 km/h | 65 km/h |

At the MAIS 1 severity level the 25th and 50th percentile values of delta-V are similar, but slightly higher at the 75th for men than women. There is a noticeable difference between the sexes in the 50th and 75th percentile delta-V for MAIS 2 drivers. The delta-V distributions for MAIS 3+ are similar, though women start to incur this severity of injury at a slighter lower crash severity than men. This indicates women have a lower delta-V threshold for AIS 2 injury, including many bone fractures.

Figure 17 shows the location of AIS 1 injuries for MAIS 1 drivers. An individual may receive an AIS 1 injury to more than one body region. The rate of injury to the head and arm is similar (30% and 40% respectively). The proportion of women with injuries to the leg, spine, abdomen, pelvis and chest is significantly higher than for men (chi-squared, 5df $\chi^2_{0.95}$=11.07, $\chi^2_{test}$=36.1, $p<0.05$). Whilst most of these injuries are bruises, abrasions and lacerations, the spinal injuries include a very substantial proportion of soft tissue neck injury (whiplash).

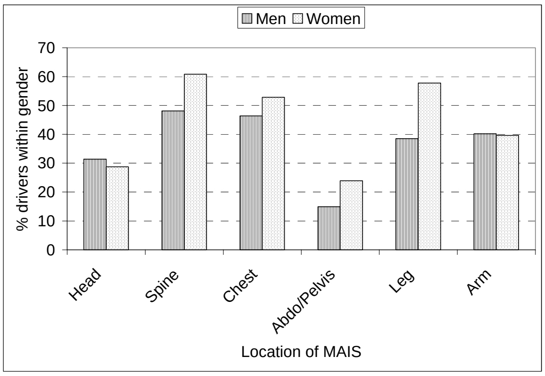


**Figure 17 - Location of AIS 1 injury for MAIS 1 restrained drivers in frontal collisions (CCIS N=1851)**

Figure 18 shows the location of AIS 2 injuries to MAIS 2 drivers. The difference between the genders are not statistically significant but still noticeable (chi-squared, 5df $\chi^2_{0.95}$=11.07, $\chi^2_{test}$=3.8, $p>0.05$). In the absence of whiplash injuries, the incidence of spinal injury diminishes though is still slightly higher for women. A higher proportion of men than women receive AIS 2 injuries to the head and arm, whilst AIS 2 chest and leg injuries are more prevalent among women. These AIS 2 injuries include many skeletal fractures and for the head include a brief loss of consciousness. For both sexes the chest is the region in which the highest proportion of drivers had an AIS 2 injury, which include many sternum and rib fractures.

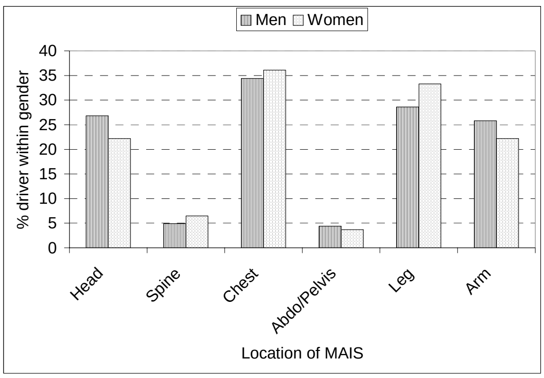


**Figure 18 - Location of AIS 2 injury for MAIS 2 restrained drivers in frontal collisions (CCIS N=603)**

At the MAIS 3+ injury level the chest remains the region in which the highest proportion of drivers had a maximal injury (Figure 19). A higher proportion of men have injury to the head and women to the chest and legs. Although the difference in this table is not statistically significant, it shows a consistent trend for restrained drivers (chi-squared, 5df, $\chi^2_{0.95}$=11.07, $\chi^2_{test}$=4.7, p>0.05).

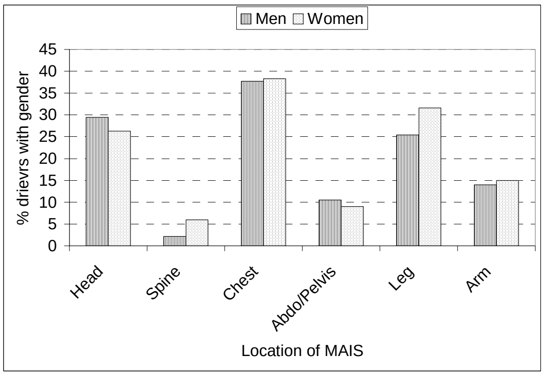


**Figure 19 - Location of most severe injury for MAIS 3+ restrained drivers in frontal crashes (CCIS N=358)**

## DISCUSSION

The results presented show that the driver population is distinctly bimodal in certain physical and behavioural attributes As the proportion of female drivers continues to grow there is an ever decreasing rationale for discriminating in favour of men in the design of vehicle structural and restraint systems.

Women have more collisions at the beginning and end of the working day, Monday to Friday and less across the weekend than men do. They are involved more frequently in collisions at junctions and have slightly more rear end collisions whereas men have a higher proportion of frontal crashes. Women also have proportionally more collisions during the months of October, November and February, a time associated with changes in lighting conditions across the peak hour. These circumstantial results are difficult to interpret as they are influenced by behavioural and sociological issues which in turn effect gender exposure. The effects of exposure at this level of detail are difficult to determine with the available data and further research in this area is required before many conclusions can be made.

It is clear that women tend to drive smaller and lighter cars than men, a situation that is intrinsically disadvantageous. Thomas (1999) concludes that the mass of a car is a key factor that determines injury outcome. Further research should be conducted to understand the underlying reasons behind this trend and to look for ways to address issues of compatibility at the vehicle design stage.

The female population is distinctly shorter and lighter than men, in the crash population as in the general population. The characteristics of the 50% percentile male roughly correspond to a 90th to 95th percentile female and so only the extremes of the female population are accounted for by either the 50th percentile male dummy or the 5th percentile female dummy that may be used in future crash tests. The physical differences between men and women have been suggested as an explanation for the greater vulnerability of women to injury.(Foret-Bruno 1990, Cerrelli 1994, Laberge-Nadeau 1993).

There is little significant difference in the type of frontal collision experienced by men and women, though men exhibit a slightly higher propensity towards more collisions with trucks and fixed roadside objects. Men are on the whole older as drivers than women are. Restrained female drivers are however more frequently injured at all severity levels than their male counterparts in frontal collisions. AIS 1 injuries are not generally associated with impairment but those to the spine include a high proportion of neck strain, which can cause a great deal of pain for substantial periods following the crash. The difference in neck musculature between men and women is often suggested to be an important factor in neck injuries (Cerrelli 1994, Laberge-Nadeau 1993). Whilst women consistently have a higher incidence of spinal injury men have a higher proportion of head injury. Further research would be required to see if these were causally related, for example by head contacts for men preventing a spinal injury occurring. Foret-Bruno (1990) in a study of the risks of thorax injury to belted occupants in frontal impacts concluded that female skeletons are less able to sustain the same stresses as males. The data presented in this paper shows women to have a higher propensity toward skeletal chest injury and that these injuries occur at a lower delta-V than for men. The fact that differences exist between the rate of injury to men and women again points to the desirability of optimised restraint systems. It is recognised that changes aimed at reducing the occurrence of skeletal chest injury to women, such as more flexible seat belts, could be at the expense of men who might be heavy enough to stretch further forward and make injurious contact with frontal components of the passenger compartment.

Ideally a number of physical or computer-simulated crash tests should be developed that accommodate the difference in male and female characteristics. This in conjunction with further results from real world accident data would allow for vehicle design that truly benefited the whole population.

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