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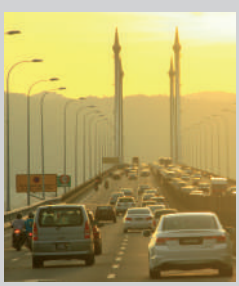

Research Report

Analysis of Front and Rear Passenger Car Occupant Injuries Involved in Road Crashes

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Contents

List of Tables

List of Figures

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Abstract

In Malaysia, passenger car comprises 40% of all total registered vehicles on the roads and account about 3000 fatalities every year. Although many studies already documented the injury pattern of passenger car crashes, nevertheless the differences in injury pattern between front-seated and rear-seated passengers are still missing. Thus, this study was conducted to specifically analyze the injury severity among front-seated and rear-seated passengers.

The data were collected retrospectively from closed files of the third-party bodily injury (TPBI) insurance claims database for the period 2011 – 2015. A systematic random sampling technique was used to select the cases due to the large sampling frame.

In summary, the results indicate that the different seating position produced different injury type. Extremities and thorax injuries were mostly found on the driver while head and face injuries were mostly found among front and rear passenger. In comparison between all seating position, front passenger had the highest percentage of severe injury. Further study using more complete dataset is needed to better understand the association between vehicle safety features such as seatbelt, airbag and injury severity for different seating positions.

1. Background

In a car crash, an occupant's injury pattern and severity may vary depending on the different crash impact and his/her seating position. Studies using various methods have found that rear-seat occupants in passenger cars face a lower risk of death or injury compared to the front-seat occupants (Evans & Frick, 1988; Braver et al., 1998; Berg et al., 2000; Glass et al., 2000). In the U.S., only a small number of rear-seat occupants were reported to have died or sustained severe injuries (USDOT, 2010) as the number of rear-seat occupants in the country was relatively lower compared to Europe or other developed countries (Trowbridge & Kent, 2009). Therefore, more focus and attention have been given to protect the front-seat occupants while the injury countermeasures and efforts to understand the risk factors to the rear occupants have been neglected.

However, a study by Durbin et al. (2015) posited that rear-seated occupants may be more vulnerable to injury than front-seated occupants, who are protected by advanced safety technology. This suggests that attention needs to be shifted to the rear-seat occupants as well. As mentioned in Liu and Pressley (2016), most studies of rear occupants have focused on child occupants, specifically emphasizing the use of child restraints or booster seats; while overlooking the safety of adult rear occupants. Further, recent studies (Kuppa et al., 2005 and Bilston et al., 2010) have indicated that the risk of fatality and injury is high when an older person occupy the rear seat. This suggests a strong relationship between age factor and the injury severity to a rear-seat occupant.

During side crashes, the initial point of impact and crash side relative to an occupant seating position play important roles to the rear occupant's injury severity. Teoh and Lund (2011) said that drivers of vehicles with "good" safety rating were reported to be 70% less likely to die inside crashes compared to those in poorly rated vehicles. However, Raneses and Pressley (2015) noted that older rear-seat adult occupants registered a different outcome than front occupants in fatal side collisions. All these findings suggest that there is a difference in terms of the injury severity to the front and rear occupants.

Perhaps, the various vehicle technologies on the current passenger cars may be related to the injury differences between the rear and front occupants.

The disparity in injury patterns among passenger car occupants was not only found between rear and front passengers. The injury pattern among rear occupants may also differ depending on the crash impact direction. According to Samaha and Elliott (2003), same side crashes were reported to have a higher serious injury and fatality rates compared to other crash types. In same side crashes, occupants seated on the same side of the crash were more likely to suffer severe or fatal injury compared to occupants on the opposite side or in the middle seat; after controlling for seat belt status (Raneses & Pressley, 2015).

In Malaysia, passenger cars make up 40% of the total registered vehicles on the road and are involved in about 3000 road traffic deaths every year. Although many studies have documented the injury pattern in passenger car crashes, findings on injury pattern differences between front- and rear-seat passengers are still lacking. This warrants for a detailed study to be conducted on the injury severity among the front- and rear-seat car occupants.

2. Methods

Data for the study were collected retrospectively from closed files of the third-party bodily injury (TPBI) insurance claims database for the period 2011 – 2015. A systematic random sampling technique was used to select the cases due to the large sampling frame. Out of the available and archived data, a total of 500 car crash cases involving third party claimants were identified. Information regarding the demographic data, crash narratives and injury details were retrieved from various sources including police, adjuster, medical, opinion and assessment reports available for the selected cases.

Narratives of the accidents retrieved from the police report and adjuster report were enough to provide information on the crash circumstances. Meanwhile, the medical report in the database provided adequate injury information for each of the car victims. The data for each case was retrieved from a database provided by the insurance company named Merimen system. A complete set of each case containing all the above-mentioned reports was systematically stored in the system.

In the study, the injury information was related to the car occupants involved in an accident. Injury to the body region and severity coding used in the study was based on the Abbreviated Injury Scale (AIS), updated version 2008. AIS is an anatomical injury scoring system ranging from minor (AIS 1), moderate (AIS 2), serious (AIS 3), severe (AIS 4), critical (AIS 5) to maximum (AIS 6) severity. It was originally developed to measure injury severity for blunt force trauma received during motor vehicle crashes. AIS codes were assigned using medical records supplied in the data. In order to minimize AIS coding error, two personnel trained to code AIS were dedicatedly assigned over the study period to code the injuries.

Maximum Abbreviated Injury Scale (MAIS) was then utilized to determine the level of injury severity. MAIS is the greatest AIS injury sustained by an occupant. Car occupants may have multiple injuries of varying severity and may have more than one injury with

the greatest MAIS. Injury cases with MAIS less than three are categorized as mild, while MAIS 3 and above are considered severe.

3. Results and Discussions

Out of the 500 cases selected, there were 436 drivers, 280 front passengers and 196 rear passengers with the incidence of injuries or fatalities. Table 1 shows the distribution of occupant's injuries and fatalities according to seating positions. The distribution of injury severity and fatalities was consistent among all three categories with the proportion of fatalities accounting for about 6% across all occupant types. The drivers registered the highest proportion of serious injuries compared to the occupants in other seating positions. In terms of fatalities, the most common causes of death were polytrauma, head injuries and thorax injuries.

Table 1 Distribution occupants' injuries and fatalities by seating position

Occupant	AIS≤2 N (%)	AIS≥3 N (%)	Fatal N (%)	Total
Driver	336 (77.1)	71 (16.3)	29 (6.7)	436
Front passenger	226 (80.7)	39 (13.9)	15 (5.4)	280
Rear passenger	163 (83.2)	22 (11.2)	11 (5.6)	196

Figure 1 shows the age distribution among the car occupants according to their seating position. For drivers and front occupants, the highest percentage was for the 25 – 29 years age group, followed by the adjacent groups (Figure 1). Rear-seat occupants differed markedly from front-seat occupants with regard to their age with the majority of rear occupants ranging from children to adolescents ages 1 – 17 years; with the highest percentage of occupants being between 0 and 4 years. Adults only accounted for about 40% of the rear-seat occupants. This finding was similar to previous research where more than half of all rear occupants were below the age of 13 years, and 3 out of 4 were younger than 20 years (Durbin et al., 2015).

Figure 2 to 4 show the occupants' injury severity in relation to their seating position and age. Driver injury severity was almost identical across all age groups. Compared to

younger adults (age 18 – 34), older adults recorded a higher proportion of injury severity (AIS 3+). For front passengers, the age group with the highest proportion of severe injury was 18 – 34 years. For rear passengers, the most vulnerable age group to suffer severe injury was 55+ years, with nearly 30% of the victims in the group registering AIS 3+ injury.

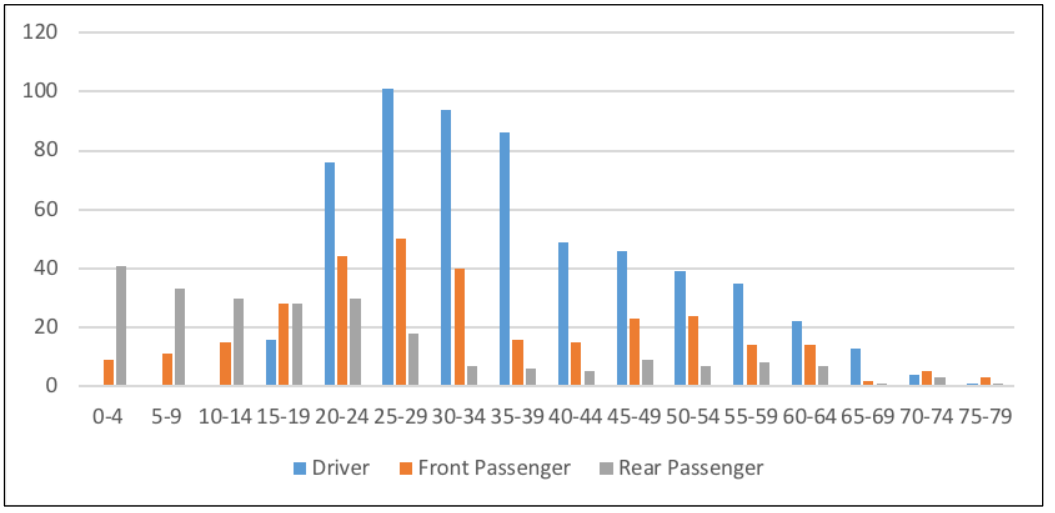

Figure 1 Distribution of occupant age by seating position

The distribution of severe and fatal injury to children below 9 years was not much different for front- and rear-seat positions. However, for children ages, 10 to 17, the proportion of severe and fatal injury was much higher for those in the rear position (10.7%) compared to the front position (19.4%). The finding in this study was comparable to a previous study that showed children below 9 years being better protected in the rear-seat compared to the front-seat.

For adults over 55+ years, almost 30% of them in the rear-seat position suffered severe injuries and fatalities as opposed to being in the driver position (24.1%) and front passenger position (16.7%). The findings mirror a previous study that showed older adults being less safe in the rear seats, as they faced the highest risk compared to other age groups for both serious and fatal injury incidences (Durbin et al., 2015).

Figure 5 shows the injury severity according to gender and seating position. Although, most front-seat occupants (64.3%) were female, a bigger proportion of passengers with severe injury was for male occupants. There was no difference in the proportion for passengers with severe injury in the rear seating positions.

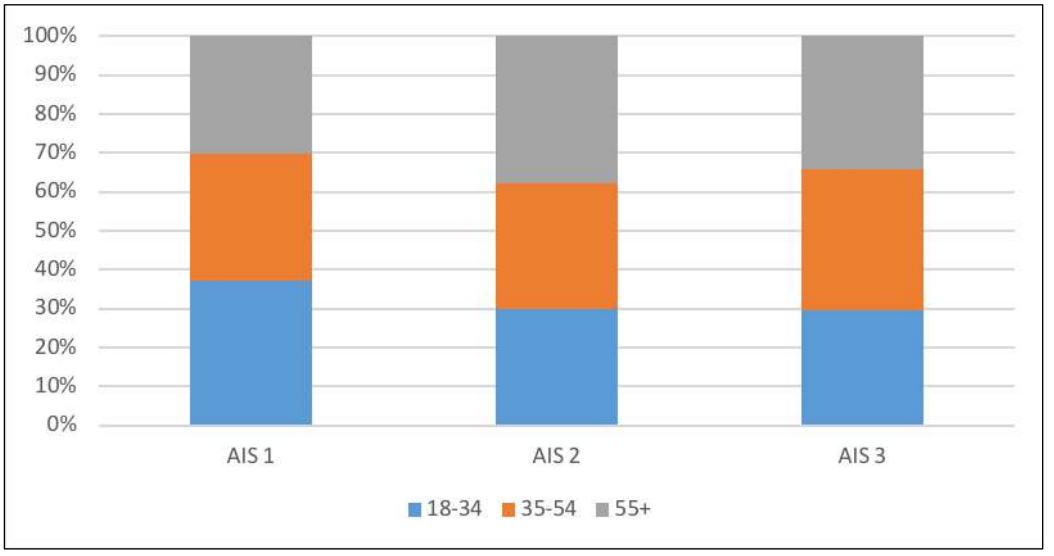

Figure 2 Distribution of driver passenger injury severity by age

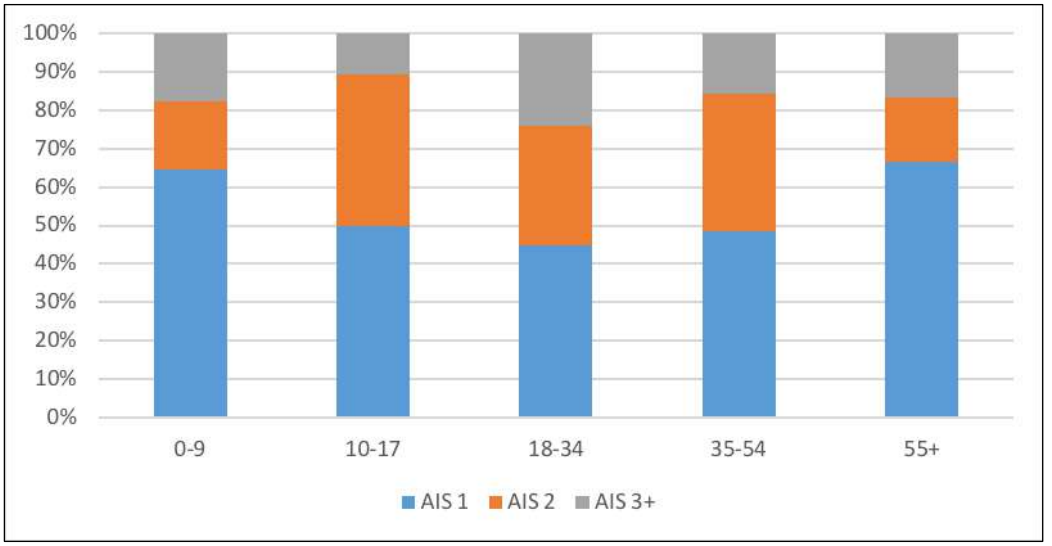

Figure 3 Distribution of front passenger injury severity by age

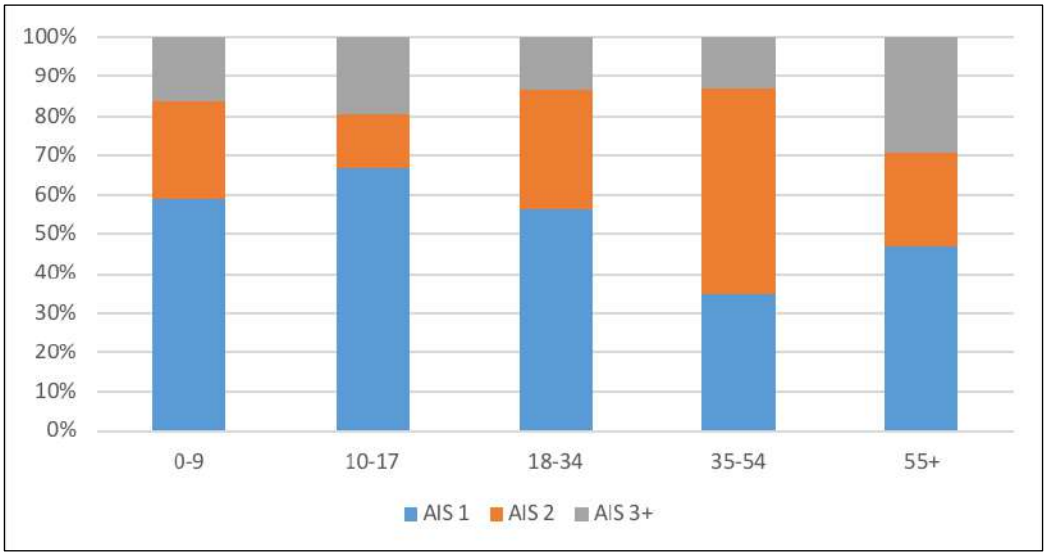

Figure 4 Distribution of rear passenger injury severity by age

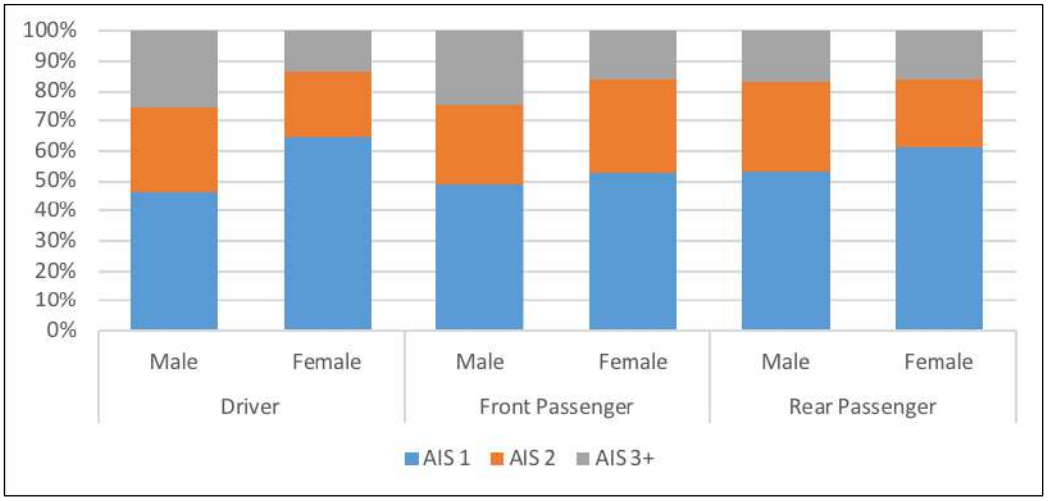

Figure 5 Distribution of occupant injury by gender and position

Overall, injuries to lower and upper extremities followed by head and face were the commonest across all occupant positions. Injuries to the neck were very few and were suffered by only about 5% of the car occupants in each position. Figure 6 shows the distribution of AIS≥3 injured occupants by body region and position. The distribution of injured body region was nearly identical for all positions except that the rear occupants had a significantly higher proportion of head injuries compared to the driver and front passenger. For AIS≤2 injured occupants, there was a difference in injury distribution by body region between each position. Compared to the driver, the front passengers and the rear occupants had a higher proportion of head injuries relative to lower extremity injuries (Figure 7). In addition, the proportion of thorax injuries to the rear occupants was significantly lower compared to the drivers and front passengers.

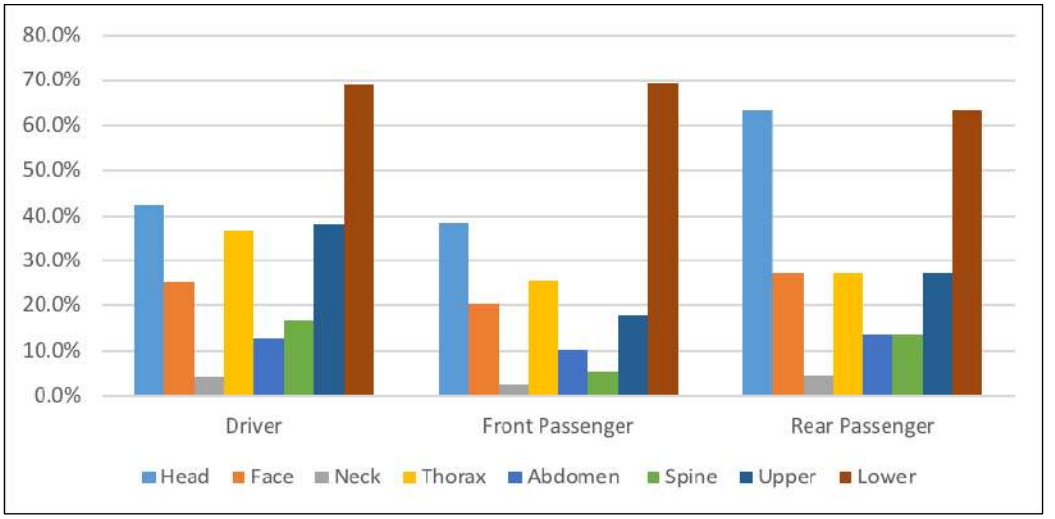

Figure 6 Distribution of MAIS≥3 occupants' injury by body region and position

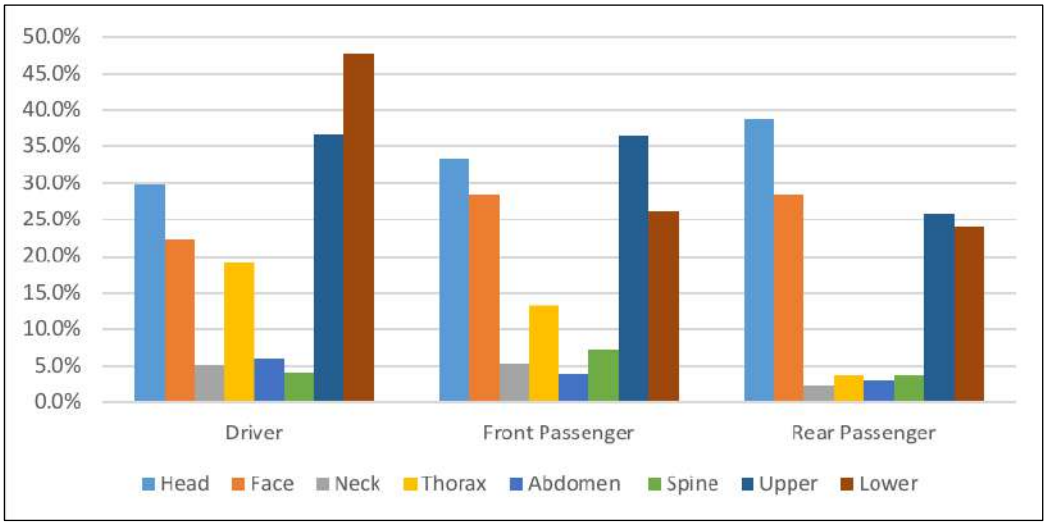

Figure 7 Distribution of MAIS≤2 occupants' injury by body region and position

In terms of gender, 80% of the total drivers were male, 64% of the total front passengers were female and 54% of the total rear passengers were female. This finding is comparable with a previous study (Nedic et al., 2015) noting that drivers were mostly male while front- and rear-seat passengers were mostly female. Moreover, the majority

of male drivers mirrors the findings of other studies (Cuerden et al., 1997; Morgan, 1999; Shimamura et al., 2004) where more than 60% of the drivers were male.

Figure 8 shows the driver injury distribution by body region and gender. Both male and female driver manifested a similar injury distribution with lower and upper extremity being the commonest of injuries. In most body regions, male drivers registered a higher proportion of injury compared to female except for the neck and abdomen.

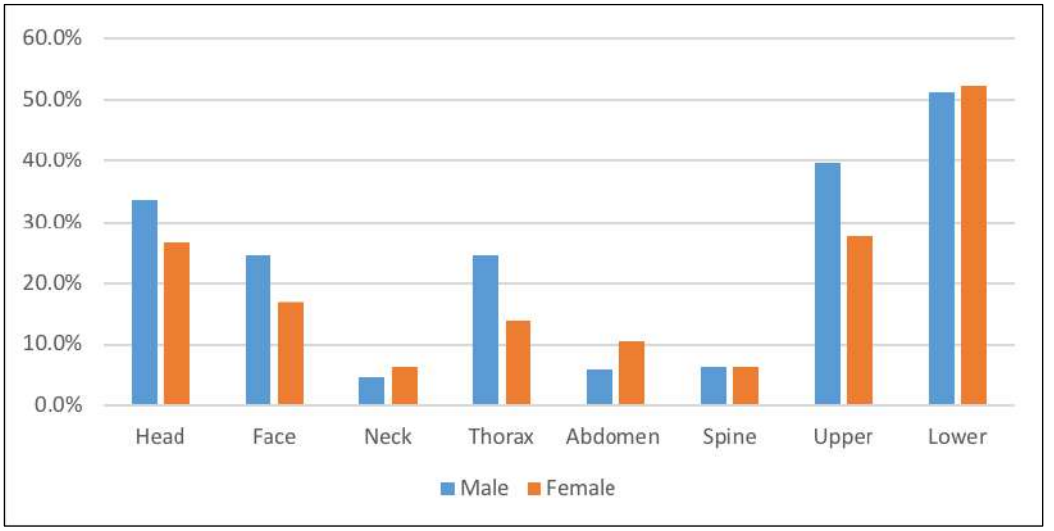

Figure 8 Distribution of injury of driver by body region and gender

Figure 9 shows the front occupant injury distribution by body region and gender. The proportion of female front passengers' head injuries were significantly higher compared to male front passengers with more than 60% of the female front occupants suffering head injuries compared to male with 30%. Moreover, the female front occupants also suffered higher injuries proportion compared to male for the neck, thorax, abdomen and spine regions.

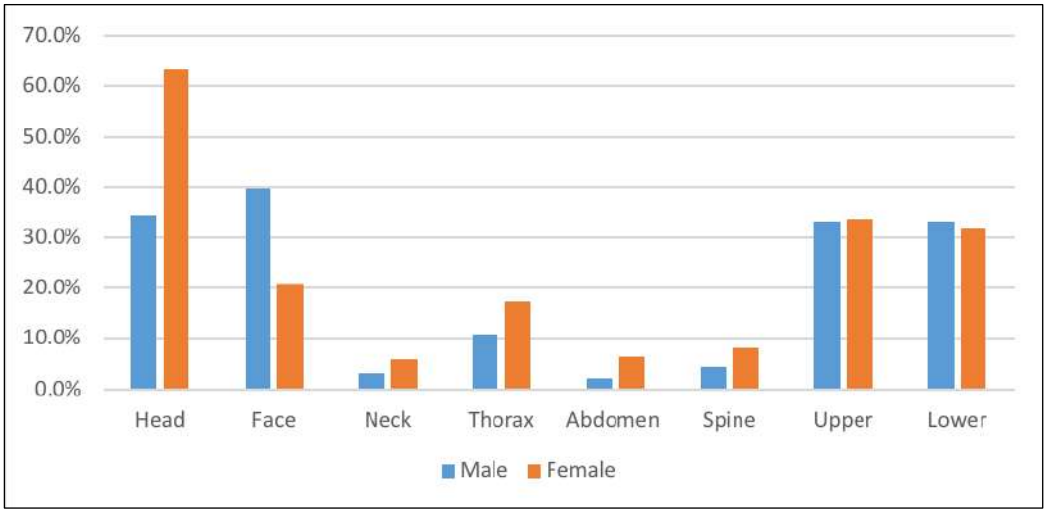

Figure 9 Distribution of injury of front passenger by body region and gender

Figure 10 shows the rear occupants' injury distribution by body region and gender. Female rear occupants had a higher proportion of lower extremity injuries compared to male. Across all seating positions, face injuries consistently had a higher proportion for the male occupants compared to the female occupants. Conversely, female occupants consistently had a higher proportion of neck and abdomen injuries compared to the male occupants for all seating positions.

It was reported that female occupants consistently recorded a higher incidence of spinal injury whilst male occupants had a higher proportion of head injury. However, the findings of the study indicated that for front passengers, female occupants had a higher proportion of both head and neck injuries compared to male occupants. 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).

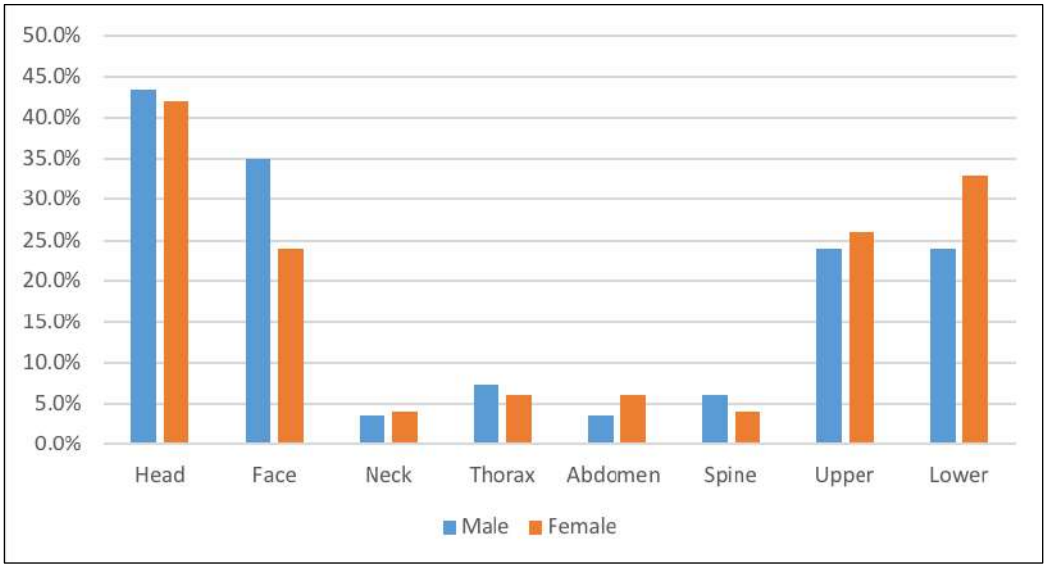

Figure 10 Distribution of injury of rear passenger by body region and gender

Table 2 shows the characteristics of severely and non-severely injured occupants involved in crashes. The non-severe and severe-injury groups did not differ in terms of age and seating position. However, severe injuries were more often reported for male occupants than for female occupants (p = 0.002). Table 3 contains the results of odds ratio analysis. When a comparison was made between the seating positions, male drivers were 2 times more likely to be severely injured in crashes compared to female drivers (OR 2.2, 95 % CI 1.165 – 4.136). No significant difference between gender injury severity for front and rear passengers were observed. Kim et al. (2016) also reported that severe injuries were more often reported for male than for female patients.

Table 2 Characteristics of severely and non-severely injured occupants involved in crashes

Variable	Non-severe injury n = 724, (%)[a]	Severe injury n = 187, (%)[b]	p value[c]
Age, mean ± SD (years)	32.6 ± 16.5	33.9 ± 16.4	0.341
Position			
Driver	336 (46.4)	100 (53.5)	0.186
Front passenger	226 (31.2)	54 (28.9)	
Rear passenger	162 (22.4)	33 (17.6)	

Gender			
Male	400 (55.5)	127 (68.3)	0.002
Female	321 (44.5)	59 (31.7)	

a Non-severe injury was defined as ISS ≤14

b Severe injury was defined as ISS ≥16

c Categorical variables were compared by $\chi 2$ test and Fisher's exact test, and continuous variables were compared by student's *t*-test

Table 3 Odd ratio of severe injury between gender in all seating positions

Variable	Odds ratio (95% CI)	*p* value
Driver		
Female	Reference	
Male	2.195 (1.165 – 4.136)	0.015
Front passenger		
Female	Reference	
Male	1.736 (0.950 – 3.170)	0.073
Rear passenger		
Female	Reference	
Male	1.066 (0.498 – 2.283)	0.869

In contrast to the study findings, Welsh and Lenard (2001) found that restrained female drivers were more frequently injured at all severity levels than their male counterparts across all impact types. In addition, Bose at al. (2011) found that the odds for a belt-restrained female driver to sustain severe injuries were 47% higher than for a belt-restrained male driver involved in a comparable crash. The current finding is not directly comparable to the previous studies as the drivers selected were not exclusively identified to have used the seatbelt.

Several characteristics of our data may have contributed to an attenuation of the observed risks of serious injury associated with front seating. Unlike in the US studies, most vehicles in this study were not equipped with passenger frontal airbags. Perhaps, this explains the high number of drivers who sustained thorax injuries compared to those in other seating positions.

Our study has a few limitations. Data on restraint use were unavailable for the study sample. Thus, in this study, injury reduction due to the use of seatbelts could not be ascertained and compared with previous studies in the literature. The effects of an airbag deployment, crash severity and crash direction were also not investigated.

4. Conclusions

In summary, the study indicates that the different car occupant seating positions produced different injury types. Extremities and thorax injuries were mostly recorded among the drivers while head and face injuries were mostly found among front and rear passengers. Comparing across all the seating positions, the front passenger had the highest percentage of severe injury. A further study using more complete dataset is needed to better understand the relationship between vehicle safety features (such as the seatbelt, airbag) and injury severity for different seating positions.

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