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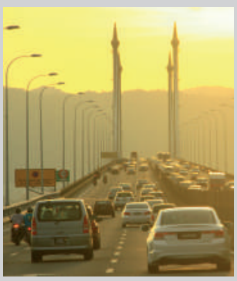

Research Report

Effect of Seatbelt Wearing on Injury Severity in Passenger Vehicle Fatal Collisions

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Abstract

Seatbelt wearing is among the major determinant of occupant survivability as road traffic collision is discussed. In Malaysia, very limited information can be found on seatbelt wearing compliance and its effect on injury severity. In this study, an examination of the actual passenger vehicle collision data was conducted among crashes investigated by the Malaysian Institute of Road Safety Research (MIROS). The data includes cases within 2007 and 2014. The result indicates very low seatbelt compliance among the crash victims. It was revealed that injuries and fatalities are more prominent between unbelted occupants. The data demonstrate that survivability is slight increases if seatbelt was utilised, even in a severe collision. In view of injury levels, belted occupants are less likely to suffer a higher level of injury severity as compared to those unbelted. Pearson chi-square and logistic regression analysis were performed to evaluate the factors associated with seatbelt wearing and injury severity. As a result, the behaviour of seatbelt wearing was found to be positively associated with occupant gender, seating position and age. Whereas, vehicle deformation extent and vehicle mass were determined to be associated with survivability. These findings could assist the road safety practitioners as well as decision-makers in gaining further insight into the real seatbelt wearing scenario and the resulted injury among the crash victims involving in fatal crashes on Malaysian roads.

1. Introduction

Death due to road traffic collision has been recognised as a worldwide public health problem. While travelling in a vehicle, a sudden change in vehicle speed as a result of collision may cause injuries to the occupant. This collision involves three (3) different mechanisms, which are the vehicle-collided object, occupant-vehicle interior parts and internal organs-chest wall/skeletal structure. According to Krug et al. (2009), the second mechanism contributes to the worst injury severity level. Correspondingly, the seatbelt was intervened to minimised this relative movement, between vehicle and occupant.

In Malaysia, the importance of seatbelt was recognised almost 50 years back. This is reflected by the enforcement of mandatory use of seatbelt law in 1978. However, this initial enforced law only covers for drivers and front-seat passengers. This law was then extended to the rear passengers on the 1 January 2009**,** about 30 years later. This slow progress on seatbelt enforcement has limited its widespread use among Malaysian (Kulanthayan et al., 2004).

Several studies can be found focusing on Malaysian seatbelt wearing data. Norlen et al. (2010) reported low seatbelt compliance among road users in Putrajaya, especially for the rear occupants. A similar study in 2011 (Mohamed et al., 2011), covering wider locations beyond the administrative centre of Putrajaya, also reported the low rear seatbelt usage. A more recent seatbelt study, which was conducted during Ops Selamat 7/2015, reported a decrease in seatbelt wearing rate as compared to the previous Ops Selamat. This finding exhibits an alarming situation on seatbelt wearing behaviour among Malaysian road users.

Ng et al. (2013) revealed that age, gender, driving experience and education level have a significant effect on seatbelt wearing compliance. In contrast, Mohamed et al. (2011) found no association between wearing rate and education level. Otherwise, the same report reported that factors like the seatbelt enforcement activities, seatbelt knowledge and attitude towards seatbelt compliance have a significant influence on the seatbelt wearing rate. It can be observed that these studies are actively conducted within the past ten years, in which a limited publication can be found before. Limitation of these studies are mainly on the analysed data, which is based on the self-reported approach and observation survey method. Therefore, the correlation between seatbelt wearing and resulted injury could not be performed.

The lack of actual Malaysian crash data in the existing seatbelt studies has led to the execution of this study. It is essential to understand the real scenario in Malaysia on seatbelt wearing compliance and the effect of seatbelt wearing on the crash casualty. In this study, factors associated with seatbelt wearing as well as injury severity were also evaluated. Furthermore, this report identifies possible countermeasures to tackle the highlighted associated factors.

1.1 Objectives

This study aims to:

i. Determine the effect of seatbelt wearing on survivability
ii. Identify seatbelt wearing associated factors
iii. Identify survival associate factors

The outcomes of this study are the identification of possible countermeasures. This would assist in supporting relevant policies to be adopted at the national level.

1.2 Scope and Limitation

The study was conducted for high profile passenger vehicle crashes investigated by the MIROS Crash Reconstruction Unit from 2007 until 2014. In particular, it involves passenger vehicle crashes with three (3) fatalities and above. The crash investigation was covering areas of Peninsular Malaysia, Sabah and Sarawak based on news reported in the Media Portal.

Limitation in this study includes several factors. First, data collected is based on vehicle availability during the crash investigation; otherwise, the case was excluded in the analysis. Second, seatbelt wearing compliance was determined based on investigators individual judgement, which was performed based on the observation of physical evidence. Therefore, a variation of opinion may exist during the examination. However, the difference is minimised by practising the MIROS crash investigation procedure.

2. Literature Review

In this section, variables that have been reported having a significant influence on seatbelt compliance and occupant survivability were reviewed. It was divided into two (2) main subsections which are occupant and vehicle variables.

2.1 Occupant Variables

Occupant behaviour in seatbelt wearing is determined by individual preference. However, this preference is affected by several aspects. Various studies were conducted to gain insight into this aspect. Predictors related to occupant variables, which were mainly observed in seatbelt prevalence studies include gender, seating position and age.

In view of gender, several studies have reported that violation of seatbelt compliance is more dominant between males. According to a retrospective review of two years motor vehicle crashes patient data in the USA, 55% of men were unbelted (Lerner et al., 2001). Boakye et al. (2018) through an observation survey, focusing on front seat passengers travelling at night also revealed a similar finding. Otherwise, females are found to be more likely to wear seatbelts (Vecino-Ortiz et al., 2014). On top of the high seatbelt wearing rate among females, a safer seatbelt system is required for pregnant women to minimise the risk of seatbelt-neck contact (Hitosugi et al., 2017). Yamada et al. (2017) suggested a thorough examination of pregnant women who suffers seatbelt injuries, to prevent intrauterine fatal death.

The second seatbelt wearing predictor is the seating position. In China, drivers showed the highest rate of seatbelt compliance, followed by front-seat passenger and rear-seat passenger (Huang et al., 2011). A similar trend was reported by Lerner et al. (2001) and Kulanthayan et al. (2004) through a study conducted in the USA and Malaysia, respectively. However, Briggs et al. (2008) identified factors such as gender, race and academic background are associated with seatbelt compliance among US high school student regardless of seating position.

This dissimilarity demonstrates that seatbelt wearing factors may differ between region and community group. A roadside interview conducted in two different regions in Turkey (Milder et al., 2013) demonstrates this scenario, in which a wide gap of awareness level was evaluated between Ankara and Afyonkarahisar, even though both are in the same country. An observational study conducted in four countries (Vecino-Ortiz et al., 2014) including Egypt, Mexico, Turkey and Russia also exhibits a significant variance of seatbelt wearing rate between countries. The reason may be due to the difference in system, behaviour, background and other related local culture. For example, it was revealed that seatbelt enforcement activity could increase road user perception of being caught and increase their seatbelt compliance. Ones with experience of being caught by an enforcement officer for not wearing rear seatbelt poses a higher tendency to fasten seatbelt (Mohamed et al., 2011).

In terms of age, very low compliance among children was reported in China (Huang et al., 2011). Similarly, Briggs et al. (2008) found that younger students in the US have a higher tendency not to wear seatbelt while travelling in a vehicle. By comparing all age ranges, it was demonstrated that seatbelt wearing rate increases as occupant age increases (Lerner et al., 2001; Milder et al., 2013). These consistent findings reflect that maturity stage may affect the seatbelt wearing decision.

According to The National Institute of Mental Health (2011), brain development evolves and looks like an adult only at the early 20s. In another study made by Salthouse (2010), the author discovers that the deterioration of human mental performance starting at the age of 60. By referring to an article by BBC (2011), the maturity age of a brain can be summarised according to human growth. An introduction of mental development (introduction stage) is at the age of born until the age of 10, while the growth of mental development (growth stage) is at adolescence stage age of 11 to 17 years old. The mature phase of a mental (mature stage) is at adulthood stage of human growth, 18 to 60 years old, while declining of human mental (decline stage) is at the age of 60 until death. Definition of each category is listed in Table 1.

Table 1 Definition of age classification by maturity stage

Maturity stage	Definition
Introduction	born until 10 years old
Growth	11 to 17 years old
Mature	18 to 60 years old
Decline	60 years old to death

*The National Institute of Mental Health (2011), (Salthouse, 2010) and BBC (2011)

Other variables that were determined associated with seatbelt compliance are race, income level (Lerner et al., 2001) and driving behaviour such as drinking and driving (Briggs et al., 2008). Also, Boakye et al. (2018) reported that travelling time, particularly at late night, also led to the high non-compliance. A self-reported survey among young drivers in Athens, Greece (Chliaoutakis et al., 2000) highlighted that seatbelt usage corresponded to drivers' imitation to their surroundings, i.e. family, friends and co-driver, self-protection awareness and legality attitude towards law and regulations. The imitation factor is consistent with findings reported by Boakye et al. (2018), in which unbelted drivers have a significant influence on the unbelted front passenger. These variables are interesting to be highlighted in advocacy programs to increase awareness.

2.2 Vehicle Variables

Injury severity is believed to be highly correlated with vehicle crash severity and compatibility. A crash vehicle severity is generally classified by the deformation extent based on Collision Deformation Classification (SAE J224, 1980). Figure 1 shows deformation extent classification by impact type, which is frontal, side and top impact. The rear impact is taking similar classification as frontal but in the opposite direction. As for the side impact (figure indicates nearside impact), the opposite direction applies to the offside impact.

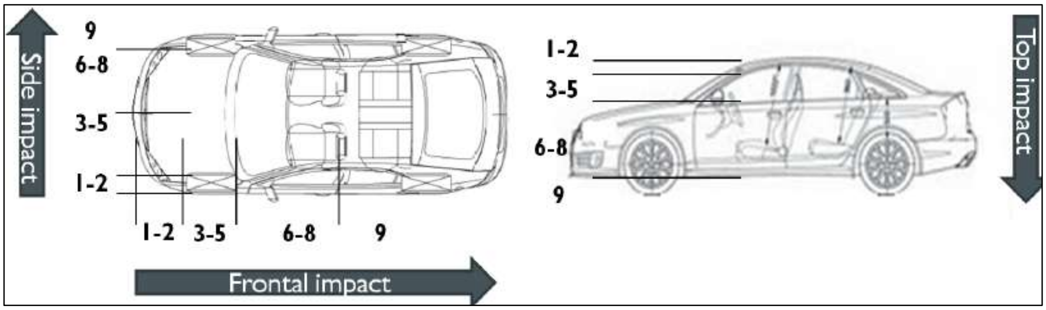


Figure 1 Deformation extent classification by impact type (Collision Deformation Classification, 1980)

The other element observed is vehicle compatibility. According to the Code of Federal Regulations (2013), passenger automobiles are classified by interior volume index or seating capacity (40 CFR 600.315-08, 2011) as listed in Table 2. Passenger car, multipurpose vehicle (MPV), sport utility vehicle (SUV) and van are differing in its volume and capacity. Meanwhile, in this classification, the passenger car is further classified by its curb weight. It was evidenced in a physical study conducted by the Insurance Institute for Highway Safety (Nolan, 2013), which found that the mass and size of a vehicle have an inverse relationship with occupant injury risk in crashes.

Table 2 Automobile vehicle classification (Code of Federal Regulations, 2013)

Automobile vehicle	Belted	Curb weight
Passenger car	Mini	680–907 kg
	Light	908–1134 kg
	Compact	1135–1360 kg
	Medium	1361–1587 kg
MPV		Manufacturer classification
SUV		Manufacturer classification
Van		Manufacturer classification

Despite its association with injury, vehicle aspect was also found to be associated with seatbelt wearing. A study conducted in East Tennessee (Boakye et al., 2018) reported that males occupying passenger cars and pickup trucks have a higher tendency to unbelted while travelling. Likewise, in Malaysia Mohamed et al. (2011) through roadside observation and survey found that rear passengers of Multipurpose Vehicle (MPV)/Sport Utility Vehicle (SUV) were two (2) times more likely to wear seatbelts as compared to rear passengers of a car.

In this study, the reported variables, including occupant and vehicle, were evaluated for Malaysian seatbelt wearing data based on MIROS crash investigations. Details of the analysis and evaluation were described in the following section.

3. Methodology

This study involves MIROS crash investigation data, particularly on passenger vehicles. These passenger vehicle crashes are the high profile crash cases investigated by MIROS crash reconstruction unit from the year 2007 until 2014. The high profile crashes refer to the passenger vehicle collision resulting in three (3) fatalities and above.

This study focuses on frontal cases because seatbelt is designed best for the frontal collision. Therefore, the evaluation of seatbelt effectiveness will involve those cases. In addition to the universal occupant variables such as gender and age, other crash data, including seatbelt wearing, injury severity of the crash victim and collision deformation, will be acquired.

Determination of seatbelt wearing will be carried out based on the respective crash physical evidence. It was determined through observation of abrasive marks on seatbelt webbing or other parts of the belting system. Figure 2, shows an example of the abrasive marks left on the seatbelt, as the seatbelt wearing indication.

As for injury severity, it was classified according to their level of severity, which is fatal, severely injured, slightly injured or uninjured. Severe injury refers to the cases which require the patient to be admitted in a hospital for further medical treatment, while the slight injury is otherwise. In contrast, uninjured crash victims are those who did not require any treatment. Where appropriate, the fatality rate was determined and correlated with occupants and vehicle variables in evaluating their association. It was calculation as in Eq. (1).

$$Fatality\ rate = \frac{Fatality}{Total} \times 100\% \qquad (1)$$

Figure 2 Abrasive marks indicating seatbelt wearing

Crashed vehicle impact was then determined according to SAE J224 (1980). Information on the severity of the crash impact will be obtained based on the Collision Deformation Classification for the most significant impact sustained by each vehicle in a crash case. Table 3 summarised the deformation extent classification and its represented value, which was utilised in the analysis section. In this study, vehicle severity is labelled 1 as mild vehicle intrusion without interrupting occupant compartment. The second level of severity denoted as 2, comprised of 4 to 5 deformation extent. At this level of intrusion, indirect damage may be experienced at the front passenger compartment. The third level of severity denoted as 3, directly involves deformation up to the front passenger compartment, with deformation extent of 6 to 8. Lastly, the most severe extrusion denoted as 4, where deformation extended beyond the front passenger compartment.

Table 3 Deformation extent classification and its represented value

Deformation extent	Represented value	Definition
1 – 3	1	Up to front axle
4 – 5	2	Up to windscreen
6 – 8	3	Up to front passenger compartment
9	4	Up to rear passenger compartment

The data analysis process was performed using the SPSS software. This process aims to analyse the data using descriptive statistics, chi-square and odds ratio analysis. The intention of determining p-value from the chi-square test is to determine whether or not the association is statistically significant. On the other hand, odds ratio analysis is intended to quantitatively measure the association between two (2) nominal variables. Another measure used in the evaluation relationship between two (2) tested variables is relative risk. It is calculated based on the formula shown in Eq. (2).

$$Relative\ Risk = \frac{Risk\ group}{Control\ group} \quad (2)$$

4. Results and Discussions

This section discusses the results and findings of the study. It is divided into four (4) subsections; descriptive analysis of the data, seatbelt wearing and injury severity, seatbelt wearing associated factors and survival associate factors.

4.1 Descriptive Analysis

In this study, a total of 268 crashes involving 376 passenger vehicles and 1299 occupants were analysed. Table 4 shows the detailed description of the analysed data. It was categorised by vehicle and occupant element. Vehicle element consists of type and origin, while occupant element consists of gender and age.

Passenger vehicle can be generally classified into four (4) classes, which are car, Multi-Purpose Vehicle (MPV), sport utility vehicle (SUV) and van. Crashes involving cars recorded the highest percentage (70.6%). As for vehicle origin, almost half of the analysed crashes involving local vehicles (48.4%). This may occur due to the high number of these vehicles on the Malaysian road.

In terms of gender, the analysed data involves the males (54.8%) more than females (32.8%). Another occupant element observed in this study is age, which is classified by maturity stage in human. It can be noted that a significant number of crash victims involve mature age group (54.7%), with the age of 24 to 44 recorded the highest percentage (30 %). In comparison between age group, introduction age group have a higher likelihood to be the high profile crash victims (12.2%) as compared to growth (7.2%) and decline (4.7%). This result implies that this group has a higher risk to be involved in the high profile crashes than the other two (2) groups.

Table 4 Description of the analysed data

Classification		Details	Percentage (%)
Vehicle class		Car	70.6
		MPV	9.3
		SUV	8.3
		Van	6.0
Vehicle origin		Local	48.1
		Import	31.6
		Unknown	20.2
Gender		Male	54.8
		Female	32.8
		Unknown	12.4
Age	Introduction (12.2%)	New born to 1	2.6
		2 to 3	2.3
		4 to 6	4.2
		7 to 10	3.1
	Growth (7.2%)	11 to 12	1.7
		13 to 15	3.0
		16 to 17	2.5
	Mature (54.7%)	18 to 23	12.3
		24 to 44	30.0
		45 to 60	12.4
	Decline (4.7%)	61 to 70	3.6
		> 70	1.1

4.2 Effect of Seatbelt Wearing on Injury Severity

Figure 3 shows the percentage of survivals and fatal occupants according to seatbelt compliance. Comparison of the seatbelt wearing compliance percentage revealed that only 25.8% of passengers were belted while another 74.3% were unbelted. The unbelted occupants are significantly higher than belted, with an almost three (3) times ratio. This value shows a very low awareness of seatbelt wearing among vehicle occupants in Malaysia.

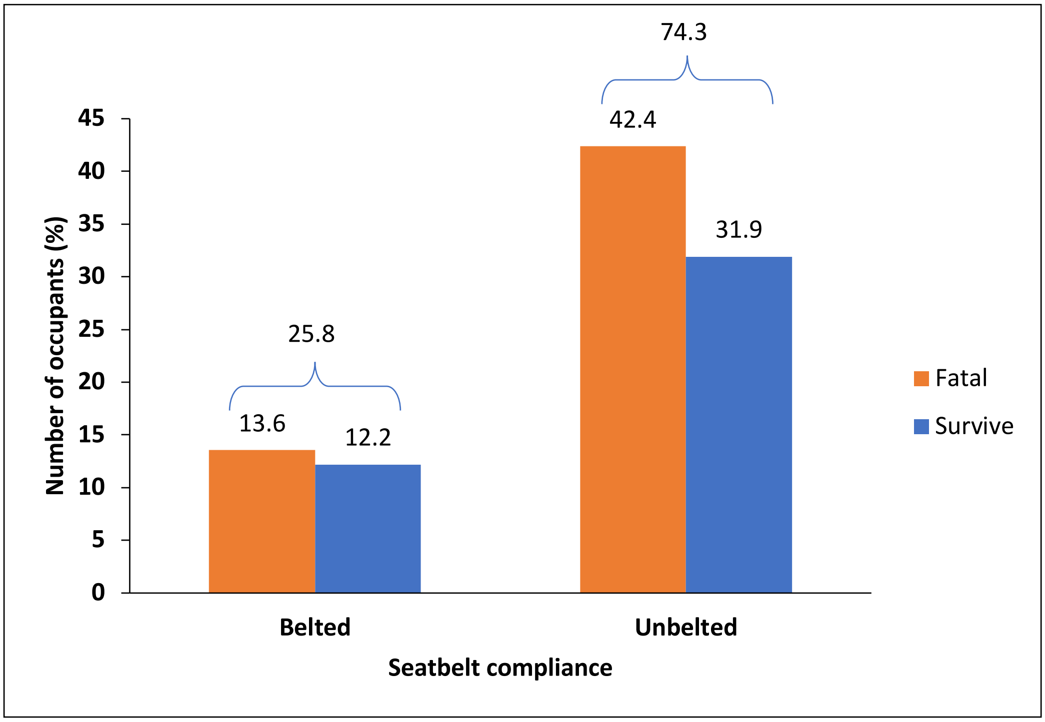


Figure 3 Percentage of survivability by seatbelt compliance

The relative risk of fatality is 1.14 for belted occupants and increases to 1.33 among unbelted occupants. Another indication, which is fatality rate, showed that belted occupants have 52.7% probability of being killed in a crash. Even though seatbelt is well recognised to save lives in a collision, this high probability may due to the nature of investigated cases, which is severe crashes with severe vehicle deformation extents, incompatible crash partner, over-occupancy, etc. These factors will be further discussed in section 4.4. Nevertheless, the probability of being killed in a crash is increased by 5% to 57.0% for unbelted occupants. These results exhibit that survivability in a crash is slight increases if a seatbelt was utilised, even in a severe collision.

Figure 4 shows the distribution of injury severity by seatbelt compliance. It was revealed that injuries and fatalities are more prominent between unbelted occupants. Out of the total crash victims, unbelted fatal occupants account for 43.3%, unbelted severely injured occupants 16.4% and unbelted slightly injured occupants 12.6%. In view of each injury severity level, the unbelted occupants comprise 76% of fatalities, 77% of severe injuries and 69% of slight injuries (see Figure 5a).

In contradict, the percentage of injury suffered by belted occupants is skewed right to the lower injury severity level (see Figure 5a). Even though unbelted occupants were more than belted at all injury levels, the probability of suffering lower injury risk is increased when seatbelt was utilised. In a comparison of injury level, belted occupants have more possibility to suffer a slight injury (22.2%) than severe injury (18.8%), as depicted in Figure 5b. These results explained that belted occupants are less likely to suffer a higher level of injury severity as compared to those unbelted. This figure supports that seatbelt is efficient in minimising injury levels in a collision.

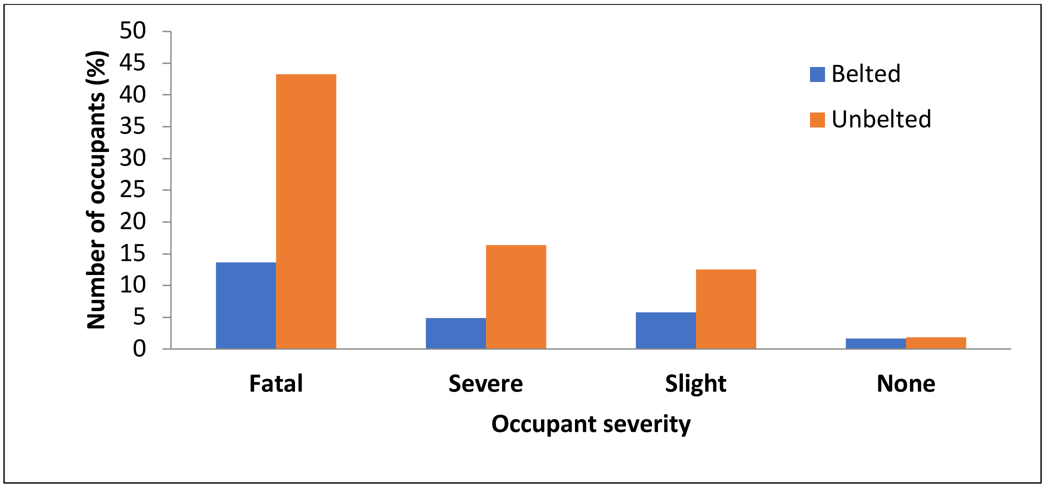


Figure 4 Distribution of injury severity by seatbelt compliance

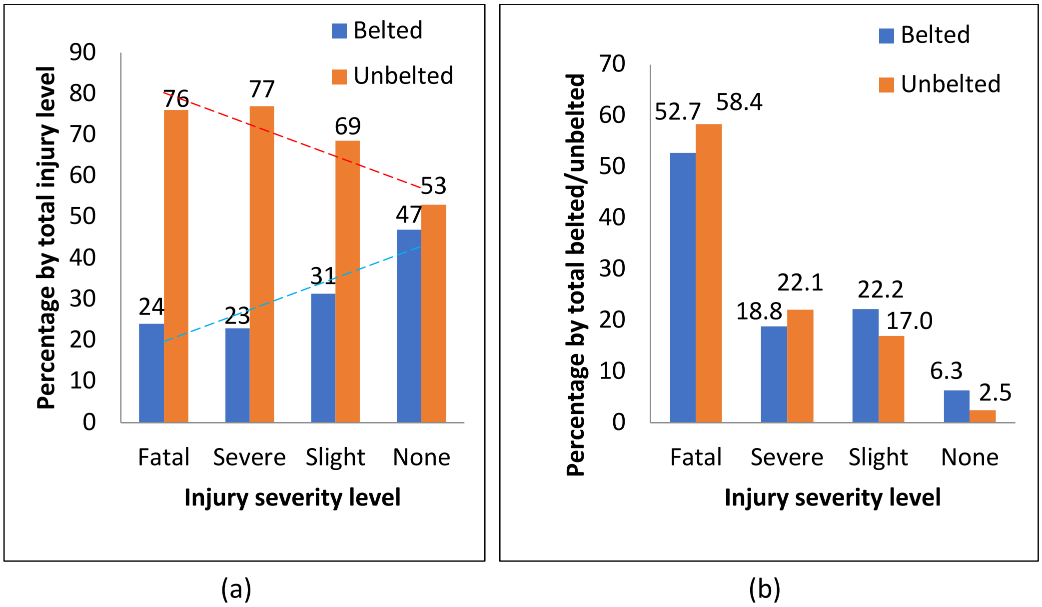


Figure 5 Proportion of belted and unbelted: (a) by injury severity level (b) by belted or unbelted

The effect of seatbelt wearing on occupant injury severity was recognised. The next subsections will discuss the factors associated with seatbelt compliance (Section 4.3) and injury severity (Section 4.4).

4.3 Seatbelt Wearing Associated Factors

Seatbelt wearing in high profile crashes were determined to be mainly associated with occupant variables. Table 5 shows seatbelt wearing compliance by gender. The p-value of the chi-square test for the factors related to seat belt wearing compliance was presented. It also gives the odds ratios (ORs) with 95% confidence intervals (CI).

Cross-tabulation between genders (dependent variable) and seatbelt wearing compliance (independent variable) give P-value of less than 0.001 indicates that genders show a significant relationship with seatbelt wearing compliance. Generally, an unbelted occupant is significantly higher than belted for both type of gender, 71.2% of males and

81.3% of females. An odd ratio value of 1.76 indicates that male has a higher likelihood of wearing seatbelt compare to female. The reason may be associated with their seating position, as discussed follows.

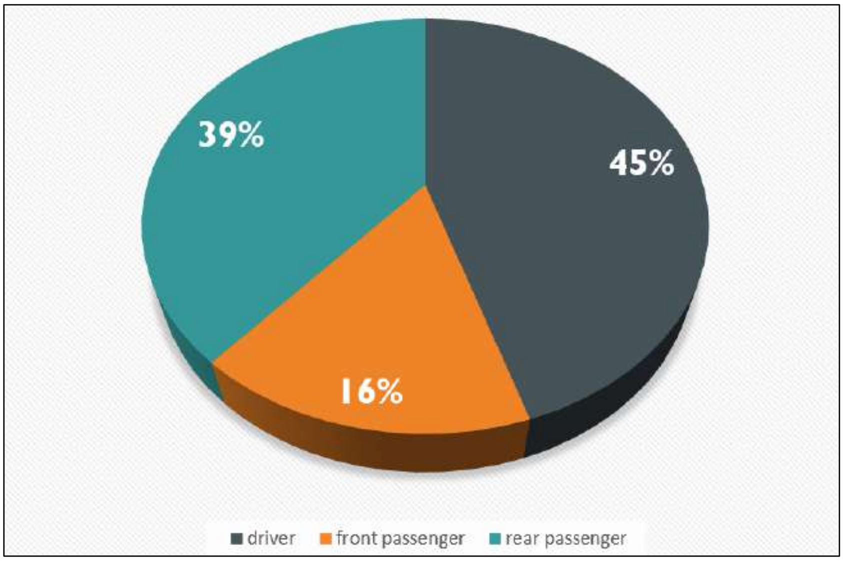
Table 5 Seatbelt compliance by gender (% within row, column)

Factors	Belted	Unbelted	P-value	Odds ratio (95% CI)
Male	193 (28.8, 71.2)	477 (71.2, 58.5)	<0.0001	1.759 (M:F)
Female	78 (18.7, 28.8)	339 (81.3, 41.5)		

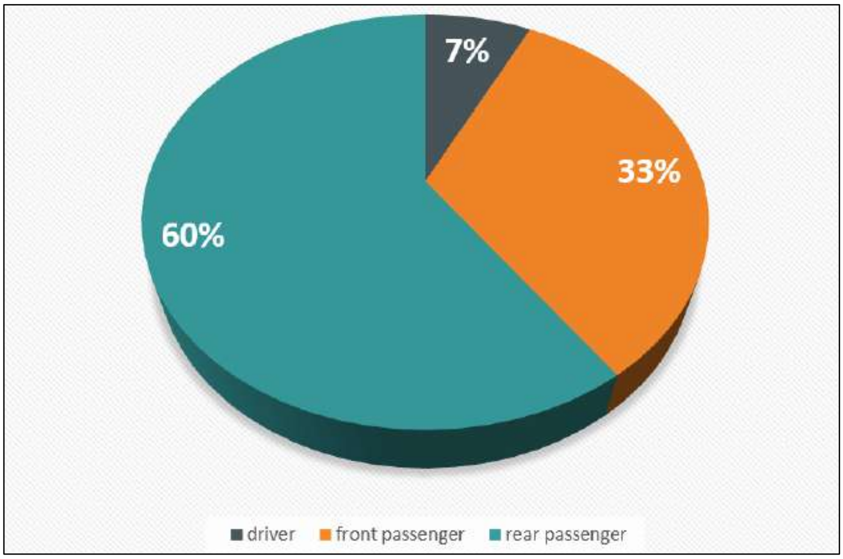
Table 6 shows seatbelt compliance by seating position. Seating position also has a significant association with seatbelt compliance, in which p-value is less than 0.0001. Percentage of belted drivers is slightly more (52.1%) than unbelted (47.9%). Unlike drivers, very low seatbelt compliance was observed between passengers, regardless of their seating position, either front or rear. 64.1% of front passengers were found to be unbelted. Surprisingly, it is very rare to found belted rear passengers, in which only 3.7% of rear passengers were found to be buckled up their seatbelt.

Table 6 Seatbelt compliance by seating position (% within row, column)

Factors	Belted	Unbelted	P-value	Odds ratio (95% CI)
Driver	190 (52.1, 61.5)	175 (47.9, 19.0)	<0.0001	1 (ref)
Front passenger	97 (35.9, 31.4)	173 (64.1, 18.8)		1.94 (D:F)
Rear passenger	22 (3.7, 7.1)	574 (96.3, 62.3)		28.33 (D:R)



(a)



(b)

Figure 6 Seating position by gender: (a) males (b) females

Odds ratio analysis revealed that drivers are 1.9 times more likely to wear seatbelt than front passenger and 28.3 times more likely to wear seatbelt than rear passengers. This high ratio is alarming the actual situation of seatbelt compliance in Malaysia. It reflects that a proactive countermeasure is crucial to improve the compliance rate, especially for the rear passengers.

Since seating position plays a critical role in seatbelt wearing compliance, it was classified into gender, as shown in Figure 4. It can be observed that females are more prominent to be passengers than males. A total of 83% of females are passengers. 33% of them were sitting at the front passenger seat, and 60% of them were sitting at the back. This seating position scenario may be the factor that contributes to the lower wearing rate among females as compared to the males.

Another occupant factor that was found to be significant with seatbelt compliance is occupant age. As mentioned in the literature review section, age was classified into four (4) categories according to human maturity stage, which are introduction, growth, mature and decline. Table 7 shows the seatbelt compliance by the age category. Most of the occupants were not wearing seatbelt, regardless of their age. However, comparing between maturity stages, the majority of seat belt wearing compliance was contributed by mature stage with 88.5% followed by decline with 5.6%, growth with 3.3% and introduction with 2.6%.

Table 7 Seatbelt compliance by age category (% within row, column)

Factors	Belted	Unbelted	P-value	Odds ratio (95% CI)
Introduction	7 (4.7, 2.6)	141 (95.3, 18.6)	<0.0001	9.93 (M:I)
Growth	9 (9.5, 3.3)	86 (90.5, 11.3)		4.71 (M:G)
Mature	238 (33.0, 88.5)	483 (67.0, 63.6)		1 (ref)
Decline	15 (23.1, 5.6)	50 (76.9, 6.6)		1.64 (M:D)

Odds ratio analysis is taking the mature stage, which is the most advantaged category, as the reference for other maturity stage variables. The highest odds ratio is the introduction stage with an odds ratio of 9.93. This result revealed that the introduction age category recorded very poor seatbelt compliance, in which the mature age group is almost ten (10) times more likely to wear seatbelt than this category. This result also reflects the very low usage of child restraint system (CRS) in Malaysia.

As the maturity stage increases, the seatbelt wearing compliance also increases. Mature is 4.49 times more likely to wear seatbelt than growth stage. As for the decline stage, the odds ratio of 1.64 indicates a reduction in seatbelt wearing compliance as compared to the mature stage. This odds ratio analysis exhibits an increasing pattern of seatbelt wearing compliance down the age group. However, there is a slight decrease in seatbelt wearing rate among declined age group even though they have passed the maturity stage. This finding may be due to the transition phase of full mandatory seatbelt wearing in Malaysia that was just taken place in less than ten years.

Due to these circumstances, the introduction of any kind of reminder, through appropriate system installed in a vehicle, is required to increase the seatbelt wearing rate. Furthermore, strategic advocacy and awareness program should be conducted to the targeted focus group, where compliance is relatively low.

4.4 Survival Associated Factors

Survival factors in high profile crashes were determined to be mainly associated with vehicle variables. Table 7 shows the occupant survivability by deformation extent. Vehicle severity of 1 to 4 is referring to the deformation extent classification as listed in Table 8. Percentage of survival is 70.1% in category 1, and reduces to 51.7 in category 2, 36.4% in category 3 and 23.2 in category 4. This result showed that survivability decreases as the deformation extent increases.

Category 1 was set as a reference in comparing the odds to be fatally injured since it has the lowest fatality rate among other categories. Odds ratio analysis showed that the category 2 with deformation extended up to the fifth level has a higher likelihood of occupants to die in a crash with 2.182 times greater than category 1 (deformation extent of 1 to 3).

Probability of fatal increased to 4.083 times greater than category 1 when the vehicle intrusion extended to the front passenger compartment (deformation extent of 6 to 8). When the crash extended until rear passenger compartment (deformation extent of 9), the odds ratio value indicates a very high likelihood of fatal. This extensive vehicle extrusion has 7.761 times tendency to die in a crash as compared to the mild extrusion (deformation extent of 1 to 3).

Table 8 Survivability by deformation extent (% within row, column)

Vehicle severity	Fatal	Survive	P-value	Odds ratio (95% CI)
1	53 (29.9, 9.2)	124 (70.1, 27.7)	<0.0001	1 (ref)
2	125 (48.3, 21.8)	134 (51.7, 29.9)		2.182 (2:1)
3	260 (63.6, 45.3)	149 (36.4, 33.3)		4.083 (3:1)
4	136 (76.8, 23.7)	41 (23.2, 9.1)		7.761 (4:1)

The increasing value of the odds ratio demonstrates the decrease in occupants' survivability as the vehicle severity increases. Survivability is inversely proportional to the deformation extent. This finding exhibits the importance of safety measures to ensure minimum vehicle intrusion in a crash. This could be directly correlated with minimising vehicle speed or even optimisation of vehicle design, to minimise passenger compartment interruption with loading impact.

Another vehicle factor that was found to be significant with occupant survivability is vehicle mass. Table 9 shows the occupant survivability by vehicle mass category. Vehicle mass is categorised into four (4) main groups, which is car, MPV, SUV and van, as listed previously in Table 2. The significant p-value indicates that survival of occupants is related to vehicle mass.

Most of the occupants were in cars (70.6%), and the highest proportion of them is involving light cars. They contribute 60.7% of the cars' occupants. This may due to the high volume of this vehicle category on the Malaysian roads. In view of each vehicle category, survivability is the lowest in mini cars (31.6%). Medium cars, which poses the highest vehicle mass among cars, recorded the highest survival rates (50%). Bigger passenger vehicles like SUV, MPV and van exhibit higher survival rates, with 57.3%, 58.3% and 64.1% respectively. This finding demonstrates that survivability increases when a crash victim occupying vehicle with higher mass.

Quantitative evaluation by odds ratio analysis showed that occupant in light cars has an odd of 1.1 times more than mini to be fatally injured. This result implies that light and mini cars have almost similar occupant survivability. As the vehicle mass category increases to compact and medium cars, survivability improved considerably. Occupants in mini-cars are 1.6 and 2.2 times more likely to be fatal compared to compact and medium cars, respectively.

Furthermore, as for higher vehicle mass, SUV and MPV exhibit almost similar odds ratio value of 3, which means that occupants in these categories are three (3) times greater survivability than mini cars. Meanwhile, van recorded the highest survivability among all passenger vehicle categories, in which occupant in mini cars is 3.8 times more likely to be fatal than the van.

Lower mass and smaller vehicle size increase the occupant fatality risk. This may attribute to the factor of vehicle compatibility in a crash. This data pattern is consistent with a finding reported by Nolan (2013). Among the possible intervention in addressing vehicle compatibility is an improvement on vehicle crush structure. This is vital for maximum impact absorption and simultaneously minimise intrusion to the passenger compartment, which may cause harmful direct physical contact to the occupants.

Table 9 Occupant survivability by vehicle mass category

Factors		Fatal	Survive	P-value	Odds ratio (95% CI)
Car	Mini	119 (68.4, 15.2)	55 (31.6, 9.0)		1 (ref)
	Light	373 (66.3, 47.6)	190 (33.7, 31.0)		1.102 (Mini/Light)
	Compact	83 (57.2, 10.6)	62 (42.8, 10.1)		1.616 (Mini/Compact)
	Medium	23 (50.0, 2.9)	23 (50.0,3.8)	<0.001	2.164m (Mini/Medium)
SUV		44 (42.7, 5.6)	59 (57.3, 9.6)		2.901 (Mini/SUV)
MPV		75 (41.7, 9.6)	105 (58.3, 17.2)		3.029 (Mini/MPV)
Van		66 (35.9, 8.4)	118 (64.1, 19.3)		3.868 (Mini/Van)

5. Conclusion and Recommendations

The low seatbelt wearing compliance exhibits the low awareness of the importance of seat belt wearing among vehicle passengers in Malaysia. This study has three (3) main objectives. The first objective is to determine the effect of seatbelt wearing on survivability. Data from this study has shown that the possibility to survive in a crash is increased if a seatbelt was utilised. It was revealed that injuries and fatalities are more prominent between unbelted occupants. Otherwise, belted occupants are less likely to suffer a high level of injury severity as compared to unbelted. Interestingly, the percentage of injuries suffered by belted occupants is skewed to the lower injury severity level. These findings explain that seatbelt is efficient in minimising injury levels in a collision.

The second objective is to identify seatbelt wearing associated factors. It was found to be associated with the occupant variables, which are gender, seating position and age. Male has a higher likelihood of wearing seatbelt compared to female. Unlike drivers, very low seatbelt compliance was observed between passengers, especially those at the rear. Since females are more prominent to be passengers than males, it could be the factor that contributes to the lower wearing rate among females than males. In terms of age, poor seatbelt compliance among introduction age category reflects the very low usage of child restraint system (CRS) in Malaysia. Seatbelt wearing compliance increases as the maturity stage increases, followed by a slight decrease among decline age category. This finding may attribute to the transition period of the rear seatbelt compliance due to the delayed enforcement for the rears.

The third objective is to identify survival associate factors. It was found to be associated with the vehicle variables, which are deformation extent and mass. This study revealed that survivability decreases as the deformation extent increases. An extensive vehicle intrusion has a very high tendency to cause fatality to vehicle occupant in a crash. As for the vehicle mass comparison, it was demonstrated that survivability increases when a crash victim occupying vehicle with higher mass. Light and mini cars have almost similar occupant survivability. Similarly, SUV and MPV also exhibit almost similar survivability, with survivability of occupants in these categories is three (3) times higher than mini cars.

Alternatively, the following recommendations are proposed based on the above findings:

i. Appropriate awareness program should be carried out to the targeted focus group, where compliance is relatively low. The focus should be on the rear passengers, mainly involves females and children.
ii. The content of such program should emphasise on the importance of seat belt wearing in minimising injury levels in a collision.
iii. The importance of minimising vehicle intrusion as a result of a collision is another important note to be highlighted in the awareness program. One of the possible countermeasures is by reducing vehicle speed, which involves the driver's control without incurring additional costs.
iv. Simultaneously, vehicle capability on impact energy absorption should be evaluated to minimise passenger compartment interruption with loading impact.
v. Usage of child restraint system (CRS) should be encouraged and regulated in transition phases to increase proper seatbelt wearing among the introduction age group.
vi. Mandatory installation of seatbelt reminder in a vehicle should be considered to improve the seatbelt wearing compliance rate, especially for the rear passengers.
vii. Seatbelt extender is designed to increase the length of the existing seatbelt, adding more ergonomic aspect to big sized occupants for seatbelt compliance. However, the misuse of this device to deactivate seatbelt reminder eliminates the seatbelt advantage. Therefore, a control mechanism, especially in terms of rules and enforcement on the substandard component in the aftermarket and usage violation, should be reviewed in addressing this issue.

Recommendations for future study:

i. A similar study is recommended to be conducted to further observe the collision effect on a crashed vehicle on occupant survivability. This may include the principal direction of force on the vehicle, crash partner, etc.
ii. The study should consider availability of airbag and possible vehicle travelling speed upon collision.
iii. A cross-country study to be conducted in order to provide relevant information on the associated factors and strategies to increase the seatbelt compliance rate.

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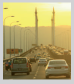

Research Report

Effect of Seatbelt Wearing on Injury Severity in Passenger Vehicle Fatal Collisions

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