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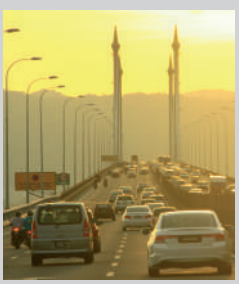
Research Report

Crash Type and Associated Injury of Non-Fatal Motorcycle Crashes at T-Junction



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Abstract

The crash configuration of crashes involving motorcycle is quite extensive due to the size of motorcycle is relatively small as compared to other vehicles. In addition, the motorcycle-related injuries are expensive. The current data on motorcycle crash pattern in Malaysia were carried out by Abdul Manan (2011) and Sharifah Alyana et al. (2010) which focused on fatalities of motorcycle crashes while characteristic of non-fatal motorcycle crashes had been studied by Phang et al. (2000), 17 years ago. Therefore, this study is focusing on nan-fatal motorcyclist on current data (5-year period: 2011 - 2015) and injuries pattern among motorcyclist associated with the crash type of the crash. The objectives of the study were to: (i) investigate trends of occurrence of pre-crash roadway situations (crash typing) involved motorcycle crashes in Malaysia; (ii) identify injuries related to the crash type; and (iii) recognise the injuries severity of the corresponding crash type. The results show more than half (57%) of the motorcycle and passenger car crashes happened at T-junction followed by midblock with 27%. The majority (75%) of the cases occurred at municipal road and in urban area. A total of 642 accident cases with injury were found to occur at T-junction. From the 642 cases at T-junction, seven (7) types of crash typing were identified appropriate with the cases involved. They are approach turn, angle 1/2, rear-end, U-turn, side swipe, overtaking and both turning. Approach turn crashes with passenger car is making a turn while motorcycle was traveling straight ahead on primary roads was the highest action that cause collision among motorcycle and passenger car at T-junction in the study. However, in term of injury severity, the most hazardous crash types identified was among angle 1/2 crashes where passenger car/motorcycle is coming out from an access point and turning into same direction with the motorcycle/passenger car that is travelling straight. Four (4) body regions to be the most regions being injured in every crash types include lower extremity, upper extremity, face and head with the injury severity is higher at lower extremity region compared to other regions.

1. Introduction

Malaysia is one (1) developing country in South East Asian region which undergoes a rapid economic growth since year 1990s. The rapid economic growth has also increased the motorisation industry in the country. The growth of registered vehicles is about 4% per year since the year 1999. Alongside this, the number of road traffic accident and fatalities increasing each year. According to the Malaysia Road Transport Department, in the year 2013, the total number of registered motorcar and motorcycle was 583,060 and 528,508 respectively. The cumulative amount of vehicles in Malaysia specifically for motorcycle is increasing by 5% from the year 2012 to 2013 that may indirectly cause the increasing number of crashes involving motorcycles in Malaysia. The crash configuration of motorcycle is quite extensive due to the relatively small size of motorcycle compared to other vehicles.

According to Preusser D. F. et al. (1995), one (1) technique for studying how and why crashes occur, and for developing targeted countermeasures, is crash type or crash configuration analysis. Crash type analysis involves the development of definitions that identify groups of crash events with common causal and/or pre-crash characteristics, such as common driver behaviour, roadway situations, and movements of the involved vehicles. The focus is on vehicle movement within defined roadway situations. Developing crash types is conventionally based on three (3) steps: (1) analysing police crash reports and classifying crashes based on common pre-crash behaviour and/or situations; (2) reading additional reports to test the integrity of the preliminary classification; and (3) developing crash type definitions for each of the identified crash groups.

The disparities between injuries sustained by motorcyclists and automobile-occupants in road accidents suggest that it can be much more hazardous to ride a motorbike than to drive an automobile in terms of injury outcome. Motorcyclists' susceptibility to accident injuries in nature may act synergistically with the complexity of conflicting

movements and manoeuvres between motorcycles and automobiles to increase motorcyclists' injury severities at junctions (Pai, 2009). In addition, a junction-type crash could be more severe to motorcyclists than a non-junction case as a result of the fact that some of the injuries crashes such as angle collision commonly take place (Pai & Saleh, 2008).

Motorcyclist injuries remain an important cause of devastating disability, long hospitalisation and death. This is statistically significant as it affects mainly the young active segment of the population who are crucial to the economy. To determine if there are additional feasible countermeasures that can reduce motorcycle crashes and crash injuries, a more thorough understanding of how and why these crashes occur, using more current data, is needed. Hitherto in Malaysia to the best of author knowledge there are no such studies conducted on non-fatal motorcyclist with injury using current data.

Current data on motorcycle crash pattern in Malaysia were carried out by Abdul Manan (2011) and Sharifah Alyana et al. (2010) which focused on fatalities of motorcycle crashes while characteristic of non-fatal motorcycle crashes had been studied by Phang et al. (2000), 17 years ago. This study is focusing on non-fatal motorcyclist on current data (5-year period: 2011 - 2015) specifically at T-junction and injuries severity among motorcyclist. Crash type of the crash is an additional point in the study.

2. Objectives of the Study

The primary goals of the study are to:

i. Investigate trends of occurrence of pre-crash roadway situations (crash typing) involved in motorcycle crashes in Malaysia
ii. Identify injuries related to the crash type
iii. Recognise the injuries severity in the specific crash type

3. Methodology

3.1 Data Source

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. The study criteria need to be met during the data collection. The study criteria are; (i) two-vehicle crashes, (ii) accidents in which involving rider only and (iii) rider must be injured and has injury information. For two-vehicle crashes, it must involve one (1) motorcycle colliding with passenger car. Out of the available and archived data, a total of 642 non-fatal motorcyclists of third party claimants were identified to occur at T-junction. Information regarding the demographic information, crash narratives and injury details were retrieved from various sources of the report such as police report, adjuster report, medical report, opinion report and assessment report available in the selected cases.

Narratives of the accidents were retrieved from the police report and adjuster report. From the retrieval accident narratives, crash circumstances and crash types were formed. Meanwhile, the medical report available in the database has provided adequate injury information for each motorcyclist involved. Each data for each case were retrieved from a database provided by the insurance company named Marimen system. A complete set of a case containing all the reports mentioned above was systematically stored in the Marimen system.

3.2 Categorisation of Crash Typing

Crash typing in the study was determined according to three (3) categories, which are road environment, the travel direction of both crash partners and pre-crash motion of the motorcyclist or passenger car driver. Narrative of the accident is very crucial in order to identify the crash configuration of each case. Seven (7) types of road environment were determined in the study, which is T-junction, midblock, cross-junction, merging, roundabout, U-turn and others. For travel direction, consist of same, different and opposite direction. Meanwhile, there are seven (7) categories of crash type according to pre-crash motion of the motorcycles and passenger cars were defined at T-junction in the study. The description of each crash type categories is explained in respective table in the result and discussion session.

3.3 Injury Coding

In the study, the injury information was on the rider of the motorcycle that was involved in an accident. Injury to the body region and severity coding used in this study are based on the Abbreviated Injury Scale (AIS), updated version 2008. The 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 minimise the AIS coding error, two (2) personnel who were trained to code AIS were dedicatedly involved during the study period to code the injuries.

Maximum abbreviated injury scale (MAIS) was then assigned to determine the level of injury severity. The MAIS is the greatest AIS injury sustained by the occupant. The motorcyclist may have multiple injuries of varying severity and may have more than one (1) injury with their greatest MAIS. Cases with injury with MAIS less than three (3) are categorised as mild, and MAIS 3 and above are considered severe.

3.4 Analysis

The data obtained at T-junction was analysed to investigate further the relationship between identified crash types and injuries sustained by body region by conducting a frequency table. Injury sustained by each victim in the study could be more than one (1). As for that, the number of injury will not tally or equal to the number of case. At least one (1) injury will be counted as a body region if there is a record of injuries or injuries at that specific region. The frequency of the injury distribution is presented according to gender.

4. Results and Discussion

4.1 Road Type

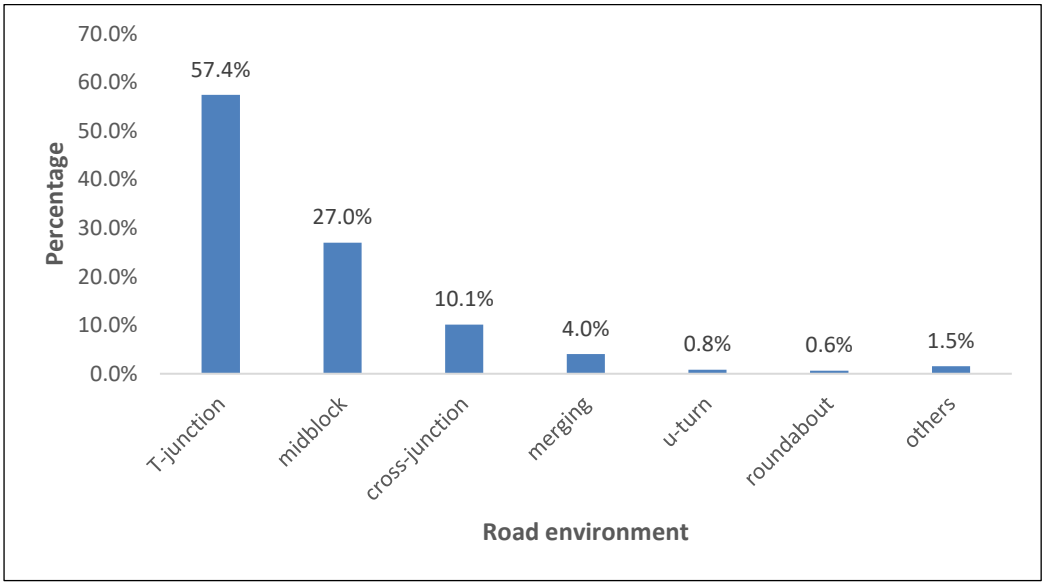


Figure 1 Distribution of cases in different road type

There are seven (7) types of road that have been identified in the study as shown in figure 1. The results show more than half (57%) of the motorcycle and passenger car crashes happened at T-junction followed by midblock with 27%. The majority (75%) of the cases occurred at municipal road and in an urban area.

According to Abdul Manan (2014), most motorcycle crashes in Malaysia involving fatalities occurred at straight road section with several access point (three-legged junction) connecting to villages, plantations and industrial areas. Further analysis of the

crash type and associated injury pattern was explored at the T-junction as this type of roads will be considered as primary road in the study.

4.2 Crash Type and Injury at T-Junction

A schematic diagram was drawn to represent the identified crash typing in the study. The injury pattern and injury severity sustained by the motorcyclist specifically to the rider associated with the recognised pre-crash motion was distributed according to his/her gender.

A total of 642 accident cases with injury were found to occur at T-junction. From the 642 cases, seven (7) crash types were identified appropriate with the cases involved. The identified crash types are approach-turn, angle 1/2, rear-end, U-turn, sideswipe, overtaking and both-turning as shown in Figure 2. In each crash types, there are subcategories that have been considered based on the first vehicle making the said motion. In total, there are 16 crash types were identified to occur at T-junction based on the pre-crash motion made by each vehicle involved. The result for each injury associated to the crash types at the T-junction is tabulated in Table 1 to Table 7.

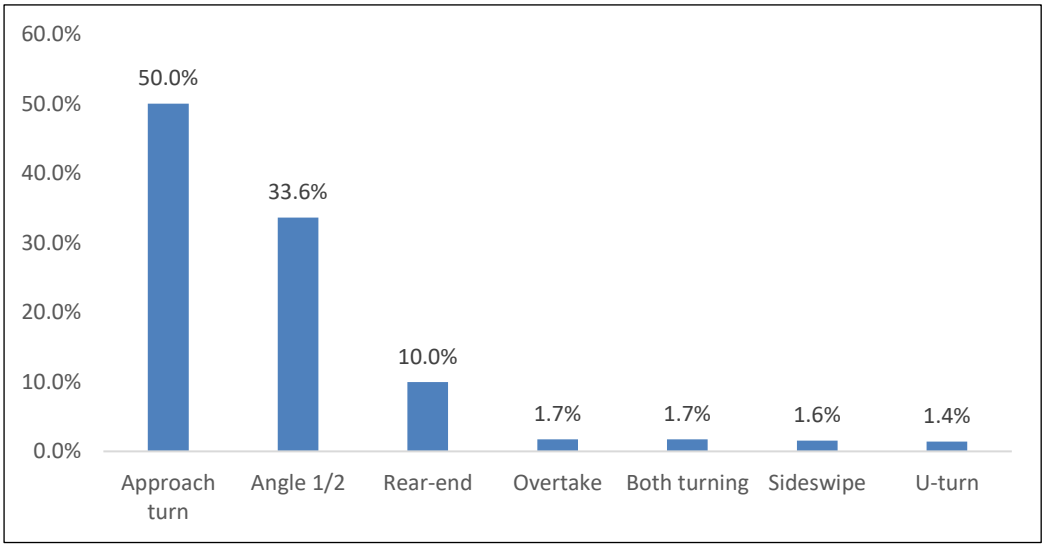


Figure 2 Identified crash typing at T-junction

4.2.1 Approach-Turn

In approach-turn crashes at T-junction, there are Approach-turn A (passenger car is making a turn) and Approach-turn B (motorcycle is making a turn). In addition, two (2) subcategories are defined in each approach-turn group. The subcategories are defined according to the direction of travel of both vehicles prior to the accident. They are:

i. Approach-turn A1: Passenger car and motorcycle are at opposite travel direction and the passenger car is making a turn
ii. Approach-turn A2: Passenger car and motorcycle are at the same travel direction and the passenger car is making a turn
iii. Approach-turn B1: Passenger car and motorcycle are at opposite travel direction and the motorcycle is making a turn
iv. Approach-turn B2: Passenger car and motorcycle are at same travel direction and the motorcycle is making a turn

There are 321 out of 642 cases (50%) involved in approach-turn crashes at T-junction (Figure 2). Table 1 shows that Approach-turn A has the highest (295 out of 321) cases compared to Approach-turn B (26 cases). Further analysis shows that in Approach-turn A alone (A1 and A2), 87% (257 out of 295) are male with age range from 11 - 20 years old (39%) followed by 21 - 30 years old age range (33%). Overall, both male and female rider in this group sustained the highest injury at lower extremity. However, in Approach-turn A2, upper extremity injury shows the highest percentage among male riders with 32.3% compared to 28.1% injury to the lower extremity. In Approach-turn B (B1 and B2) groups, 20 out of 26 total cases are male riders and most of the injury in this group was at the lower extremity regardless of gender.

In term of injury severity, majority of the riders that involved in approach-turn crashes at T-junction suffered MAIS 1 - 2 (255 out of 342). For Approach-turn A crashes, Approach-turn A1 appeared to be more dangerous compared to Approach-turn A2 crashes as a higher portion of riders suffered MAIS ≥ 3 was found in Approach-turn A1 crashes (A1:24.9% vs A2:12.7%). For crash type Approach-turn B, there was no significant difference of MAIS 1 - 2 and MAIS ≥ 3 for both approaches turns crashes B1 and B2. This finding mirrors the study by Pai (2008) that revealed motorcyclists were more injurious

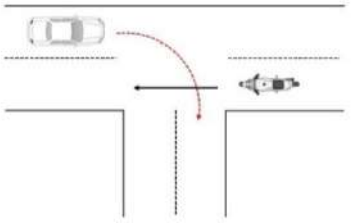
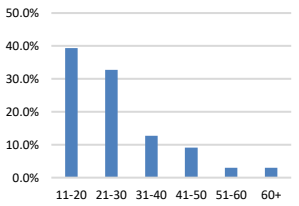
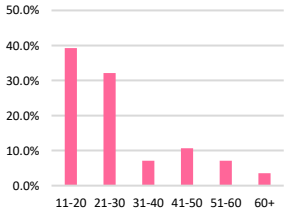
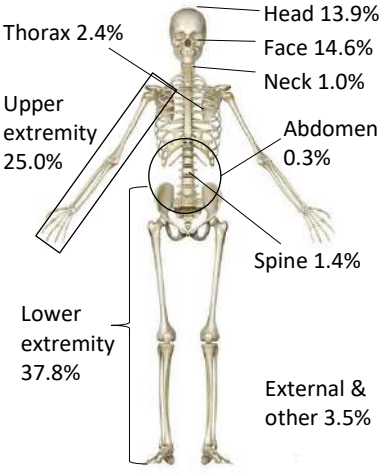
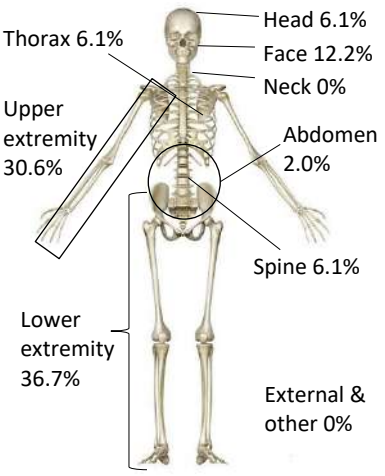
in Approach-turn A1 crashes than other approach turns type of crashes. For Approach-turn A crashes, researchers (Clarke et al., 2007; Hole et al., 1996; Hurt et al., 1984; Peek-Asa & Kraus, 1996; Williams & Hoffmann, 1979) have suggested that the principal factors in this crash type could be the failure of a turning driver to see the approaching vehicle (e.g., look but did not see), to adequately judge the time available to clear the intersection, or to yield right of way to an approaching motorcycle. Figure 3 and Figure 4 show the example of real-world crashes which demonstrated the vehicle drivers' failure to see the approaching motorcycles.

Figure 3 Approach-turn A1 crashes: A turning passenger car failed to see approaching motorcycle from the opposite direction

Figure 4 Approach-turn A2 crashes: A turning passenger car failed to see approaching motorcycle from the same direction

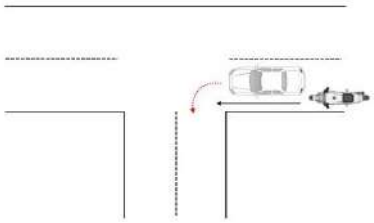
For Approach-turn B crashes, about 31% (8 out of 26) of the motorcyclists involved were older riders aged 60 and above. In contrast, in Approach-turn A crashes there were only about 5% (14 out of 295) of the older riders.

Table 1 Demographic and injury pattern of crash type (approach turn) at T-junction

1.	**Pre-crash motion**	Approach-turn A1: N = 193  Passenger car and motorcycle are at **opposite travel direction** and the **passenger car is making a turn.**
	Age group	♂ N = 165  ♀ N = 28 
	Injury pattern	♂  MAIS 1 - 2: 74.5%, MAIS ≥ 3: 25.5% ♀  MAIS 1 - 2: 78.6%, MAIS ≥ 3: 21.4%

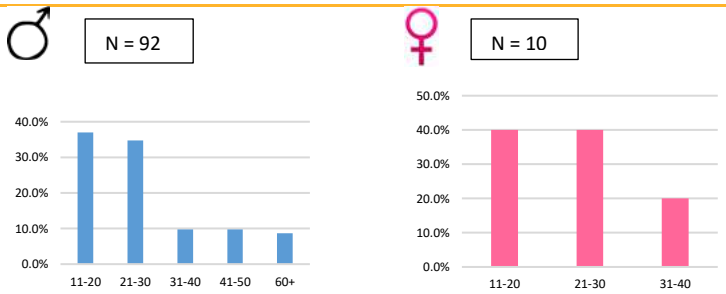
2. Pre-crash motion

Approach-turn A2: N = 102

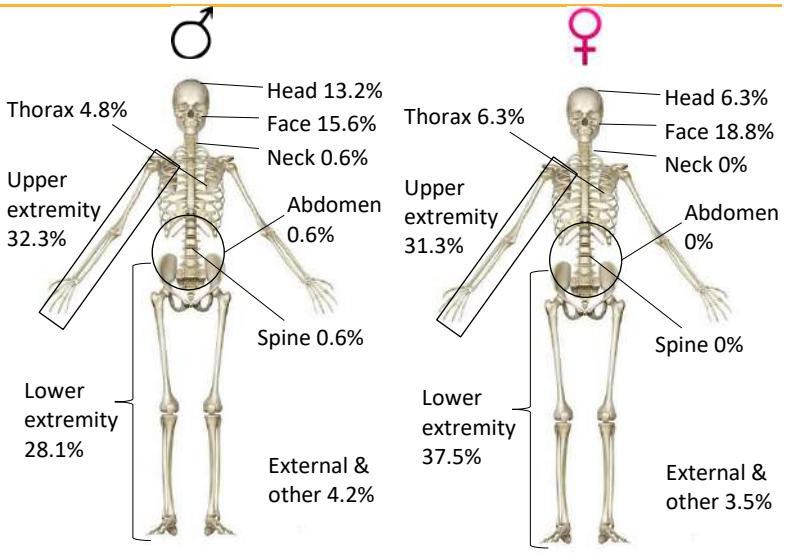


Passenger car and motorcycle are at **same travel direction** and the **passenger car is making a turn.**

Age group



Injury pattern

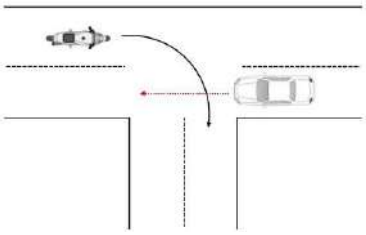


MAIS 1 - 2: 85.9%,
MAIS ≥ 3: 14.1%

MAIS 1 - 2: 100%,
MAIS ≥ 3: 0%

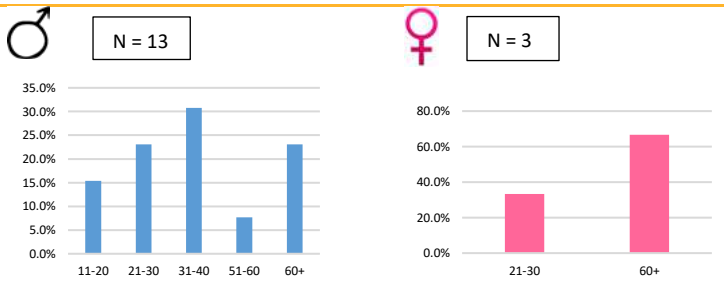
3. Pre-crash motion

Approach-turn B1: N = 16

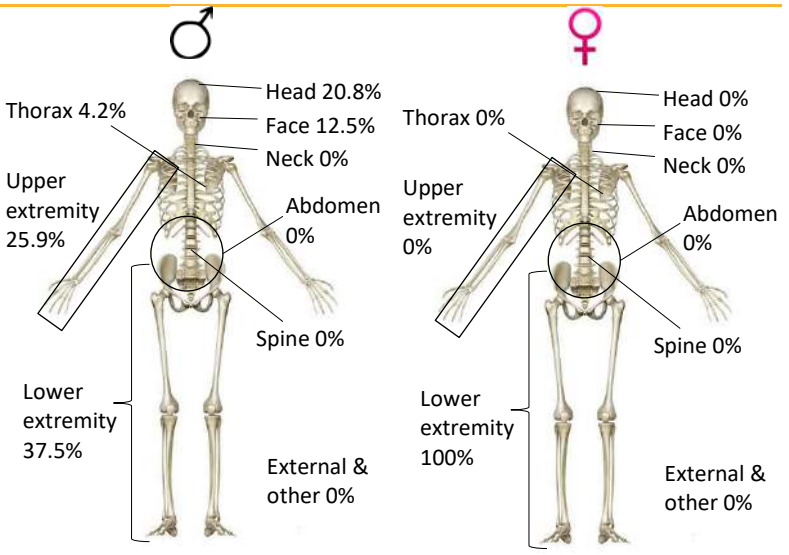


Passenger car and motorcycle are at **opposite travel direction** and the **motorcycle is making a turn.**

Age group



Injury pattern

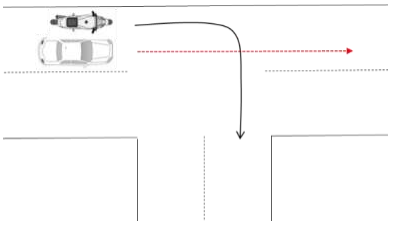


MAIS 1 - 2: 76.9%,
MAIS ≥ 3: 23.1%

MAIS 1 - 2: 100%,
MAIS ≥ 3: 0%

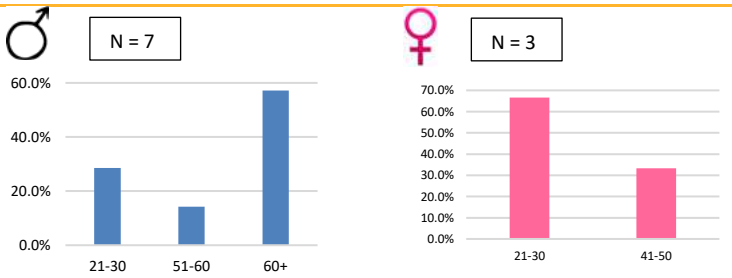
4. Pre-crash motion

Approach-turn B2: N = 10

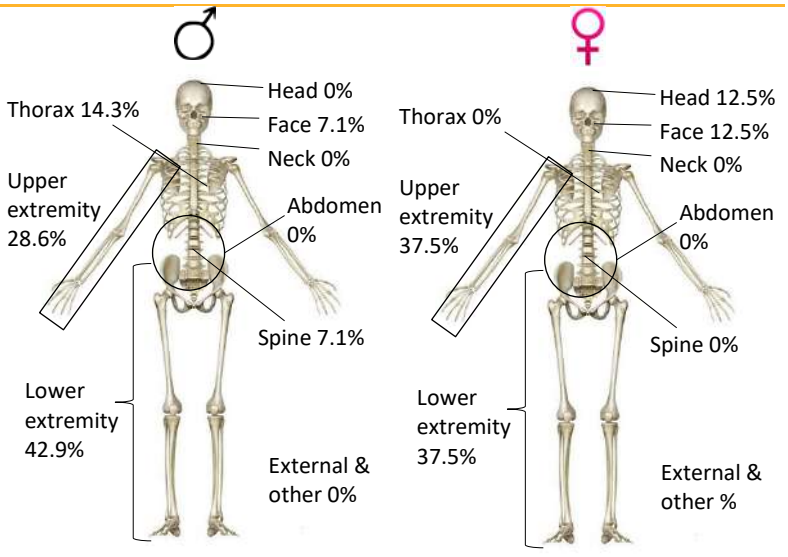


Passenger car and motorcycle are at **same travel direction** and the **motorcycle is making a turn.**

Age group



Injury pattern



MAIS 1 - 2: 71.4%,
MAIS ≥ 3: 28.6%

MAIS 1 - 2: 100%,
MAIS ≥ 3: 0%

4.2.2 Angle 1/2

Crash types of angle are determined when passenger car and motorcycle travelling from different travel direction. Angle type of crash is divided into two (2) group of configurations:

i. Angle 1 is defined as when passenger car/motorcycle is coming out from an access point and turning into different direction with the motorcycle/passenger car that is travelling straight.
ii. Angle 2 is defined as when passenger car/motorcycle is coming out from an access point and turning into same direction with the motorcycle/passenger car that is travelling straight.

Angle 1 and Angle 2 and their subcategories are portrayed by schematic drawing in Table 2. A total of 216 cases were found in Angle 1 and 2 crashes where 68% (146 out of 216) contained in Angle 1 and remaining 32% (70 out of 216) is Angle 2 crashes.

In Angle 1 crashes, situation where passenger car is making a turn (Angle 1A) is higher (125 cases) than situation where motorcycle is making a turn (Angle 1B) with 21 cases only. Both crashes in Angle 1 group, male rider show the highest with 84% (123 out of 146) and most of them are younger rider, age from 11-30 years old. Injury to the extremities shows a dominant percentage among other body region in both motion and gender.

Figure 5 shows the example of real-world crashes for the most frequent angle crashes (Angle 1A) at T-junctions. The crash happened as a result of right of way violation by the passenger car that failed to see of the travelling-straight motorcycle that was suddenly popped out behind the truck from overtaking manoeuvre. This problem has been highlighted by researchers (Clarke et al., 1999; Kim & Boski, 2001; Preusser et al., 1995) which suspected that motorcycles' improper overtaking manoeuvres would reduce their visibility because they generally popped out in traffic streams. They even suggest that blockages of direct visibility may play a significant role in approximately half of automobile–motorcycle crashes involving right-of-way (ROW) violation.

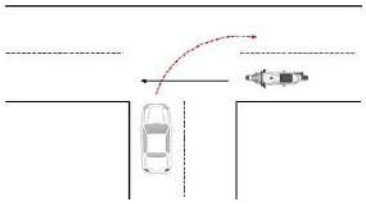
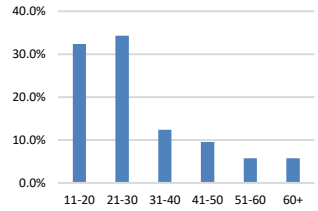
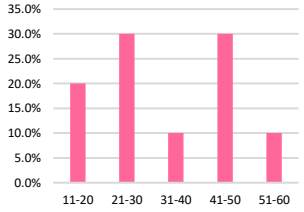
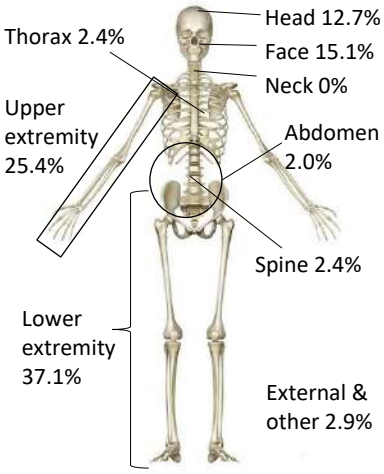
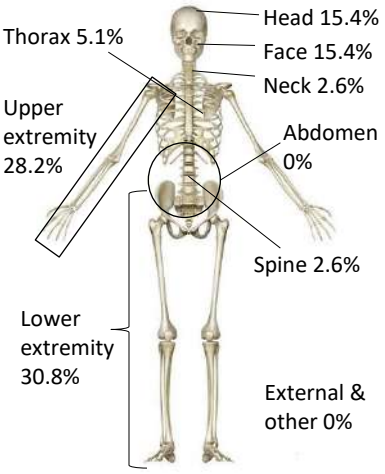
Figure 5 Angle 1A crashes: A right-turn passenger car failed to see travelling straight motorcycle.

In Angle 2 crashes, there are four (4) subcategories which are Angle 2A L, Angle 2A R, Angle 2B L and Angle 2B R. The description for each subcategory can be seen in Table 2. In all subcategories, male is the dominant (57 out of 70) where out of 57, 37 male riders are age from 11-30 years old. In male rider, extremities, face, head and thorax were the most common body region being injured in all subcategories. However, lower extremity still the highest body region being injured except for Angle 2B R where injury at upper extremity is higher than lower region. The proportion of female rider in Angle 2 was very small with 13 cases only.

In term of injury severity, majority of the motorcyclists that involved in angle crashes at T-junction suffered MAIS 1 - 2 (157 out of 216). For Angle 1 crashes, Angle 1B appeared to be more dangerous compared to Angle 1A crashes as higher portion of motorcyclists suffered MAIS ≥ 3 was found in Angle 1B crashes (1B:38.1% vs 1A:23.2%). For Angle 2 crashes, Angle 2B is significantly more dangerous to motorcyclists as almost half (9 out of 20) suffered MAIS ≥ 3 injury compared to Angle 2A crashes which only 26% (13 out of 50) suffered MAIS ≥ 3 injury. However, in comparison between Angle 1 and Angle 2, injury severity of rider in Angle 2 is more severe with 31% (22 out of 70) of the riders suffered MAIS ≥ 3 injury.

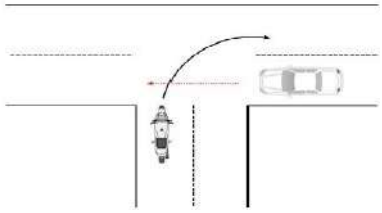
This finding, when compared to the study by Pai (2008) that revealed the most hazardous crash patterns were angle perpendicular and angle oblique crashes where one (1) travelling-straight motorbike collided with a right-/left-turn car travelling from the minor road. This study's findings differ such those injuries were greatest in collisions where a right-/left-turn motorcycle infringed upon the passenger car's right-of-way.

Table 2 Demographic and Injury pattern of crash types (Angle 1 & 2) at T-junction

1.	**Pre-crash motion**	Angle 1A: N = 125  **Passenger car is turning** to different direction of travel and **motorcycle is travelling straight**.
	Age group	♂ N = 105  ♀ N = 20 
	Injury pattern	♂  MAIS 1 - 2: 78.1%, MAIS ≥ 3: 21.9% ♀  MAIS 1 - 2: 70.0%, MAIS ≥ 3: 30.0%

2. Pre-crash motion

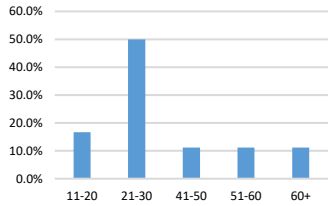
Angle 1B: N = 21



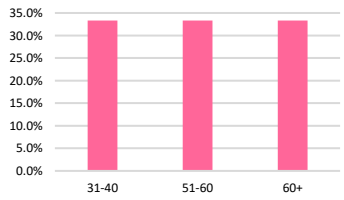
Motorcycle is turning to different direction of travel and **passenger car is travelling straight.**

Age group

♂ N = 18

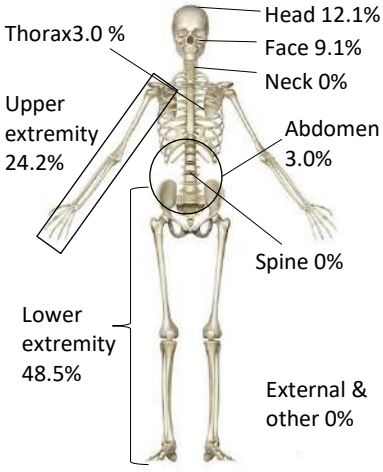


♀ N = 3



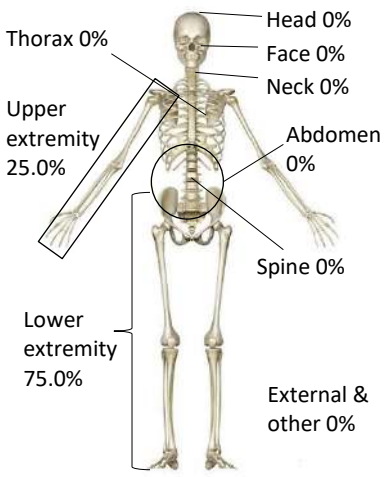
Injury pattern

♂



MAIS 1 - 2: 61.1%,
MAIS ≥ 3: 38.9%

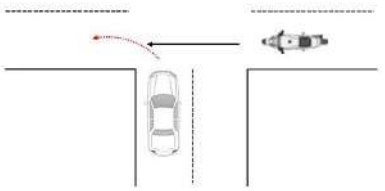
♀



MAIS 1 - 2: 66.7%,
MAIS ≥ 3: 33.3%

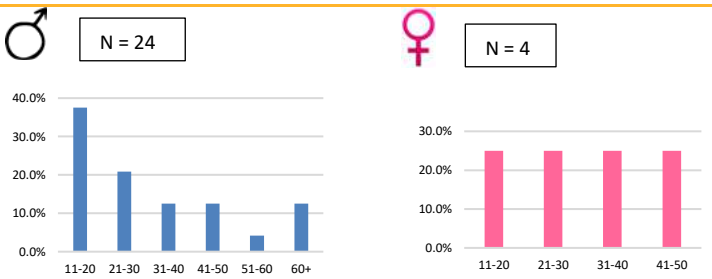
3. Pre-crash motion

Angle 2A L: N = 28

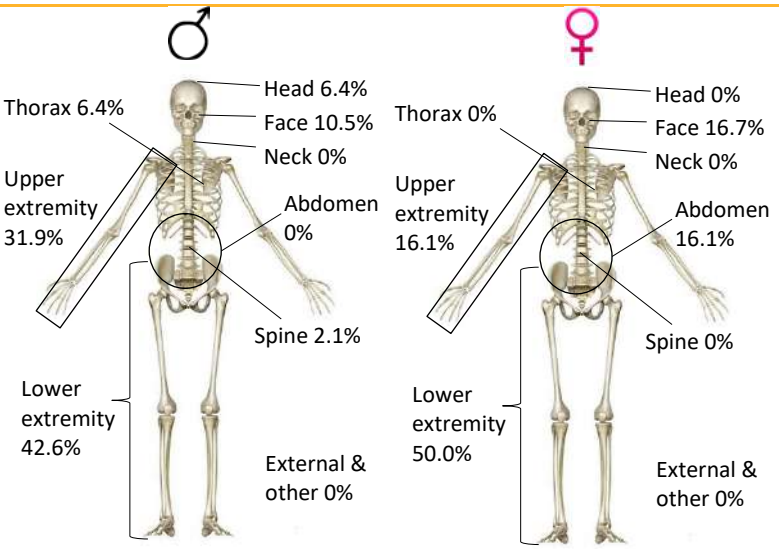


Motorcycle is travelling straight and **passenger car is turning left in the same direction of travel**.

Age group



Injury pattern

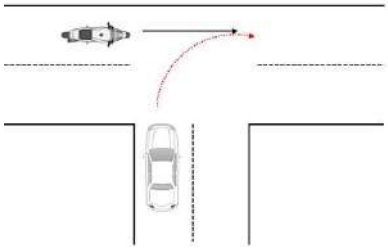


MAIS 1 - 2: 66.7%,
MAIS ≥ 3: 33.3%

MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

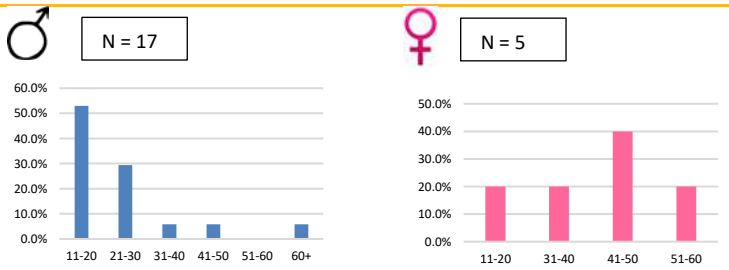
4. Pre-crash motion

Angle 2A R: N = 22

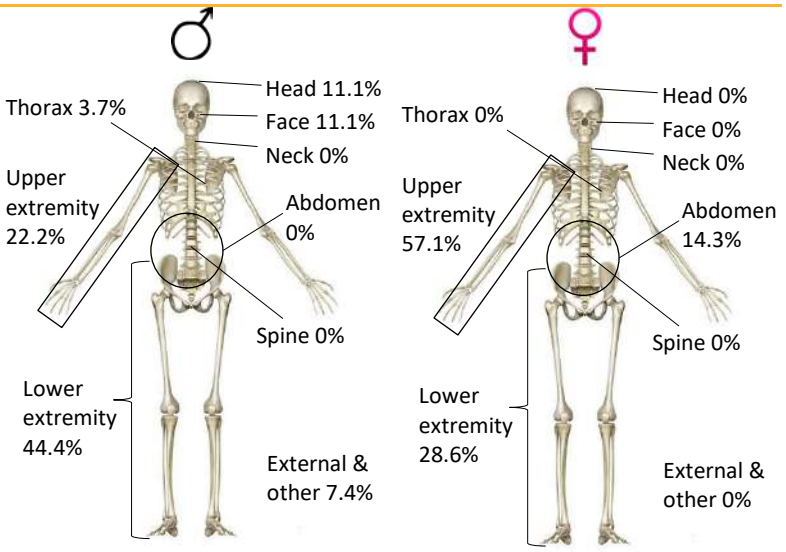


Motorcycle is travelling straight and **passenger car is turning right in the same direction of travel.**

Age group



Injury pattern

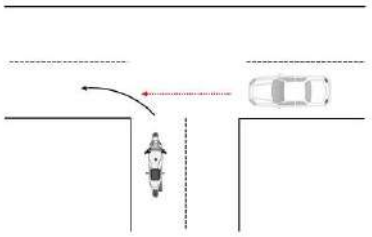


MAIS 1 - 2: 70.6%,
MAIS ≥ 3: 29.4%

MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

5. Pre-crash motion

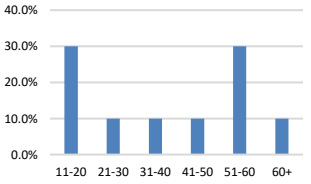
Angle 2B L: N = 10



Passenger car is travelling straight and **motorcycle is turning left in the same direction of travel.**

Age group

♂ N = 10

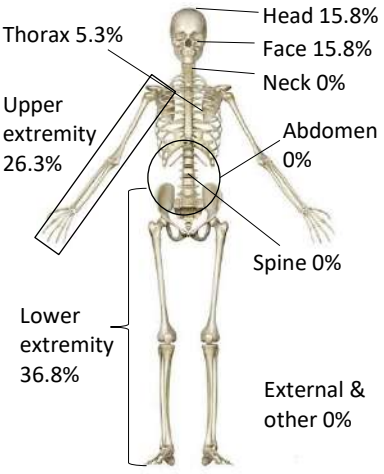


♀ N = 1

Age: 51 - 60

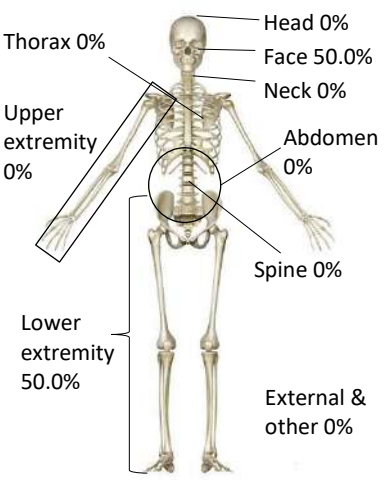
Injury pattern

♂



MAIS 1 - 2: 70.0%,
MAIS ≥ 3: 30.0%

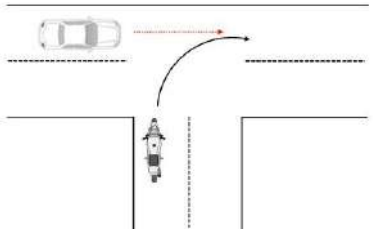
♀



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

6. Pre-crash motion

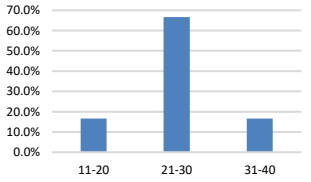
Angle 2B R: N = 9



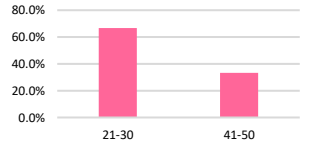
Passenger car is travelling straight and **motorcycle is turning right to the same direction of travel.**

Age group

♂ N = 6

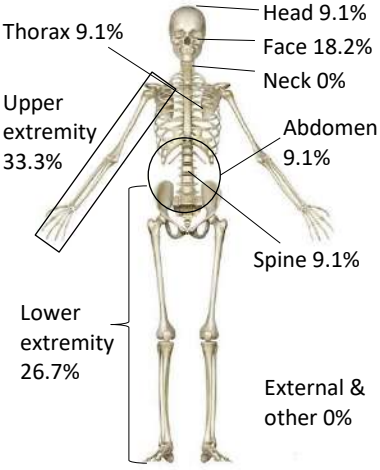


♀ N = 3



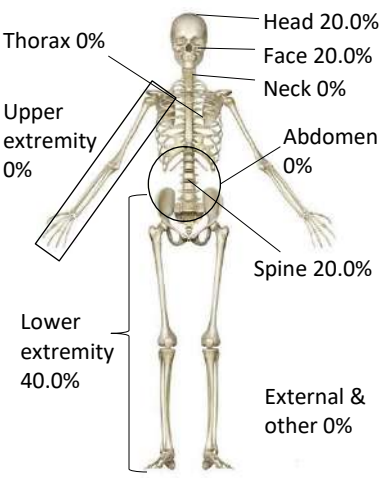
Injury pattern

♂



MAIS 1 - 2: 33.3%,
MAIS ≥ 3: 66.7%

♀



MAIS 1 - 2: 33.3%,
MAIS ≥ 3: 66.7%

4.2.3 Rear-End

Rear-end crash type is a category when one (1) motorcycle and one (1) vehicle travelling at same travel directions collide with each other while one (1) of the vehicles is making a turn at the T-junction. This is further categorised into Rear-end A (a motorcycle is rear-ended by a passenger car) and Rear-end B (a motorcycle rear-ends a passenger car). A total of 64 cases involved rear-end crashes at T-junction. In Table 3, the result shows that 49 cases out of total rear-end cases were from Rear-end B where the 92% (45 out of 49) of the riders are male and mainly aged from 11 - 30 years old. Meanwhile for Rear-end A category, 15 cases were found and 9 cases (60%) involved are older riders aged from 41 and above.

There is a significant difference in the rider age range for Rear-end B, and Rear-end A. Different rider behaviours among younger and older riders could lead to this situation. Age plays a part in the causes of accidents but also the results of suffering injuries as the biomechanical load limits of the elderly compared to the younger people are significantly reduced (Otte et al., 2010). According to Clarke et al. (1998), the younger rider was found to be inexperience, inattention, or risky driving behaviours that could have explained the higher number of the younger rider involved in rear-end B motion.

In term of injury, the distribution of injury for each category are similar with lower extremity is the main region being injured and the MAIS 1 - 2 is the dominant (53 out of 64). In comparison between rear-end crashes, rear-end B crashes were more severe as a higher portion of riders suffered MAIS ≥ 3 were found in Rear-end B crashes (20.4%) compared to Rear-end A crashes (6.7%). According to Pai and Saleh (2007), injuries due to Rear-end A tend to be greatest at uncontrolled junctions. However, there is no information on the control measure at the T-junction during the study conducted.

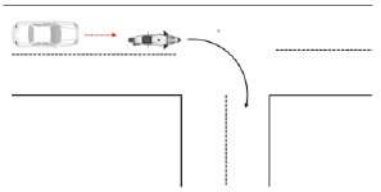
The finding for the rear end crash in the study is in agreement with other findings that indicated the majority of rear-end crash involving motorcycle were from motorcycle crashed into the rear other passenger car. Research by NHTSA 2007 shows that of the 204 rear-end crashes between motorcycles and passenger vehicles, in 139 (68%) crashes the role of the motorcycle in the crash was recorded as striking the passenger vehicle, and in 59 (29%) crashes the role of the passenger vehicle was recorded as striking the

motorcycle. Rear-end and head-on crashes represent 19% and 6% of all multi-vehicle crashes and are more likely due to the actions of the motorcyclist (RTA, 2010). Rear end collisions appear to be generally due to the rider failing to maintain a sufficient space to the vehicle in front.

Table 3 Demographic and Injury pattern of crash type (rear-end) at T-junction

1. Pre-crash motion

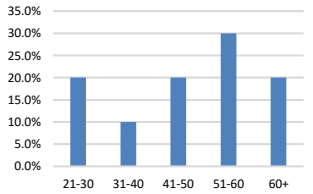
Rear end A: N = 15



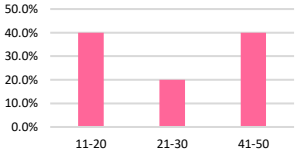
Motorcycle is making a turn and passenger car hit motorcycle from rear.

Age group

♂ N = 10

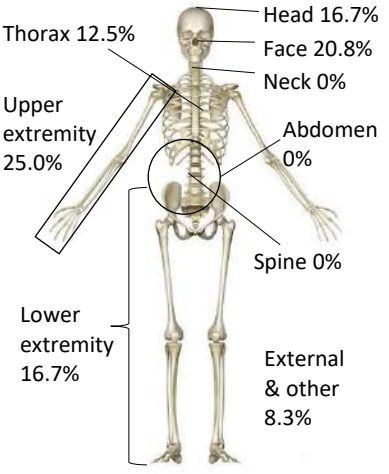


♀ N = 5



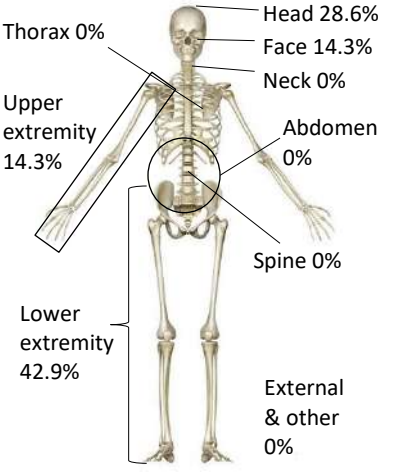
Injury pattern

♂



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

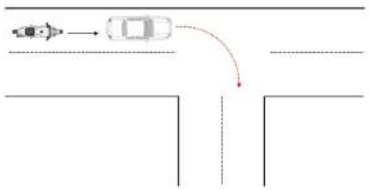
♀



MAIS 1 - 2: 80.0%,
MAIS ≥ 3: 20.0%

2. Pre-crash motion

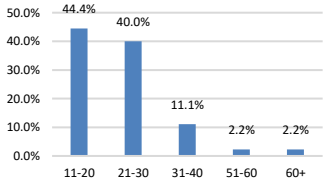
Rear end B: N = 49



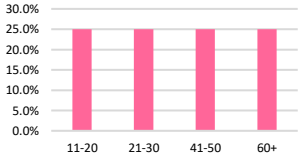
Passenger car is making a turn and motorcycle hit passenger car from rear.

Age group

♂ N = 45

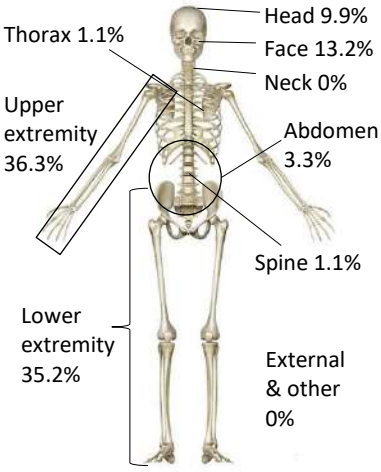


♀ N = 4



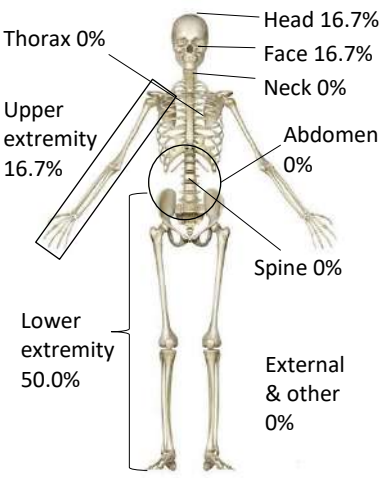
Injury pattern

♂



MAIS 1 - 2: 80.0%,
MAIS ≥ 3: 20.0%

♀



MAIS 1 - 2: 75.0%,
MAIS ≥ 3: 25.0%

4.2.4 Both-turning

Both-turning is defined as a motion that occurs while one (1) motorcycle and one (1) passenger car are travelling from different arms of junctions, making a turn and collide with each other. Eleven (11) cases were found to be in both turning, involved only one (1) female rider and the remaining is male rider. As other crash types, lower extremity shows the most region being injured with majority of the injuries are at MAIS 1 - 2 (mild injury) for both male and female riders as shown in Table 4. Violation of right of way could be one (1) of the reasons in both turning collision where typical response of the car driver is that they looked in the appropriate direction but simply failed to see the motorcycle (Crundall et al., 2012).

4.2.5 Sideswipe

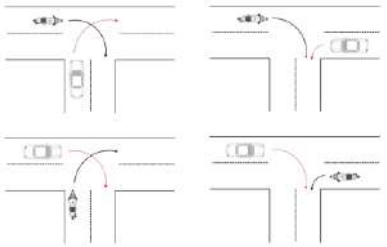
There were ten (10) cases involved sideswipe crashes. As shown in Table 5, this crash type predominantly involved male rider (6 out of 10). The most common injury was to the upper and lower extremities. There were no significant different between the group in term of demographics and injury patterns. Majority of the riders that involved in both turning and sideswipe crashes at T-junction suffered MAIS 1 - 2 (19 out of 21). Only two (2) out of 11 of riders involved in both-turning crashes suffered MAIS ≥ 3 injury while none riders involved in sideswipe crashes suffered MAIS ≥ 3 injury.

According to Pai and Saleh (2008), during sideswipe crash, motorcyclists being thrown off their balance or ejected and/or subsequently having second crash-contact with ground or second collision partner in addition to the first contact with the first vehicle. Therefore, the injuries suffered by the motorcyclist could be severe. This contradicts with the study findings where all the riders suffered mild injury (MAIS 1 - 2). Motorcycles frequently are in the blind spots of other drivers (Pai & Saleh, 2008) and even obscuration from A-frame pillars of passenger car (Crundall et al., 2012). This situation may be one (1) of the causes of sideswipe crash among motorcycles.

Table 4 Demographic and Injury pattern of crash type (both-turning) at T-junction

1. Pre-crash motion

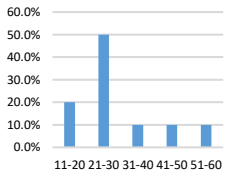
Both turning: N = 11



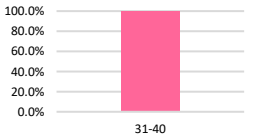
Passenger car and motorcycle are making a turn to **different/same** direction of travel.

Age group

♂ N = 10

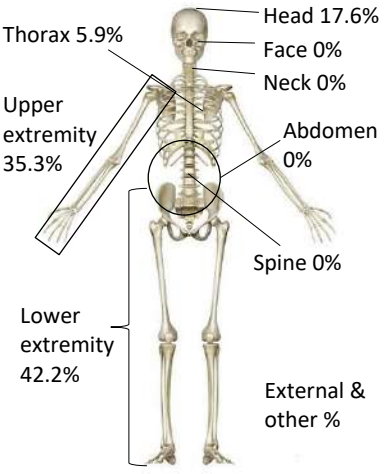


♀ N = 1



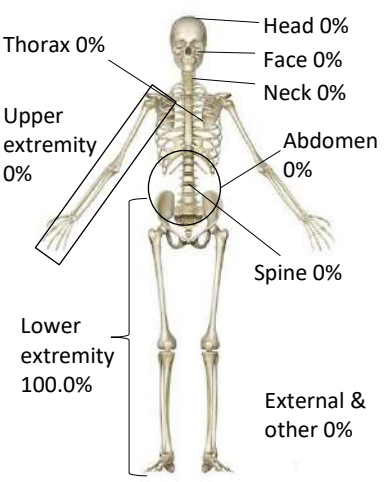
Injury pattern

♂



MAIS 1 - 2: 80.0%,
MAIS ≥ 3: 20.0%

♀

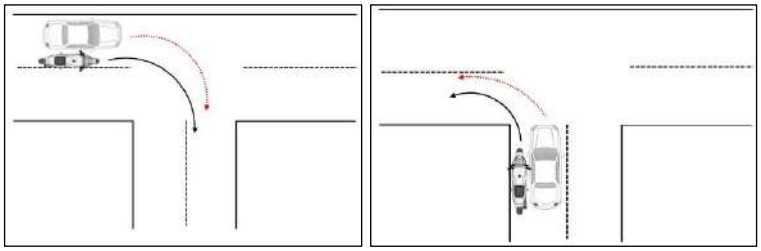


MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

Table 5 Demographic and injury pattern of crash type (sideswipes) at T-junction

1. Pre-crash motion

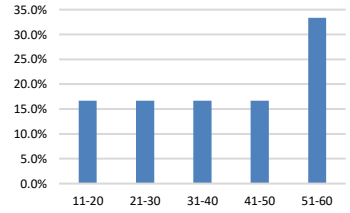
Sideswipe: N = 10



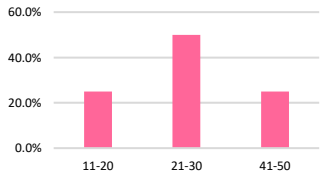
Passenger car and motorcycle are side by side are making a turn.

Age group

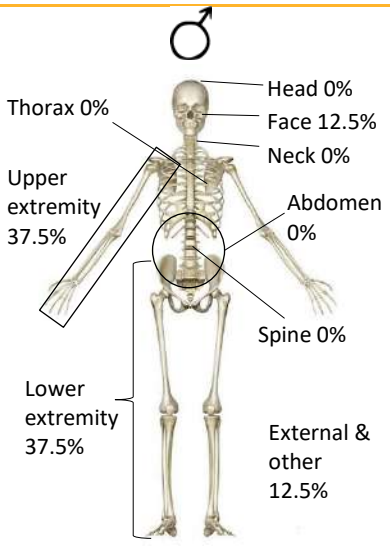
♂ N = 6



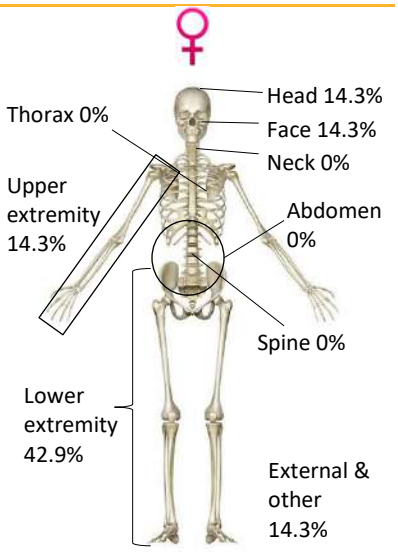
♀ N = 4



Injury pattern



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

4.2.6 U-turn

There were nine (9) cases involved U-turn crashes at T-junction. In the study, U-turn crash is categorised into two (2), which are T-junction U-turn A and T-junction U-turn B. Table 6 shows the subcategory descriptions, demographics and injury patterns. Five (5) cases found in T-junction U-turn A and four (4) cases for T-junction U-turn B. Both category male rider is the dominant (eight (8) out of nine (9)). The most common injuries for all categories were to the lower, upper extremities and face with lower extremity is the highest injury recorded. In term of injury severity, only one out of nine of riders involved in both U-turn crashes suffered MAIS ≥ 3 injury.

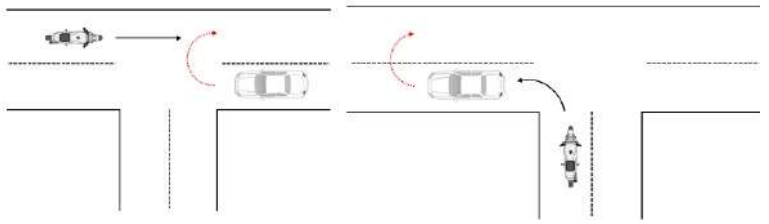
4.2.7 Overtaking

Same with U-turn, there also two (2) categories in overtaking crashes at T-junction which are Overtaking A (passenger car is overtaking motorcycle at T-junction) and Overtaking B (motorcycle is overtaking passenger car at T-junction). A total of 11 cases involved overtaking crashes at T-junction where four (4) cases in Overtaking A category and seven (7) cases in Overtaking B category as shown in Table 7. All male rider at Overtaking A category sustained injury at lower and upper extremities while female rider sustained injury at head and face region. For Overtaking B, the injuries sustained by male rider was found at almost all body region and the injuries were mild injury (MAIS 1 - 2). Nevertheless, the female rider in this category only injured at lower extremity and the injuries are severe (MAIS ≥ 3). In term of injury severity, only two (2) out of 11 riders involved in overtaking crashes suffered MAIS ≥ 3.

Table 6 Demographic and injury pattern of crash type (U-turn) at junction

1 **Pre-crash motion**

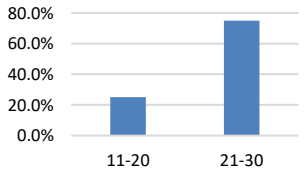
U-turn A: N = 5



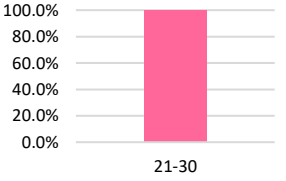
Passenger car is making a U-turn at T-junction.

Age group

♂ N = 4

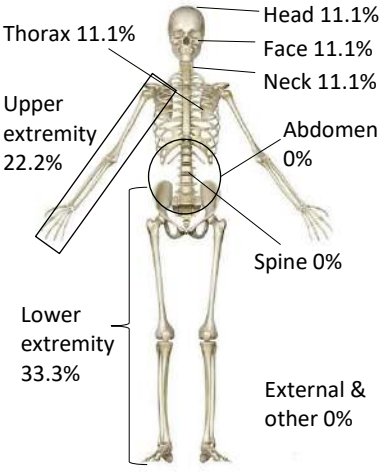


♀ N = 1



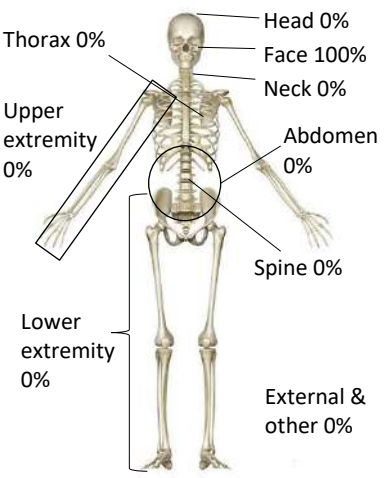
Injury pattern

♂



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

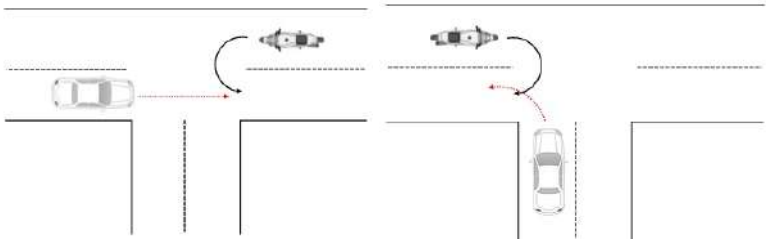
♀



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

2 Pre-crash motion

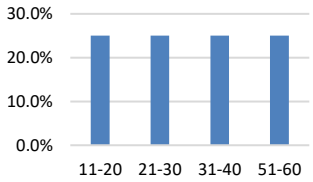
U-turn B: N = 4



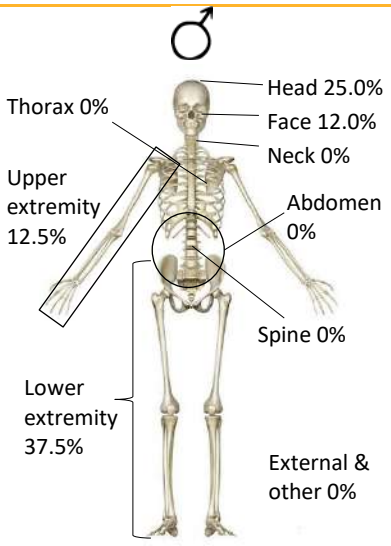
Motorcycle is making a U-turn at T-junction.

Age group

♂ N = 4 ♀ N = 0



Injury pattern



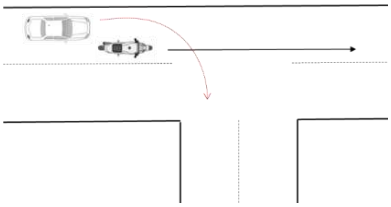
No female rider in this category

MAIS 1 - 2: 75.0%,
MAIS ≥ 3: 25.0%

Table 7 Demographic and Injury pattern of crash type (overtaking) at T-junction

1 Pre-crash motion

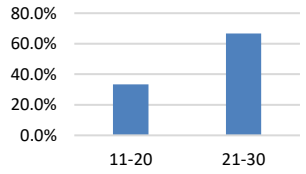
Overtaking A: N = 4



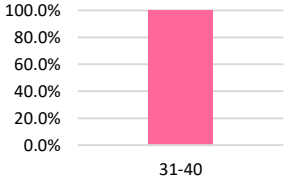
Passenger car is overtaking motorcycle and making a turn at T-junction.

Age group

♂ N = 3

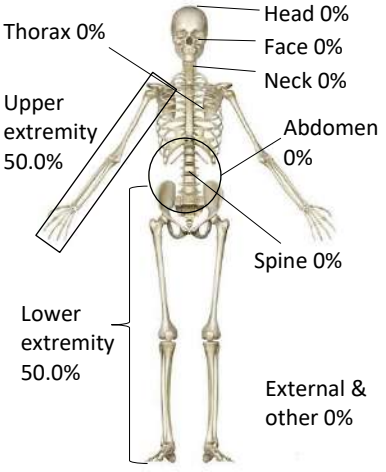


♀ N = 1



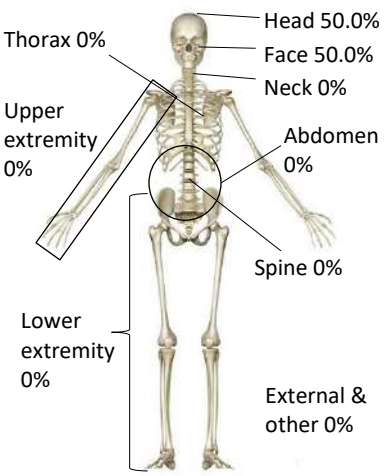
Injury pattern

♂



MAIS 1 - 2: 66.7%,
MAIS ≥ 3: 33.3%

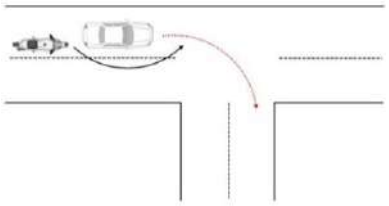
♀



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

2 Pre-crash motion

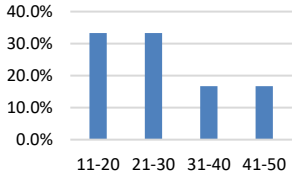
Overtaking B: N = 7



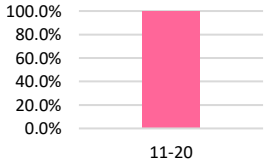
Motorcycle is overtaking passenger car at T-junction.

Age group

♂ N = 6

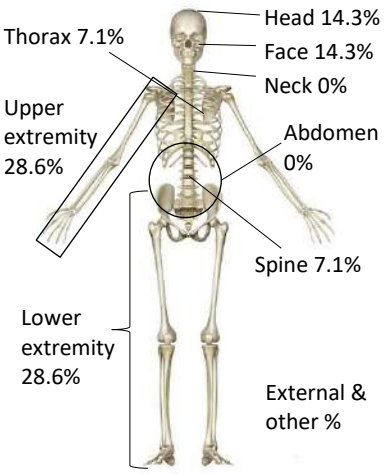


♀ N = 1



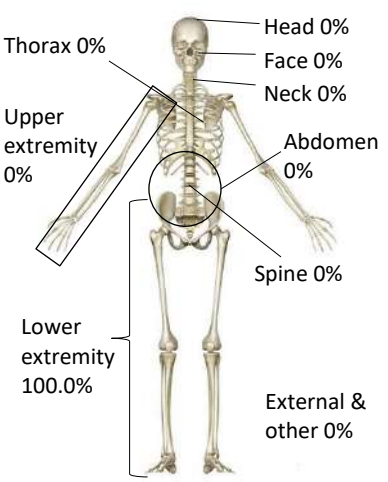
Injury pattern

♂



MAIS 1 - 2: 100.0%,
MAIS ≥ 3: 0%

♀



MAIS 1 - 2: 0%,
MAIS ≥ 3: 100.0%

5. Summary of Findings

Crash types that happened during motorcycle and passenger car collision at T-junction and injury severity of riders have been successfully identified in the study. The findings are:

a) Approach-turn:
- Half of total crashes at T-junction are contributed to approach-turn crashes.
- Approach-turn A has the highest (295 out of 321) cases compared to approach-turn B (26 cases).
- In approach-turn, A group, approach-turn A 1 crashes appeared to be more dangerous compared to approach-turn A 2 crashes as a higher portion of motorcyclists suffered MAIS ≥ 3 was found in approach-turn A 1 crashes (A1:24.9% vs A2:12.7%).
- There was no significant difference in term of injury severity between approach-turn A and approach-turn B.

b) Angle 1/2:
- A total of 216 cases were found in Angle 1 and 2 motions where 68% (146 out of 216) contained in Angle 1 and remaining 32% (70 out of 216) is Angle 2 motion.
- Injury to the extremities shows a dominant percentage among other body region in both Angle 1/2 and gender.
- For Angle 1 crashes, Angle 1B appeared to be more dangerous compared to angle 1A.
- For Angle 2 crashes, Angle 2B is significantly more dangerous to motorcyclists as almost half (9 out of 20) suffered MAIS ≥ 3 injury compared to Angle 2A crashes which only 26% (13 out of 50) suffered MAIS ≥ 3 injury.

- In comparison between Angle 1 and Angle 2, injury severity of rider in Angle 2 is more severe with 31% (22 out of 70) of the riders suffered MAIS ≥ 3 injury.

c) Rear-end

- A total of 64 cases involved rear-end crashes at T-junction where majority of the cases (76.6%) are from rear-end B crashes.
- The distribution of injury for each category is similar with lower extremity is the main region being injured and the MAIS 1 - 2 is dominant.
- In comparison between rear-end crashes, rear-end B crashes were more severe as higher portion of motorcyclists suffered MAIS ≥ 3 were found in rear-end B crashes (20.4%) compared to rear-end A crashes (6.7%).

d) Both-turning

- Eleven (11) cases were found to be in both-turning, involved only one (1) female rider and the remaining are male riders.
- Lower extremity shows the most region being injured with the majority of the injuries are at MAIS 1 - 2 (mild injury) for both male and female riders.

e) Sideswipe

- There were ten (10) cases involved sideswipe crashes.
- There were no significant difference between the group in term of demographics and injury patterns.

f) U-turn

- Nine (9) cases were involved in U-turn crashes at T-junction with five (5) cases found in U-turn A and four (4) cases for U-turn B.
- The most common injuries for all categories were to the lower, upper extremities and face.
- Only one (1) out of nine (9) of riders involved in both U-turn crashes suffered MAIS ≥ 3 injury.

g) Overtaking

- A total of 11 cases involved overtaking crashes at T-junction where four (4) cases in Overtaking A and seven (7) cases in Overtaking B.
- In term of injury severity, only two (2) out of 11 riders involved in overtaking crashes suffered MAIS ≥ 3 (one (1) male from Overtaking A and one (1) female from Overtaking B).

6. Conclusion

In a nutshell, approach-turn crashes with passenger car is making a turn while motorcycle was travelling straight ahead on primary roads was the highest action that causes collision among motorcycle and passenger car at T-junction in the study. However, in term of injury severity, the most hazardous crash types identified were among angle 1/2 crashes where passenger car/motorcycle is coming out from an access point and turning into same direction with the motorcycle/passenger car that is travelling straight.

Four (4) body regions seem to be the most region being injured in every crash types. They are lower extremity, upper extremity, face and head with the injury severity are higher at lower extremity region compared to other regions. In addition, the study also shows that the number of injury at face region is more than the number of injury to the head among rider that involved crashes at T-junction.

7. Recommendation

In this research, it provides information on the most hazardous road environment in Malaysia in term of frequency of crashes and severity of injury at the said road environment. The findings could be used to enhance enforcement efforts to prevent the same situation happened at T-junction. In term of future research, an examination on the location factors (signalised and un-signalised junction) and temporal factors associated with the junction-road crashes should be conducted. In addition, with the support from police database on black spot area among T-junction in Malaysia could potentially be a fruitful method to improvise implementation of police-enforcement strategies.

Furthermore, public information and safety education programmes, especially at driving school, can be formulated using the study findings in order to educate road user especially on giving right-of-way at junctions. For example, safety education programmes may be directed toward certain motorists such as male riders or drivers of passenger car.

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Research Report

Crash Type and Associated Injury of Non-Fatal Motorcycle Crashes at T-Junction

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