Emergency Braking Patterns of Trained and Untrained Riders

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Abstract: - The complexity of motorcycle braking systems remains in the different applications of brakes using both hands and legs. In comparison to passenger vehicle systems that use brake pedals to slow down, motorcycles usually have independent front and rear braking. Furthermore, motorcycles have a high center of mass with a short wheelbase. This may result in loss of control during harsh braking. Thus, the motorcyclist's braking technique is important in producing safe braking. The objective of this project is to understand the difference between the braking technique of people who have attended defensive riding training (trained) with those people who did not attend (untrained). Both trained and untrained riders used higher rear braking force than front braking force at all test speeds. The trained riders improved the front braking force by 26.8% and reduced the rear braking force by 18.2% when the test speed changed from 30 km/h to 50 km/h. Thus, the deceleration produced by trained riders linearly increased with the increment of speed. On the other hand, untrained riders improved front and rear braking force by 15.6% and 3.4% respectively from 30 km/h to 40km/h. No change in braking force was found when the speed increased from 40 to 50 km/h, thus producing similar deceleration at both speeds respectively. This may increase the risk to the rider because, at higher speeds, the motorcycle produces a higher braking distance and time if a similar force is applied. Further analysis shows that trained riders used deceleration in the range of 0.40-0.49 at the speed of 30 km/h, and adjusted the motorcycle deceleration to 0.60-0.69 at the test speed of 40 and 50 km/h. Nevertheless, the untrained riders produced deceleration in the range of 0.5-0.59 in all test speeds.

Key-Words: - motorcycle, anti-lock braking (ABS)

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1 Introduction

A high number of motorcycles contain independent front and rear braking. During braking, the dynamic load transfer is higher for the front than the rear wheelbase due to an elevated center of mass and short wheelbase. The allotment of front and rear braking force applied depends on the rider's skills [1]. One of the issues highlighted with motorcycle crashes is the inadequate application of braking [2]. Insufficient or hard braking may result in tire locking or a higher stopping distance. The stopping distance with rear brakes only will result in almost double compared to the stopping distance produced using front and rear brakes together [3]. The introduction of safety technology like Motorcycle anti-lock-braking (ABS) has shown an improvement in motorcycle stability but can only be effective if braking is applied [4]. Therefore, the need for further training for motorcyclists to improve their evasive action and braking is further discussed.

Crundall [5] differentiated the riding skill between novices with riding experience of less than one year, experienced who have ridden more than three years, and advanced riders, who have passed the advanced riding course and have three years' experience riding. The simulation experiment was conducted at different speeds (60 mph and 40 mph) and different bend corners. At the speed of 60 mph, all riders ride at the mean of 55 mph. However, at the speed of 40 mph, advanced riders ride at a slower speed of 35 mph compared to novice and experienced riders at 37.1 mph and 37.6 mph respectively. Additionally, advanced riders position themselves at the center of the road and regularly change their position on the lane. In contrast, novice riders ride near the curb of the road and are most likely to defy the speed limit. The position helps advanced riders for a better view of the road and detect oncoming hazards. The experienced riders were also reported to vary their lane position during riding but slightly less compared to advanced riders. In another simulation study, the tester was found to apply the brake later when facing the real hazard compared to near-miss situations [6]. The results show the importance of advanced training in helping motorcyclists diagnose and act based on the severity of the situation.

Ivers et al [7] argued that the coaching program introduced to novice riders was found to be ineffective. Riders who have attended the coaching program are 2.1 times more likely to be involved in a crash compared to those who did not attend [8]. The training is found to encourage overconfidence among the trainers, thus resulting in speeding and higher near-miss crashes. While the knowledge of hazard perception shows improvement, there is no direct relation to support that the knowledge of hazard perception can reduce crash risk. There is also a possibility that the novice riders joining the coaching program have limited road experience thus exposing them to higher risk. It is to be noted that the training program should be emphasized with experienced riders to improve their current riding skills, hazard detection, and fixing bad habits, rather than novice riders who encourage impetuous riding behavior.

In [2], the author analyzed the crash data to investigate key riding skills required by motorcyclists when facing high-risk situations. Just over 70% of the crashes occurred when the motorcyclists were traveling on a straight path. Half of rear-end collisions are caused by motorcyclists' errors in detection. Head-on, sideswipe, and single-vehicle crashes occurred due to motorcyclists' errors in decision and execution. There was an attempt by the riders to avoid the crash. Nonetheless, 43% and 38% of the cases demonstrate inefficient braking and swerving, respectively. Previous experimental work has identified that expert riders demonstrate deceleration rates 52% higher than novice riders during emergency braking [9]. Furthermore, the riding experience is unassociated with the effectiveness of deceleration. Thus, the techniques of proper handling and emergency braking should be taught to motorcyclists to reduce the injury severity risk.

In Malaysia, 43.7% of crash fatalities involving motorcycles occurred on a straight road, followed by 19.7% on a bent road [10]. The highest crash configuration is head-on collision (19.0%) and out-of-control (18.9%). This crash situation requires rider skills to control braking, maneuver, and stability of motorcycles. To the best of the author's knowledge, only a few references in the literature examined the braking performance of Malaysian riders. Ariffin et al. [11] conducted braking test at the dry path with the speed of 50 km/h using different low cc motorcycles. It was found that the highest deceleration of 0.85g was achieved using both front and rear brakes on the motorcycle equipped with a disc and drum. In contrast, the lowest deceleration of 0.35g was produced using a motorcycle with the application of rear brakes only. Yuen et al. [12] investigated a test on a bend road and found that all the testers applied a higher rear brake than a front brake, and only increased the intensity of the brake less than 50m distance from the curve. However, both studies do not use the accuracy of the data logger. This study aims to investigate the braking pattern of Malaysian riders during emergency braking using a single ABS motorcycle. The data is important because Malaysia is in the move towards mandatory ABS for motorcycles with engine capacity of 150cc and above.

2 Problem Formulation

Figure 1 shows the motorcycle diagram representing forces acting during braking. During braking, the loads on the front wheel (N_f) and rear wheel (N_r) are calculated using:

$$N_f = mg\frac{b}{a+b} + (S_f + S_r)\frac{h}{a+b} \qquad (1)$$

$$N_r = mg\frac{a}{a+b} - (S_f + S_r)\frac{h}{a+b} \qquad (2)$$

where. m is the overall mass, g is the acceleration due to gravity, a and b are the distance from the front and rear wheelbase to the center of mass, S_f and S_r are the front and rear braking forces and h is the height of the center of mass. Based on the equation of motion

$$S_f + S_r = m\ddot{x} \qquad (3)$$

$$N_f = mg\frac{b}{a+b} + (m\ddot{x})\frac{h}{a+b} \qquad (4)$$

$$N_r = mg\frac{a}{a+b} - (m\ddot{x})\frac{h}{a+b} \qquad (5)$$

During hard braking, the load on the front wheel will increase while on the other hand, the load on the rear wheel decreases. To avoid rear wheel lift, the calculation of the maximum deceleration is shown below:

$$\ddot{x} < g\,\frac{a}{h} \qquad (6)$$

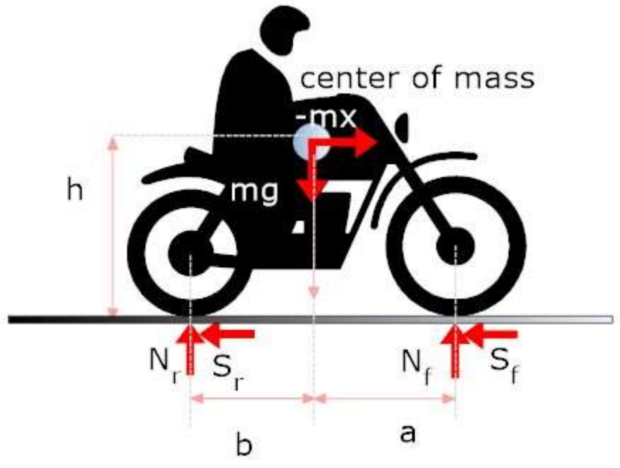

Fig. 1: motorcycle braking diagram

Based on the calculation, the rider should produce deceleration below 0.91g to avoid rear wheel lift.
Mean Fully Developed Deceleration (MFDD) is calculated using the equation below.

$$MFDD = \frac{(v_{08})^2 - (v_{01})^2}{25.92*(s_{01} - s_{08})} \quad (7)$$

Where v_{08} is the speed at 80% of the brake trigger activation speed, v_{01} is the speed at 10% of the brake trigger activation speed, s_{01} is the distance at which the speed is v_{01} and s_{08} is the distance at which the speed is v_{08}.

3 Methods

Motorcycle SYM VF3i LE (185 cc) with front ABS is used in this study. The test was conducted on a dry asphalt road surface with a length and width of 100 m and 2 m respectively. 100 riders with valid motorcycle licenses are recruited from advertisements. The riders are divided into two groups. 22 people are train riders, people with valid motorcycle license driving, and have attended defensive riding training. 78 people are untrained riders, people with valid motorcycle licenses driving but do not participate in further riding training. The age distribution for both riders is shown in Figure 2. Sensor models HKM PK 1.0 and 2.0, attached to the VBOX 3i data logger are used to examine the front and rear brake force respectively. The riders are asked to achieve traveling speeds of 30, 40, and 50 km/h and safely apply brakes until the motorcycle stops. Each speed configuration is repeated three times to calculate the average reading. The riders are advised to apply brakes as usual in an emergency.

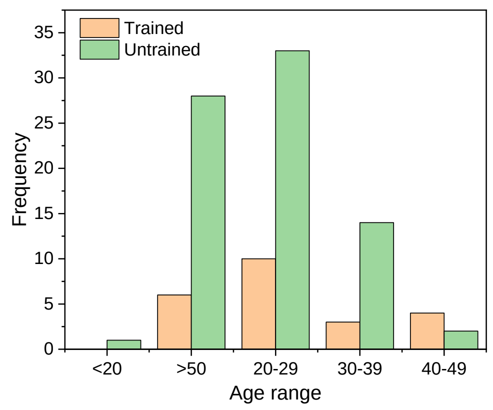

Fig. 2: Age distribution of trained and untrained riders participating in this test

4 Results

Figures 3 and 4 exhibit the average front and rear brake force produced by trained and untrained riders. Both trained and untrained riders produced higher rear braking force than front braking force at all traveling speeds. Nevertheless, the trained riders applied higher braking force than untrained riders. A study conducted by Yuen et al. [12] also reported that the Malaysian tester applied higher rear braking than front braking during cornering. This may be due to the fear of tire locking during braking.

It appears in Figure 3 that the trained riders slightly increased the front braking force by 26.8% and reduced the rear braking force by 18.2% with the increment of speed from 30km/h to 50 km/h. This action shows that trained riders adjusted the front force to produce higher deceleration at higher speeds, thus reducing braking distance and time. This is aligned with Dunn et al. [13], who reported that the proper technique of braking taught in riding courses is by gradually increasing the front brake force as the speed decreases.

The front and rear braking force pattern for untrained riders in Figure 4 shows a similar trend. The average front and rear brake force slightly rose by 15.6% and 3.4% respectively when the speed was changed from 30 to 40 km/h. The main difference between the braking force of trained and untrained riders is shown when the speeds changed from 40 to 50 km/h. No change is detected in the braking force of the untrained riders at the speeds of 40 and 50 km/h. This is a main concern because at a higher speed, using similar forces will result in lower deceleration, thus producing higher braking distance and braking time.

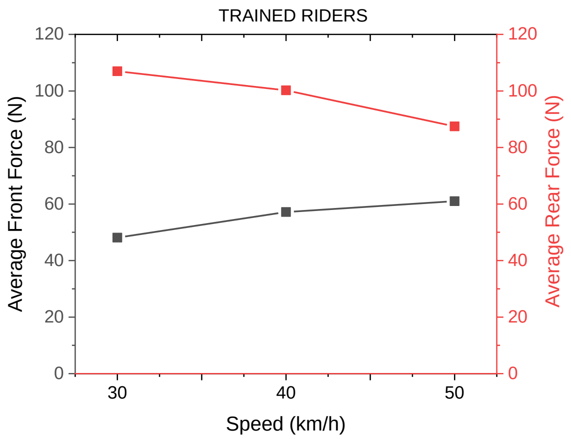

Fig. 3: Average front and rear braking force produced by trained riders

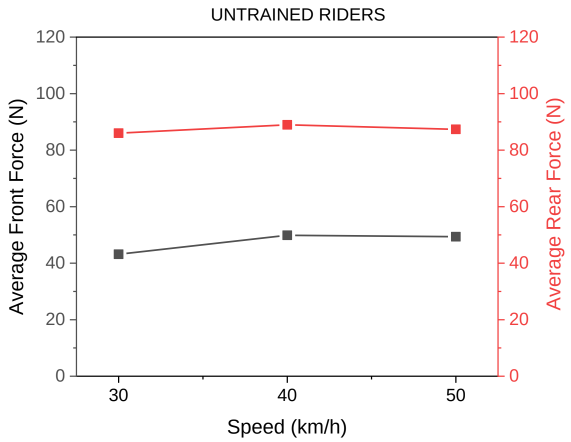

Fig. 4: Average front and rear braking force produced by untrained riders

The graph of deceleration and Mean Fully Developed Deceleration (MFDD) of trained and untrained riders are shown in Figure 5. From the graph, trained riders produce lower deceleration at 30 km/h compared to untrained riders. This may be due to low risk at a low speed of 30 km/h. The deceleration of trained riders increased linearly with the increment of traveling speed. These values correlate with a higher ratio of front-to-rear brake force produced by trained riders at the speeds of 40 and 50 km/h, as previously shown in Figure 3. As put forward by Chakraborty [14], a great load is transferred to the front tire during deceleration, thus greater front braking force will result in better braking performance. No deceleration change is detected on the untrained riders at the speeds of 40 and 50 km/h. A possible explanation for this is due to the similar braking forces used in both speeds, as was mentioned in Figure 4. The increment of deceleration is greatly correlated with the increment of front brake usage [15]. On the other hand, the MFDD value is higher for all speeds for trained riders. The highest deceleration produced by trained and untrained riders are at 0.65g and 0.56g. These values correlate favorably with Ecker et al. [16] who reported train riders and untrained riders tested on a dry path produced an average deceleration of 0.65g and 0.57g respectively. The author argued that almost half of the riders did not apply full braking, especially those with one year and less experience who produced lower deceleration at 0.57 g. Davoodi et al [17] reported an average deceleration rate of 0.46 g on dry roads. The deceleration is lower in this study because the test motorcycle is not equipped with ABS.

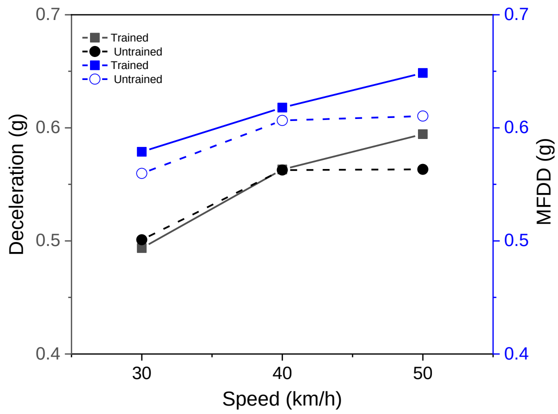

Fig. 5: Deceleration and MFDD of trained and untrained riders produced at different speed

Figure 6 presents the normalized number of train riders with the deceleration produced at different speeds. At low speeds, most of the trained riders maintain low deceleration at the range of 0.4-0.49. However, the deceleration is increased to 0.6-0.69 when the traveling speed is at 40 and 50 km/h. The highest deceleration recorded by trained riders is at 0.82 g, closer to the 0.91 g which is the value limitation for rear wheel lift. The analysis shows that with proper distribution of braking force, the optimum braking force can be achieved while maintaining motorcycle stability. Figure 7 shows that regardless of the traveling speed, the untrained riders maintain the same deceleration within the range of 0.5-0.59. This can be dangerous as at higher speeds, the braking distance and time will be increased thus increasing the risk of the rider during emergency braking. Further tests carried out by Huertas Leyva et al[18] found that experienced riders with limited access to training usually underutilize the motorcycle ABS braking capacity. By introducing minimal training and exercising, novice riders can achieve similar deceleration produced by experienced riders using motorcycles with ABS.

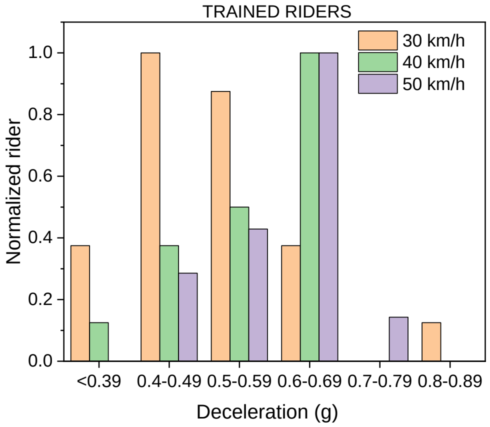

Fig. 6: Deceleration produced by normalized trained riders

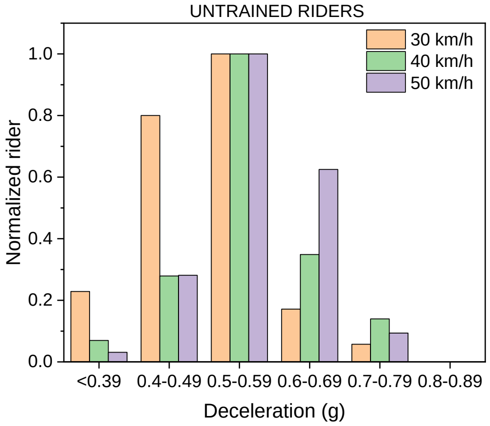

Fig. 7: Deceleration produced by untrained riders

5 Conclusion

Our research underlined the importance of motorcycle braking skills, as the matter is complicated compared to passenger vehicle braking. The analysis demonstrates that while trained riders adjusted the braking force and deceleration according to the test speed, no significant changes were detected in untrained riders, especially at higher speeds. This experiment utilized a motorcycle with a single ABS. Consequently, the deceleration produced by a motorcycle without ABS might even be lowered if conducted by a non-trained rider. As motorcycles are the highest mode involved in crash fatality, one of the proposed engagements is to encourage and offer defensive riding training widely to the user. With the move towards mandatory ABS in Malaysia, training using ABS motorcycles is important to ensure the rider conducts optimal braking and utilizes the safety technology.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed to the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.