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Relative Risk of Fatal Injury in "High-Performance-Small-Motorcycle" Crashes in Malaysia

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This study presents an analysis of injuries (severe and fatal) sustained by "high-performance-small-motorcycle" users in Malaysia and establishes the relationship between fatality risk and human factors, exposure and vehicle factors resulting from motorcycle crashes. From the data gathered a statistical model based on logistic regression modeling technique has been developed. Five variables found to have a significant influence on fatality risk ($p<0.05$) were age, location sites, engine capacity, object/vehicle struck and collision types.

Keywords: "High-performance-small-motorcycles"; Fatality Risk; Motorcycle Crashes; Logistic Regression

INTRODUCTION

A high-performance-small-motorcycle (HPSM) is a light-weight motorized two-wheeler, not classified as scooter, weighing less than 100 Kg which and is stylish and aerodynamically designed to travel faster than 100 km/hr. The HPSM is one of the major modes (about 60%) of personal transport in Malaysia. This is because HPSMs are cheap, affordable and "reliable" compared to other motor vehicles.

For the last decade or so, the number of registered motorized two-wheelers (motorcycles and scooters) has increased tremendously from 830,834 in 1976 to 4,328,997 in 1997. Of this, about 95% are HPSMs (PDRM, 1993; 1997). Along with the increase in numbers, casualties amongst the HPSM users have increased dramatically particularly in the last decade (Figure 1). Of the 6,304 fatalities in 1997, approximately 55% involved HPSMs. Radin *et al.* (1995) have noted that their overall relative risk of being killed and seriously injured is about 20 times higher compared to car occupants. This group of road users therefore represents an important target for road safety research.

This study presents an analysis of the injuries sustained by HPSM users and the relationship between injury outcomes and (i) the riders' characteristics (e.g. age, sex, riding experience), (ii) their exposures (type of road traveled on, object struck), and (iii) vehicle factors (engine capacity, model of motorcycle) result-

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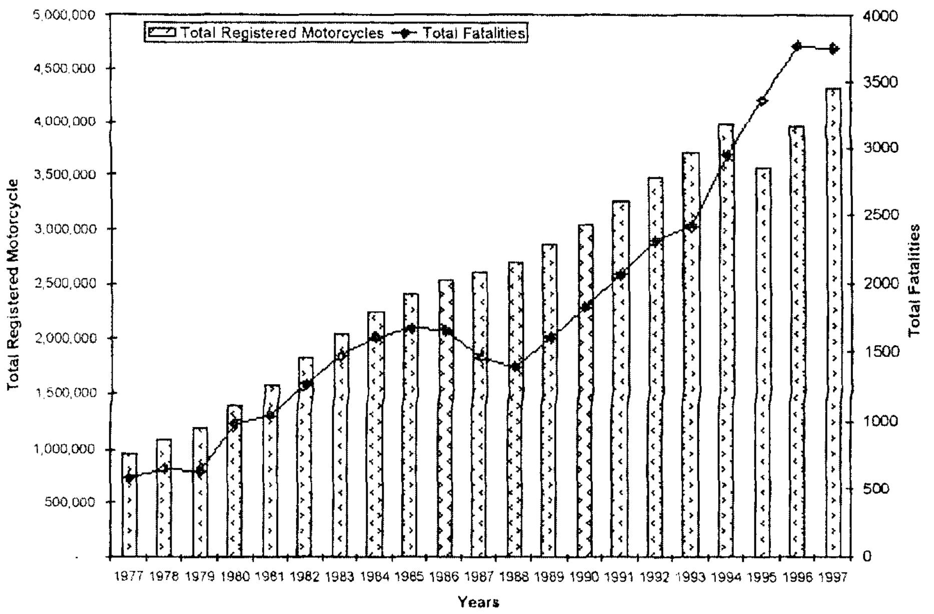

FIGURE 1 Total registered motorcycles and total number of fatally injured motorcyclists in road crashes (Source: Royal Malaysia Police (PDRM) 1993, 1997)

ing from HPSM crashes. The outcome of the research should provide a base for the government to carry out more strategic programs to alleviate problems and concerns related to HPSM usage. Further, this research has led to the establishment of a comprehensive crashworthiness database for Malaysia. It should be noted that currently there is no such system is available for injury control measures.

METHODOLOGY

Place of Study

In this study, the data were collected on all HPSM crashes that occurred on a public road within the Kajang, Hulu Langat, Cheras and Kuala Lumpur regions. These regions are the catchment areas of the Kajang and Jalan Bandar Police Stations. These police stations were selected to represent the catchment area of Klang Valley for to the following reasons:

1. The annual crash rates for serious and fatal injuries are ranked among the highest in Malaysia (PDRM, 1997).
2. Co-operation provided by the regional police and hospital departments facilitated easy access to road crash victim incidents and medical reports.
3. Characteristics of various motorcycle crashes within the study area were essentially identical to motorcycle crashes in other areas in Malaysia (PDRM, 1997).

Sample Selection

Data were collected on crash victims admitted as in-patients or who had died as a result of HPSM crashes in Hospital Kajang, Hospital Universiti Kebangsaan Malaysia and Hospital Kuala Lumpur, between 1 January 1998 and 31 December 1998 as well those involved in HPSM crashes within the catchment areas of the participating police stations.

Police Records

In Malaysia, traffic accidents are recorded and investigated by the Royal Malaysian Police. When the police are aware of an accident involving at least one injured person, they will go on site and complete an investigation form. Therefore, in this study data collection was carried out on a weekly basis by retrieving information on previous crashes notified to the police for that particular week. Details on the incident, location of motorcycle and other vehicles involved were collected using a specially designed crashworthiness form. Casualty information such as name, age and gender were then utilized to match and retrieve hospital notes in order to understand the pattern of injuries.

Hospital Records

Injuries requiring hospital admission were collected prospectively from all wards involved in the management of injured patients. Once notified of a motorcyclist who was still in the hospital, the researcher would get permission from the staff nurses of the ward to interview the victim. On being granted permission, the researcher would visit the victim and describe the purpose of the study and request for consent to participate. If the victim agreed, the researcher would verbally administer the questionnaire and record responses. Injury information was subsequently obtained from hospital reports, where appropriate. Details of each casualty's injuries, principal diagnosis and treatment period were extracted and recorded on an injury data form prepared for this study. Injuries sustained by each patient were scaled using the Abbreviated Injury Scale (AIS) (AAAM, 1990). In presenting the distribution of injuries, the Maximum AIS (MAIS), was used to describe the overall injuries.

Death Records

All deaths occurring after any injury during the study period were recorded. If the patient had died on the spot or was hospitalized, this list was completed by a study of all the deaths recorded in the participating hospital data file.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), release 7.5. In the analysis, motorcyclists were assigned into two groups of severity: fatal and non-fatal. These constituted dichotomous dependent variables. Univariate analysis was performed initially to identify the potential risk factors that significantly influence the fatality risk among motorcyclists under Malaysian conditions. To further understand the problem, a multivariate model was developed using the following approach. All available and potentially relevant independent variables were included in the initial model. The stepwise logistic regression technique was used to estimate the odds ratios (OR), at 5% level of significance as a determinant of the variables that should be considered for inclusion; and the forward stepwise selection method was used to decide the variables that were to be included or omitted from the model (Hosmer and Lemeshow, 1989).

RESULTS

Analysis of Odds Ratios (OR)

In this analysis, both rider and pillion rider information was included for further analyses. Information on a total of 412 motorcyclists involved in motorcycle crashes was available for analysis during the study period. However it must be remembered that all of the sample is always available for analysis. If values are missing for a few variables or if they cannot be ascertained, it will have the effect of reducing the sample size available for analysis.

Age and Gender

The age and gender of motorcycle riders were examined to assess their effects in influencing fatality risk outcome. Gender was not found to be significant in influencing the injury severity. Age was entered as a continuous variable, and it was found to influence fatality risk. The odds of being a fatal compared to a non-fatal rider increased with increasing age. The odds of experiencing a non-fatal to fatal injury for an increment in one year of age was 1.02.

To further assess the effects of age, age distribution was divided into two categories as shown in Table I. The odds ratios for the categories were determined using the age group (≤40 years) as reference, which was assigned an odds ratio of 1.00. It was observed that the odds ratios for the age groups had an increasing trend, with about a one-third increase in odds ratio for riders above 40 years of age.

TABLE I Odds Ratios and 95% Confidence Interval (95% CI) by age of motorcyclists involved in HPSM crashes

Age of Riders (years)	*Injury Severity*				*Total*	*OR*	*95% CI*
	Non-fatal		*Fatal*				
	Male	*Female*	*Male*	*Female*			
≤ 40	184	20	144	10	358	1.00	Reference
> 40	20	2	30	2	54	1.39	1.03 1.86
The following model was based on age as a continuous variable							
Variable	Coefficient	S. E.		Sig.		OR	95%CI
Age	0.0213	0.0095		0.0254		1.02	1.00–1.04
Const.	-0.7686	0.2754		0.0053			
Z = −0.7686 + 0.0213Age							

(χ^2 = 5.075, df= 1, p = 0.0243) Z: Fatality risk of motorcyclists

TABLE II Odds Ratios and 95% Confidence Interval (95% CI) by engine capacity of motorcycles involved in HPSM crashes

Engine Capacity (C.C)	*Injury Severity*		*Total*	*OR*	*95% CI*
	Non-fatal	*Fatal*			
HPSM < 150 c.c.	165	125	290	1.00	Reference
HPSM ≥ 150 c.c.	27	50	77	1.56	1.20 2.03

(χ^2= 11.723, df=1, p = 0.0006)

TABLE III Odds Ratios and 95% Confidence Interval (95% CI) due to type of object struck in HPSM crashes

Type of Object Struck	*Injury Severity*		*Total*	*OR*	*95% CI*
	Non-fatal	*Fatal*			
Passenger car	85	48	133	1.00	Reference
Other Motorcycle	31	17	48	0.57	0.33–0.97
Light Commercial Vehicle	16	36	52	2.33	1.37–3.97
Heavy Goods Vehicle	19	36	55	1.97	1.18–3.26
Trees, Lamp posts, Poles	17	25	42	1.53	0.88–2.65
Others	46	19	65	0.43	0.26–0.70

(χ^2= 38.145, df= 5, p< 0.0001)

TABLE IV Odds Ratios and 95% Confidence Interval (95% CI) due to collision type in HPSM Crashes

Collision type	Injury Severity		Total	OR	95% CI
	Non-fatal	Fatal			
Head-On	9	39	48	3.89	2.19–6.91
Rear-end	30	19	49	0.57	0.35–0.92
Others	69	55	124	0.72	0.50–1.03
Lateral Collision	98	69	167	1.00	Reference

(χ^2= 27.865, df= 3, p< 0.0001)

TABLE V Odds Ratios and 95% Confidence Interval (95% CI) due to type of location in HPSM crashes

Type of Location	Injury Severity		Total	OR	95% CI
	Non-fatal	Fatal			
Non-junction	111	144	255	1.00	Reference
Junction	73	40	113	0.65	0.52–0.82

(χ^2= 14.062, df= 1, p = 0.0002)

Engine Capacity

Table II shows the fatality risk according to engine capacity. The logistic regression model was developed with the engine capacity as a categorical variable with reference to the smallest engine capacity group (< 150 cc). This is because the majority (over 90%) of the motorcycles in Malaysia had a engine displacement of less than 150 cc. Engine capacity of the motorcycle was found to influence fatality risk, with motorcyclists riding larger bikes being at greater fatality risk compared to those on smaller bikes.

Type of Vehicle/Object Struck

Injuries are generated by a change in velocity (Δv) of a vehicle during a crash phase. However, Δv is in turn dependent upon the crash type and collision object (Kallberg and Luoma, 1996). For this study, the Δv could not be ascertained. This is because the meticulous data collection at the scene of the accident which will assist in reconstructing the accident are lacking. As the Δv could not be ascertained, the fatality risk among motorcyclists was only assessed according to the object struck and collison type in motorcycle crashes. The objects struck were grouped as passenger cars (32.2%), motorcycles (12.3%), light commercial vehicles (LCVs) (14.5%), heavy commercial vehicles (HCVs) (14.2%), trees, lamp posts and poles (10.5%), and others (16.2%).

Injury severity was likely to be greater in LCV and HCV collisions, followed by trees and poles collisions, compared to passenger cars. The odds ratio of fatal injuries was higher in LCVs, HCVs, trees, lamp posts and poles collisions compared to collision with passenger cars (Table III). The odds of sustaining a fatal injury was two times higher in collision with LCVs and HCVs and one and half times higher in the case of collisions with trees, lamp posts and poles.

Collision Type

In assessing the influence of collision types on fatality risk, the lateral collision was classified as the reference group (Table IV). From this analysis, it could be seen that the odds ratios of head-on collision type significantly influenced the fatality risk. It was reasonable to expect the odds for sustaining fatal injuries to be higher in an head-on collision compared to other collision types.

Type of Location

Fatality risk in terms of accident location was classified as "junction" and "non-junction" sites. Junction accidents are those which occur within a distance of 50 meters from the junction such as crossroads, T-junction, roundabout etc. Non-junction accidents, on the other hand, are defined as having occurred 50 meters away from the junction. This definition was only used for the initial categorization of accident location. A comparison of collisions at non-junction sites with collisions at junction sites (Table V) revealed that the odds of experiencing fatal injuries were about one and half times greater at non-junction sites compared to junction sites.

Multivariate Analysis

To further analyze the data, a multivariate model was developed using unconditional logistic regression models (Rothman, 1986). Continuous data such as age was categorized using not more than three categories. In order to keep the analysis simple, interaction terms were not considered in this study. The variables and corresponding definitions used for the analyses are shown in Table VI.

TABLE VI Description of variables to be included into multivariate analysis

Variable	*Acronym*	*Unit*	*Type*	*Design Value*
Dependent			Categorical	
Injury Severity	Severity	-	Non-fatal	0
			Fatal	1
Independent				
Age	Age	Years	Categorical	
			≤ 40	0
			>40	1
Gender	Gender	–	Categorical	
			Male	0
			Female	1
Object Struck	Object	–	Categorical	
			Others	0
			LCVs and HCVs	1
			Trees, Lamp posts and Poles	2
Collision Type	Colltype	–	Categorical	
			Head-on	0
			Non-Head-on	1
Location Sites	Sites	–	Categorical	
			Non-junction	0
			Junction	1
Engine capacity	Engine	c.c.	Categorical	
			<150 cc	0
			≥150 cc	1

TABLE VII Logistic regression on fatality risk resulting from HPSM crashes in Malaysia

Variable	*B*	*Df*	*Sig.*	*OR*	*95% CI*
Age(1)	0.4671	1	0.0103	1.60	1.12–2.28
Object		2	0.0000		
Object(1)	0.6842	1	0.0012	1.98	1.31–3.00
Object(2)	0.2608	1	0.3130	1.30	0.78–2.15
Colltype(1)	-0.7713	1	0.0002	0.46	0.31–0.70
Site(1)	-0.3683	1	0.0084	0.69	0.53–0.91
Engine(1)	0.5213	1	0.0009	1.68	1.24–2.29
Const.	1.4512	1	0.0000		

$Z = 1.4512 + 0.4671 Age(1) + 0.6842 Object(1) + 0.2608 Object(2) - 0.7713 Colltype(1) - 0.3683 Site(1) + 0.5213 Engine(1)$

($\chi^2 = 80.214$, df= 6, $p < 0.0001$)

Table VII shows the estimated coefficients and odds ratios of the multivariate analysis that predict fatality risk factors. A total of five variables were found to significantly influence the fatality risk ($p<0.05$) of motorcycle crashes. However, gender was not found to be significant in influencing fatality risk. Results in the multivariate analysis were observed to be consistent with the results in the analysis of odds ratios.

DISCUSSION

Age has been a well-recognized risk factor for motorcycle crashes of all severities. This is in line with evidence that fatality risk increases at older ages for fatal crashes. Broughton (1988) in his study found that the rate of injury crash involvement decreased in those aged over 50 while the rate of fatal crashes increased. Bragg (1981) also found that older age categories had the highest relative risk of fatality. The result of the analysis of age in this study is also consistent with previous studies (Broughton, 1988; Bragg, 1981), where an increase in age was strongly associated with an increase in fatality risk.

However, some researchers have shown that the risk of injury crash decreases with increasing age (Taylor and Lockwood, 1990; Kraus *et al.*, 1992; Haworth *et al.*, 1997; Mullin, 1997). It is important to note that these studies included all minor spills as well. As such, Taylor and Lockwood (1990) excluded fatalities in their study. However, the present study considered those injuries resulting in hospital admission, all deaths resulting from any injury, and motorcyclists who had died on the spot as a result of motorcycle crashes.

Previous studies have found a positive correlation between gender and fatality risk (Evans, 1991; Begg *et al.*, 1994; Langley *et al.*, 1994). Male riders were found to be at greater fatality risk than female riders; however, this study suggests no evidence of any association between gender and risk. This was as expected since the majority (over 90%) of our casualties were males. As only a very small proportion of our sample constituted female subjects, no strong association would therefore be found between gender and fatality risk.

The relationship between fatality risk and engine capacity (c.c. rating) of the motorcycle has been well debated. Results of this study showed a generally positive association between engine capacity and fatality rates. This is in line with the findings by Hurt *et al.* (1981), Jonah *et al.* (1981), Pedder *et al.* (1990) and Taylor and Lockwood (1990). Therefore more detailed research is warranted to further understand the need for safety features of HPSM, as they appear to be inferior in design compared with the standard larger foreign bikes.

In assessing the influence of collision types on fatality, the findings generally show that motorcyclists are at greater fatality risk in motorcycle-Heavy Commercial Vehicle (mc-HCV) or motorcycle-Light Commercial Vehicle (mc-LCV) collisions. This is in line with the findings of Mohan *et al.* (1984) and Walz *et al.* (1990) who showed that motorized-two-wheeler riders are more likely to sustain fatal injuries when involved in crashes with light and heavy vehicles such as buses and trucks. Studies that examined the effects of vehicle size and mass ratio (Evans, 1993; Buzeman *et al.*, 1998; Thomas and Frampton, 1999) can probably explain why such collisions (mc-HCVs and mc-LCVs) are more severe. In an impact with a HCV or LCV, the greater mass of these vehicles compared to that of a motorcycle produces an adverse mass ratio effect on the motorcycle. Thus, the lighter weight of HPSM would lead to an increase in fatality risk compared to LCVs and HCVs. Furthermore, the higher stiffness of HCVs and LCVs is relatively unyielding, and not easily deformable, and are of a relatively "open" physical form than the motorcycle (Scoot *et al.*, 1995), which may lead to an incidence of under-run when a collision occurs (Radin Umar, 1996). Besides, LCVs and HCVs are the groups of vehicles with relatively high levels of aggressivity for their level of crashworthiness (Cameron *et al.*, 1999) compared to motorcycles. Hence, motorcyclists usually end up with severe injuries in such collisions.

On the other hand, motorcyclists colliding with trees, lamp posts and poles were found to have a relatively higher fatality risk compared to passenger cars. This is because the objects struck are usually narrow and the events tend to be non-energy absorbing impacts (Ahamedali, 1994). Upon collision, the motorcycle and motorcyclists absorb almost all the impacting energy, which in turn result in greater injury severity.

Severity of a crash depends on the velocity change (Δv) and the driving speed of a vehicle during a collision. The relation between driving speed and Δv is influenced by crash type, and mass of the vehicle and collision object. For instance, in a head-on collision, the increase in Δv can be several times higher than the increase in driving speed (Kallberg and Luoma, 1996), resulting in greater the fatality risk for a motorcyclist. This is because during a head-on collision with another vehicle, the rider who is less protected and widely exposed, will move forward as the motorcycle begin to decelerate, hence loading the structure of the opponent vehicle and leading to severe injuries. Moreover, the finding from this study was consistence with the finding by Peek-Asa and Kruas (1996) who reported that riders in head-on collisions were to have significantly highest average ISS score, highest average number of injuries per rider and were more likely to be fatally injured compared to other crash types. This is because riders in head-on motorcycle collision were more likely to be speeding than riders in an approaching turn collision. Thus motorcyclists usually end up with severe injuries.

Riders involved in non-junction crash sites were found to have greater fatality risk than those at junction sites. This could be due to vehicles travelling at higher speeds at non-junction sites. On the other hand, vehicles are normally expected to have lower speed movements while approaching or pulling out from junction sites. Haworth *et al.* (1997) reported that riders were more conscious when approaching junction sites, as they would look all around and be prepared to brake. Furthermore, they also found that inexperienced riders were more likely to slow down while approaching a junction site. From these observations, it can be inferred that lower travelling speeds might reduce the injury severity suffered by motorcyclists during a crash.

CONCLUSIONS

Based on this research, the following conclusions can be drawn:

1) Motorcycle riders of older age experience greater fatality risk as a result of motorcycle crashes. For motorcyclists aged above 40 years, the estimated odds ratios were about 50% higher than those who were 40 years or less.

2) Collisions between motorcycles and LCVs, HCVs, trees, lamp posts and poles are expected to carry higher fatality risks compared to those with other vehicles/objects.

3) Motorcyclists in frontal collision with opponent vehicles/objects experienced greater fatality risk as frontal collision leading to higher Δv due to relative speeds between collision opponent.

4) Motorcyclists of larger bikes are more likely to sustain severe injuries from motorcycle crashes.

5) Motorcycle crashes at junction sites were observed to experience lower fatality risk with odds ratios of 0.65 (95% CI = 0.52–0.82) compared to those at non-junction sites.

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