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Role of Motorcycle Running Lights in Reducing Motorcycle Crashes during Daytime; A Review of the Current Literature

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ABSTRACT

In comparison to other transportation modes, riding motorcycle is prone to accidents. Motorcyclists are more exposed to physical injury than the car drivers. Many multi-vehicle motorcycles crashes occur, there is right-of-way violation takes place in which another vehicle turns in fronts of a motorcycle, or a sudden cross of path of an on-coming motorcycle. One main factor which leads to high rate of motorcycle crashes is lack of conspicuity of motorcycles by other road users especially during day time traffic. This paper highlights previous studies on the implementation of motorcycle DRLs, focusing on the efficacy of the DRLs to improve motorcycle conspicuity. This paper reviews the impacts of DRL by motorcyclists on multi-vehicle motorcycle crash. The three categories of effects of motorcycle DRLs were reviewed. All literature, supporting that operating headlights during daytime appears to be an influential and effective approach to reduce rate of collision by improving motorcycle's conspicuity in traffic. The motorcycle DRLs managed to reduce about 4 to 20% of motorcycle crash risk. This paper also recommends that motorcycle DRLs must be used globally, especially in countries with high motorcycle accidents to improve the safety of the riders as well as their pillion riders.

Keywords: Injury prevention; Road traffic accidents; Daytime running light; Rider safety; Motorcycle crash.

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Introduction

Motorcycles are aninteresting mode of transportation, but has high rate of fatal accidents in developed and developing countries [1,2]. Rolison *et al*., [3] reported that fatality and injury rate among the motorcyclists and their pillion riders is the highest in comparison to other road users. The death rate for a motorcyclist per mile travelled is estimated to be at least 10 times higher compared to a car passenger [4-7]. In contradiction of motorcyclists' popular image, they are generally a vulnerable group of road users.

National Highway Traffic Safety Administration (NHTSA) [8] reported that in the United States, 13% of total traffic accidents were accounted by the motorcyclists, in which 4,462 motorcyclist involved death and 90,000 motorcyclist were injured. That was such a high rate of crashes, in while motorcycles

made up of only 3% of all registered vehicles and account of only 0.4% of all vehicle miles traveled. The total number of motorcyclist involved in accidents has increased by more than 50% from 2294 in 1998 to 5290 in 2008. In Britain, even though motorcycle riders were only accounted for 1% of total road users, 15% of those who died or seriously injured during road accidents were motorcyclists [9].

In developing countries, the situation is similar. A large portion of road accidents involving death and serious injuries is mostly among the motorcyclists [1,10]. In Iran, fatality statistic showed that 5000 people died and 70,000 were injured in motorcycle accidents [11,12]. Malaysia is among the Association of Southeast Asian Nations (ASEAN) countries that has the highest rate of fatality and more than 50 percent of road deaths are among the motorcyclists [13,14]. In addition, since children, teenagers and active economic population are highly involved in motorcycle crashes, much attention is directed to this kind of accident due to high rate of life lost ratio and cost involved [15,16].

It was reported that more than 50% of motorcycle crashes took place during day time, based on analysis of fatal two-vehicle crashes between passenger vehicle and motorcycle [17]. Conspicuity is the term used to describe the capacity of other road users to see and be aware on the presence of a motorcycle. Reports on motorcycle crashes provided evidence that the motorcycles were hardly seen by other vehicles drivers, especially during heavy traffic and complex visual field.

Most of vehicle drivers who were involved in vehicle-motorcycle crashes claimed that they could not prevent the collision because they did not see the motorcycles and their riders or to have seen them too late [7]. Most of the cases where the drivers fail to identify a motorcycle in crash time is due to the presence of other obstacles that restrict the driver's viewpoint, such as in passing traffic, landscape or within the vehicle itself [18,19]. Researchers have reported that most of the frontal crashes are due to lack of front motorcycle conspicuity or poor left turn gap decision by other motorists [20-23].

In comparison to cars and trucks, motorcycles are less visible to other road users. Furthermore, they are more difficult to detect as well as to determine their approaching speed, which significantly contribute to high rate of motorcycle fatalities. Most cases of motorcycle crashes could be caused by other motorists, who were most likely unaware of the motorcycles until it was too late [23-25]. This situation is named "looked-but-failed-to-see" (LBFS) phenomenon [26-31]. To reduce the rate of motorcycle crashes, Daytime Running Lights (DRLs) have been proposed to alleviate this problem. This paper highlights previous studies on the implementation of motorcycle DRLs, focusing on the efficacy of the DRLs to improve motorcycle conspicuity.

Materials and Methods

To assess the impacts of DRL based on the available literatures, selected databases and the internet were used. The effects of DRLs were reviewed. Three main categories of the literature were identified to assess value studies and other significant reports on the influences of motorcycle DRL.

1. Influence of motorcycle DRL on motorcycle conspicuity
2. Influence of motorcycle DRL on impact factors during motorcycle accidents
3. Influence of motorcycle DRL laws on motorcycle accidents

1. Influence of Motorcycle DRL on Motorcycle Conspicuity

Based on reports through numerous field testing and laboratory studies, motorcycles with DRLs are more conspicuous than motorcycles that do not have them [32-34]. To evaluate the relative conspicuity of several headlamps for motorcyclists, Donne [35] conducted a field experiment depending on the frequency of which the motorcycle was detected and recognized. The experiment was based on the notion that drivers occasionally failed to see motorcycles which were not equipped with any conspicuity aid. From the analysis, it showed that motorcycle's conspicuity was enhanced from 53.6% to 64.4% (for a 40w, 180 mm diameter headlamp). Specifications for DRLs were assessed, and it was confirmed that two lamps, and lampsmore than 180 mm diameter had more impact compared to single or smaller size lamps [36].

Williams and Hoffmann [34] conducted a laboratory experiment in both day and night conditions. They discovered that the total conspicuity improved when motorcycles were equipped with high and low beams in comparison to motorcycles with no light. It indicated that the motorcycle DRL improved motorcyclist's conspicuity by increasing difference among the motorcycle and his background.

Based on case studies done in the Australia and United States, where the headlight-use policies are already implemented, Thomson [24] conducted a similar study in New Zealand to evaluate whether the use of headlights during daytime would reduce motorcycle crashes. The results showed that the policy of using headlight during day time should be encouraged to be enforced in New Zealand, though it is not necessary for the motorcyclists to switch on headlights during daytime period. The policy would enhance motorcycle's conspicuity and decrease motorcycle accidents.

The effectiveness of headlight modulators was evaluated by testing the detection times of participants in real-world driving scenarios [37]. It was reported that the conspicuity of motorcycles by other automobile drivers and motorists increased when their low beam headlights were turned on during day time. When the headlight was turned off,

the potential conflict with the motorcyclist right-of-way experienced by other motorists and automobile drivers was higher compared to when the headlight was switched on. Based on the study, it was clear that by switching on high-and low beam headlights, as well as modulating headlights both during daytime and night-time significantly showed improvement in motorcycle's conspicuity.

The use of two DRLs was discovered to be the most effective method in the United Kingdom to increase conspicuity for motorcycles. However, the standard use of headlight usually fitted to motorcycles, a fluorescent jacket and a single running light were also found to contribute to the conspicuity of a motorcyclist. Also, Brendicke *et al*., [38] studied the effects of using general daytime running light for cars and motorcycles. They discovered that there was slight improvement in conspicuity when motorcycles applied DRL.

A study by Jenness *et al*., [39] involved collection of participants' evaluations on perceived timing to initiate left turn across the path of incoming vehicles and examined the "last safe moment" to start turning in front of an incoming motorcycles with several forward lighting treatments. In an experiment, the attention of respondents was classified into two different visual tasks outside the vehicle. There was proof that the occurrence of short safety margins was decreased during experimental lighting treatments. Generally, the result showed a promising, effective way to reduce "left turn across path" accidents by enhancing the forward lighting on motorcycles during daytime.

Within high fidelity simulated situation, Smither and Torrez [23] assessed the impacts of gender, age, vehicular DRLs and motorcycle lighting conditions on a person's capability to spot a motorcycle. This study resulted in evaluation of motorcycle's conspicuity conditions, and further analysis mentioned that there was a significant difference between reaction time for motorcycles equipped with DRLs and those without DRLs. This study revealed that DRLs were effective, and also provided realistic proof to support the implementation of motorcycle DRLs, it was essential for the motorcycle to be apparent from the surroundings. By equipping a motorcycle with DRLs, it is faster to spot it compared to those without DRLs.

2. Influence of Motorcycle DRL on Impact Factors during Motorcycle Accidents

Based on analysis of motorcycle accidents in Victoria, Australia, it was discovered that there were significant differences among different types of accidents [40]. He found that improving of motorcycles conspicuity can decrease motorcycle crashes. Data on motorcycles DRL involved in multiple vehicle crashes in between 1976-77 analyzed [18]. In comparison with the exposure sample, 50% of accident rate was reduced when headlight was operated, which showed the helpfulness of headlight use. The involvement of crash was reduced when headlamps were used in the daytime. However, there was a minor decrease in the odd ratio predicted for the duration of 1976 to 1981; resulted in decline of approximately 5% in multi-vehicle collisions during daytime. In 1981, it was estimated about five critical multi-vehicle crashes were prevented in the United States when the law of using headlight during daytime was not yet enforced. Approximately there was between 4.2 to 5.6% reduction in motorcycle collisions when motorcycle daytime headlight was being operated.

Analysis of traffic information forms provided by the New South Wales (NSW), Australia Police Officers was conducted by Vaughan *et al*., [41]. For the survey, every motorcycle was checked on the presence or absence of headlamps use. Among the 1104 motorcycles measured based on Chi-square test, there was a significant difference in the using of headlamp and 402 motorcycles involved in accidents. Maybe it was that those who were more safety conscious would activate their headlights during the day than those who did not. Among the motorcyclist of randomly selected group, there were motorcyclists who were once involved in crashes. The relative risk to be involved in crash is around three times higher when the headlights are not operated. Operating headlights during daytime appears to be aninfluential and effective approach to reduce rate of collision by improving motorcycle's conspicuity in traffic.

3. Influence of DRLs Laws on Motorcycle Crashes

Allen [42], who examined crashes for a bus company, was among the first to conduct study to determine the efficacy of DRLs. His finding showed that by making the use of DRLs mandatory was reduced by 40% the crash rate per million miles in daylight condition compared to the year before the enforcement. The impacts of daytime headlight laws in some areas in the United States were examined [43]. In the United States, in between 1975 to 1983, a law to switch on motorcycles' headlights and taillights all the time was enforced in 14 states. The implementation of laws started in 1967 when there was a dramatic increase in the use of motorcycles, which also contributed to high number of crashes involving motorcycles. The enforcement of the law was also due to increasing evidence of the daytime use of headlights and taillights which would improve motorcycle's conspicuity thus reduce the accident rate. Zador [43] for the states with the laws enforced, also discovered a significant decline in the ratio of daytime crashes to night time crashes. Further analysis showed that there was 13% decrease in percentage of motorcycle crashes during daytime for states with the laws implemented, compared to states which did not. Throughout the study, there were about 30 states which did not enforce the laws

of motorcycle daytime headlights. If all of these states did implement the laws, it was estimated that 140 more of fatal motorcycle collisions could have been avoided.

Crash evaluations were conducted in Indian, Montana, Oregon, and Wisconsin to assess the efficacy of regulation on the use of motorcycle DRLs before and after the enforcement of the law [33]. However, Janoff *et al*., [33] failed to establish a concrete set of data and allow for the standard yearly variation of daytime and night time crashes since the duration of the research (before and after enforcement) was only between 6 to 12 months. Based on the mixed finding, daytime crashes were less compared to night time crashes in Oregon, Wisconsin and Indiana. In compare, rate of daytime crashes increased in Montana. Therefore, Janoff *et al*. concluded that motorcycle conspicuity increase with the use of high and low beam headlights as there was a decrease in rate of collisions.

The 1982 Austrian "hard-wiring" law was reported effective in decreasing the number of motorcycle collision during daytime [44]. Bijleved [44] reported a study on the effect of DRLs by motorcycles in the European Union, which was in particular focusing in Austria as the law was newly enforced in 1982.

In a study based in North Carolina, Waller and Griffin [45] discovered that the rate of daytime multi-vehicle collisions during daytime was declined after the motorcycle headlamp law was enforced. The effect of the law in North Carolina was evaluated by assessing crash data for six-year duration from 1972 to 1976. On September 1, 1973, the law was enforced, at a time when motorcycle activity was lessening after reaching its peak during summer months. The percentage of motorcycle collision was compared with similar percentage for all accidents. There was a significant reduction in these accidents involving motorcycles after the law was implemented. A similar reduction was not seen for overall crashes. Based on the findings, it was concluded that the motorcycle headlamp law contributed to positive reduction in daylight multi-vehicle collisions.

The impact of mandatory motorcycle headlight use in Singapore since November 1995 was evaluated by Yuan [46]. There was no significant effect when all crashes were taken into account. However, when the crashes were classified into different level of severities, there was an important effect for serious injury cases and fatal crashes cases, but not for slightcrashes. It was suggested that the huge decline in fatal and serious crashes compared to slightcrashes was because of the use of daytime headlights that increased road users' conspicuity when a crash was about to take place, which enabled them to break longer and decrease the impact speeds [46]. It was apparent that the decrease in fatal collisions was a genuine evidence, as the rate decreased from annual average of around 40 to only 24 after a year of law enforcement.

Daytime collision in Western Australia particularly on motorcycle conspicuity from 1989 to 1994 was studied by Rosman and Ryan [47]. Australian Design Rule (ADR 19/01) was effective starting of 1992, in which all new motorcycles must be prepared with headlights which automatically turned on when the motorcycle was in used. There were four crash types of collisions that were considered: head on, side swipe opposite direction, direct right and indirect right angle. A slight decrease was observed in daytime crashes between cars and motorcycles; however, it was not statistically significant. This could be due to small sample size of new motorcycles throughout the researchtime, and extensive rise in the use of daytime headlights voluntarily among the motorcyclists.

By using NSW data from the Australian Road Fatality Database from 1992 to 1995, a similar analysis was conducted by Attewell [48]. Attewell did not distinguish between the conspicuity-related collisions and others, but merely made comparison on the numbers of collisions for single motorcycle and vehicle-motorcycle crashes that caused in injury or death for motorcycles riders that pre- or post-dated the implementation of Australian Design Rule (ADR 19/01). A 2% decline in the ratio of motorcycle-vehicle accidents for all collisions of different severity level showed that the ADR possessed several impacts. The impact was greater for deadly accidents; however, this was only with regarded tojust 16 fatal crashes with post ADR machine involved.

It has been several years that many states in the US have enforced laws for the motorcycle to use headlights during daytime. California has implemented law that requires all motorcycles to ensure headlights that turn on routinely once the engine is ignited since 1972. Only in 1978 the compliance with the law was effective. The impacts of growing use of headlights before and after the implementation of the Californian law was studied [49]. The odd ratio for fatalities was determined for every year from 1976 to 1981. However, there was no important pattern found, which Muller [49] in other study assessed the legislation of motorcycle DRL in California had been promising in minimizing daytime crashes number. The result found a small decrease in the number of multi-vehicle accidents.

Lights of all the cars and motorcycles must be turned on during daytime in Finland and Sweden. Rumar [50] conducted an assessment research of DRL in Sweden. His finding indicated that use low-beam light during day time would manage to minimize the number of accidents. There was a decline in multiple vehicle crashes during daytime by 32% and 4% at night. This study has affected the legislation change in Sweden and numerous other countries.

Based on two studies in Malaysia to preliminarily analyze short-term influence of motorcycle DRLs, Radin Umar *et al*., [51] discovered a substantial drop there was in several motorcycle crashes. Further, at the same pilot areas conspicuity-related accidents

among motorcycles were analyzed [51]. Radin model showed that the motorcycle DRL managed to reduce motorcycle collisions by about 29%.

Discussion

Motorcyclists are prone to accidents. Due to lack of protection, motorcycle accidents cause severe injuries once a collision occurs. In addition, since many victims are young people, these crashes normally cause high death rate and high social-economic costs to those severely injured. This is why a moderate decline in the number of crashes will provide significant advantages to the potential victims and social-economic wellbeing for the community.

The high risk of motorcycle multiple collisions is always associated with low level of motorcycle conspicuity. Therefore, there is a huge essential to communicate on the conspicuity-related issue to the motorcyclists' community to persuade vehicle drivers to be alert on incoming motorcycles. Switching on the motorcycle headlights will guarantee that it will be distinct from the background, though the light level is low. This will improve the chance of detection which depending on the visual system properties, and will sustain as a functioning visibility aid in the long run. Theoretically, DRL is a mode to compensate for both low expectancy and low target value. DRLs will practically deliver a strong distinction which they are seen against the background.

This review summarizes that motorcycle DRLs are effective in reducing motorcycle crashes. Nevertheless, resistance to implement motorcycle DRLs in both developing and developed countries are still occurring despite their proven effectiveness. This review also shows that motorcycle DRLs are not only increasing motorcycle conspicuity, but also gives positive impacts on other drivers' response time. Therefore, in Austria, Germany, Belgium, France, Portugal and several other countries, it is mandatory to switch on motorcycle lights during daytime. Due to positive impacts on increasing conspicuity by other road users, the DRL is made mandatory for car drivers too in certain countries. This review is a collection of current available proof that motorcycle DRL can prevent motorcycle crashes. A dependable assessment on the efficacy of motorcycle DRL will help in road safety research, particularly on cost feasibility to impose DRL legislation and enforcement in countries where rate of motorcycle fatalities is high. This paper concluded that motorcycle DRLs manage to lessen the risk of collision about 4 to 20%. The review also supports the notion that motorcycle DRLs must be actively promoted globally to enhance the safety of their pillion riders.

Conflict of interest: None declared.

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