Motorcycle Literature Review

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Introduction

Motorcycle safety policy has become a highly debated topic in recent years, frequently discussed by legislators and community members seeking a balanced approach that protects these vulnerable road users without imposing overly restrictive measures. Effectively addressing this issue requires an understanding of the factors fueling the debate. According to the National Highway Traffic Safety Administration, 80% of all motorcycle crashes result in injury or death [1], a statistic that is especially concerning given motorcycles represent a small fraction of all registered vehicles. This literature review seeks to summarize key data on motorcycle safety, examining how the use of protective gear impacts injury outcomes and exploring the relationship between motorcycle type and crash severity.

Impact of Helmet Laws

The relationship between motorcycle helmet laws and injury reduction is well-documented and widely supported. Research on the impact of helmet legislation [2] shows that states in the U.S. with universal helmet laws—a requirement for all riders to wear helmets—experienced a 36% to 45% decrease in motorcycle crash fatalities. In contrast, states with partial helmet laws, which mandate helmet use for only certain groups of riders (e.g., those under a specific age), saw a 22% to 45% increase in fatality rates compared to states with universal helmet mandates. Intriguingly, states with partial helmet laws reported a 1% to 81% increase in fatality rates when compared to states without any helmet law in place, illustrating that partial mandates may not be as effective in reducing fatalities.

Multiple studies reinforce these findings, with research [15, 18] consistently showing a significant reduction in fatalities in states with universal helmet laws. One study found that in areas where helmet mandates were repealed, motorcycle fatalities increased fourfold [14]. These findings align with other evidence suggesting that head injuries are the leading cause of death in motorcycle crashes, and the use of helmets significantly mitigates this risk [13]. In addition to the declining rates associated with motorcycle helmet mandates, the study found that other laws have also been associated with fewer motorcycle fatalities, such as laws restricting acceptable blood alcohol content.

Impact of Helmet Use on Injury Prevention

Research on helmet use and injury reduction has delved into specific factors such as helmet type, fit, and fastening. For example, one study analyzes the effectiveness of different types of motorcycle helmets and their ability to prevent head injury [3]. This study sampled a population of motorcyclists that presented to the emergency department with head injuries over an 8-month period. Motorcyclists who presented to the emergency department but did not sustain a head injury were used as the control group for the study. The study found that motorcyclists that did not use helmets were four times more likely to sustain a head injury, and ten times more likely to sustain a brain injury than riders that used helmets. This increased frequency of head

injury is corroborated in other studies as well [11, 12, 19, 21]. In addition, riders wearing partial-coverage helmets were twice as likely to sustain a head injury or brain injury in comparison to riders with full-face helmets. This study also analyzed the effectiveness of helmet fastening and found that motorcyclists with loosely fastened helmets were twice as likely to sustain a brain injury when compared to riders with firmly fastened helmets.

Emphasizing the importance of helmet fixation, a study in Malaysia explored the effect of helmet fit compared to helmet type. This study observed injured motorcyclists admitted to hospitals and surveyed them on crash details, including helmet usage and fastening. The participants wore various helmet types, including open-face, tropical, and full-face helmets, while some wore no helmet at all. The findings revealed that motorcyclists whose helmets dislodged during the crash were five times more likely to sustain head injuries and four times more likely to suffer severe head trauma. The study concluded that secure helmet fixation plays a more substantial role in preventing head injuries than helmet type alone.

These studies collectively underscore the critical importance of proper helmet usage, fastening, and design in reducing head and brain injuries in motorcycle crashes.

Other Forms of Protective Gear

While there has been extensive research conducted on the efficacy of motorcycle helmets and their ability to mitigate injury, there are other forms of protective clothing for motorcyclists that have not been as thoroughly studied. These garments include motorcycle jackets, gloves, motorcycle pants, and motorcycle boots. However, there have been some studies conducted which highlight the benefits of these pieces of gear. A study conducted by the University of Sydney; Australia interviewed over 200 motorcyclists who sustained some form of injury from a motorcycle crash to gain insight into just how effective motorcycle clothing actually is in terms of mitigating injury. The results of the study showed that motorcyclists who wore a motorcycle jacket, pants, or gloves were significantly less likely to be admitted to a hospital following the crash [5, 20]. The findings further indicate that riders had a significantly reduced risk of injury if those garments were also fitted with body armor. The results also indicate that non-motorcycle boots provided more protection than other forms of casual footwear such as shoes or sneakers. However, no association between the use of body armor and reduced fractures was established, indicating that the armor is only effective at reducing tissue damage.

These findings are reaffirmed by another study also conducted by the University of Sydney that analyzed the effectiveness of protective motorcycle clothing by observing the health outcomes of injured motorcyclists within 6 months following the crash. The methods of the study consist of an initial interview and review of medical records for each subject followed by a mailed survey two and six months after the crash. Subjects were placed in three groups: fully protected (motorcycle jacket and pants), partially protected (motorcycle jacket only), and unprotected

(neither jacket nor pants were used). Unsurprisingly, riders who were partially protected or fully protected were shown to be hospitalized for a shorter duration and reported less pain immediately after the crash in comparison to those within the unprotected group. In the two-month survey, the unprotected group was more likely to have disabilities or reduced physical function than the fully protected and partially protected groups [6]. By the six-month mark, while differences in physical function between groups had diminished, fully protected riders had a higher likelihood of full recovery, with significantly faster recovery times than unprotected riders. These findings align with studies linking helmet use to lower injury severity scores, highlighting the broader value of comprehensive protective gear for motorcyclists in minimizing injury severity and promoting quicker recovery [17].

Relation Between Gear Usage and Bike Type

The use of protective clothing has been viewed from other angles as well. A study featured in Emergency Medicine International highlights the association between the use of protective gear and the type of motorcycle being driven. The goal of the study "Roles of Motorcycle Type and Protective Clothing in Motorcycle Crash Injuries" was to identify subgroups of motorcyclists with a higher accident risk and evaluate the efficiency of protective clothing for preventing injuries [7]. The study analyzed the characteristics of motorcycle crashes over the period of one year and resulted in the inclusion of 226 motorcyclist patients that were recruited through the emergency department. Each subject was interviewed before leaving the ED. The interview focused on information about the accident, what protective clothing was used, location of injury, speed, and alcohol consumption. The patients were then divided into two groups: those that drove light motorcycles, and those that drove heavy motorcycles. For this study, light motorcycles are defined as having an engine limit of $125cm^3$, and heavy motorcycles are defined as having an engine volume greater than $125cm^3$.

The results showed that the usage of helmets and motorcycle pants was significantly higher among heavy motorcycle drivers than light motorcycle drivers; and that jackets, gloves, and shoes were also used more by heavy motorcycle drivers to a lesser degree. The study also found that motorcycle jackets, pants, and shoes were not protective against fractures or systemic injuries but were an effective measure for preventing soft-tissue damage. Ultimately, the study concluded that riders of heavy motorcycles tend to use more protective gear and that light motorcycle riders were the most vulnerable group of road users.

How Motorcycle Type Influences Crash Outcome

This association between motorcycle type and crash outcome is explored further in "Role of motorcycle type in fatal motorcycle crashes", a study featured in the Journal of Safety Research. Specifically, the aim of the study is to explore the association between motorcycle performance capability and risky riding behaviors like speeding. To do this, motorcycles were classified into 10 different types based on certain design characteristics and were then placed into

the following groups: cruiser/standard, touring, sport touring, sport/unclad sport, supersport, and other. The study then analyzed driver death rates per 10,000 vehicles of each type, examining the factors that made the crash fatal. The findings indicate that driver death rates for supersport motorcycles were four times higher than the death rates for cruisers and standard motorcycles [8]. Further, supersport drivers who sustained fatal injuries were most likely to have been speeding. Despite this, these same drivers were shown to be the most likely to wear helmets and least likely to be under the influence of alcohol when compared to drivers of other motorcycle types. Other studies have also found that sport/supersport drivers were more likely to wear protective equipment such as helmets, motorcycle jacket etc. [16]. Overall, increased engine displacement was associated with higher driver death rates for each motorcycle type.

This higher death rate among supersport drivers is reaffirmed by "Characteristics of motorcycle crashes in the US", which analyzes data from fatal motorcycle crashes to identify their contributing factors and trends. The study analyzed data from the Fatality Analysis Reporting System (FARS) between the years 2000-2007 and compared it with motorcycle registration data. The study also used data from the Federal Highway Administration and the Census of Transportation, Vehicle Inventory and Use Survey; the NHTSA National Automotive Sampling System/General Estimates System (NASS/GES); and the Office for Defects Investigation. Some of the factors that were investigated include the association between crash type and location, helmet use, bike type (sport, touring, cruiser), and alcohol impairment. The study posits that helmet use is the most important component of preventing injuries and fatalities in a motorcycle crash, and that motorcyclists without helmets are 40% more likely to sustain a fatal head injury. The study also found that the rate of fatal crashes differed by motorcycle type due to each bike type being largely preferred by different demographic groups. Sport and Super Sport bikes, for example, are very popular among young male riders (age 16-25) who may be less inclined to use protective equipment than riders in other demographics. The findings also highlight that the crash fatality rate is 3 times higher among riders of sport/super sport bikes when compared to touring and cruiser style motorcycles. Further, sport motorcycles are associated with a higher percentage of risky behavior and a higher percentage of high-speed crashes (>65 mph). Findings also indicate a difference in fatality rate of crashes within the sport motorcycle subgroup itself, citing that sport motorcycles with engine sizes above 750 cc have higher rates of fatal crashes than sport motorcycles below 750 cc. In addition to this, an association between helmet use and alcohol-related impairment was discovered. Showing that 30% of fatally injured riders were impaired, and 44% of fatally injured riders were not using helmets. Finally, the study cites NHTSA findings showing that motorcycle fatalities increased by 20% in states that repealed helmet use laws [9].

A study conducted by The Institute of Transport Economics in Norway titled "Traffic safety among motorcyclists in Norway: A study of subgroups and risk factors" further reinforces the previously mentioned trend among sport motorcycles. The study aimed to identify risk factors of motorcycle crashes that are unique to each subgroup of motorcyclist (e.g. age groups, bike types)

by presenting motorcyclists with a questionnaire designed to collect information about rider characteristics, riding behaviors, and accident risk; then comparing those results to analyses of fatal motorcycle crashes in Norway that occurred from 2005 to 2008. The study corroborated the popularity of sport motorcycles among young males and that this group is the most at risk of being involved in fatal crashes. This is because riders within this group were shown to have a combination of low riding experience, higher exhibition of risky behaviors, and poor hazard perception ability [10]. These factors contribute significantly to the higher incidence of fatal crashes among young sport bike riders, who are often either inexperienced with a specific bike type or with motorcycles in general.

Overall, these studies collectively emphasize that while sport and supersport motorcycles attract riders who tend to wear protective gear, these types of bikes are also associated with higher rates of speeding and risky behaviors, which contribute to disproportionately high fatality rates. Helmet use, experience, and specific safety laws are key factors in reducing crash fatalities, especially among high-risk groups such as young, inexperienced sport bike riders.

Conclusion

This review aimed to summarize and synthesize available research on motorcycle protective gear, the influence of motorcycle type on crash characteristics and outcomes, and the interplay between these factors. The analysis reveals a notable gap in the literature, particularly regarding the effect of motorcycle type on crash dynamics and the potential association between protective gear usage and motorcycle type. These areas are underexplored and present valuable directions for future research.

Further studies could specifically investigate the relationship between bike type and crash outcomes by controlling for age demographics, as most research points to young males as the primary owners of sport bikes, which are statistically shown to be the most hazardous. A key question remains: are the elevated crash rates among sport bikes due to their speed capabilities and design, or do they reflect riskier behaviors associated with a younger demographic of riders—behaviors that could potentially manifest across different bike types? As the current population of sport bike riders ages and gains experience, future research might shed light on whether the observed crash trends stem from rider demographics or from inherent risks associated with certain motorcycle types.

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