Exploring the Associations of Rider Age and Experience on Motorcycle Injury Crash Risk: Evidence from A Case-Control Study

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ABSTRACT

Motorcycle riding offers travel options, freedom, and thrill to road users. However, motorcyclists are more vulnerable to a substantially higher risk of crashes and severe injuries than motorized users. Understanding the factors contributing to motorcycle crash risk, especially rider age, experience, and training, is essential for developing effective safety measures. This study explores the relationships between these variables and motorcycle crash risk to identify potential safety interventions. Rider age, experience, and training can account for a substantial portion of the risk. Using a unique and comprehensive matched case-control database of the Motorcycle Crash Causation Study, this study analyzes the dependencies of injury crash risk on riders' age, inexperience, and training levels while controlling for other factors, such as alcohol use by the rider. The data consists of 350 cases (injury crash-involved riders) vis-à-vis 700 controls (similarly-at-risk non-crash-involved riders). Based on a conditional logit analysis accounting for the matched case-control structure of the data, "risk curves" are created to understand the relationships between rider age and injury crash risk. Results suggest that younger riders have a heightened injury crash risk, which reduces with increasing age. Each additional year is associated with a 3.31% reduction in the odds of an injury crash, although a non-linear specification is also tested. Each year of rider experience is associated with a 2.69% reduction in the odds of an injury crash, and participation in training programs during recent years is associated with lower crash risks.

Key Words: Motorcycle rider, Motorcycle Crash Causation Study (MCCS), Case-control design, Injury crash risk, Riding experience, Training programs, Blood alcohol concentration (BAC).

INTRODUCTION

Motorcycles and bicycles are convenient and affordable modes of transportation. They offer a thrilling sense of freedom with the joy of exploration. In terms of parking and maneuvering, they are found to be more appealing and flexible compared to regular motor vehicles, mainly in densely populated areas [1-3]. However, among them, motorcyclists are more vulnerable to higher risks of crashes and severe injuries than other motorized users. Motorcycle crash injuries and fatalities are key public health issues causing significant economic losses in the U.S. and globally. During 2002-2015, motorcycle-involved fatalities increased by 48%, while those related to passenger vehicles (cars and light trucks) decreased by 32% [4]. Motorcycles, being a two-wheeler mode of transportation, differ from motor vehicles in terms of physical operations, weight, size, and exposure of the operator (driver/rider). Due to factors including smaller size, more powerful engines, and lack of adequate rider protection, motorcycles are highly unstable and vulnerable to crashes [5]. Compared to driving vehicles, riding a motorcycle is physically challenging, as the visibility and stability of riders are affected due to their direct exposure to climatic conditions [6]. In addition, the availability of powerful motorcycles and their increasing use for recreational trips has increased the risk of motorcycle injuries and fatalities [7]. Besides the loss of valuable lives and associated health care costs, motorcycle crashes put an extra burden on society through emergency response and insurance costs [8]. Understanding the factors contributing to motorcycle crash risk, especially rider age, experience, and training, is essential for developing effective safety measures. Rider characteristics, such as gender, age, and experience, may significantly influence rider behavior and attitudes. Crash risk is higher for younger and inexperienced riders due to their higher risk-taking behavioral and attitudinal predispositions [9-11]. Experienced riders also tend to have lower crash risk than less experienced riders [11-14]. For instance, young adults' brains are still developing, which can affect their risk perception and decision-making capabilities, and an age-related decline in reaction times and physical abilities may increase the risks for older adults. Also, inexperienced riders may not be skilled or familiar with handling emergencies effectively, making them more susceptible to crashes.

A synthesis of past studies indicates that most of the studies focused on the factors associated with injury severity of motorcycle crashes – shedding light on important predictors such as rider behaviors, roadway, environmental, and motorcycle characteristics [15-20]; while some investigated the associations of key factors affecting motorcycle crash risks [1, 9, 10, 12-14, 21-24]. Impairment and substance use are associated with an increased crash risk [10, 25-27]. Motorcyclists with positive blood alcohol concentration (BAC) are more likely to be found at fault for the crash and less likely to wear crash helmets when compared with those with negative BAC [28]. While findings on the effectiveness of formal training are mixed [29-31], a few studies have suggested lower crash risk for riders with recent participation in motorcycle training courses [10]. Moreover, personal protective equipment, a key protection against injuries in case of a crash, was reported to be more prevalent among trained motorcyclists [32]. Compared to purely cross-sectional frameworks, a case-control study design is better suited to examine different groups retrospectively and identify predictors of crashes, which are rare outcomes. Additionally, case-control designs can better identify key risk factors or predictors of rare outcomes in an exposed group (e.g., injury-involved riders) and disentangle the marginal impacts of such risk factors by analyzing their prevalence vis-à-vis unexposed groups (e.g., non-crash-involved riders). Yet, very few studies have used a case-control framework to analyze determinants of injury crash risk - mainly due to the difficulty of collecting such data [10, 11, 14, 24]. In the case-control framework, crash risk is computed while comparing cases (crash-involved riders) with controls (not-crash-involved riders) matched on temporal and spatial factors [9, 10, 12-14, 24, 33, 34]. While some studies analyzed data on cases and controls to quantify crash risk, their data, in most cases, are based on a limited sample size or traditional questionnaires comprised of subjective and unvalidated data.

Using a unique and comprehensive matched case-control database of the U.S. Motorcycle Crash Causation Study (MCCS), this study examines the associations of crash risk with riders' age, inexperience, and training level, while controlling for other factors, such as alcohol use by the rider. Rider age, experience, and training can account for a substantial portion of the risk. This study assesses the relationships between these variables and motorcycle injury crash risk to identify promising safety interventions. The data used in the study consists of 350 cases (injury crash-involved riders) vis-à-vis 700 controls (similarly-at-risk non-crash-involved riders). Based on a conditional logit analysis accounting for the matched case-control structure of the data, "risk curves" are created to understand the relationships between rider age and injury crash risk. The study further examines the role of participation in motorcycle training programs and the use of alcohol on riders' propensity for involvement in an injury crash. The practical implications of our results suggest a greater emphasis on the significance of age and riding experience in licensing, specifically for younger and inexperienced riders. Notably, participation in training programs can help riders (especially frequent traffic offenders) enhance their skills and reduce crash risks.

METHODOLOGY

Data Source and Study Design

The study uses Federal Highway Administration (FHWA) Motorcycle Crash Causation Study (MCCS) data, which is a comprehensive data source funded by the United States Department of Transportation [35]. The MCCS data include detailed information about 350 motorcycle injury crashes collected through on-scene investigations in Orange County, California, and interviews with 700 control riders [10, 35]. For each case (motorcycle crash), data on two controls are obtained, which are then matched with the case (regarded as 'baseline') based on the day of the week, time of the day, roadway type, location (rural/urban), travel direction, and weather conditions [10, 35]. Using a triplet (including one case with two controls) as a unit of analysis in a matched case-control framework, the associations of policy-sensitive factors (with emphasis on rider age, experience, sleeping hours, motorcycle training level, and alcohol use) with crash risk are quantified (Figure 1). For detailed information about MCCS data, please see [10].

The MCCS data included detailed information about crash sites and riders for certain time spans, like during, before, and after crashes [10, 35]. Rider information includes (but is not limited to) rider age, rider experience, hours of sleep before riding, alcohol use by the rider (checked through blood alcohol concentration (BAC) level), and training level, i.e., training programs attended by the rider (e.g., none, basic, experienced, professional). It also includes comprehensive data on roadway conditions, traffic controls, and environmental details that might have contributed to the occurrence of a crash [10, 35]. Crash data based on police reports exhibits subjectivity and biases – especially concerning injury information [10, 36-41]. MCCS provides a unique and objective source of in-depth injury information collected through rigorous post-crash evaluation protocols – linking information from hospital discharge reports, emergency room records, and medical reports from private clinics [10]. For details, see [10]. Motorcycle crash risk is the probability of a rider getting involved in an injury crash. While crash frequency data may provide useful insights into how key factors relate to motorcycle crash frequency [42, 43]; such studies may not unveil the exposure of the population to motorcycle crashes [10]. This study applies a matched case-control design to quantify the associations of variables of interest (i.e., rider age, rider experience, hours of sleep before riding, alcohol use by the rider, and training level of the rider) with motorcycle injury crash risk.

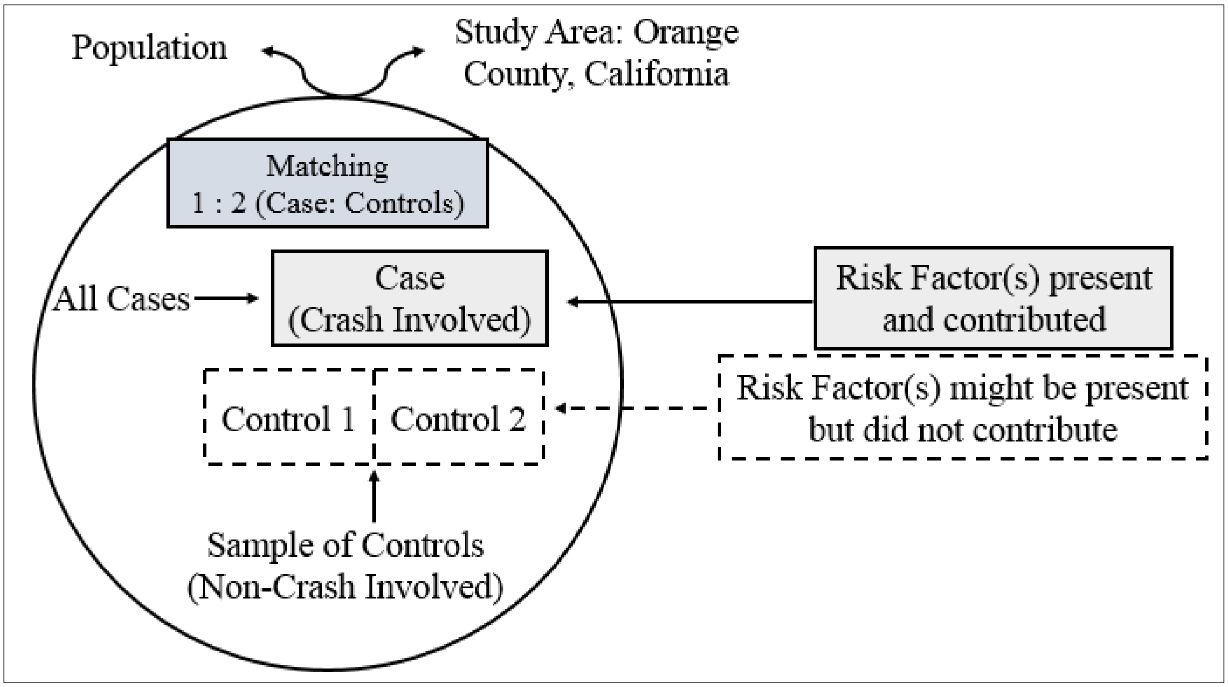

Figure 1 Matched case-control framework

Note: *The arrow indicates that it is a subsample for controls selected from a population in the study area and may not be considered as the whole population of the motorcyclists in the study area.*

Conditional Logistic Regression: Case-Control Framework

Statistical models are developed to explore the crucial links between motorcycle crash risk and its key correlates, focusing on experience and age. To account for the matched case-control structure in the data, conditional logistic regression has been widely used [10, 44]. Note that conditional logistic regression accounts for the dependence among the elements within a triplet (including one case and two controls) that arises due to matching cases and controls by a set of matching variables. Traditional unconditional logistic regression cannot account for this dependence structure in a case-control design [10]. The general equation for the conditional logit model can be given as follows [10, 45, 46]:

$$Y_i^* = \beta X_i + \mu_i \qquad (1)$$

Where: Y_i^* indicates the latent unobserved crash propensity of any rider i, β indicates vector of parameters to be estimated for a set of explanatory variables (X_i); and μ_i indicates random disturbance. Note that the latent unobserved crash propensity (Y_i^*) can be related to the observed crash propensity (Y_i) [10, 45, 46]:

$$Y_i = \begin{cases} 1 & if\ Y_i^* > 0 \\ 0 & otherwise \end{cases} \quad (2)$$

Here, $Y_i = 1$ indicates a case (when a rider is involved in a motorcycle injury crash), whereas $Y_i = 0$ indicates the control observation (non-crash-involved rider). The following equations can be used to determine the likelihood of rider (i) getting involved in the crash [10]:

$$P_i = prob\ [\beta X_i + \mu_i > 0]$$
$$P_i = prob\ [\mu_i > (\beta X_i)] \quad (3)$$
$$P_i = 1 - F(-\beta X_i)$$

Note that F indicates the cumulative density function. The coefficients obtained from the logit models provide useful information about the direction of the association with the response variable; however, it does not facilitate easier interpretation. The odds ratio enables easier interpretation:

$$Odds\ Ratio = \frac{\left(\frac{p(Y=1|X+1)}{p(Y=0|X+1)}\right)}{\left(\frac{p(Y=1|X)}{p(Y=0|X)}\right)} \quad (4)$$

An odds ratio of greater than one indicates that the chances of $Y = 1$ (rider involved in a crash) increase with an increase in X (i.e., explanatory variable) and vice versa. The percent change in odds of response outcome with a unit change in the explanatory variable can be determined as:

$$\%\ Change\ in\ Odds\ (Crash\ Risk) = 100\ (Odds\ Ratio - 1) \quad (5)$$

While odds ratios provide direct and meaningful insights, predictive margins can be computed to examine the predicted probabilities of the response outcome at any specific value or over a range of values of the specific explanatory variable. All the analysis was performed in Stata v18.

RESULTS

Descriptive Statistics

Statistics reveal that the mean experience (in years) of riders in the not-crash-involved group is 20.52 years, which is significantly higher than that of crash-involved riders (13.04 years) (Table 1). The mean age of riders within the crash and control groups was 36.55 and 45.10 years, respectively, suggesting that younger riders are more likely to be in the injury-crash-involved group (Table 1). For more details about the distribution of riders based on riding experience and age (both in case and control groups), please refer to Figure 2 and Figure 3, respectively. Notably, the proportion of older and experienced riders is higher in the non-crash involved group (control groups) (Figure 2-3). Statistics also reveal that 40% of the non-crash-involved riders have negative BAC, which is significantly higher than that in the injury crash-involved riders group (16.5%) (Table 1). The means of all variables (except indicator for Hispanic, African-American, and others/not reported riders) were statistically significantly different between the case (crash-involved riders) and control (not-crash-involved riders) groups (Table 1). All the 350 crashes reported in the MCCS data are injury crashes (among which < 0.5% were fatal crashes), including no property damage only (PDO). The reason for having no PDO crashes may be that motorcycle crashes mostly include some injuries (ranging from minor to fatal injury) due to their higher vulnerability or might not have been reported to the police or hospital (due to no injury) from where the crash details were extracted. As observed in past studies, motorcycle crashes typically include some injuries, thus including a relatively lower percentage of PDO crashes [47].

TABLE 1 Descriptive statistics of the key variables

Variables	Crash Involved Riders (N = 350)			Not Crash-Involved Riders (N = 700)			Independent group t-test (H_a: μ_2-μ_1>0)
	Mean (μ_1)	S. D	Min/Max	Mean (μ_2)	S. D	Min/Max	
Motorcycle riding experience (years)	13.039	14.155	0/47	20.516	17.048	0/69	Pass
Rider age (years)	36.546	14.260	16/73	45.066	14.558	17/84	Pass
Negative blood alcohol concentration (BAC)* (1 if yes, 0 otherwise)	0.165	0.372	0/1	0.398	0.489	0/1	Pass
Year of Training							
Training between 2001–2010*	0.091	0.289	0/1	0.290	0.454	0/1	Pass
Training between 2011–2015*	0.069	0.253	0/1	0.196	0.397	0/1	Pass
Race of Rider							
Hispanic*	0.1057	0.3079	0/1	0.0386	0.1927	0/1	Fail
White American*	0.7343	0.4423	0/1	0.8671	0.3396	0/1	Pass
African-American*	0.0429	0.2028	0/1	0.0171	0.1298	0/1	Fail
Asian*	0.0429	0.2028	0/1	0.0586	0.2349	0/1	Pass
Others/not reported*	0.0743	0.2626	0/1	0.0186	0.1351	0/1	Fail

Note: ** indicates binary variables for which their "mean" values, if multiplied by 100%, will show the corresponding percentages. Where N indicates sample size; μ_1 and μ_2 indicate the mean of the crash and control group, respectively; S.D indicates the standard deviation, H_o indicates the null hypothesis (μ_2 - μ_1= 0), and H_a indicates the alternative hypothesis (μ_2 μ_1>0). Note that "Pass" shows that H_a can be accepted at 95% confidence instead of H_0 and vice versa.*

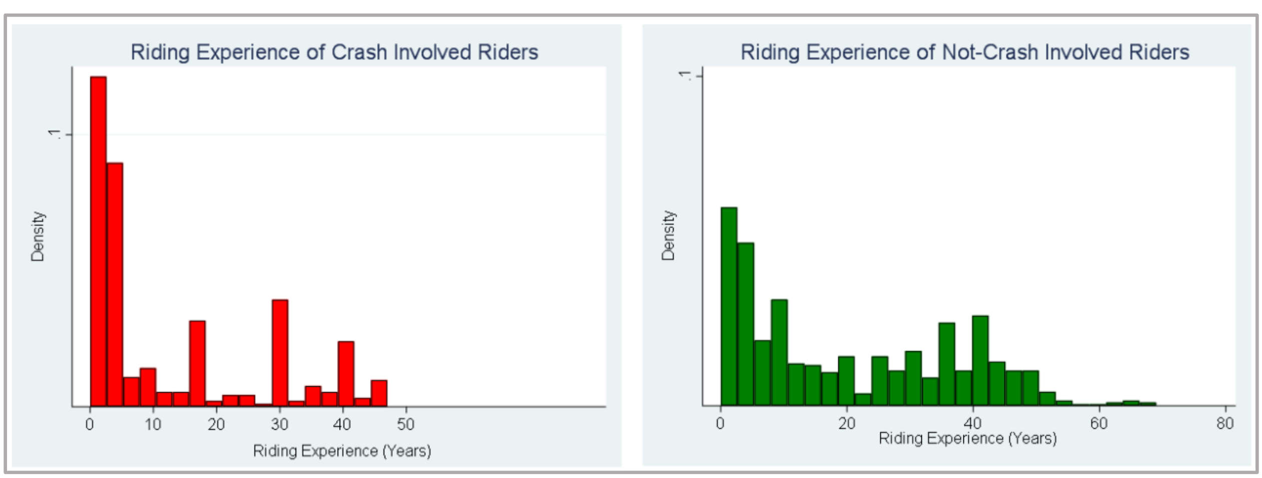

Figure 2 Distribution of riders based on riding experience (years)

Figure 3 Distribution of riders based on rider age (years)

Correlational Analysis

Based on Pearson Correlation, it is found that rider age and experience have statistically significant correlations with motorcycle injury crashes (Table 2). Only rider age (years) and riding experience (years) showed a significant positive correlation per 95% confidence level. All included variables' variance inflation factors (VIF) are checked after fitting the final model (as shown in Table 3). VIF for all other variables was less than 3, which warrants no collinearity issues among the three key explanatory variables included in the model (Table 2). Note that a VIF lower than 10 is acceptable, and lower than 5 is good [48-51].

TABLE 2 Correlation matrix of the crash and key explanatory variables

	Crash	Rider Age (Years)	Motorcycle Riding Experience (Years)
Crash	1.000		
Rider Age (years)	- 0.268*	1.000	
Motorcycle Riding Experience (years)	- 0.214*	0.787*	1.000

*Note: * indicates that the correlation between corresponding variables was significant at 95% confidence level.*

Modeling Results

To gain deeper insights, conditional logit analysis is conducted while accounting for case-control setup. The models are systematically derived while considering statistical significance, specification parsimony, and theoretical justification. The key correlates of motorcycle crash propensity include rider age, rider experience, participation in motorcycle training programs, and an indicator of blood alcohol concentration (BAC), as shown in Table 3. The final model specification uses a 90% confidence level criterion to retain variables. Polynomial terms are added to the conditional logit link function to capture the potential non-linearities associated with age. Polynomial terms up to order 5 were considered for the age variable, with an order-2 polynomial giving the best results. The results of the linear-in-parameters logit model (Model 1) and non-linear logit model (based on order-2 polynomial term for age) (Model 2) are shown in Table 3. Rider age and its square term showed a statistically significant correlation with injury crash risk (Table 3). Also, based on AIC, BIC, and log-likelihood value, Model 2 shows a superior fit to the data as compared to Model 1 (Table 3). A model based on fine-grained age categorizations was also developed, but it did not show any significant improvement as compared to Model 2 in terms of AIC and BIC (results not shown for brevity). Based on the results of Model 1 and best-fit Model 2, both rider age (years) and riding experience (years) are statistically significant and have negative correlations with crash risk, indicating that younger and inexperienced riders have higher odds of getting involved in a crash (Table 3). Results also indicate that, as compared to no training or if the training was received before 2001, the injury crash risk reduces for those motorcyclists who received training during 2001-2010 or 2011-2015, i.e., in recent years (Table 3). Importantly, the models show that sober riders (tested negative for BAC) have statistically significantly lower injury crash risk (Table 3). Other important results related to demographic factors can be found in Table 3.

TABLE 3 Estimation results of the conditional logit model

Variables	**Model 1 – Linear Model**				**Model 2 – Non-Linear Model**			
	Coef.	**t-stat**	**Odds Ratio**	**% Change in Odds**	**Coef.**	**t-stat**	**Odds Ratios**	**% Change in Odds**
Motorcycle riding experience (years)	-0.0231	-2.31	0.9772	-2.28	-0.0272	-2.72	0.9731	-2.69
Rider age (years)	-0.0337	-3.13	0.9669	-3.31	-0.1777	-4.35	0.8372	-16.28
*Squared term for rider age (rider age*rider age)*	---	---	---	---	0.0017	3.71	1.0017	0.17
Negative blood alcohol concentration (BAC)* (1/0)	-1.3895	-6.17	0.2492	-75.08	-1.4137	-6.19	0.2433	-75.67
Year of Training (base = no training or training received before 2001)								
Training between 2001–2010*	-1.8074	-7.11	0.1641	-83.59	-1.9165	-7.26	0.1471	-85.29
Training between 2011–2015*	-2.1104	-7.04	0.1212	-87.88	-2.3447	-7.40	0.0959	-90.41
Race of rider (Base = White American)								
Others/not reported	1.3187	2.70	3.7386	273.85	1.3773	2.81	3.9642	296.42
Hispanic	0.8942	2.62	2.4454	144.53	0.9171	2.59	2.5020	150.20
African-American	1.0249	2.08	2.7868	178.68	1.1800	2.28	3.2545	225.45

Asian	-0.4443	-1.09	0.6413	-35.87	-0.4797	-1.16	0.6190	-38.10
Model Summary								
Number of Observations	1,050				1,050			
Number of triplets	350				350			
Degrees of Freedom	9				10			
Log-likelihood at convergence	-239.7793				-232.9885			
AIC	497.5587				485.9769			
BIC	542.1676				535.5424			

DISCUSSION

Several useful insights are obtained based on the results of the conditional logit models shown in Table 3. Results suggest that younger and inexperienced motorcycle riders have a heightened injury crash risk, which reduces with increasing age and gaining experience. Model 1 results suggest that each additional year of age and experience is associated with 3.31% and 2.28 % reductions in the odds of an injury crash. The results and findings discussed in the subsequent paragraphs refer to the best-fit non-linear model (Model 2). Based on the results of Model 2, the findings of the study indicate that the odds of a rider getting involved in a crash reduced by 16.28% with a unit increase in rider age (years). This finding suggests a relatively higher crash risk for younger riders, which is intuitive and can be attributed to their potentially risky riding behaviors. Similar findings are also suggested by previous studies [10, 12, 52, 53]. The odds ratio does not capture the intrinsic non-linearity associated with the S-shaped curve fitted by the conditional logit model. Due to the fitted S-shaped curve underpinned in logit models, the association of the explanatory variable (e.g., age) with crash risk varies across the range of age. To explore the varying levels of associations, Figure 4 visualizes the predicted probabilities of crashes computed at different values of rider age (while keeping all other covariates at their mean values) for Model 2 (linear-in-parameters but non-linear-in-variables) to assess the true effects of age on the crash risk. Referring to the predictive margins plot of Model 2 (including polynomial terms for age), the plot visualizes the non-linearity attributable to the variable rider age obtained from a non-linear-in-variables model. The relationship between age and crash risk follows a U-shaped pattern – providing useful insights. For instance, compared to riders aged between 40 and 60, the probability of a crash is higher for riders aged younger than 40 years and older than 60 years. Note that younger riders (shown on the extreme left side in the plot) have relatively higher crash risk than older riders (illustrated on the extreme right side in the plot). The study's findings show that although both younger and older riders exhibit high crash risks, the risk for younger riders is even higher. Conceptually, the statistically significant quadratic term for rider age included in Model 2 suggests that ignoring non-linearity in the associations of rider age could lead to underestimation of the 'effect' size and hide important patterns embedded in the data.

The other key finding of the study is that riders who received motorcycle training during recent years are expected to have a lower risk of a crash than riders who either did not receive formal motorcycle training or received it before 2001. The odds of a rider being involved in a crash would reduce by 85% and 90% if the rider received the motorcycle training during 2001-2010 and 2010-2015, respectively (as compared to those who either did not receive the training or received it before 2001), thus indicating the importance of motorcycle training in reducing the crash risk.

This finding is also intuitive, as participation in formal training programs can help motorcycle riders enhance their safety perception and riding skills. Moreover, motorcycle training programs have improved in recent years due to national and statewide efforts for motorcycle safety [54]. The results further reveal that inexperienced riders are at a higher crash risk; for instance, with a unit increase in the riding experience, the odds of riders getting involved in a crash reduce by 2.69%. This finding is expected as an experienced rider may respond more skillfully, avoiding any safety-critical situations compared to an inexperienced rider. Previous studies also reported similar findings [10, 12, 52, 53]. Referring to the role of impairment, the odds of riders getting involved in a crash reduce by 75.67% if a rider tests negative for BAC. This indicates that impaired or drunk riding increases the odds of riders getting involved in crashes. This finding is intuitive and aligned with the previous studies [55]. Lastly, compared to white American riders, African-American and Hispanic riders have higher odds of getting involved in a crash.

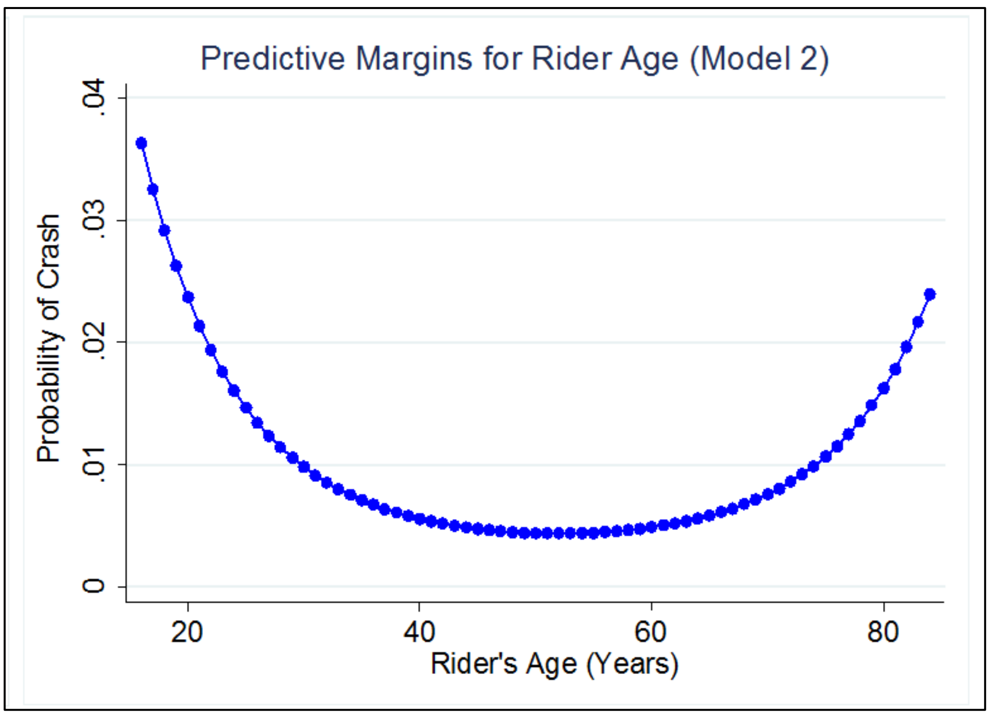

Figure 4 Predicted crash probabilities versus rider age (Best-fit non-linear Model 2)

LIMITATIONS

This study uses comprehensive and carefully collected data from MCCS, which not only includes extensive details about the motorcycle crash (referred to as 'case' in the study) (i.e., rider-related factors, roadway environment, and motorcycle-related factors) but also includes information about the controls, which were collected via detailed interviews, keeping similar characteristics. While this study provides useful insights, we recognize that MCCS data was collected in Orange County, California, with its unique socio-demographic and riding behavioral characteristics. Therefore, the findings of this study may not be generalized to other parts of California or the U.S. Also, note that all crashes included in MCCS data are injury crashes, while including only 1-2 fatal crashes (<0.1% of total crashes). Moreover, the MCCS data include a limited sample size of crashes;

hence, by increasing the sample size, some of the PDO crashes may also get reported. Moreover, some data on important factors like rider age, rider experience, and hours of sleep (before riding) were missing. For instance, MCCS data do not include experience, sleep hours (before riding), and rider age for 15.62% (N = 164), 17.14% (N = 180), and 0.57% (N = 6) of the riders, respectively. The median values of these variables based on the various age groups were imputed to utilize these significant percentages of observations. First, all the riders are categorized into various age groups, i.e., 15 – 25 years, 25 – 35 years, 35 – 45 years, 45 – 55 years, 55 – 65 years, 65 – 75 years, and greater than 75 years. The median values for each of the variable(s) within each age group were determined based on non-missing values, which were then used to replace the missing values for each variable within each age group. The final data, after cleaning and imputation, considered in the analysis consists of 1,050 observations (riders), which include 350 cases (crash-involved riders) and 700 controls (non-crash-involved riders). In the future, it would be better to collect complete data for all riders (both cases and controls), which can help explore the associations of these factors with crash risk.

CONCLUSIONS

The key focus of this study was to explore safety risks associated with younger and inexperienced riders. Moreover, the study also examined how participation in motorcycle training programs and alcohol use could affect a rider's propensity for involvement in a crash. Extensive data collected via the Motorcycle Crash Causation Study by the U.S. Department of Transportation was analyzed in the study. A conditional logit model is developed to fully account for the matched case-control data structure to achieve study objectives. Polynomial terms are used for rider age while controlling for other covariates to capture the non-linear association of rider age with crash risk. The non-linear model based on polynomial terms exhibited considerably improved fit compared to the linear-in-variables counterpart based on AIC and BIC statistics. Accounting for nonlinearity in the associations of age on crash risk improved model performance and led to several useful insights. Findings indicate that younger riders have a heightened crash risk, which reduces with increasing age. Each additional year is associated with a 3.31% reduction in the odds of a crash, although a non-linear specification is also tested. In addition, compared to motorcycle riders aged between 40 and 60 years, the younger and older riders are at higher crash risk (whereas younger riders have even greater crash risks than older riders). The study also reveals that inexperienced riders have higher odds of getting involved in crashes. Each year of rider experience is associated with a 2.69% reduction in the odds of a crash. Empirical evidence shows that participation in training programs during recent years is associated with lower crash risks. The crash risk reduces if the riders did formal motorcycle training in recent years (2001-2010 and 2010-2015) compared to those who did not receive any motorcycle training or received it before 2001.

From a practical implications standpoint, more emphasis is needed on the significance of rider age and riding experience in licensing regulations, specifically for younger, inexperienced, and older riders (60+ years). Training programs can help riders enhance their skills and safety perceptions. Furthermore, conducting awareness campaigns to advocate safety risks associated with alcohol use and risky riding (especially for younger riders) may help reduce motorcycle crashes. The dependencies between rider age, riding experience, speed, and injury severity, given a crash, can be explored as part of future work.

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AUTHOR CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: study conception and design: Muhammad Adeel, Numan Ahmad, Behram Wali, Asad Khattak; data collection: Muhammad Adeel, Numan Ahmad; analysis and interpretation of results: Muhammad Adeel, Numan Ahmad, Behram Wali; draft manuscript preparation: Muhammad Adeel, Numan Ahmad, Behram Wali, Asad Khattak. All authors reviewed the results and approved the final version of the manuscript.

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