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Impact of COVID-19 on Safety Performance for Motorcycles: Pre-and during-Pandemic Conditions

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Abstract

Florida has the highest number of motorcycle fatalities in the United States and contains the second largest population of registered motorcycles. The COVID-19 pandemic influenced the roads, traffic, and driving behavior in the continental United States. Motorcycle crashes decreased during the COVID-19 years (2020 and 2021) while the fatality rates increased. The purpose of this study is to 1) investigate motorcycle crashes before and during the Pandemic period to understand the impacts on motorcycle safety and contributing factors to the crash severity levels; 2) develop the crash predictive model for different degrees of severity in motorcycle crashes in Florida. Florida statewide crash data were collected. T tests have been conducted to compare the contributing factors between two periods. The injury severities are significantly different among all five levels between those during normal period and the Pandemic period. A crash predictive model has been developed to determine the facts to injury severity levels for motorcycle crashes. A total of eight variables are found to significantly increase the injury severity levels for motorcycle crashes during the Pandemic period.

Keywords

Motorcycle Crash, Pandemic, Injury Severity, Contributing Factors

1. Introduction

The COVID-19 pandemic influenced the roads, traffic, and driving behavior in the continental United States. A few past studies showed that there was a decrease in traffic volume with an increase of severe crashes [1]-[3]. Although traffic volume was decreasing during the pandemic, the total fatalities increased by

20.8% from 2019 to 2020 [4]. The increased frequency of severe crashes during COVID is possibly due to less congestion on the roads and the availability to reach higher speeds on highways. The speed effect tends to happen in urban areas where there was high congestion and then there is no congestion; this is what took place during COVID in California. Traffic volumes decreased by 22% and total crashes decreased by 49%. However, severe crashes increased by nearly 25% [5].

Motorcyclists represent about 3.4% of Florida's registered vehicles; however, motorcycle crashes account for about 20% of traffic fatalities while less than 1% of vehicle miles traveled [6]. The number of annual motorcycle fatalities observed in Florida has more than doubled over the past twenty years [7]. COVID-19 restricted travel patterns as there was a travel ban during the peak lockdown months in the United States. **Figure 1** lists the comparison of motorcycle crashes by severity levels before COVID (2017-2019) and during COVID (2020-2021). Motorcycle crashes decreased during the COVID-19 years while the fatal crashes almost doubled, and the injury crashes increased 50% from 22% to 33% in average.

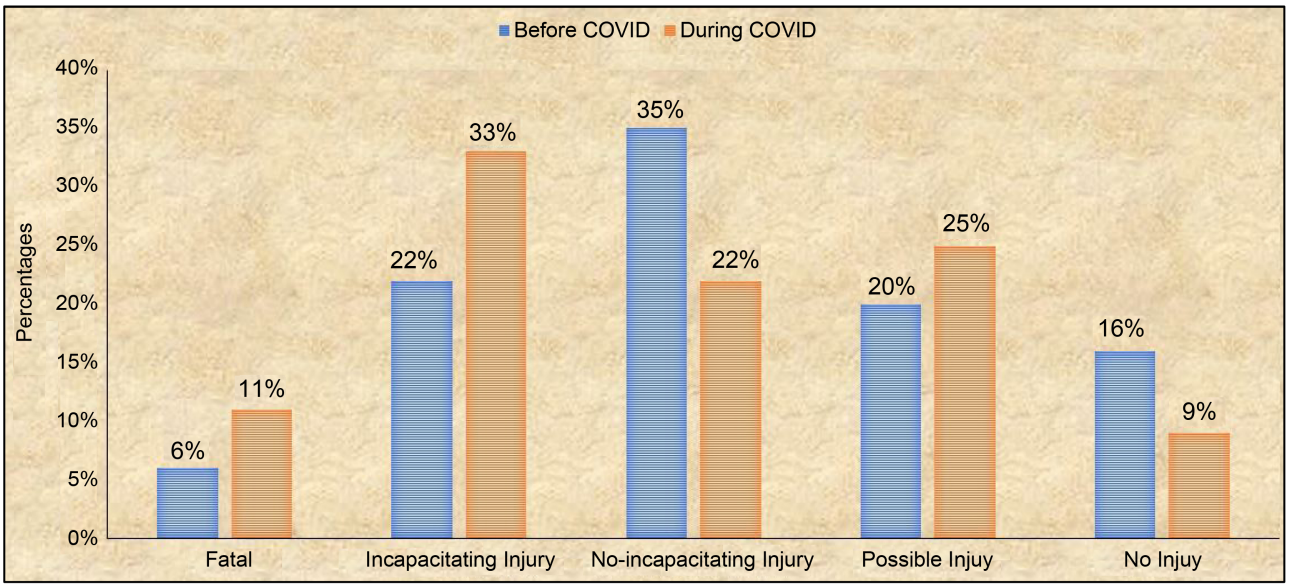

Figure 1. Comparison of motorcycle injury severity levels before COVID (2017-2019) and during COVID (2020-2021).

Some of the common risk factors in motorcycle crashes include lack of helmet use. Since motorcycles vary in design and performance capabilities, motorcyclists may select certain motorcycle types based on driving preferences [8]. Conversely, motorcycle performance capabilities may influence the likelihood of risky driving behaviors such as speeding [9]. Factors such as time-of-day, sleep deprivation, and drug/alcohol impairment may also affect the safety of motorcyclists [10]. The goal of this research is to investigate motorcycle crashes before and during the COVID-19 pandemic to better understand the impacts of the pandemic on motorcycle safety and the contributing factors to crash severity le-

vels.

Predictive models are used frequently for motorcycle crashes to determine the contributing factors. For example, the study in Malaysia examined a variety of roadway elements to determine the contributing causes of motorcycle fatalities. The study found out that increases in access points and average daily volume are the leading indicators of motorcycle fatalities [11]. However, this model does not apply for motorcycle crashes during Pandemic as the traffic volume decreases and no significant change of access density for a short time of period. So far, there have been limited studies on the impacts on motorcycle crashes and its unique contributing factors.

In summary, there is limited research on motorcycle crashes during the Pandemic and the previous research is not applicable. The purpose of this study is to 1) investigate motorcycle crashes before and during the pandemic to understand the impacts of pandemic on motorcycle safety and contributing factors to the crash severity levels; 2) develop crash a predictive model for different degrees of severity in motorcycle crashes in Florida during the Pandemic period.

2. Data Collection and Methodology

2.1. Data Collection

The historical crash data were obtained from the FDOT crash database SSOG is website [12]. Each crash record has the details of crash characteristics and related factors, such as crash types, roadway conditions, weather, injury severity levels, lighting conditions, moving status, geographical coordinates, etc. The SSOG is system contains the data available for state-maintained highways in Florida. Pre-Pandemic data was analyzed from three years prior to the Pandemic (Year 2017-2019), as the normal period to establish a baseline. The pandemic period (Year 2020-2021) was selected as a comparison with the normal period. Crash data counts of all motorcycle crashes for these two time periods were pulled from the database and were analyzed to determine the impacts.

2.2. Statistical Analysis

Cross-sectional comparisons have proved to be valuable and were performed by past studies [13]. For the collected crash data, statistical tests (t tests and proportionality tests) were used to quantitatively evaluate whether the safety performances are statistically significant between two time periods for different variables [14]-[16]. A significance level of 0.05 was selected. The t-test is given by Equation (1):

$$t = \frac{\left|p_1 - p_2\right|}{\sqrt{\frac{p_1\left(1-p_2\right)}{m} + \frac{p_1\left(1-p_2\right)}{n}}} \tag{1}$$

where p_1 is proportion of a particular type of crash for one variable before COVID; p_2 is proportion of a particular type of crash for the same variable dur-

ing COVID; m counts the total number of crashes before COVID; and n counts total number of crashes during COVID.

Results from this study will help set a baseline for the data that will be analyzed involving post-COVID19 motorcycle crashes. Statistical analysis (t-tests) will be used to determine the contributing factors that significantly different before and during the pandemic areas.

2.3. Crash Model Development

Many statistical models have been applied to model injury severity levels. Multinomiallinear regression model is the commonly used one to determine the major contributing factors to injury severity levels. The standard model described within can be modified and calibrated to a specific roadway or jurisdiction using the Equation (2):

$$Y = \alpha + \beta_n x_n + \varepsilon \tag{2}$$

where Y is injury levels (1, 2, 3, 4, 5) during Pandemic period; α is a constant value; β_n are the coefficients of the contributing factors at a 95% of confidence level; and x_n are the variables are significant at a 95% confidence level.

Twenty-six variables were initially selected and listed in **Table 1**, included one categorical variable, twenty-three dummy variables and two continuous variables. Five injury level outcomes were coded from 1 to 5. The roadway conditions include the area types (rural/urban), crash time (day/night), five lighting conditions, three driving types (speeding, aggressive, distracted), six crash types, four weather conditions, the road surface condition (dry/wet), post speed limit, and AADT (average annual daily traffic in thousand, the crash The crash types defined by the first harmful events (rear-end, head-on, angle, sideswipe, rear to side, and rear to rear). A study from Viginia found out that when motorcycle traffic volume is unknown, the total AADT did not produce substantial bias, and thus the SPFs utilizing total AADT are sufficient for use [17]. Thus, the AADT will be directly used as the variable in the model.

3. Data Analysis Results

3.1. Statistical Analysis Results

T-tests and proportionality tests were conducted to compare whether there are significant differences in injury severities and common contributing factors before and during the Pandemic. **Table 2** lists the test results for all the selected variables with a 95% confidence level. A total of 14,956 motorcycle crashes were reported for the normal period while 5018 crashes were found for the Pandemic period. The injury severities are significantly different among all five levels between those occurring before COVID and during COVID, as listed in **Figure 1** and **Table 2**. The percentage of fatal crashes is 83% more and 50% more. As a result, the Pandemic has played a significant role in increasing the percentage of severe motorcycle crashes. The results evidence that even though the total crashes decreased in average, the injury severity levels are significantly higher at

Table 1. Selected explanatory variables.

Type	Variable	Value	Description	Count	Percent
Categorical	Injury Levels	5	Fatal Injury	212	8.018%
		4	Incapacitating Injury	548	20.726%
		3	Non-Incapacitating	684	25.870%
		2	Possible Injury	866	32.753%
		1	No Injury	334	12.632%
Dummy	Area	1	Urban	2480	93.797%
		0	Rural	164	6.203%
	Alcohol/Drugs	1	Present	136	5.144%
		0	Not Present	2508	94.856%
	Daytime	1	Yes	1708	64.599%
		0	No	936	35.401%
	Dusk	1	Yes	113	4.274%
		0	No	2531	95.726%
	Dawn	1	Yes	33	1.248%
		0	No	2611	98.752%
	Dark-Lighted	1	Yes	642	24.281%
		0	No	2002	75.719%
	Dark-Not Lighted	1	Yes	144	5.446%
		0	No	2500	94.554%
	Dark-Unknown Lighting	1	Yes	4	0.151%
		0	No	2640	99.849%
	Speeding	1	Yes	119	4.501%
		0	No	2525	95.499%
	Aggressive Driving	1	Yes	112	4.236%
		0	No	2532	95.764%
	Distracted Driving	1	Yes	406	15.356%
		0	No	2238	84.644%
	Rear-End	1	Yes	1054	39.864%
		0	No	1590	60.136%
	Head-On	1	Yes	122	4.614%
		0	No	2522	95.386%
	Angle	1	Yes	1005	38.011%
		0	No	1639	61.989%
	Sideswipe	1	Yes	447	16.906%
		0	No	2197	83.094%

Continued

	Rear to Side	1	Yes	12	0.454%
		0	No	2632	99.546%
Dummy	Rear to Rear	1	Yes	4	0.151%
		0	No	2640	99.849%
	Clear Weather	1	Yes	2294	86.762%
		0	No	350	13.238%
	Cloudy Weather	1	Yes	262	9.909%
		0	No	2382	90.091%
	Rainy Weather	1	Yes	77	2.912%
		0	No	2567	97.088%
	Fog, Smog, Smoke	1	Yes	11	0.416%
		0	No	2633	99.584%
	Road Wet	1	Yes	142	5.371%
		0	No	2502	94.629%
	Posted Speed > 30 mph	1	Yes	2502	94.629%
		0	No	142	5.371%
Continuous	AADT	Average Annual Daily Traffic (in Thousands)		1300 - 26,900	
	Posted Speed	Posted Speed Limit (in mph)		25 - 70	

a 95% of confidence level during the pandemic period.

Speeding and distracted driving are significantly different between the two periods with t values of 2.05 and 28.3, accordingly. Speeding is the major contributing factor to motorcycle crashes overall; while it is even more dangerous and counts a significantly higher percentage of crashes than those for normal the normal period. However, there are significantly lower motorcycle crashes caused by distracted behaviors. 31% of motorcycle crashes account for distracted driving while only 12% during the COVID period. The reason can be the lower of the traffic volume/congestion and people are driving at a higher speed with less interruptions. The use of drugs and alcohol had significant effects on the motorcycle crashes, with a value of 7.03, 4.15 for drugs and 2.8 for both alcohol and drug involved. The possible reason can be the lock-down impacts and more drivers/roadway users tend to have alcohol and drug involved due to the lock-down and pressures during the special period.

On the contrary, the crash types are not significantly different between the two periods as well as weather and lighting conditions at a 95% of confidence level. The comparisons between the periods are listed in **Figures 2-4** for lighting conditions, weather conditions, and crash types respectively. The crash types are the same as those during the normal period for motorcycle crashes as no significant increase or decrease of certain type of crashes due to the Pandemic. About 26% percentages of crashes are angle, the same as front-end crashes. The weather

Table 2. Statistical test results of COVID-19 impacts on motorcycle crashes.

Factors	t-Values	Result (95% Confidence Level)
Fatal Crash	10.58	Significant
Incapacitating Injury	15.75	Significant
No-Incapacitating Injury	19.99	Significant
Possible Injury	7.06	Significant
No Injury	15.08	Significant
Speeding	2.05	Significant
Distracted Driving	28.3	Significant
Alcohol Involved	7.03	Significant
Drugs Involved	4.15	Significant
Both Alcohol and Drugs Involved	2.18	Significant

and lights impacts are also not observed during the two time of period. Most of the crashes occur during clear weather conditions (about 90%) for both periods, and 4% under rainy conditions. Over 60% of motorcycle crashes occurred during daytime and about 30% at nighttime.

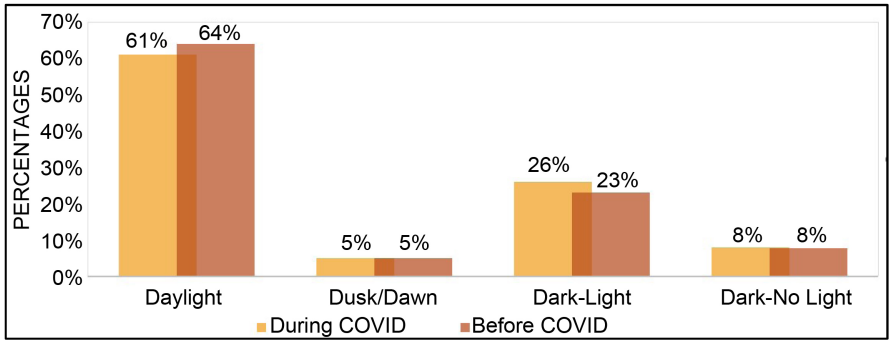

Figure 2. Impacts of lighting conditions on motorcycle crashes before and during pandemic.

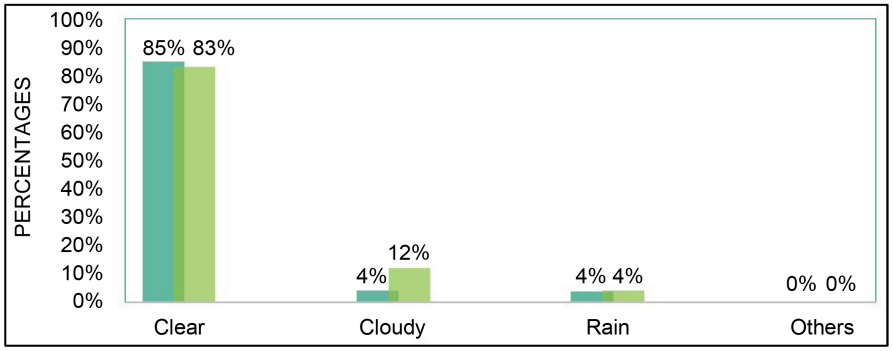

Figure 3. Impacts of weather conditions on motorcycle crashes before and during pandemic.

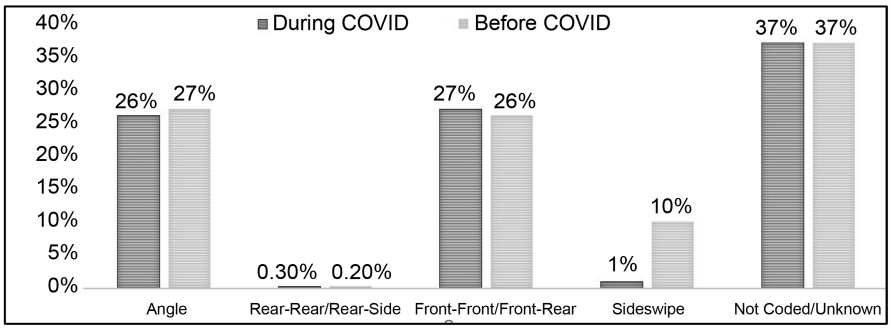

Figure 4. Comparison of motorcycle crash types before and during pandemic.

3.2. Statistical Model Results

Table 3 lists the final model results with the explanatory variables at a 5% significant level. SPSS is a powerful and widely used statistical model tool. This research used SPFF to develop the predictive model of crash severity levels, from 1 to 5. All the selected dummy and continuous variables were initially input into the software and the results are summarized for significant variables only.

A goodness of fit test was performed by the SPSS software as well and a full summary of the goodness of fit of the linear regression model can be found in Table 4. The model is well fitted with the likelihood Chi-square of 427.572 at a 0.000 significant level. The A total of eight variables out of twenty-six initially selected variables are found to significantly increase the injury severity levels for motorcycle crashes during the Pandemic period, including area type, posted speed limit < 30 mph, alcohol/drug involved, daylight, clear weather, head-on collision, angle collision, and speeding.

Over 93% of the crashes occurred in urban areas while less than 7% occurred in rural areas. Crashes occurring in urban areas are more likely to be involved in severe crashes compared to rural areas. The negative sign for posted-speed limit indicates that while motorcycle travels in a lower speed, especially lower than 30mph, can significantly reduce the severity levels. The result is consistent with the previous study [12] [13]. Similar to the variable of speeding, no speeding can significantly reduce the injury level with a coefficient of −0.7.

The results are consistent with the statistical analysis. The more speeding riders, the more severe crashes occurred during the pandemic period. The similar results can be found for alcohol/drugs involved. If no alcohol/drug involved in the rider, the less percentage of severe levels occurred with a coefficient of −1.026. Riders under drugs or alcohol influenced are more likely to involve in severe crashes than not involved in either of them.

For the daytime and weather conditions, riders are more likely to be involved in severe crashes if crashes occurred at night and/or no clear weather, like runny, foggy, and/or smoke condition. One important finding is that even the percentages of nighttime crashes are not significantly different for normal period and the Pandemic period. This may relate to other significant variables. Riders are likely to operate at a relatively high speed with limited views.

Table 3. Statistical model results for motorcycle crashes during the pandemic period.

Parameter	Coefficient	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	Df.	Sig.
Constant	5.080	0.1655	4.756	5.405	941.724	1	0.000
Functional Class	0.558	0.0860	0.389	0.726	42.046	1	0.000
Posted Speed <30 mph	−0.557	0.0916	−0.737	−0.377	36.959	1	0.000
Not Drugs/Alpohol Inolved	−1.026	0.0946	1.212	−0.841	117.610	1	0.000
Not Daylight	0.100	0.0438	0.014	0.185	5.180	1	0.023
Not Clear Weather	0.166	0.0611	0.046	0.285	7.355	1	0.007
No Head-On Collision	−0.420	0.1003	−0.616	−0.223	17.499	1	0.000
Not Angle Collision	−0.503	0.0431	−0.587	−0.418	136.061	1	0.000
No Speeding	−0.700	0.1001	−0.897	−0.504	48.950	1	0.000

Thus, a more severe consequence might occur at night during the Pandemic period. The same result can be found for weather conditions. Riders are more likely to be involved in severe crashes under severe weather conditions during Pandemic period. Example, when it was raining and the road was wet and slippery, riders are more likely to involve in injuries and severe outcomes.

The negative sign for not angle crashes or not head-on crashes indicate that these two crash types can cause higher injury levels compared to rear-end and side swipe crashes. This finding is similar as the variables of weather and lighting conditions. Even though the percentages of crash types do not change significantly from normal period to the Pandemic period; the type of crashes does impact the severity levels of crashes. Riders involved in head-on, and angle are likely to have severe injuries. However, AADT has been found not to be significantly associated with the severity levels for motorcycle riders. It is intuitive that it may increase the possibility of crash occurrence, however, due to the low volume of traffic during the Pandemic period, the traffic volume does not increase or decrease the significant level of injury at all.

4. Conclusions and Limitations

This study has investigated motorcycle crashes before and during the Pandemic

Table 4. Goodness of fit of statistical model for motorcycle crashes during the pandemic period.

Likelihood Ratio Chi-Square	Df.	Sig.	
427.572	8.000		
	Value	**Df.**	**Value/df.**
Deviance	2959.142	2635	1.123
Scaled Deviance	2644.000	2635	
Pearson Chi-Square	2959.142	2635	1.123
Scaled Pearson Chi-Square	2644.000	2635	
Log Likelihood	−3900.539		
Akaike's Information Criterion (AIC)	7821.079		
Finite Sample Corrected AIC (AICC)	7821.162		
Bayesian Information Criterion (BIC)	7879.879		
Consistence AIC (CAIC)	7889.879		

period to understand the impacts of pandemic on motorcycle safety and contributing factors to the crash severity levels. A crash predictive model has been developed to determine the facts to injury severity levels for motorcycle crashes. A total of 14,956 motorcycle crashes were reported for the normal period while 5018 crashes were found for the Pandemic period. T tests have been conducted to compare the contributing factors between two periods. Five injury levels, fatal, incapacitating injury, non-incapacitating injury, possible injury, and no injury, were selected for the model. A total of eight variables out of twenty-six initially selected variables are found to significantly increase the injury severity levels for motorcycle crashes during the Pandemic period.

The Pandemic has played a significant role in increasing the percentage of severe motorcycle crashes. The results evidence that even though the total crashes decreased in average, the injury severity levels are significantly higher at a 95% of confidence level during the Pandemic period. Crashes occurring in urban areas are more likely to be involved in severe crashes compared to rural areas. Speeding is the major contributing factor to motorcycle crashes overall; while it is even more dangerous and counts a significantly higher percentage of crashes than those for normal the normal period. While motorcycles travel in a lower speed, especially lower than 30 mph, and can significantly reduce the severity levels. The results are consistent with the statistical analysis and predictive models. The more speeding riders, the more severe crashes occurred during the pandemic period.

The use of drugs and alcohol had significant effects on the motorcycle crashes. Most of the crashes occur during clear weather conditions (about 90%) for both periods, and 4% under rainy conditions. Over 60% of motorcycle crashes occurred during daytime and about 30% at nighttime. However, riders are more likely to be involved in severe crashes if crashes occurred at night and/or no

clear weather, like runny, foggy, and/or smoke conditions. One important finding is that even the percentages of nighttime crashes are not significantly different for normal period and the Pandemic period. This may relate to other significant variables. Riders are likely to operate at a relatively high speed with limited views. Thus, a more severe consequence might occur at night during the Pandemic period. The same result can be found for weather conditions. Riders are more likely to be involved in severe crashes under severe weather conditions during Pandemic period.

The crash types remain same as those during the normal period for motorcycle crashes as no significant increase or decrease of certain type of crashes due to the Pandemic period. However, similar findings can be found for the variables of weather and lighting conditions. Even though the percentages of crash types do not change significantly from normal period to the Pandemic period; the type of crashes does impact the severity levels of crashes.

The results from this study can help researchers, engineers, and policy makers to identify the key factors to motorcycle crashes, especially severe crashes. The information can be used to develop materials for safety campaigns, public awareness campaigns, and educational programs, locally, statewide, and nationally. For example, speeding is one of the leading factors to crashes while it is even more severe during the pandemic period. New technologies can be developed to control the speed to prevent and mitigate the impacts of motorcycle crashes. One of the limitations of this study is the availability of the data resource. There may be underreported motorcycle crashes which may not be included in the study. The data after Pandemic are not available as well. The future study is to include the crashes after the Pandemic to understand the overall impacts.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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