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Risk Factors for Traffic Crash Fatalities in Older Motorcyclists: A Study Linking Police Traffic Crash Dataset with Cause of Death Dataset

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SUMMARY

Background: In Taiwan, many older adults ride motorcycles for outdoor activities. The identification of the factors leading to fatalities in these older motorcyclists is essential for improving motorcycle safety. In the traffic crash dataset of the National Police Agency (NPA), only the crash victims who die within 24 hours after an accident are officially categorized as fatally injured. This study refined severity level of a fatal injury using the 30-day definition instead of the 24-hour definition, and investigated the factors affecting older motorcyclist fatalities in traffic crashes.
Methods: This study linked the NPA traffic crash dataset and the causes of death dataset of the Ministry of Health and Welfare to modify the definition of "fatally injured" in NPA traffic crash dataset to the international 30-day definition. This study built a logistic regression model to investigate the factors affecting older motorcyclist fatalities.
Results: Older motorcyclists accounted for 35% of the motorcyclist fatalities; safety problems for older motorcyclists were serious. Several risk factors were found, including motorcyclist characteristics (e.g., alcohol use and traffic violation behaviors), environmental factors (e.g., lighting conditions), vehicle factors (e.g., type of conflict vehicle), and drivers of the conflict vehicles driving under the influence of alcohol.
Conclusion: Older motorcyclists accounted for a considerable proportion of crash fatalities in Taiwan. Among the violation behavior factors affecting older motorcyclist fatalities, we particularly identified drunk driving to be a serious issue. Thus, the implementation of a zero-tolerance drunk-driving law by setting a low legal blood-alcohol limit is strongly recommended.

1. Introduction

In Taiwan, the official traffic crash dataset was compiled and maintained by the National Police Agency (NPA), Ministry of the Interior. Before 2008, the injury severity reported by the police in the crash report was classified into four levels: fatally injured, injured, not injured, and unknown. The fatally injured category applies to victims who died within 24 hours of a traffic crash due to their injuries. The World Health Organization (WHO) and the Organization for European Cooperation and Development defined traffic fatality as a case in which victims died within 30 days of a traffic crash (hereafter, 30-day definition).[1,2] This is the international definition of traffic fatality that was recommended by organizations, such as the International Road Traffic and Accident Database, the United Nations Economic Commission for Europe, and WHO, and has been adopted by most countries.[3] In response to this 30-day definition, the NPA has added one more category (i.e., death of the victim occurring between 24 hours and 30 days) in the crash report since 2008. However, as the police are not required to check and report if the victim died between 24 hours and 30 days of a traffic crash, most fatalities that fit within the 30-day definition remain assigned to the injury level of "injured".

Motorcycles are a popular transportation mode in Taiwan because of their convenience and affordability. As of December 2018, the number of registered motorcycles was 13,776,210. On an average, there is one motorcycle for every 1.7 persons. Chen indicated that many older people in Taiwan use motorcycles for several trip purposes (e.g., shopping, visiting a friend, and seeing a doctor), especially older people living in rural districts.[4] Thus, identifying the factors that cause older motorcyclists fatalities is essential to improving motorcycle safety and reducing the number of fatal crashes in older motorcyclists. Most traffic crash occurrences are attributable to human factors, including traffic violation behaviors. In this study, traffic violation behaviors were defined as driver actions that contribute to traffic crashes. Several studies have examined the effect of traffic violations on injury severity for people involved in traffic crashes. For instance, Ayuso et al. investigated the associations between drivers' injury severities and traffic violations.[5] The analyzed results revealed that some traffic violations (e.g., speeding, driving an overloaded vehicle, and driving into the opposite lane) are associated with a higher probability of serious or fatal crashes. In addition to analyzing the risks drivers who exhibit violation behaviors pose to themselves, Penmetsa et al. investigated the risks the

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drivers pose to other drivers by violating traffic rules.[6] Different factors have been investigated in the studies related to motorcyclist injury severities.[7–15] The affecting factors summarized from those studies are as follows: traffic violation behavior factors (e.g., running a red light), age, gender, helmet use, alcohol use, vehicle factors (e.g., crashes involving a heavy vehicle), lighting conditions, hour-of-crash and weather conditions.

An objective of this study was to refine the "fatal injury" severity level by using the 30-day definition instead of the 24-hour definition by linking the official NPA traffic crash dataset and the causes of death dataset that was compiled by the Ministry of Health and Welfare (MOHW). Another study objective was to investigate the factors resulting in fatal injury of older motorcyclists.

2. Linking and analysis of traffic crash dataset and cause of death dataset

The Health and Welfare Data Science Center (HWDC) of MOHW collected and managed over 30 health-related databases, and researchers can apply to HWDC for analyzing the datasets. HWDC has established information security norms for the use of the datasets that are in line with the international standard ISO27001. Moreover, researchers can analyze the datasets in an isolated and privacy-protected computer room located in HWDC. We applied to the Joint Institutional Review Board (JIRB), Taipei Medical University (TMU), for the ethical approval of this study. After obtaining the IRB approval (TMU-JIRB number: N201606028), we applied to HWDC to obtain the permission for linking the NPA traffic crash dataset and the MOHW causes of death dataset for this study to determine if the traffic crash victims died within 30 days after a crash. Personal ID was used to link the two datasets. The study period was from 2013 to 2017.

Table 1 presents the difference between the numbers of fatalities in the NPA traffic crash dataset and the MOHW causes of death dataset based on the age group. The injury levels recorded by the police may be incorrect. As recorded in the NPA dataset, a total of 270 victims passed away between 24 hours and 30 days after a traffic crash; however, none of the victims died within 30 days according to the MOHW dataset. A total of 4,137 victims died within 30 days of the traffic crashes; the data was recorded for all ages. However, these victims were categorized as "injured," "not injured" or "unknown" in the NPA traffic crash dataset (i.e., 2,495 victims aged < 65 years, and 1,642 victims aged ≥ 65 years). Individuals aged 65 years or above accounted for 35% of the fatalities.

Table 2 presents the total number of older adults involved in traffic crashes and the number of fatalities based on the type of vehicles. A total of 140,709 older adults (54.0%) were riding motorcycles at the time of crashes. Among the 5,106 fatalities, 2,484 (48.6%) victims were riding motorcycles, followed by the pedestrian (1,341, 26.3%) and cyclist (733, 14.4%) victims. These figures indicate that the enhancement of motorcycle safety for older motorcyclists is crucial in Taiwan.

3. Violation behaviors affecting older motorcyclist fatalities

Table 3 presents the number of older motorcyclist fatalities and the fatality rate when motorcyclists violate rules (i.e., the violation behaviors indicated in the NPA crash reports). Failing to yield and running a red light are the top two serious traffic violation behaviors. A total of 408 motorcyclists died because they failed to yield, which is a fatality rate of 2.10%. A total of 194 older motorcyclists died because they ran a red light, which is a fatality rate of 2.54%. Moreover, 439 older motorcyclists died because they did not pay attention to the traffic ahead. In addition to the traffic violation behaviors mentioned above, the fatality rate of the following causes of crashes was above the average fatality rate (i.e., 1.77%): drunk driving, improper lane changes or turning, making an illegal left or U-turn, and violating a traffic sign or marking.

Table 4 illustrates the numbers of motorcyclist fatalities and the fatality rate based on the older motorcyclist breath alcohol concentration (BrAC) levels. In Taiwan, the conviction standard of the BrAC level for the drunk-driving law is an alcohol level greater than 0.15 mg/L. Among the motorcyclists who might be driving under the influence of alcohol at the time of the crash, 448 had an unknown BrAC level. It is possible that they did not have the breath- and blood-alcohol tests because they were too seriously injured. Among the different categories of the different BrAC levels, the motorcyclists at a BrAC level less than or equal to 0.15 mg/L exhibited the highest fatality rate (9.2%). The problem for this group is also very serious.

4. Logistic regression model for identifying factors affecting older motorcyclist fatalities

This study developed logistic regression models to explore the factors affecting older motorcyclist fatalities. Numerous explanatory

Table 2
Number of older adults involved in traffic crashes and number of fatalities by vehicle type.

Vehicle type	Total		Died within 30days	
	Persons	%	Persons	%
Motorcycle	140,709	54.0	2,484	48.6
Pedestrian	25,141	9.7	1,341	26.3
Bicycle	23,095	8.9	733	14.4
Passenger car	44,329	17.0	134	2.6
Light truck	10,208	3.9	88	1.7
Heavy truck	442	0.2	3	0.1
Tractor-trailer	112	0.0	0	0.0
Bus	20	0.0	0	0.0
Passenger	13,705	5.3	251	4.9
Others	2,692	1.0	72	1.4
Total	260,453	100.0	5,106	100.0

Table 1
Differences between the numbers of fatalities recorded in the NPA traffic crash dataset and MOHW causes of death dataset by age group.

Categories of injury severity levels in NPA traffic crash dataset	Victims linked with MOHW causes of death dataset		
	Dying within 30 days		Surviving beyond 30 days
	Age < 65	Age ≥ 65	All ages
Dying within 24 hours	5,948	2,614	0
Dying between 24 hours and 30 days	1,197	850	270
Injured	2,344	1,602	1,988,516
Not injured	142	38	1,144,613
Unknown	9	2	38,698
Totals	9,640 (65%)	5,106 (35%)	14,746

Table 3
Numbers of older motorcyclist fatalities and fatality rate by older motorcyclist causes of crashes.

Cause of Crash	No. of motorcyclist fatalities (a)	No. of motorcyclist non-fatalities	Total (b)	Fatality rate (%) (a)/(b)
Not paying attention to traffic ahead	439	26,316	26,755	1.64
Failing to yield	408	19,012	19,420	2.10
Running a red light	194	7,477	7,671	2.53
Making illegal left/U-turn	171	8,915	9,086	1.88
Violating traffic sign/marking	77	4,029	4,106	1.88
Not keeping safe lateral distance from other vehicles	61	4,774	4,835	1.26
Drunk driving	61	1,460	1,521	4.01
Improper lane change or turning	53	2,499	2,552	2.08
Driving in the wrong direction	40	2,289	2,329	1.72
Not paying attention to other vehicles when starting from a standstill	28	2911	2939	0.95
Other causes	173	12,014	12,187	1.42
Unknown	480	21,320	21,800	2.20
Not at fault (no cause found)	299	25,209	25,508	1.17
Total/average	2,484	138,225	140,709	1.77

Table 4
Numbers of older motorcyclist fatalities and fatality rate by the older motorcyclist BrAC level.

BrAC level	No. of motorcyclist fatalities (a)	No. of motorcyclist non-fatalities	Total (b)	Fatality rate (a)/(b)
Not drunk driving	1,842	132,476	134,318	1.4%
0 mg/l < BrAC ≤ 0.15 mg/l	86	844	930	9.2%
0.15 mg/l < BrAC ≤ 0.55 mg/l	36	973	1,009	3.6%
BrAC > 0.55 mg/l	72	1354	1,426	5.0%
Unknown	448	2578	3,026	14.8%
Total/average	2,484	138,225	140,709	1.8%

variables were considered, including motorcyclist characteristics (i.e., age, gender, helmet use, alcohol use, driving license qualification, personal cause of crash), environmental factors (i.e., time of the day, lighting conditions, and weather conditions), and vehicle factors (i.e., types of other vehicles involved in the motorcycle crash). The violation behaviors and alcohol use of drivers of the conflict vehicles were also considered. The influential factors in Table 5 affecting older motorcyclist fatalities were as follows:

(1) Gender: Male older motorcyclists were more likely to be fatally injured than female older motorcyclists. As pointed out by Chang et al.,[7] the effects of gender on motorcyclist injury severities were inconsistent in numerous studies. Further study is recommended to investigate the reasons for this result.
(2) Age: The older the motorcyclists, the higher were the odds ratios for dying in crashes. Similar results were found in the studies by Chang et al.[7] and Schneider et al.[9]
(3) Helmet use: Older motorcyclists who did not wear helmets were more likely to be fatally injured than older motorcyclists who wore helmets. This result is consistent with the findings of numerous studies.[7,9,10,11,13] In addition to the effect of helmet use on motorcyclist injury severities, in the study by Wali et al.,[14] it was found that partial coverage helmets were associated with lower likelihood of crash involvement. There are different types of helmets in Taiwan, further study is suggested to investigate the effects of the types of helmets on motorcyclist injury severities and the likelihood of crash involvement.
(4) Driving license qualification: Older motorcyclists who did not have a license or did not have a valid license (e.g., license suspended or revoked) were more likely to be fatally injured than older motorcyclists with a valid license. We also found that 15.8% of the victims in the crashes did not have a license for riding a motorcycle. The reasons for this behavior should be determined, and countermeasures should be developed to encourage older motorcyclists to obtain a valid license.
(5) Type of conflict vehicle: Older motorcyclists were more likely to be fatally injured if the conflict vehicle was a heavy vehicle (i.e., tractor, trailer or semi-trailer, big truck, or bus) than if the conflict vehicle was another motorcycle. Motorcyclists are vulnerable road user. As pointed out in the studies,[7,10,11,12,15] when motorcyclists collide with heavy vehicles, the injury severity level is higher. Traffic safety education for motorcyclists should include training courses to help motorcyclists understand how to respond to safety problems related to heavy vehicles, such as the heavy vehicle's blind spots and/or the problem of the rear axle or trailer off-tracking, especially when a heavy vehicle is making a turn at intersections.
(6) Violation behaviors: If older motorcyclists exhibit the following violation behavior at the time of the crash, they were more likely to be fatally injured: running a red light, failing to yield and making improper lane changes or turning. The influences of the problems of running a red light[7,10] and failing to yield[10] on motorcyclist's injury severity level were found in numerous studies.
(7) Driving under the influence of alcohol: Older motorcyclists who were driving under the influence of alcohol were more likely to be fatally injured than those driving sober, especially older motorcyclists who had a BrAC level less than or equal to 0.15 mg/L. By comparing the odds ratio values in the models for all the violation behaviors, we particularly found that drunk driving is a serious problem (the odds ratios for drunk driving were the highest).
(8) Driver of the conflict vehicle driving under the influence of alcohol: Older motorcyclists were more likely to be fatally injured if the driver of the conflict vehicle was driving drunk with a BrAC level of over 0.15 mg/L. The problem of drunk driving is very serious and may result in fatalities for older motorcyclists who are not driving drunk.
(9) Lighting conditions: Older motorcyclists were more likely to be fatally injured if the light condition was night without light. Similar results were found in the studies[8,10,12] by Geedipally et al., Savolainen et al. and Shaheed et al.
(10) Hour-of-crash: Older motorcyclists were more likely to be fatally

Table 5
Logistic regression model for identifying the factors affecting older motorcyclist fatalities.

Analysis of maximum likelihood estimates				
Variable	Parameter estimate	Wald Chi-Square	Pr > ChiSq	Odds ratio
Intercept	-5.99	6511.69	< .001	-
Gender				
Male	0.37	41.28	< .001	1.45
(baseline: Female)				
Age				
75–84	0.46	80.23	< .001	1.58
85 and over	0.75	62.81	< .001	2.13
(baseline:65–74)				
Helmet use				
No	1.68	466.16	< .001	5.37
Unknown	0.64	110.07	< .001	1.89
(baseline: Yes)				
Driving license qualification				
Without a license	0.38	41.20	< .001	1.47
Without a valid license	0.30	4.60	0.032	1.35
Unknown	-0.77	19.14	< .001	0.46
(baseline: With a valid license)				
Type of conflict vehicle				
Tractor trailer/semi-trailer	2.80	431.16	< .001	16.47
Big truck	2.32	428.48	< .001	10.18
Big bus	1.80	129.03	< .001	6.08
Small truck	1.49	448.83	< .001	4.45
Passenger car	0.81	181.19	< .001	2.25
Large motorcycle	-0.08	0.11	0.736	0.92
Bicycle	-0.22	0.43	0.512	0.80
(baseline: Motorcycle)				
Running a red light				
Yes	0.66	66.05	< .001	1.94
(baseline:No)				
Failing to yield				
Yes	0.50	68.80	< .001	1.65
(baseline:No)				
Improper lane change or turning				
Yes	0.32	4.70	0.030	1.38
(baseline:No)				
Driving drunk				
0 mg/l < BrAC ≤ 0.15 mg/l	1.85	198.25	< .001	6.33
BrAC > 0.15 mg/l	1.05	57.90	< .001	2.86
Unknown	2.71	1229.10	< .001	15.01
(baseline: Not drunk driving)				
Drivers of the conflict vehicle driving drunk				
0 mg/l < BrAC ≤ 0.15 mg/l	0.37	2.48	0.115	1.45
BrAC > 0.15 mg/l	0.89	38.24	< .001	2.43
Unknown	-0.69	26.61	< .001	0.50
(baseline: Not driving drunk)				
Lighting conditions				
Morning or dawn	0.13	1.10	0.295	1.14
Night with light	0.05	0.32	0.569	1.05
Night without light	0.86	17.77	< .001	2.35
(baseline:daylight)				
Hour-of-crash				
23:00~05:59	0.76	41.31	< .001	2.13
(baseline: 06:00~22:59)				

Association of the predicted probabilities and observed responses: percent concordant = 78.3.
Hosmer and Lemeshow goodness-of-fit test: chi-square = 9.66, df = 8, Pr > chi-square = 0.29.

injured if the hours of crashes were between 11 p.m. and 5 a.m. In general, motorcycle riding speed and vehicle driving speed during late-night and early morning are higher than other hours. This could be one of the reasons.

5. Discussion

As shown in Table 1, the injury severity levels in the NPA traffic crash dataset may be incorrect. To improve road safety and reduce the number of fatalities, it is important to have correct fatality data in the NPA traffic crash dataset that conforms to the 30-day definition. This study recommends the establishment of an official data process mechanism to regularly revise the data of the injury severity levels in the NPA traffic crash dataset by linking it to the MOHW causes of death dataset and adding a complementary data field to the NPA traffic crash dataset to revise the victim death records.

Numerous studies[8,9,11–13] found out that alcohol use was associated with high risk of severe injury. This study found that older motorcyclists who were riding under the influence of alcohol were more likely to be fatally injured than older motorcyclists who were riding sober, especially for older motorcyclists with a BrAC level of less than or equal to 0.15 mg/L (i.e., under the conviction standard of the BrAC level). This result may be because older motorcyclists may drive dangerously under the influence of alcohol, although their BrAC level is not over 0.15 mg/L. Non-older motorcyclists may also have the problem. Moreover, the drivers of the conflict vehicles who drive while drunk cause crashes, thus resulting in fatalities for older motorcyclists. This study recommends the promotion of a zero-tolerance drunk-driving law by setting a low legal blood-alcohol limit.

This study also recommends enhancing the traffic safety education for older motorcyclists. Due to their decreased motor control and overall physiological and sensory degradation (e.g., longer reaction time and vision problems), countermeasures pertaining to educational strategies have to be developed by conducting further studies for older motorcyclists to avoid the following high-risk violation behaviors: drunk driving, running a red light, failing to yield, not paying attention to the traffic ahead, making improper lane changes or turning, making an illegal left or U-turn, and violating a traffic sign or marking. In addition, the injury severity level of motorcyclists colliding with heavy vehicles is high, and this is another important safety education aspect. As "helmet use" was associated with a lower risk of fatal injuries, the safety concept of wearing a helmet should be promoted.

6. Conclusions and suggestions

Older motorcyclists accounted for a considerable proportion (35%) of crash fatalities, and among the fatalities, 2,484 (48.6%) older victims were riding motorcycles between 2013 and 2017. The enhancement of motorcycle safety and identification of the factors leading to fatalities in these older motorcyclists are crucial for the aged society of Taiwan. As expected, the study results present that the injury severity levels in the NPA accident dataset may be incorrect. To refine the severity level of a fatal injury using the 30-day definition, this study suggests to add a complementary data field to the NPA traffic crash dataset to revise victim death records by linking it to the MOHW causes of death dataset to assist relative road safety research. Additionally, numerous contributing factors affecting older motorcyclist fatalities were found, including motorcyclist characteristics, alcohol use of drivers of the conflict vehicles, types of conflict vehicles and environmental factors. The study results indicate the need to develop several countermeasures to improve older motorcyclists' safety, such as motorcycle training courses and implementation of a zero-tolerance drunk-driving law by setting a low legal blood-alcohol limit.

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References

1. World Health Organization. *Global Status Report on Road Safety 2009.* Geneva, Switzerland: World Health Organization, Department of Violence & Injury Prevention & Disability (VIP); 2009. Available at https://www.who.int/violence_injury_prevention/road_safety_status/2009/en/. Accessed March 01, 2019.
2. International Traffic Safety Data and Analysis Group, OECD. *Reporting on Serious Road Traffic Casualties.* Paris, France: OECD; 2011. Available at https://www.itf-oecd.org/sites/default/files/docs/road-casualties-web.pdf. Accessed March 01, 2019.
3. Montella A, Andreassen D, Tarko AP, et al. Crash Databases in Australasia, the European Union, and the United States: Review and Prospects for Improvement. *Transp Res Rec.* 2013;2386:128–136.
4. Chen WH. Exploring travel characteristics and factors affecting the degree of willingness of seniors in Taiwan to use an alternative service bus. *Transp Res Rec.* 2010;2182:71–78.
5. Ayuso M, Guillén M, Alcañiz M. The impact of traffic violations on the estimated cost of traffic accidents with victims. *Accid Anal Prev.* 2010; 42:709–717.
6. Penmetsa P, Pulugurtha SS. Risk drivers pose to themselves and other drivers by violating traffic rules. *Traffic Inj Prev.* 2017;18(1):63–69.
7. Chang F, Li M, Xu P, et al. Injury severity of motorcycle riders involved in traffic crashes in Hunan, China: A mixed ordered logit approach. *Int J Environ Res Public Health.* 2016;13(7):714.
8. Geedipally SR, Turner PA, Patil S. Analysis of motorcycle crashes in Texas with multinomial logit model. *Transp Res Rec.* 2011;2265:62–69.
9. Schneider WH, Savolainen PT. Comparison of severity of motorcyclist injury by crash types. *Transp Res Rec.* 2011;2265:70–80.
10. Savolainen P, Mannering F. Probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes. *Accid Anal Prev.* 2007; 39:955–963.
11. Rifaat SM, Tay R, Barros AD. Severity of motorcycle crashes in Calgary. *Accid Anal Prev.* 2012;49:44–49.
12. Shaheed MSB, Gkritza K, Zhang W, et al. A mixed logit analysis of two-vehicle crash severities involving a motorcycle. *Accid Anal Prev.* 2013; 61:119–128.
13. Islam S, Brown J. A comparative injury severity analysis of motorcycle at-fault crashes on rural and urban roadways in Alabama. *Accid Anal Prev.* 2017;108:163–171.
14. Wali B, Khattak AJ, Khattak AJ. A heterogeneity based case-control analysis of motorcyclist's injury crashes: Evidence from motorcycle crash causation study. *Accid Anal Prev.* 2018;119:202–214.
15. Waseem M, Ahmed A, Saeed TU. Factors affecting motorcyclists' injury severities: An empirical assessment using random parameters logit model with heterogeneity in means and variances. *Accid Anal Prev.* 2019; 123:12–19.