Journal of Forensic and Legal Medicine 70 (2020) 101917

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: http://www.elsevier.com/locate/yjflm

Research Paper

Differences in severity of injuries between motorcyclist and bicyclist fatalities in single vehicle collisions

Arisa Takeda [*], Mirae Koh, Tomoyuki Nakanishi, Masahito Hitosugi

Department of Legal Medicine, Shiga University of Medical Science, Otsu, Japan

ARTICLE INFO

Keywords:
Bicycle
Motorcycle
Single vehicle collision
Driving under the influence of alcohol
Autopsy
Older driver

ABSTRACT

To understand the injury severity of bicyclists and motorcyclists in single vehicle collisions, we performed a retrospective analysis of forensic autopsy cases of 25 motorcyclists and 14 bicyclists performed from 1999 to 2018. Collision details, injury characteristics, and involvement of alcohol were examined. The injury severity between bicyclists and motorcyclists was compared. The average age of victims was 62.3 years. All motorcyclists and no bicyclists wore a helmet. Motorcyclists had more severe injuries than bicyclists (mean Injury Severity Score of 42 and 27, respectively). The motorcyclists had more severe chest injuries but fewer severe facial injuries than bicyclists, owing to the difference in collision velocity or rate of helmet use ($p < 0.05$). Alcohol was present in the blood of 52.0% of bicyclists but no motorcyclists. The mean blood alcohol concentration of these bicyclists was 1.59 mg/mL. The bicyclists under the influence of alcohol had more severe injuries to neck and upper extremities than non-drunken bicyclists ($p < 0.05$). Our results may be useful for determining the cause of death and reconstructing the mechanisms of fatal injuries in bicyclists and motorcyclists.

1. Introduction

Road traffic injury is a common public issue globally. According to the World Health Organization, 1.3 million people die annually in road collisions worldwide.[1] In Japan, the number of motorcyclist injuries and fatalities in 2018 was 54,441, accounting for 10.3% of persons who had been injured or killed in traffic-related collisions.[2] In addition, motorcyclist fatalities accounted for 17.4% of all road traffic fatalities in 2018, an increase from 15.9% in 2000. Likewise, the number of bicyclist injuries and fatalities in 2018 was 84,383, accounting for 15.9% of persons who had been injured or killed in traffic-related collisions,[2] while bicyclist fatalities represented 12.8% of all road traffic fatalities in 2018, compared with 10.9% in 2000.

As the bodies of most bicyclists or motorcyclists are exposed and lacking in protective equipment, they particularly suffer from direct forces. If these individuals are involved in collisions with other vehicles or objects, they first sustain the impact from the offenders and then from the road surface. Therefore, to reconstruct the collision scene and mechanisms of injuries, forensic pathologists have to distinguish whether the injuries are formed by the primary collision or by falling to the road. For pedestrians involved in vehicle collisions, most of the injuries with the 1990 revision of the Abbreviated Injury Scale (AIS) score of 2 or more (AIS 2+) are due to vehicle crash injuries, i.e., the lower extremities hit by the front, the thorax by the bonnet, and the head and neck by the windscreen of the vehicle. However, for bicyclists most AIS 2+ injuries were caused by impact with the road surface.[3] According to an international review of single-bicycle crashes, of between 60% and 95% of bicyclists admitted to hospitals or treated at emergency departments, an average of 17% of fatalities involved single-bicycle crashes.[4] Therefore, as forensic pathologists we have to understand the injuries sustained in single vehicle collisions because they may largely contribute to the severity of injuries. However, to date there have been no reports that compare these types of injuries between bicyclists and motorcyclists. Therefore, to help reconstruct the mechanisms of such trauma, we examined the injuries caused only by contact with the road surface. Our study may provide useful information for forensic pathologists who examine bicyclist and motorcyclist fatalities and lead to effective interventions that will improve road safety.

2. Materials and methods

2.1. Data collection

Between September 1999 and March 2014, the Department of Legal

* Corresponding author. Department of Legal Medicine, Shiga University of Medical Science, Tsukinowa, Seta, Otsu, Shiga, 520-2192, Japan.
E-mail address: arisa204@belle.shiga-med.ac.jp (A. Takeda).

https://doi.org/10.1016/j.jflm.2020.101917
Received 10 June 2019; Received in revised form 22 November 2019; Accepted 26 January 2020
Available online 29 January 2020
1752-928X/

Medicine at Dokkyo Medical University School of Medicine conducted 295 forensic autopsies on traffic collision-related fatalities occurring in Tochigi Prefecture. Between April 2014 and August 2018, the Department of Legal Medicine at Shiga University of Medical Science conducted 61 forensic autopsies on traffic collision-related fatalities occurring in Shiga Prefecture. From these autopsies, motorcyclists' or bicyclists' self-inflicted cases were selected. We defined a motorcycle as a two-wheeled vehicle with an engine of 50 cc or more, and a bicycle as a two-wheeled vehicle principally propelled by the rider. In this study, we defined self-inflicted accidents as falls and obstacle collisions (all crash types in which only the bicyclists and motorcyclists are involved). Other typical crash types, as well as collisions with other vehicles or pedestrians, were excluded. We also excluded cases in which the victim died of disease because the contribution of the accidents to disease onset was undetermined in these cases. In total, 14 motorcyclists (13 male, 1 female) and 25 bicyclists (23 male, 2 female) were included in this study.

The following data were obtained from each victim's record.

(1) Physical data: Age, sex, height, and body weight of the victim as measured at autopsy were examined. Past medical history, including a history of medication, was provided by relatives and/or the police when known. We define either hypertension, hyperlipidemia, or diabetes mellitus type 2 as lifestyle disease.
(2) Collision details: We surveyed how and when each collision occurred. We then clarified whether the motorcyclist collided with a vehicle or object. If not, this means that the victim had lost control of the motorcycle or bicycle and fell without coming into contact with other vehicles or objects. Furthermore, whether a helmet was worn was recorded.
(3) Involvement of alcohol and drugs: Blood alcohol level was measured by gas chromatography. Drug screening tests used the Triage Drugs of Abuse (DOA) immunoassay kit on urine samples. This test screens for eight drugs: phencyclidine, tetrahydrocannabinol, benzodiazepines, opiates, cocaine, barbiturates, amphetamine, and tricyclic antidepressants. For victims who were pronounced dead at the scene or prior to arrival at the hospital, blood and urine taken at the autopsy were used for analysis. For victims who were admitted to the hospital, blood and urine taken at the emergency room immediately after their arrival were used.
(4) Injury characteristics: The cause of death, the anatomical region injured, and the type of injury were examined. Anatomical injury severity was assessed for all victims. The Injury Severity Score (ISS) and AIS were calculated for each victim.[6,7] The AIS was used to categorize injury type and severity in each body region on a scale from 1 (minor) to 6 (clinically untreatable). The ISS, which is useful for assessing the severity of multiple injuries, is the sum of the squares of the highest AIS score in each of the three most severely injured body regions.

This study was performed under the approval of the Ethics Committee, Shiga University of Medical Science.

2.2. Statistical analysis

Means with standard deviation (SD) for the values that followed the normal distribution, and medians with interquartile range (IQR) for values that did not follow the normal distribution, were used to summarize continuous variables. To compare mean age, height, and body weight of the victims, an F test was first performed to examine the homogeneity of variance. An unpaired t-test was used for equal variance and Welch's t-test for unequal variance. A chi-squared test was used to compare the rates of driving or riding under the influence of alcohol and wearing of a helmet between the two groups. A Mann–Whitney test was used to compare the AIS and ISS values in the two groups of victims. Differences with a p value of <0.05 were considered statistically significant.

3. Results

3.1. Overview

Continuous variables were summarized by using mean ± SD. The victims' ages ranged from 27 to 88 years, with a mean of 62.3 ± 16.3 years. The mean height of the victims was 164.0 ± 9.2 cm, with mean body weight of 63.6 ± 14.1 kg. Fifteen victims had medical histories, 22 victims had no previous illnesses, and medical histories were unknown for two victims. Among the 15 victims (38.5%) with a known medical history, 10 (34.5%) suffered from lifestyle diseases; hypertension was the most common condition (6 persons), followed by diabetes mellitus (3 persons), hyperlipidemia (2 persons), and heart or cerebrovascular disease (1 person). Thirteen victims (33.3%) had driven under the influence of alcohol with a mean blood concentration of 1.59 ± 0.84 mg/mL. No bicyclists or motorcyclists had a positive result from the Triage DOA, showing that none had driven or ridden under the influence of psychotropic or illicit drugs. The information from the police investigations also showed that neither overdoses of prescribed medicines nor use of medicines that impair driving were involved.

3.2. Collision scene

All the motorcyclists, but none of the bicyclists, were wearing helmets. Upon arrival of the emergency crew, 14 victims were pronounced dead and not transported to the hospital; 21 victims (including two cases of cardiopulmonary arrest) were transported to the hospital and subsequently died.

3.3. Cause of death

Cervical spinal injuries and drownings were the most common cause of death (13 victims), followed by intracranial injuries (five victims), intrathoracic or intra-abdominal injuries (four victims), aortic injuries (two victims), asphyxia (one victim), and severe pelvic fracture (one victim).

3.4. Injury severity

Continuous variables were summarized by median with IQR [25% quartile, 75% quartile]. The ISS in all victims ranged from 3 to 75 (median, 27.0 [15.5, 32.5]). Seven victims (13.8%; six bicyclists and one motorcyclist)) had an ISS of <10. On comparing injured body regions, the neck had the highest AIS score (2.0 [0, 5.0]), followed by head (1.0 [0, 3.0]), chest (1.0 [0, 3.0]), lower extremities (1.0 [1.0, 1.0]), body surface (1.0 [1.0, 1.0]), upper extremities (1.0 [1.0, 1.0]), face (1.0 [0, 1.0]), and abdomen (0 [0, 1.0]).

3.5. Comparison

First, we compared the physical characteristics of the victims (Table 1). No significant differences were found between the motorcyclists and bicyclists regarding age, height, and body weight.

Next, we found that all of the motorcyclists were wearing a helmet, whereas none of the bicyclists wore any helmet (Table 1, $p < 0.001$). Alcohol was detected in the blood of the majority of bicyclists but not in any motorcyclist ($p < 0.001$). The mean blood alcohol concentration of all bicyclists, including those who had not been drinking, was 0.9 ± 1.0 mg/mL. This rose to 1.59 ± 0.84 mg/mL among the bicyclists who had been drinking.

Comparison of ISS and AIS scores between the two groups is shown in Table 2. The ISSs of the motorcyclists were significantly higher than those of the bicyclists ($p = 0.003$). The AIS scores for the chest were significantly higher for the motorcyclists than for the bicyclists ($p =$

Table 1
Comparison of the physical characteristics and background of the victims.

	Motorcyclists (n = 14)	Bicyclists (n = 25)	*p* Value
Age (years)	54.7 ± 20	63.7 ± 12.7	0.113
Height (cm)	166.2 ± 9.9	160.9 ± 8.7	0.213
Weight (kg)	69.3 ± 18.6	60.8 ± 10.0	0.156
Alcohol (%)	0	52	0.001
m	0	0.9 ± 1.0[a]	–
Helmet use (%)	100	0	<0.001

[a] The mean blood alcohol concentration of all bicyclists, including those who had not been drinking.

0.017). Only the bicyclists' AIS scores for the face were significantly higher than those of motorcyclists ($p = 0.046$).

Finally, we compared ISS and AIS scores between the bicyclists who had been drinking alcohol and those who had not (Table 3). There was no significant difference in ISSs between the two groups ($p = 0.87$). However, the AIS scores of most of the body regions were higher for the bicyclists under the influence of alcohol than others, with statistical significance in the neck ($p = 0.039$) and the upper extremities ($p = 0.03$) regions.

4. Discussion

In cases of single collisions involving bicyclists or motorcyclists, it is difficult to clarify the mechanism of injuries because there are fewer witnesses in comparison with collisions with other vehicles. Therefore, more evidence regarding instances of bicyclists and motorcyclists suffering falls while driving a bicycle or motorcycle, as reported in the present study, needs to be gathered.

In Japan, the dramatic rise in aged persons presents a potential nationwide problem on the roads. Bicycles are usually used as means of transportations by aged persons. Of the bicycle fatalities recorded in 2018, 67.5% accounted for persons aged 65 or older.[2] Recently, motorcycles also have become increasingly popular as means of transportations by aged persons. According to the analysis of motorcycle market trends in Japan, persons older than 60 years accounted for 32.1% of purchasers of new motorcycles in 2017. Moreover, of the motorcycle-related fatalities in 2018, 22.3% were persons aged 65 or older.[2] Both motorcyclists and bicyclists require physical balance when riding, and are more likely to lose control with increasing age. Older bicyclists and motorcyclists are considered more vulnerable to injuries and more likely to be hospitalized after collision than their younger counterparts.[5] One study suggested that older bicyclists and motorcyclists had more severe injuries and longer stay in the intensive care unit.[6] Therefore, more useful interventions for older bicyclists' and motorcyclists' safety are needed to decrease the incidence of such traffic fatalities. Because the average age of our study subjects was 62 years, the results may contribute to alerting stakeholders to the need for adequate interventions regarding this issue.

Table 2
Comparison of injuries in motorcyclists and bicyclists.

		Motorcyclists (n = 14)	Bicyclists (n = 25)	*p* Value
ISS		42 [26.3, 75]	27 [11, 27]	0.003
AIS	Head	1 [1, 3]	1 [0, 3]	0.362
	Face	0.5 [0, 1]	1 [1, 1]	0.046
	Neck	2 [0, 5]	3 [0, 5]	0.903
	Chest	2 [1, 4]	0 [0, 1]	0.017
	Abdomen	0 [0, 2.8]	0 [0, 1]	0.142
	Upper extremities	1 [1, 1]	1 [1, 1]	0.232
	Lower extremities	1 [1, 1]	1 [1, 1]	0.985

AIS, Abbreviated Injury Scale score; ISS, Injury Severity Score. ISS and AIS values are median [interquartile range].

Table 3
Comparison of injuries in bicyclists who had and had not been drinking alcohol.

		Under the influence of alcohol (n = 10)	Not under the influence of alcohol (n = 13)	*p* Value
ISS		22 [6.5, 27]	27 [11, 27]	0.869
AIS	Head	0.5 [0, 1]	1 [1, 3]	0.205
	Face	1 [0.25, 1]	1 [1, 1]	0.410
	Neck	0 [0, 2.5]	5 [1, 5]	0.039
	Chest	0 [0, 2.5]	1 [0, 1]	0.946
	Abdomen	0 [0, 0.75]	0 [0, 0]	0.545
	Upper extremities	1 [1, 1]	1 [0, 1]	0.030
	Lower extremities	1 [1, 1]	1 [1, 1]	0.212

AIS, Abbreviated Injury Scale score; ISS, Injury Severity Score. ISS and AIS values are median [interquartile range].

Although to date injury patterns and features of bicyclists or motorcyclists have been discussed on the basis of autopsy results,[7–11] no report has compared the injury patterns and severity between bicyclists and motorcyclists based on similar mechanisms of injuries. Because this study deals with the single vehicle collisions whereby victims only fall to the ground, patterns and types of injuries of motorcyclists are considered similar to those of bicyclists. In this study, both bicyclists and motorcyclists had higher AIS scores for the neck region (median of 3 and 2, respectively), which represents an important finding. When a victim suffers head injuries, indirect force may be applied to the neck and cause subsequent involvement of the cervical spine or spinal cord. Such phenomena have previously been reported in bicyclist and motorcyclist fatalities.[12,13] Therefore, in addition to severe injuries to the head or chest, neck injuries should be also suspected in injured motorcyclists or bicyclists regardless of the severity of head injury. Aging is extant in developed countries, and the possibility of contracting neck injuries can increase with age owing to degenerative changes within the cervical spine.

This study showed some specific differences between motorcyclists and bicyclists. We found that ISS and AIS for the chest were significantly higher in motorcyclists than in bicyclists. These differences are considered a consequence of the riding velocity. Contact with the road at higher velocities leads to higher-energy impacts.

The AIS for the face region of bicyclists was significantly higher than that of the motorcyclists, undoubtedly because all motorcyclists wore a helmet while no bicyclist carried head protection. A full-face type helmet protects the whole face and a half-type helmet protects the upper face; bicyclists without helmets therefore are prone to abrasion, laceration, dental trauma, and/or maxillofacial fractures. According to a study from the Netherlands, over 10 years 11.4% of oromaxillofacial fractures were bicycle-related injuries.[14] Although these injuries are not life threatening they are often associated with severe morbidity, loss of function, disfigurement, and significant financial cost.[15] However, as reported herein, although all motorcyclists wore a helmet they sustained head injuries of severity similar to those of bicyclists despite traveling at higher speed. This result was well in accordance with the previous result that bicyclists had sustained more frequent critical injuries and severe head and neck injuries than motorcyclists, owing to less frequent helmet use.[6] For this reason, the need for compulsory legislation for helmet use with faceguards for bicyclists and motorcyclists has been stressed.[16]

We determined that riding a bicycle under the influence of alcohol is a serious problem, as 52.0% of the bicyclists who were killed were under the influence of alcohol. Under the current Japan Road Traffic Act, driving under the influence of alcohol is prohibited. In Japan, the legal blood alcohol concentration limit for driving is 0.3 mg/mL. However, this rule has been actively enforced only for vehicle drivers and motorcyclists. Police management and penalties for noncompliance have been seldom applied to bicyclists. Unfortunately, no comprehensive statistics about riding bicycles under the influence of alcohol in Japan are available. However, forensic autopsy samples showed that 64.7% of bicyclists killed in Okayama, 59.0% in Kochi, and 55.0% in Kumamoto were riding under the influence of alcohol, higher percentages than we found in the present study.[17–19] Driving under the influence of alcohol leads to mishandling of the vehicle and constitutes a major risk in causing a collision. According to an analysis of Virginia crash data, bicyclists under the influence of alcohol increased the probability of fatality by 36.7% and doubled the probability of severe injury.[20] Another analysis based on the National Automotive Sampling System revealed that severity of injuries was significantly greater when bicyclists had been drinking alcohol.[21] Although it has previously suggested that bicyclists were more likely to have a higher education level than non-bicyclists,[22,23] this evidence does not correlate with the habit of riding under the influence of alcohol. Avoidance of riding under the influence of alcohol will likely contribute to a decrease in fatal bicycle collisions.

Previously, we compared the injury severities of bicyclists with death from disease and trauma.[11] In the disease-death victims the mean ISS was 4.2, indicating that the victim had suffered from minor injuries to any part of the body when falling on the road. Because we considered that bicyclists with disease-related deaths revealed less severe injuries even if riding on bicycles or motorcycles, we omitted cases with disease-related collisions. We consider that this exclusion led higher reliability our analyses.

This study has some limitations. First, the sample size was small because the autopsy rates for motorcyclists and bicyclists are low owing to the police management system in Japan. However, for the obtained sample we performed analyses with adequate statistical methodology. In future, similar analyses may be required but with larger sample sizes. Second, we did not obtain information concerning the types of motorcyclists' helmets. Clarification of helmets, i.e., full-face and half-face types, can augment the comparison of injury severity on the face. Therefore, to obtain more detailed findings, especially for facial injuries, further research with sufficient information regarding the type of helmet is required. Third, blood concentration of prescribed medicines in victims was not determined. However, according to the police report, no one showed overdose of these medicines and the use of medicines that may impair driving, so we believe that this limitation did not affect the conclusion. In future, quantitative examinations of levels of prescribed medicines might be helpful in analyzing fatal accidents involving bicyclists or motorcyclists. Forth, in this study, we could not compare the time of day or the nature of the journey. Some victims were found dead and it was not possible to determine the exact time of the accident. Also, most of the victims were older people, with a mean age of 62.3 years, so many did not have a job and/or were living alone, making it impossible to determine the purpose of their journey. Further study with deep background of the victims may validate our study.

We believe that the results of this study may be useful for forensic pathologists who seek to determine the cause and mechanism of death in bicyclists and motorcyclists. Moreover, these results may contribute to an eventual decrease in bicycle and motorcycle fatalities if they are applied appropriately to develop preventive safety measures.

Funding

The authors received no funding concerning this study.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. We thank Hugh McGonigle, from Edanz Group (www.edanzediting.com/ac), for editing a draft of the manuscript.

References

1. Peden M, Sminkey L. World Health organization dedicates World Health day to road safety. *Inj Prev*. 2004;10:67.
2. e-Stat, the Portal Site of Official Statistics of Japan. Statistics about road traffic, annual report in 2018 [in Japanese] https://www.e-stat.go.jp/en.
3. Öman M, Fredriksson R, Bylund PO, Björnstig U. Analysis of the mechanism of injury in non-fatal vehicle-to-pedestrian and vehicle-to-bicyclist frontal crashes in Sweden. *Int J Inj Contr Saf Promot*. 2016;23(4):405–412.
4. Schepers P, Agerholm N, Amoros E, et al. An international review of the frequency of single-bicycle crashes (SBCs) and their relation to bicycle modal share. *Inj Prev*. 2015;21(e1):e138–e143.
5. Pai CW, Lin HY, Tsai SH, Chen PL. Comparison of traffic-injury related hospitalisation between bicyclists and motorcyclists in Taiwan. *PloS One*. 2018;13 (1), e0191221.
6. Wagner J, Rai A, Ituarte F, Tillou A, Cryer H, Hiatt JR. Two-wheel vehicular trauma: an age-based analysis. *Am Surg*. 2012;78(10):1066–1070.
7. Olds K, Byard RW, Langlois NE. Injury patterns and features of cycling fatalities in South Australia. *J Forensic Leg Med*. 2015;34:99–103.
8. Gomei S, Hitosugi M, Ikegami K, Tokudome S. Assessing injury severity in bicyclists involved in traffic accidents to more effectively prevent fatal bicycle injuries in Japan. *Med Sci Law*. 2013;53(4):194–198.
9. Hitosugi M, Takatsu A, Shigeta A. Injuries of motorcyclists and bicyclists examined at autopsy. *Am J Forensic Med Pathol*. 1999;20(3):251–255.
10. Töro K, Hubay M, Sótonyi P, Keller E. Fatal traffic injuries among pedestrians, bicyclists and motor vehicle occupants. *Forensic Sci Int*. 2005;151(2–3):151–156.
11. Hitosugi M, Koseki T, Miyama G, Furukawa S, Morita S. Comparison of the injury severity and medical history of disease-related versus trauma-related bicyclist fatalities. *Leg Med*. 2016;18:58–61.
12. Hitosugi M, Takatsu A, Shigeta A. Injuries of motorcyclists and bicyclists examined at autopsy. *Am J Forensic Med Pathol*. 1999;20:251–255.
13. Hitosugi M, Shigeta A, Takatsu A, Yokoyama T, Tokudome S. Analysis of fatal injuries to motorcyclists by helmet type. *Am J Forensic Med Pathol*. 2004;25: 125–128.
14. Boffano P, Roccia F, Gallesio C, et al. Bicycle-related maxillofacial injuries: a double-center study. *Oral Surg, Oral Med, Oral Pathol, Oral Radiol*. 2013;116:275–280.
15. Brasileiro BF, Passeri LA. Epidemiological analysis of maxillofacial fractures in Brazil: a 5-year prospective study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;102(1):28–34.
16. Júnior SM, Santos SE, Kluppel LE, Asprino L, Moreira RW, de Moraes M. A comparison of motorcycle and bicycle accidents in oral and maxillofacial trauma. *J Oral Maxillofac Surg*. 2012;70(3):577–583.
17. Miura M, Yamasaki Y, Itani M, Yoshitome K, Yamamoto Y, Miyaishi S. The importance of forensic autopsy information for understanding fatal bicycle accidents. *Nihon Iji Shinpo*. 2015;4750:38–42 [in Japanese].
18. Furumiya J, Nishimura H, Nakanishi A, Hashimoto Y. Analysis of fatal bicycle traffic accidents from the perspectives of social medicine and traumatology. *Res Pract Forensic Med*. 2013;56:175–179 [in Japanese].
19. Yonemitsu K, Oshima T, Nishitani Y. Detection of alcohol and drugs in forensic autopsy cases of traffic accidents in Kumamoto prefecture (1999-2008). *J Jpn Council Traffic Sci*. 2012;12(1):3–12 [in Japanese].
20. Robartes E, Chen TD. The effect of crash characteristics on cyclist injuries: an analysis of Virginia automobile-bicycle crash data. *Accid Anal Prev*. 2017;104: 165–173.
21. Helak K, Jehle D, McNabb D, Battisti A, Sanford S, Lark MC. Factors influencing injury severity of bicyclists involved in crashes with motor vehicles: bike lanes, alcohol, lighting, speed, and helmet use. *South Med J*. 2017;110(7):441–444.
22. Gopinath B, Jagnoor J, Craig A, et al. Describing and comparing the characteristics of injured bicyclists and other injured road users: a prospective cohort study. *BMC Publ Health*. 2016;16:324.
23. Heesch KC, Garrard J, Sahlqvist S. Incidence, severity and correlates of bicycling injuries in a sample of cyclists in Queensland, Australia. *Accid Anal Prev*. 2011;43(6): 2085–2092.