Are full-face helmets the most effective in preventing head and neck injury in motorcycle accidents? A meta-analysis

Soramon Chaichana\(^a\), Thatchanon Asawalalsaeng\(^a\), Pat Veerapongtongchai\(^a\), Paiboon Chattakul\(^b\), Sittichai Khamsaib\(^b\), Patnarin Pongkulkiat\(^b\), Verajit Chotmongkol\(^b\), Panita Limpawattanab\(^a\), Soramon Chaichana, Thatchanon Asawalalsaeng, Pat Veerapongtongchai, Paiboon Chattakul, Sittichai Khamsaib, Patnarin Pongkulkiat, Verajit Chotmongkol, Panita Limpawattana, Jarin Chindaprasir, Vichai Senthong, Chetta Ngamjarus, Yuwares Sittichanbuncha, Amnat Kitkhuandee, Kittisak Sawanyawisuth

\(^a\) Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand
\(^b\) Department of Medicine, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand
\(^c\) Department of Epidemiology and Biostatistics, Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand
\(^d\) Department of Emergency Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand
\(^e\) Department of Surgery, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

A R T I C L E   I N F O

Keywords:
Prevention
Road traffic accidents
Risk factors

A B S T R A C T

Motorcycles are the most common type of vehicle involved in traffic deaths in developing countries. Although helmets can provide protection against injury, there is limited evidence available regarding which type of helmet best protects against head and neck injuries in this setting. This review was conducted based on articles in the PubMed, Scopus, and Web of Science databases. We compared full-face helmets with other types of helmet with regard to head and neck injury prevention in road accidents involving motorcyclists. Of 702 studies, six were eligible with a total of 6,529 participants. When compared with partial and open helmets, the odds ratio of full-face helmets was 0.356 (95% CI of 0.280, 0.453) and 0.636 (95% CI of 0.453, 0.894), respectively, for reduction of head and neck injuries. In conclusion, full-face helmets reduced head and neck injuries in motorcycle accidents to a greater extent than other types of helmet. Policy makers should recommend that motorcyclists use full-face helmets.

1. Introduction

Motorcycles are the most common type of vehicle involved in traffic deaths in developing countries (Erenler and Gümüş, 2019). The Institute for Health Metrics and Evaluation reported that in 2016, road injuries were the leading cause of death and disability and were ranked as the second most common cause of premature death in Thailand (Institute for Health Metrics and Evaluation, 2018). The WHO reported that road traffic deaths were highest in Africa and South-East Asia in 2016, with rates of 26.6 and 20.7/100,000 people, respectively (Global status report on road safety, 2018).

Studies spanning previous decades have found head injury to be the most common type of injury in autopsied victims of motorcycle accidents (41.4%) (Faduyile et al., 2017). A 2017 report from Nigeria also found that craniocerebral injuries were the cause of death in 50.7% of motorcycle fatalities (Faduyile et al., 2017). A Cochrane review found that wearing a helmet protected against death and head injury with significant odds ratios of 0.58 and 0.31, respectively (Liu et al., 2008).

There are three common types of helmet: full face, open face, and half (or partial) coverage. The motorcycle helmet laws in many countries do not specify helmet type. A study from Korea found that only full face and open face helmets significantly reduced head injuries in motorcycle accidents with a coefficient of −0.368 (p < 0.001) and −0.235 (p 0.040), respectively (Sung et al., 2016). However, half-coverage helmets did not significantly lower the risk of head injury (p value 0.101). A Cochrane review published in 2008 found that there were insufficient data to conclude which helmet type was most effective in reducing the risk of injury. This is because the five studies included in the meta-analysis did not show significant differences in terms of head or cervical injuries between full-face and open-faced helmets, with odds ratios ranging between 0.76 and 1.13 (Liu et al., 2008). This study, thus, aimed to determine the most effective helmet type in preventing head and cervical injuries in motorcycle accidents. These data may be useful in shaping future helmet laws.
Summary of studies comparing full-face and half-coverage helmets with regard to head and cervical outcomes in motorcyclists who had road accidents.

Table 1
Summary of studies comparing full-face and half-coverage helmets with regard to head and cervical outcomes in motorcyclists who had road accidents.

| Factors/Study                        | Lam et al | Ramli et al | Yu et al |
|-------------------------------------|-----------|-------------|----------|
| Country                             | Taiwan    | Malaysia    | Taiwan   |
| Year                                | 2015      | 2014        | 2011     |
| Study design                        | Case-control | Case-control | Matched case-control |
| Inclusion                           | - patients with ICD-9 codes 800-804, 850-854 (brain concussion, intracranial hemorrhage, skull-bone fracture) - motorcycle crash - over 17 years of age | - all motorists or passengers - all ethnic groups - all injury types and levels of severity - all age groups and genders - all injury types and levels of severity were involved in a motorcycle crash in the Catchment area (southern Klang Valley) during the study period (2010-2011) | - Age > 15 y - Lived in Taichung - Visited the emergency room at China Medical University Hospital due to motorcycle injuries |
| Exclusion                           | Any cases with missing data on helmet use, helmet type, or cervical spine injury | Motorcyclists who did not sustain any injury, or discharged themselves from hospital care without a definitive diagnosis, and those involved in road crashes outside Klang Valley | Riders who were not operating a motorcycle—i.e. those who were riding a minibike, a bicycle or a tricycle or wore a safety helmet for construction or were involved in a crash outside the city of Taichung |
| Numbers of participants             | 5,225 patients; 173 (3.3%) case group and 5,052 (96.7%) control group | 755 participants; 391 (51.8%) facial injuries and 364 (49.2%) no facial injury | 458 pairs of case-control; not all helmeted |
| Primary outcome                     | Cervical spine injury | Facial injury | Head injury |
| Full-face helmet with head injury, n | 28         | 6          | 50         |
| Full-face helmet without head injury, n | 1,259     | 12         | 73         |
| Half-coverage helmet with head injury, n | 104       | 304        | 274        |
| Half-coverage helmet without head injury, n | 3,385     | 293        | 208        |
Table 2 Summary of studies comparing full-face and open helmets on head and cervical outcomes in motorcyclists who had road accidents.

| Study | Year | Country | Design | Inclusion | Exclusion | Study size | Primary outcome(s) | Full-face helmet | Open helmet | Note |
|-------|------|---------|--------|-----------|-----------|------------|-------------------|-----------------|-------------|------|
| Itihasi et al. | 2014 | Brazil | Retrospective | Fatal motorcycle accidents | Patients with facial injuries or death | 36 | Number of severely injured body regions | 9* | 16* | NA |
| Cini et al. | 2014 | Brazil | Case-control | Patients with facial injuries from a motorcycle accident | Patients with facial injuries or death | 1,628 | Number of severely injured body regions | 9** | 9** | NA |
| Lopes Albuquerque et al. | 2014 | Brazil | Retrospective cohort | Motorcyclists who died in traffic accidents from 1998 to 2002 | Incomplete hospital records or refusal to participate | 253 | Number of injuries | 24*** | 24*** | NA |
| Yu et al. | 2014 | Taiwan | Matched case-control | Those with injuries to any part of the body or cervical spine injury | All who used full-face helmets | 458 | Number of injuries | 50 | 73 | 106 |

Note: NA: not available; * indicates severe head injury; ** indicates zygomatic fracture; ***indicates traumatic brain injury.

The main finding of this review is that full-face helmets were better than other types of helmet at preventing head and cervical injuries in motorcycle accidents. This review had a large sample size (6,529 participants) and found that full-face helmets were the most effective at preventing head and cervical injuries in motorcycle accidents (Fig. 4). Full-face helmets had significant protective effects on the outcomes compared with either half-coverage helmets (Fig. 2) or open helmets (Fig. 3).

Each helmet type has its own advantages and disadvantages. The full-face helmet has no articulation, but it may be heavier or cause discomfort and limitations with regard to visibility. Half-coverage or open helmets tend to be lighter but require articulation during use. Therefore, a rider's choice of helmet type may depend on individual preference or local regulations (Dapilah et al., 2017). Two studies—one from Brazil and one from Iran—reported that more motorcyclists wore full-face helmets than open helmets (69% in Brazil and 76% in Iran) (Cini et al., 2014; Amirjamshidi et al., 2011). However, the rate of full-face helmet use was only 2.4% in a study from Malaysia (Ramli et al., 2014). A study from Australia found that full-face helmets may result in a somewhat lower rate of cervical spine injury than open helmets (14.4% vs 18.2%) (O'Connor et al., 2002).

The main finding of this review is that full-face helmets were better than other types of helmet at preventing head and cervical injuries in motorcycle accidents. All analyses were compatible between traditional and RevMan calculations. The risk of head and cervical injuries for riders who used full-face helmets was 64% lower compared with those who used half-coverage helmets (Fig. 2), 36% lower than in those who used open helmets, and 57% lower when compared with both those who used half-coverage helmets and those who used open helmets (Fig. 4). A study from Malaysia showed that factors were significantly associated with facial injuries in motorcycle accidents: helmet use and helmet fixation (Ramli et al., 2014), of which helmet fixation had the greatest effect. Full-face helmets provided greater fixation than the other articulated helmets. Additionally, riders in Thailand are five times less likely to use helmets than in the other regions.
more likely to remove their helmet prior to a traffic accident than those in the US (25% vs 5%) (Ouellet and Kasantikul, 2006). Wearing an open or half-coverage helmet may make it easier to remove. However, full-face helmets may cause discomfort due to the greater heat and humidity in tropical countries like those in Southeast Asia (de Rome et al., 2012). Nevertheless, if a rider wears a full-face helmet, his/her risk of head and neck injury will likely be lower than if he/she uses an open/half-coverage helmet.

There were some limitations in this study. First, the six studies included in the analysis were from only four countries: two from Taiwan, two from Brazil, one from Malaysia, and one from Japan. Second, the definitions of head and cervical injury were not uniform among the studies, particularly in those that compared full-face and open helmets (Fig. 3). In addition, the eligibility criteria for participants varied among the studies. Most of the studies enrolled patients involved in motorcycle accidents, but the study by Lam et al. enrolled all ICD-9 patients (n = 5,225) (Lam et al., 2015), and another enrolled autopsied cases (n = 36) (Hitosugi et al., 2004). Third, comparisons of full-face versus open helmet had high heterogeneity as calculated using RevMan (I² of 59%). Finally, the studies focused only on head and cervical injury and did not include other parts of body. However, these types of injuries accounted for over 50% of injuries motorcycle accident victims. The analysis in this study was not adjusted for other factors such as severity of crash.

5. Conclusions

Full-face helmets reduced head and neck injuries in motorcycle accidents to a greater extent than other types of helmet. Policy makers should recommend that motorcyclists use full-face helmets.

Financial disclosure

The authors have nothing to disclose.

CRediT authorship contribution statement

Soramon Chaichan: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft. Thatchanon Asawalertsaeng: Methodology, Formal analysis, Investigation, Visualization. Pat Veerapongtongchai: Methodology, Formal analysis, Investigation, Visualization. Paiboon Chattakul: Methodology, Investigation, Visualization, Supervision. Sittichai Khamsai: Methodology, Investigation, Visualization, Supervision. Patnarin Pongkulkiat: Methodology, Investigation, Visualization, Supervision. Verajit Chotmongkol: Methodology, Investigation, Visualization, Supervision. Panita Limpawattana: Methodology, Investigation, Visualization, Supervision. Vichai Senthong: Methodology, Investigation, Visualization, Supervision. Chetta Ngamjarus: Methodology, Investigation, Visualization, Supervision. Yuwares Sittichanbuncha: Methodology, Investigation, Visualization, Supervision. Amnat Kitkhuandee: Conceptualization, Methodology, Investigation, Visualization, Supervision.
Supervision, Project administration, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would like to thank North-Eastern Stroke Research Group, Khon Kaen University, Thailand.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101118.

References

Erenler, A.K., Gümüş, B., Analysis of Road Traffic Accidents in Turkey between 2013 and 2017. Medicina. (Kaunas). 55 (2019) 679. Institute for Health Metrics and Evaluation, 2018. http://www.healthdata.org/thailand (accessed 31.3.2019). Global status report on road safety 2018, 2018. https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/ (accessed 5.3.2020). Faduyile, F., Emiogun, F., Soyemi, S., Oyeewe, O., Okeke, U., Williams, O., 2017. Pattern of Injuries in Fatal Motorcycle Accidents Seen in Lagos State University Teaching Hospital: An Autopsy-Based Study. Open. Access. Maced. J. Med. Sci. 5, 112–116. Liu, B.C., Ivers, R., Norton, R., Boufous, S., Blows, S., Lo, S.K., Helmets for preventing injury in motorcycle riders. Cochrane. Database. Syst. Rev. 1 (2008) CD004333.