cogent
engineering

BIOMEDICAL ENGINEERING | RESEARCH ARTICLE

The influence of helmet on the prevention of maxillofacial fractures sustained during motorcycle accidents

Muhammad Ruslin[1,2]*, Jan Wolff[2], Harmas Yazid Yusuf[3], Muhammad Zafrullah Arifin[4], Paolo Boffano[2] and Tymour Forouzanfar[2]

*Corresponding author: Muhammad Ruslin, Department of Oral and Maxillofacial Surgery/Oral Pathology, VU University Medical Center, P.O. Box 7057, Amsterdam, MB 1007, The Netherlands
E-mail: ruslin_oms@yahoo.com

Abstract: The aim of this study was to assess the effect of half-coverage helmet use in motorcycle accidents and to investigate the difference in neuron-specific enolase serum levels in helmeted and unhelmeted person who had sustained maxillofacial fractures during motorcycle accidents. A total of 48 subjects (22 helmeted and 26 unhelmeted) sustained maxillofacial fractures were divided into three parts: upper, middle, and lower facial. All patients were scored using the Glasgow Coma Scale upon arrival at the hospital. The most prevalent maxillofacial fracture site in helmeted group was the mid-face (40.9%) and the upper-middle-lower face (26.9%) in unhelmeted group. There was no statistical significant difference between neuron-specific enolase serum levels in helmeted group (11.52 mg/ml) compared to unhelmeted group (14.49 ng/ml) ($p > 0.05$). Half-coverage helmets provided motorcyclists with only limited protection in the head and facial areas. Unhelmeted motorcycle riders sustained comparable injuries compared to half-coverage helmet users.

Subjects: Biomechanics; Medical Devices; Biomechanics and Human Movement Science; Dentistry

Keywords: neuron-specific enolase; serum; maxillofacial fractures; motorcycle accidents; helmet design

ABOUT THE AUTHORS

"The research reported in this paper relates to support from some people, especially Department of Oral and Maxillofacial Surgery/Oral Pathology VUmc. This study would have not finished without the enormous help of our team. The results of this study demonstrated that more concern should be given to helmet design (fracture-driven design). Preventing maxillofacial injuries is a valuable pursuit for improving the quality of life of the involved subjects and decreasing the socioeconomic costs of traffic injuries. As for motorcycle and bicycle accidents, the crucial role of helmets has to be acknowledged in our community and government."

PUBLIC INTEREST STATEMENT

"Motorcycles are the fastest growing sector of motor vehicles worldwide and comprise the majority of all motor vehicles in low- and middle-income countries. Of all the different types of motor vehicles used worldwide, motorcycle riders sustain the most serious injuries in the head and neck area. The main reason may because they did not always wear helmets especially when no police were around. The main reasons for not wearing helmets were discomfort and absence of police surveillance. Many helmets may appear to be standard helmets on visual inspection but in fact, they may lack those energy absorption layers that may protect the rider from injury in the event of an accident, nonetheless the prevalence of nonstandard helmets may be underestimated. The aims of this study were to assess the effects of different helmet designs (full and half-coverage helmets) in motorcycle accidents."

1. Introduction

Due to the increase of motor vehicle ownership and rapid economic development, the number of road traffic injuries is unexpectedly increasing; significantly in the next decade (Ameratunga, Hijar, & Norton, 2006). Traffic accidents are among the main etiologic factors of maxillofacial injuries and account for 34.42–80.14% of all skeletal and soft tissue injuries in the facial area (Wood & Freer, 2001). Of all the different types of motor vehicles used worldwide, motorcycle riders sustain the most serious injuries in the head and neck area which often lead to a disability or in some cases lead to mortality (WHO, 2013a).

Previous studies focused on the assessment of motorcycle accidents and have found a significant reduction in the risk of head and brain injuries in helmeted motorcycle riders compared to unhelmeted persons (Crompton et al., 2011; Houston & Richardson, 2008; Rowland et al., 1996). Another group reported that wearing a standard good-quality motorcycle helmet reduces the risk of mortality by 40% and the risk of serious injury by over 70%. Conrad, Bradshaw, Lamsudin, Kasniyah, and Costello (1996) conclude that although motorcycle riders appear to comply with the motorcycle helmet law, it is a "token compliance," less than 50% of riders were maximally protected by helmets and very little safety consciousness was found among riders.

Assessing the exact extent of brain damage caused after motorcycle accidents remains a challenge. In recent years several new biomarkers have been developed to assess the degree of neuronal injury sustained during a trauma. These biomarkers are becoming increasingly important as supplements for the Glasgow Coma Scale (GCS). Another existing biomarker is neuron-specific enolase (NSE), a protein-based enzyme found within neurons that can be used to quantify the degree of neuronal damage sustained after a head trauma (Hayes, 2004; Pineda, Wang, & Hayes, 2004; Wang et al., 2005; Wu, Zhao, Lu, Qiao, & Tan, 2004). Increased concentration of NSE can be measured in the cerebrospinal fluid and in peripheral blood after trauma; hence, neuronal damage offers a quick and reliable method of assessing the degree of brain cell damage sustained after motorcycle accidents (Ergun et al., 1998).

The aims of this study were to assess the effects of different helmet designs (full and half-coverage helmets) in motorcycle accidents and to carry out further investigation on the difference NSE serum levels in half-coverage helmet and unhelmeted persons that had sustained maxillofacial fractures during motorcycle accidents. Furthermore, correlations between NSE serum values and different maxillofacial fracture sites were also assessed.

2. Methodology

This study was approved by the Health Research Ethics Committee of Medical faculty, the University of Padjadjaran/Dr. Hasan Sadikin General Hospital Bandung, Indonesia. The study comprised of half-coverage helmeted and unhelmeted patients who had sustained maxillofacial fractures during motorcycle accidents at the urban Bandung area in Indonesia. Only hospitalized patients with maxillofacial fractures and a mild head injury that had been surgically treated within 48 h were included in this study. The riders whose helmet flied out before their head hit the ground were included as unhelmetted patients. All patients who had sustained moderate or severe head injuries were excluded from the study. Furthermore, multiple trauma and alcoholized patients were excluded from the study. The maxillofacial fractures were divided into three parts upper, middle, and lower facial. The upper part of facial skeleton comprising the frontal bone, the middle part comprising the midfacial bone: the maxilla, the nasoethmoid, and lateral midfacial bone-zygoma, and the lower part comprising the mandible. All patients in this study were scored using the GCS upon arrival at the hospital. Furthermore, computed tomography scans of all patients were also performed. Blood samples were taken from all studied patients and centrifuged for 10 min at 2.500 rotations per minute. Neuron-specific enolase measurements were performed with an electrochemiluminescence immunoassay (ECLIA) using a sandwich technique in duplicate with

NSE kits (Roche, Mannheim, Germany) and the Elecsys 2010 analyzer (Roche Diagnostics, Mannheim, Germany). This study underwent NSE screening within 24 h since the half-life of NSE in the serum is approximately 48 h (Wunderlich et al., 1999). The NSE cut-off value is 10 ng/ml (Bazarian & Merchant-Borna, 2014).

Statistical analyses were performed using Statistical Package for Social Ccience (SPSS) Version 22.0. The chi-square test was used to assess the gender, age, and site of fracture of helmeted motorcyclist. Furthermore, the independent t-test was used to calculate the mean admission of GCS, life-time NSE, and NSE results in correlation with the helmeted motorcyclist, and finally the two-way ANOVA test was used to calculate the NSE serum value related to half-coverage helmeted (Figure 1(a)) and unhelmeted motorcyclist that had sustained maxillofacial fractures.

3. Results

A total of 62 patients with mild head injuries were surgically treated in the 3-month study period. However, 14 patients should be excluded from the study since 11 patients had incomplete medical data, two patients have pulmonary disease, and one patient decided to leave the hospital before completing his treatment. From all subjects (48 patients) included in this study, it has been found that 45% (22 patients) were half-coverage helmeted and 54% (26 patients) unhelmeted. The group consisted of 41 males patients (85%) and seven females (14%) with a mean age was 27.57 years old ranging from 19 to 65years old. The most prevalent group was between 16 and 25 years old with 45% (22 subjects) were half-coverage helmeted and 54% (26 subjects) were unhelmeted.

The most prevalent maxillofacial fracture site was the mid-face 40.9% in the half-coverage helmeted group and 26.9% in upper-middle-lower in the unhelmeted group (Figure 2). All patients sustained a mild head injury during the traffic accident with the mean GCS 13.95 values upon admission were 13.95 in the half-coverage helmeted group and 13.73 in the unhelmeted group. The mean life-time NSE values were 10.89 h in the half-coverage helmeted and 13.24 h in the unhelmeted group. Furthermore, the mean NSE serum levels of the patients who had sustained a maxillofacial fracture was 11.52 ng/ml in the half-coverage helmeted group and 14.49 ng/ml in the unhelmeted group; however, there was no statistically significant difference between the two groups ($p > 0.05$) (Table 1).

The two-way ANOVA analyses showed that the NSE serum values in the half-coverage helmeted subjects who had sustained maxillofacial fractures in the upper-middle-lower sites were 33.01 ng/ml. These values were slightly higher than those recorded in the unhelmeted group 19.45 ng/ml; however, there was no statistical significant difference between the groups ($p > 0.05$) (Table 2).

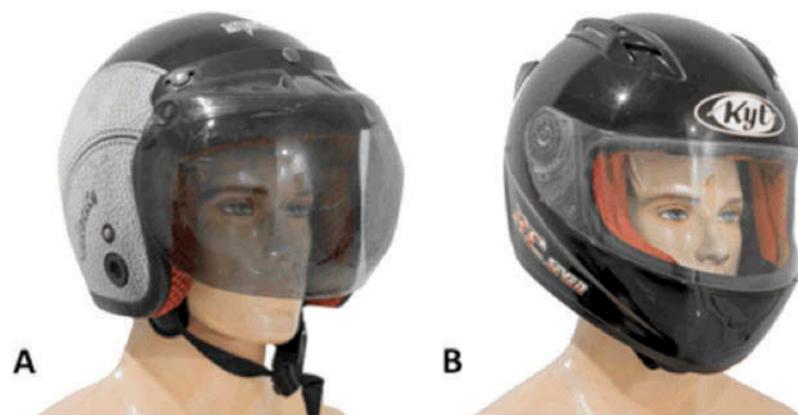**Figure 1. Types of helmet: (A) half-coverage helmet, (B) full-coverage helmet.**

Figure 2. Half-coverage helmeted and unhelmeted distribution stratified according to maxillofacial fractures site.
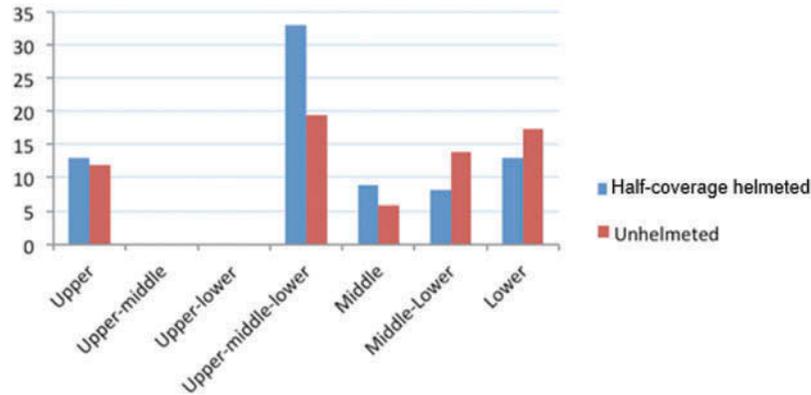

	Table 1. Patients' demographic and maxillofacial fractures, GCS, and NSE characteristics of half-coverage helmeted motorcyclist compared with unhelmeted motorcyclist involved		
Characteristic	**Half-coverage helmeted (n = 22)**	**Unhelmeted (n = 26)**	**p value**
Gender			
Male	18 (81.8%)	23 (88.5%)	0.516[a]
Female	4 (18.2%)	3 (11.5%)	
Age group (years)			
16–25	9 (41%)	17 (65.4%)	0.342[a]
26–35	8 (36.4%)	4 (15.4%)	
36–45	3 (13.6%)	4 (15.4%)	
46–55	1 (4.5%)	1 (3.8%)	
56–65	1 (4.5%)	–	
Fractures site			
Upper	5 (22.7%)	4 (15.4%)	0.118[a]
Upper-middle	–	–	
Upper-lower	–	–	
Upper-middle-lower	1 (4.5%)	7 (26.9%)	
Middle	9 (40.9%)	4 (15.4%)	
Middle-lower	3 (13.6%)	6 (23.1%)	
Lower	4 (18.2%)	5 (19.2%)	
Mean admission GCS	13.95 (0.58)	13.73 (0.72)	0.239[b]
Mean life-time NSE	10.98 (5.26)	13.24 (4.88)	0.133[b]
Mean NSE results	11.52 (6.83)	14.49 (11.52)	0.294[b]

[a]Chi-square test; [b]independent t-test, $p < 0.05$.

The NSE serum values in the unhelmeted subjects who had sustained maxillofacial fractures in the lower sites were 17.40 ng/ml. These values were slightly higher than those recorded in the half-coverage helmeted group 13.01 ng/ml; however, there was no statistical significant difference between the groups ($p > 0.05$) (Table 2).

cogent ··engineering

Fracture site	NSE		p-value
	Half-coverage helmeted	**Unhelmeted**	
Upper	12.91	11.82	0.480
Upper-middle	–	–	
Upper-lower	–	–	
Upper-middle-lower	33.01	19.45	
Middle	8.82	5.79	
Middle-lower	8.17	13.87	
Lower	13.01	17.40	

Table 2. Half-coverage helmeted and unhelmeted motorcyclist-related NSE serum level and maxillofacial fracture site

*p value *two-way ANOVA, $p < 0.05$*

4. Discussion

Motorcycles are the fastest growing sector of motor vehicles worldwide and comprise the majority of all motor vehicles in low- and middle-income countries (de Rome et al., 2011).

This study revealed that males (half-coverage helmeted 81.8% and unhelmeted 88.5%) are more frequently subjected to maxillofacial fractures than females (half-coverage helmeted 18.2% and unhelmeted 11.5%). Furthermore, maxillofacial fractures resulting from motorcycle accidents are most common amongst patients aged in the range of 16–25. These results, however, differed from those reported by Cavalcante et al. (2012) who studied the influence of helmets on facial trauma in motorcycle accidents and reported that most victims were between 21 and 40 years old (62.9%). A recent study by Cavalcante et al. (2012) reported that (94.5%) of the patients were male and the majority of patients were using a helmet (80.1%) during the accident. Furthermore, Conrad et al. (1996) reported that motorcycle riders in the urban Yogyakarta area in Indonesia did not always wear helmets especially at night when no police were around. The main reasons for not wearing helmets were discomfort and absence of police surveillance.

One of the findings in our study shows that half-coverage helmets provide limited protection against head and brain injuries. Interestingly, there is no significant difference between the half-coverage helmeted and unhelmeted group (mean GCS is 13.95 for half-helmeted and 13.73 for unhelmeted). Nevertheless, intracranial cerebral injury; intracranial hemorrhage; and face, skull vault, and cervical spine injuries are more likely to be found in fatally injured to unhelmeted motorcyclist compared to helmeted motorcyclist (Richter et al., 2001). However, a helmet is only effective when it remains on the head during the accident. Based on the findings of this study, continued efforts should be warranted to encourage the use of full coverage (Figure 1(b)). Motorcycle helmet in Bandung. One possible method of increasing the comfort of full coverage helmets is by developing lighter helmets with better ventilation especially in hot countries.

One explanation for the higher incidence of facial fractures in the upper and the middle third of the face in the half-coverage helmeted group could be due to the fact that most patients probably did not strap their helmets properly and subsequently exposed their chin area unprotected. Nevertheless, the half-coverage helmeted subjects had lower NSE values when compared to unhelmeted subjects in this study. These finding demonstrated that half-coverage helmet offers more brain protection than unhelmeted. Interestingly, the NSE serum values in the half-coverage helmeted group who had sustained maxillofacial fractures in the upper-middle-lower sites were slightly higher than in the unhelmeted group of patients. It indicates that half-coverage helmet does not protect the upper-middle-lower regions of the face and, half-coverage helmet only protects the posterior parts of the head. Furthermore, the NSE serum values in the unhelmeted group that had sustained maxillofacial

✳ cogent ·· engineering

fractures in lower facial region were slightly higher than in the half-coverage helmeted group indicating that the helmet strap may have a positive damping effect. The results of this study demonstrated that more concern should be given to helmet design (fracture-driven design).

This study has several limitations since some information was not gathered directly from the motorcycle riders experienced the accidents; hence, there are some measurement bias associated with observations of the speed, crash area of helmet, incorrect helmet uses, and rider characteristics. Many helmets may appear to be standard helmets on visual inspection but in fact they may lack those energy absorption layer that may protect the rider from injury in the event of an accident, nonetheless the prevalence of nonstandard helmets may be underestimated. It should be noted that the same clinicians carried out this investigation, and the same protocol was used throughout the present study. In addition, the number of the case involved in this study is limited. Further, to draw firm conclusion on the protection of helmeted and unhelmeted motorcycle riders associated with maxillofacial trauma, more quantitative data are mandatory.

In conclusion, the findings of this study revealed that half-coverage helmets provided motorcyclists with only limited protection in the head and facial areas. Unhelmeted motorcycle riders sustained comparable injuries compared to half-coverage helmeted users.

Author details
Muhammad Ruslin[1,2]
E-mail: ruslin_oms@yahoo.com
ORCID ID: http://orcid.org/0000-0003-0943-4000
Jan Wolff[2]
E-mail: Jan.Wolff@vumc.nl
Harmas Yazid Yusuf[3]
E-mail: harmasyazid_yusuf@yahoo.com
Muhammad Zafrullah Arifin[4]
E-mail: ipung_mza@yahoo.com
Paolo Boffano[2]
E-mail: paolo.boffano@gmail.com
Tymour Forouzanfar[2]
E-mail: T.Forouzanfar@vumc.nl
[1] Department of Oral and Maxillofacial Surgery Faculty of Dentistry, University of Hasanuddin, Makassar, Indonesia.
[2] Department of Oral and Maxillofacial Surgery/Oral Pathology, VU University Medical Center/Academic Center for Dentistry Amsterdam (ACTA), Amsterdam, The Netherlands.
[3] Department of Oral and Maxillofacial Surgery Faculty of Dentistry, University of Padjadjaran, Bandung, Indonesia.
[4] Department of Neurosurgery Faculty of Medicine, University of Padjadjaran, Bandung, Indonesia.

References
Ameratunga, S., Hijar, M., & Norton, R. (2006). Road-traffic injuries: Confronting disparities to address a global-health problem. *The Lancet, 367*(9521), 1533–1540. doi:10.1016/S0140-6736(06)68654-6

Bazarian, J. J., & Merchant-Borna, K. (2014). Tau, s-100 calcium-binding protein B, and neuron-specific enolase as biomarkers of concussion. *JAMA Neurology, 71*(7), 925–926. doi:10.1001/jamaneurol.2013.6240

Cavalcante, J. R., Oka, S. C., de Santana Santos, T., Dourado, E., de Oliveira, E., Silva, E. D., & Gomes, A. C. (2012). Influence of helmet use in facial trauma and moderate traumatic brain injury victims of motorcycle accidents. *Journal of Craniofacial Surgery, 23*(4), 982–985. doi:10.1097/SCS.0b013e31824e5b04

Conrad, P., Bradshaw, Y. S., Lamsudin, R., Kasniyah, N., & Costello, C. (1996). Helmets, injuries and cultural definitions: Motorcycle injury in urban Indonesia. *Accident Analysis and Prevention, 28*(2), 193–200. doi:10.1016/0001-4575(95)00056-9

Crompton, J. G., Bone, C., Oyetunji, T., Pollack, K. M., Bolorunduro, O., Villegas, C., … Haider, A. H. (2011). Motorcycle helmets associated with lower risk of cervical spine injury: Debunking the myth. *Journal of the American College Surgeons, 212*(3), 295–300. doi:10.1016/j.jamcollsurg.2010.09.032

de Rome, L., Ivers, R., Fitzharris, M., Du, W., Haworth, N., Heritier, S., & Richardson, D. (2011). Motorcycle protective clothing: Protection from injury or just the weather? *Accident Analysis and Prevention, 43*(6), 1893–1900. doi:10.1016/j.aap.2011.04.027

Ergun, R., Bostanci, U., Akdemir, G., Beskonakli, E., Kaptanoglu, E., Gursoy, F., & Taskin, Y. (1998). Prognostic value of serum neuron-specific enolase after head injury. *Neurological Research, 20*(5), 418–420. doi:10.1080/01616412.1998.11740541

Hayes, R. L. (2004). *Biochemical markers of brain injury: Applications to combat casualty care.* Presented at the RTO HFM Symposium on combat casualty care in ground based tactical situations: Trauma technology and emergency medical procedures (16–18). USA.

Houston, D. J., & Richardson, L. E. (2008). Motorcyclist fatality rates and mandatory helmet-use laws. *Accident Analysis and Prevention, 40*(1), 200–208. doi:10.1016/j.aap.2007.09.027

Pineda, J. A., Wang, K. K. W., & Hayes, R. (2004). Biomarkers of proteolytic damage following traumatic brain injury. *Brain Pathology, 14*, 202–209. doi:10.1111/j.1750-3639.2004.tb00054.x

Richter, M., Otte, D., Lehmann, U., Chinn, B., Schuller, E., Doyle, D., … Krettek, C. (2001). Head injury

mechanisms in helmet-protected motorcyclists: Prospective multicenter study. *The Journal of Trauma, 51*, 949–958. doi:10.1097/00005373-200111000-00021

Rowland, J., Rivara, F., Salzberg, P., Soderberg, R., Maier, R., Koepsell, & Koepsell, T. (1996). Motorcycle helmet use and injury outcome and hospitalization costs from crashes in Washington State. *American Journal of Public Health, 86*(1), 41–45. doi:10.2105/AJPH.86.1.41

Wang, K. K. W., Ottens, A. K., Liu, M. C., Lewis, S. B., Meegan, C., Oli, M. W., … Hayes, R. (2005). Proteomic identification of biomarkers of traumatic brain injury. *Expert Review of Proteomics, 2*(4), 1–12. doi:10.1586/14789450.2.4.603

Wood, E. B., & Freer, T. J. (2001). Incidence and aetiology of facial injuries resulting from motor vehicle accidents in Queensland for three-year period. *Australian Dental Journal, 46*(4), 248–288. doi:10.1111/j.1834-7819.2001.tb00293.x

World Health Organization. (2013a). *Global status report on road safety 2013: Supporting a decade of action.* Geneva, Switzerland: Author.

Wu, Y. C., Zhao, Y. B., Lu, C. Z., Qiao, J., & Tan, Y. J. (2004). Correlation between serum level of neuron-specific enolase and long-term functional outcome after acute cerebral infarction: Prospective study. *Hong Kong Medical Journal, 10*, 251–254.

Wunderlich, M. T., Ebert, A. D., Kratz, T., Goertler, M., Jost, S., & Herrmann, M. (1999). Early neurobehavioral outcome after stroke is related to release of neurobiochemical markers of brain damage. *Stroke, 30*, 1190–1195. doi:10.1161/01.STR.30.6.1190