The Effect of the Taiwan Motorcycle Helmet Use Law on Head Injuries

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A B S T R A C T

Objectives. This study evaluated the effect of the motorcycle helmet law implemented in Taiwan on June 1, 1997.

Methods. Collecting data on 8795 cases of motorcycle-related head injuries from 56 major Taiwanese hospitals, we compared the situation 1 year before and after implementation of the helmet law.

Results. After implementation of the law, the number of motorcycle-related head injuries decreased by 33%, from 5260 to 3535. Decreases in length of hospital stay and in severity of injury and better outcome were also seen. The likelihood ratio χ^2 test showed that severity decreased after the law's implementation ($P<.001$). Full helmets were found to be safer than half-shell helmets.

Conclusion. The helmet law effectively decreased the mortality and morbidity from motorcycle-related head injuries. (*Am J Public Health*. 2000;90: 793–796)

In Taiwan, motorcycles are the most common means of transportation. In 1996, there were 9 283 914 motorcycles among a total population of 21 471 448, accounting for 65% of all motor vehicles.[1] Data provided by the Interior Ministry in 1997 showed that there was 1 motorcycle for every 1.9 persons and 2.22 motorcycles per family.[2] The number of motorcycles increased by 9% from 1995 to 1996. The increase in motorcycle use has resulted in an increase in the incidence of motorcycle-related injuries. Furthermore, data provided by the Department of Health in 1996 showed that motorcycle-related injuries ranked first among all forms of injuries in years of potential life lost.[3] Over 70% of head injuries in Taiwan are caused by traffic accidents—a percentage higher than in many other countries.[4–7]

Both international and national epidemiologic surveys have reported that the vast majority of serious or fatal motorcycle-related injuries involve the head.[4,5,8,9] In Taiwan, according to the Department of Health, 77.7% of fatal motorcycle-related injuries involved the head[10]; according to data from the Interior Ministry, however, 91.6% of fatal injuries related to heavy motorcycles and 89.2% of fatal injuries related to light motorcycles involved the head.[11] Our previous studies found that 70% of head injuries were caused by traffic accidents, most of which (71%) involved motorcycles,[8,12,13] indicating a distinct correlation between motorcycle-related injury and head injury.[14]

From February to May 1994, enforcement of helmet use for motorcyclists was implemented in Taipei City. Helmet use increased from 21% in January 1994 to 79% in April 1994, reducing head injury hospitalizations by 33% and fatalities by 56%.[15] However, because this enforcement was not based on any law, and because some legislators criticized it on grounds of personal freedom, it was terminated by June 1994. Thereafter, the number of head injuries, along with their severity and outcome, returned to previous levels.

After intense lobbying and discussion, a motorcycle helmet use law was passed and implemented in the whole nation on June 1, 1997. To evaluate the effect of the law, we compared head injuries in the year before the law and in the year after implementation of the law.

Methods

Definitions

A head-injured motorcyclist was defined as a motorcycle driver or passenger who, after having received direct or indirect trauma to the head, exhibited obvious brain concussion, contusion, skull fracture, or any of their clinical manifestations, such as loss of consciousness, amnesia, neurologic deficits, and seizures. Clinical evidence of skull fractures and intracranial hemorrhages was also included to define the extent of head injury. In general, a motorcyclist with 1 or more of the aforementioned symptoms or diagnoses was registered as a head-injured motorcyclist.[4]

Only full helmets and partial-coverage helmets worn over the head by motorcycle riders to reduce the adverse effects of impact were defined as helmets. Safety hats such as those worn by construction workers were excluded because they do not usually contain an impact-absorbing liner. In addition, we excluded victims riding minibikes, bicycles, and tricycles.

Data Collection

In this case-series study, data on motorcycle head injury were collected for the year before (June 1, 1996–May 31, 1997) and after (June 1, 1997–May 31, 1998) implementation of the helmet use law. The data were collected from 56 major teaching hospitals in Taiwan. Approximately 80% of Taiwan's population is covered by these hospitals, making the data representative of the whole population. Patients dead on arrival and nonhospitalized patients were excluded from this study. Data came from the Head Injury Registry, a 10-year electronic database with more than 90 000 cases of head injury in Taiwan; this database

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Data on head injuries were recorded by experienced neurosurgeons from each hospital and were extracted by the same research assistant from the Injury Prevention Center to maximize reliability and consistency, respectively. *International Classification of Diseases, Ninth Revision* (*ICD-9*)[16] codes 800–804 (fracture of skull or face bones), 850.0 (concussion without loss of consciousness), 850.1–850. 2 (concussion with loss of consciousness), 851–851.1 (cerebral/cerebellar/brain stem contusion or laceration), 852.0–853 (extracerebral and/or intracerebral hematoma, SAH, SDH, EDH, ICH), 854.0 (unspecified intracranial injury), 900.0 (injury to blood vessels of head and neck), and 950.0–951.5 (injury to cranial nerves) were used to identify cases. Since E coding is not standard procedure in Taiwan, E codes were not available for this study. A thorough review of inpatient medical records and related examinations for all head-injury patients was carried out. Data pertaining to the identification of possible causative factors implicated in motorcycle-related head injury were recorded; these factors were age, sex, Glasgow Coma Scale score, presence of multiple systemic injuries, Glasgow Outcome Scale, and etiology (helmet use and cause and pattern of traffic accident).

Information on helmet use was obtained from the Department of Transportation. Traffic police officers were assigned to 2 crossroads in 23 towns and cities across Taiwan to count the number of helmeted motorcycle drivers and passengers per 200 motorcyclists.

Injury Coding

Severity of head injury was classified by Glasgow Coma Scale score[17] as follows: (1) severe: score of 8 or below; (2) moderate: score of 9 to 12, and patient received brain surgery or had abnormal computed tomography (CT) scan findings; (3) mild: score of 13 to 15 or conditions not meeting any of the above criteria.

The Glasgow Outcome Scale[18] was used to categorize the outcome of head injury patients at the time of hospital discharge as follows: (1) death; (2) persistent vegetative state; (3) severe disability—conscious but dependent; (4) moderate disability—disabled but independent; (5) good recovery.

Analysis

Incidence rate was not calculated for head-injured riders because a suitable denominator could not be defined for the injured-rider sample. Among the sample, body injury patterns and severity of head injuries were tested statistically before (June 1, 1996–May 31, 1997) and after (June 1, 1997–May 31, 1998) implementation of the helmet use law. Differences in interval distributions were tested with 2-tailed *t* tests. The likelihood ratio χ^2 test was used to evaluate the most severely injured body regions among the fatally injured motorcyclists. A *P* value below .05 was considered significant, and a *P* value of .05 to .10 was considered marginally significant.

Results

During the survey period, a total of 8892 hospitalized patients with motorcycle-related head injuries were identified. Seventy-five patients had incomplete medical records, and 22 were referred to other hospitals and their outcomes were unknown; thus, 8795 cases were included in the study. The ratio of males to females was 2:1, and the average age was 34.1 years (Table 1).

According to a report by the Department of Transportation and Communication in 1996, only 21% of motorcyclists wore helmets before the helmet use law. After implementation of the law, helmet use increased markedly. In September 1997, helmet use among motorcyclists increased to 95.95%, with the highest proportion seen in Taipei City (99.7%) and the lowest in Taichung City (79.1%).[14] The number of head injuries caused by traffic accidents dropped from 7591 (69.7%) in the year before the law to 5828 (66.6%) in the year after the law. After the law, motorcycle-related head injuries decreased by 33%, from 5260 (73.3%) to 3535 (67.5%) (Table 2).

A total of 5541 motorcycle-related head injuries (63%) were caused by crashes with cars, while 1407 (16%) were caused by crashes with other motorcycles. The rate of severe motorcycle-related head injuries was 1.94 times higher among males than among females ($P<.001$).

Before the law, the average length of stay in the intensive care unit for motorcycle-related head-injury inpatients was 2.14 days. After the law, this figure decreased to 1.8 days, and 72% of motorcycle-related head-injury inpatients did not need to be admitted into the intensive care unit. The average length of hospital stay decreased by 14.7%, from 10.2 days to 8.7 days.

The likelihood ratio χ^2 test showed that the severity of injury decreased after implementation of the law ($P<.001$). Before the law, determination of outcomes by the Glasgow Outcome Scale revealed that 211 head-injured patients (4.0%) died during hospitalization, 26 (0.5%) ended up in a vegetative state, 185 (3.5%) had severe disabilities, 549 (10.4%) had moderate disabilities, and 4289 (81.5%) had good recoveries. After the law, 141 (4.0%) died, 21 (0.6%) ended up in a vegetative state, 67 (1.9%) had severe disabilities, 368 (10.4%) had moderate disabilities, and 2938 (83.1%) had good recoveries. The number of hospitalized patients who died decreased by 33.2% (from 211 to 141) and the number with severe disabilities decreased by 63.8% (from 185 to 67). The likelihood ratio χ^2 test showed that outcomes were better (lower Glasgow Outcome Scale score) after implementation of the law ($P<.001$), with decreases in the rates of skull fractures (down 34.3%, from 839 to 551)

TABLE 1—Sex and Age Distribution of Motorcycle-Related Head Injuries in Taiwan, June 1996–May 1998

	Prelaw (June 1996–May 1997)		Postlaw (June 1997–May 1998)	
	n	%	n	%
Sex				
Male	3521	66.9	2366	66.9
Female	1739	33.1	1169	33.1
Age, y				
0–9	51	1.0	44	1.2
10–19	885	16.8	713	20.2
20–29	1609	30.6	1122	31.7
30–39	862	16.4	551	15.6
40–49	733	13.9	459	13.0
50–59	505	9.6	289	8.2
60–69	340	6.5	220	6.2
70+	275	5.2	137	3.9
Helmet use				
Yes	153	2.9	1630	46.1
No	5107	97.1	1905	53.9

TABLE 2—Comparison of Severity, Outcome, and Situation of Motorcycle-Related Head Injuries Before and After Implementation of the Taiwan Helmet Use Law

	Prelaw		Postlaw		
	n	%	n	%	% Change
Total no. of cases	5260		3535		33
Severity (GCS)					
Severe	484	9.2	318	9	–34.3
Moderate	521	9.9	336	9.5	–35.5
Mild	4255	80.9	2881	81.5	–32.3
Outcome (GOS)					
Death	211	4.0	141	4.0	–33.2
Vegetative state	26	0.5	21	0.6	–19.2
Severe disability	185	3.5	67	1.9	–63.8
Moderate disability	549	10.4	368	10.4	–33.0
Good recovery	4289	81.5	2938	83.1	–31.5
Loss of consciousness	1352	25.7	769	21.8	–43.1**
Neurologic deficit	560	10.6	478	13.5	–14.6**
Skull fracture	839	16.0	551	15.6	–34.3*
Intracranial hematoma	1670	31.7	1102	31.2	–34.0*
Surgery	479	9.1	279	7.9	–41.8*

Note. GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale.
*.01 < P < .05; **P < .001 (by χ^2 test).

(P < .05), patients needing surgery (down 41.8%, from 479 to 279) (P < .05), intracranial hematomas (down 34%, from 1670 to 1102) (P < .05), neurologic deficits (down 14.6%, from 560 to 478) (P < .001), and loss of consciousness (down 43.1%, from 1352 to 769) (P < .001) (Table 2).

The number of cases with associated injuries decreased by 25%, from 3386 cases before the law to 2539 cases after the law (P < .001). The number of associated injuries to the chest decreased by 52.4%, while the number of injuries to the upper extremities increased by 6.0% (P < .001). A slight increase in the number of cervical spine injuries and decrease in the number of injuries to the abdomen, whole spine, lower extremities, and face were also seen, but the results were not statistically significant (Table 3).

Motorcyclists wearing partial-coverage helmets were 1.76 times more likely to suffer fatal injuries than those wearing full helmets. In addition, full helmets were found to be safer than partial-coverage helmets (Table 4).

Discussion

This study demonstrated the effectiveness of the motorcycle helmet use law, as shown by several trends: a 33% decrease in motorcycle-related injuries; decreases in severity of injury, associated injuries, and length of hospital stay; and better outcome. Data provided by the Department of Health showed that after implementation of the helmet law, the number of motorcycle-related injuries decreased by 14%, length of hospital stay decreased by 14.5%, and costs of hospitalizations from motorcycle-related injuries decreased by an average of US $3.93 million per month. Furthermore, the total number of fatalities from motorcycle head injuries decreased by 561, from 7077 in 1996 to 6516 in 1997.

TABLE 3—Associated Injuries to Body Regions Other Than the Head Among Head-Injured Motorcycle Accident Victims in Taiwan

	Prelaw, n (%)	Postlaw, n (%)	% Change
Total associated injuries	3386 (64.2)	2539 (72.2)	–25.0*
Cervical spine[a]	124 (2.4)	126 (3.6)	+1.6
Chest	439 (8.3)	209 (5.9)	–52.4*
Abdomen	68 (1.3)	54 (1.5)	–20.6
Whole spine[b]	114 (2.2)	79 (2.2)	–30.7
Upper extremity	498 (9.5)	528 (15.0)	+6.0*
Lower extremity	517 (9.8)	369 (10.5)	–28.6
Face	810 (15.4)	529 (15.1)	–34.7

[a]Includes only injury to spinal cord.
[b]Includes injury to vertebra and spinal cord.
*P < .001 by χ^2 test.

Age Distribution

Our results showed that there were more head injuries among males than among females for all age groups, with a peak found in the 10- to 39-year-old group. In addition, after adjusting for age, we found that there were higher rates of head injuries among those aged 20 to 29 years and 70 years and older than among those in the rest of the population. Because most victims of motorcycle-related head injuries were young, the resulting cognitive, psychological, and neurologic sequelae were overwhelmingly damaging to society in terms of loss of working hours and productivity.

Associated Injuries

Although it has been reported that helmets may increase the risk of injuries to body regions other than the head,[19,20] our data showed that a significant increase was seen only in injury to the upper extremities. A slight but statistically insignificant increase was seen in cervical spine injuries. However, helmet use did not increase the risk of injuries to other body regions such as the face, chest, and abdomen.

TABLE 4—Relationship Between Helmet Use and Severe Head Injury: Taiwan, June 1996–May 1998

	OR	95% CI
Time period		
Before helmet use law	1.00	0.65, 0.78**
After helmet use law	0.71	
Helmet use		
Yes	1.00	1.76, 2.53**
No	2.11	
Helmet style		
Full cover	1.00	1.15, 2.69*
Half-shell	1.76	

Note. OR = odds ratio; CI = confidence interval.
*.001 < *P* < .01; **P < .001 (by χ^2 test.)

Law Enforcement

Unhelmeted motorcyclists caught by the police were fined the equivalent of US $15. The law was most strictly enforced in Taipei City, which has by far the largest police force in Taiwan, and accidental injury dropped from fourth to fifth in the ranking of major causes of death.[21] Policemen in other cities and counties were more lenient toward lawbreakers and often ignored unhelmeted motorcyclists. Another reason for the better results observed in Taipei City was a 6-month helmet use promotion campaign that educated Taipei citizens on the benefits of helmet use and the perils of riding a motorcycle without wearing a helmet.

Factors Affecting Results

To minimize the effect of external factors, data used throughout this study were obtained from the same 56 hospitals, and data were collected by teams of experienced neurosurgeons with a standardized questionnaire. Social, environmental, or regulatory factors other than the helmet use law may have accounted for a portion of the reduction in fatalities and injuries from one year to the next. However, we could not identify any significant changes in legislation, overall weather conditions, highway speeds, or motorcycle design features from one year to the other that would have significantly altered exposure to a crash or subsequent injury. Furthermore, an increase in the overall number of motorcycles was seen during this time.

Future Directions

Continued studies on motorcycle injury-related morbidity and mortality are necessary to determine the long-term effect of the helmet use law. Effects on related medical costs, years of potential life lost, and the National Health Insurance Plan should also be evaluated. A law banning motorcycle passengers from sitting sideways is currently being drafted; a study of the effect of such a law on motorcycle crash mortality and morbidity should also be conducted.

Conclusion

The enactment of the helmet use law in Taiwan provided a special opportunity to assess the impact of an unrestricted helmet use law. Arguments against helmet use laws usually center around issues of personal freedom vs cost to society and claims that helmets cause associated injuries. However, this study was able to show that the Taiwan motorcycle helmet use law was effective in reducing the number and severity of head injuries related to motorcycle crashes. □

Contributors

W.T. Chiu and C.C. Hung planned, designed, and conducted the study. W.T. Chiu and C.Y. Kuo gathered the data, performed the analysis, and interpreted the data. W.T. Chiu, C.Y. Kuo, and M. Chen wrote the paper, and all of the authors approved the final version.

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