Impact of Helmet Use on Injury and Financial Burden of Motorcycle and Moped Crashes in Hawai'i: Analysis of a Linked Statewide Database

Daniel J. Galanis PhD; Nikki A. Castel BS; Linda L. Wong MD; and Susan Steinemann MD

Abstract

Helmet use reduces injury severity, disability, hospital length of stay, and hospital charges in motorcycle riders. The public absorbs billions of dollars annually in hospital charges for unhelmeted, uninsured motorcycle riders. We sought to quantify, on a statewide level, the healthcare burden of unhelmeted motorcycle and moped riders. We examined 1,965 emergency medical service (EMS) reports from motorcycle and moped crashes in Hawai'i between 2007-2009. EMS records were linked to hospital medical records to assess associations between vehicle type, helmet use, medical charges, diagnoses, and final disposition. Unhelmeted riders of either type of vehicle suffered more head injuries, especially skull fractures (adjusted odds ratio (OR) of 4.48, P < .001, compared to helmeted riders). Motorcyclists without helmets were nearly three times more likely to die (adjusted OR 2.85, P = .001). Average medical charges were almost 50% higher for unhelmeted motorcycle and moped riders, with a significant (P = .006) difference between helmeted ($27,176) and unhelmeted ($40,217) motorcycle riders. Unhelmeted riders were twice as likely to self-pay (19.3%, versus 9.8% of helmeted riders), and more likely to have Medicaid or a similar income-qualifying insurance plan (13.5% versus 5.0%, respectively). Protective associations with helmet use are stronger among motorcyclists than moped riders, suggesting the protective effect is augmented in higher speed crashes. The public financial burden is higher from unhelmeted riders who sustain more severe injuries and are less likely to be insured.

Keywords

Helmet, Motorcycle, Moped, Hospital charges, Insurance

Introduction

Helmet use is an important factor in mitigating the severity of injuries from motorcycle crashes. Unhelmeted riders are more likely to have head injuries and are 3-4 times more likely to die.[1-9] In addition, unhelmeted motorcycle riders sustain more severe injuries, suffer greater disability, require longer hospital stays, and incur higher hospital charges.[2,3] Nineteen states have adopted universal motorcycle helmet laws, saving an average of $6,000 in health care costs per motorcyclist.[4] The state of Hawai'i requires helmet use only in motorcycle and moped operators and passengers under the age of 18 and prohibits passengers under the age of 7.[10]

Data specific to moped crashes and injuries are scarce and are often combined with motorcycle data. However, there are known differences in demographics and injury patterns for moped crashes. Moped riders have a higher incidence of alcohol use.[11,12] Moped crashes occur at lower speeds,[13] and riders are therefore less susceptible to serious extremity injury.[14] States have variable requirements for registration, operation, insurance, and helmet use for moped drivers. However, given the paucity of studies focused on moped riders, it is not clear if the regulations governing moped operation are well aligned with the risks of injury and liability.

This report examines moped and motorcycle riders in Hawai'i requiring medical attention at a hospital for an injury. This subset of a larger previously published sample[1] allows for a more detailed description of hospital diagnoses, charges, and principal source of payment for helmeted versus unhelmeted riders and emphasizes the public health implications of helmet usage. Diverse statewide datasets that link inpatient information with pre-hospital parameters allow us to uniquely quantify the protective effects of helmet use across the spectrum of motorcycle and moped crashes.

Methods

Emergency Medical Service Reports

This study is based on patient care reports (PCRs) from Hawai'i emergency medical service (EMS) providers from 2007 to 2009. All Hawai'i EMS providers complete PCRs electronically with standardized input screens. Discrete fields describe vehicle type (motorcycle or moped), helmet use, demographic variables, patient disposition, and a free-text space to record a narrative of the incident. All 2,923 EMS records for injured motorcyclists or moped riders over the 3-year period were reviewed. A total of 287 records were excluded from further analysis because they were related to off-road or non-traffic crashes (n = 150), riders of all-terrain vehicles (n = 77), or documented a patient transfer to another EMS unit (n = 60). Another 83 records were excluded due to unknown helmet status, resulting in records from 2,553 riders, 75% of whom (1,913) were transported to hospitals by EMS for further medical attention.

Linkage to Hospital Records

The Hawai'i Health Information Corporation (HHIC) linked EMS records to hospital records for both emergency department (ED) visits and hospitalizations. HHIC is a non-profit organization which maintains a repository of billing data abstracts for the medical records of all acute care hospitals in the state, with the exception of the ED records of one facility on the island of O'ahu.[15] Linkage of EMS records to HHIC records was accomplished deterministically, using patient name, date of birth, date of crash, and location of crash. Since HHIC maintains a master patient identifier, the definitive patient disposition and cumulative medical charges were available for patients who were transferred between hospitals in the state. Charges include those for room and board, pharmacy, laboratory, X-ray and hospital-based physician charges. Some analyses utilize a threshold of $25,000 in medical charges, to indicate treatments resulting in relatively high medical charges; $25,000

represented the 77th percentile of the distribution of medical charges. The principal source of payment was categorized into groups of interest. Payment from automobile insurance plans was considered "private insurance."

Hospital records were linked to 1,783 (93.2%) of the 1,913 transported by EMS to hospitals, leaving 130 records that could not be linked to HHIC data. These 130 patients were significantly younger than the 1,783 linked to HHIC data (33.3 versus 36.2 years, respectively, $P = .026$), and there was a higher prevalence of helmet use among motorcyclists (67.4% versus 50.0%, respectively, $P = .002$. Pre-hospital condition, as characterized by EMS personnel, was generally better among the 130 unlinked riders. Only 1.5% were in "critical" condition (indicating unstable vital signs and level of consciousness), compared to 7.8% of the other riders ($P = .01$). Patient condition was more likely to be "serious" (stable vital signs but impending deterioration) among the latter (60.9%), compared to the 130 unlinked riders (41.5%, $P < .001$). Data from these 130 riders were excluded from further analyses. Hospital records were available for another 182 riders who refused transport by EMS, but made their own way to hospitals, resulting in a final study sample size of 1,965 records.

HHIC data was used to define injury categories, using the principal diagnosis by ICD9-CM code: fractures (ICD9-CM code series 800-829), skull fractures (800-804), dislocations (830-839), sprains and strains (840-848), internal injuries (850-869), intracranial injury without skull fracture (850-854), open wounds (870-897), contusions and superficial injuries (910-924), as well as other injuries and non-injuries (ICD9-CM code less than 800). Traumatic brain injury (TBI) and spinal cord injuries were identified using the code series recommended by the CDC.[16] A category of "head injury" was also constructed, using the Barell Matrix.[17] HHIC data identified 62 patients who eventually died from their injuries, and all deaths were confirmed through linkage with the Hawai'i Department of Health's death certificate database.

Statistical Analysis

All statistical analyses for this report were performed using JMP software, version 5.[18] Differences in the distributions of categorical variables were tested using differences in proportions, while differences in the means of continuous variables were assessed by 2-tailed t-tests. Differences described as "significant" had an associated P value of less than .05. For multivariate logistic regression analyses, rider age was categorized into 4 groups: those 25 years and younger (referent group), 26 to 35 years, 36 to 54 years, and 55 years and older. Helmet status was dichotomized, with helmeted riders as the referent group. Our previous study[1] showed the associations between helmet use and injury outcomes varied considerably between motorcycle and moped riders, so all of the analyses included stratification by vehicle type. Study procedures were approved by the Hawai'i Department of Health's Institutional Review Board.

Results

Demographics

The mean age of the 1,965 patients was 35.9 years (SD 14.3 years) (Table 1). Helmeted motorcyclists were younger than unhelmeted motorcyclists on average (34.8 vs 39.0 years, $P < .001$), while helmeted moped riders were older than unhelmeted moped riders (average 37.9 vs 34.2 years, $P = .017$).

Motorcycle riders were more likely to be male (87.2%) compared to moped riders (70.0%, $P < .001$). Overall, helmet use was significantly less common among female riders (25.6%) compared to male riders (34.6%, $P = .001$). However, this association differed across vehicle types. In moped riders, helmet usage in females was significantly higher than in males (15.2% vs 9.8%, $P = .027$), but was comparable among motorcyclists (45.3% for females vs. 50.7% for males). About two-thirds of all riders were not wearing a helmet at the time of the crash. This proportion was significantly higher among moped riders (88.6%) than motorcyclists (50%, $P < .001$).

Motorcyclists were more likely to be Hawai'i residents (89.6%) compared to moped riders (77.8%, $P < .001$). Hawai'i residents were more likely to wear helmets (33.8%) compared to non-residents (27.4%, $P = .027$).

Insurance

Overall, the most common principal payer was private insurance (60.8% of patients), followed by self-pay (16.2%), income-qualifying insurance (such as Medicaid, QUEST) (10.7%), and Department of Defense (8.0%). The proportion of riders who did not utilize an insurance payer (ie, self-pay) was nearly double among unhelmeted riders (19.3%), compared to helmeted riders (9.8%, $P < .001$). The latter were also significantly less likely to have income qualifying insurance as their principle source of payment (5.0%), compared to unhelmeted riders (13.5%, $P < .001$), and more likely to have policies under the Department of Defense (17.7% versus 3.35%, respectively, $P < .001$). These differences in payer mix between helmeted and unhelmeted riders were also evident within the strata of motorcycle and moped riders.

Disposition and Pattern of Injury

Moped riders were more likely to be discharged from the ED, whereas motorcyclists were significantly more likely to be hospitalized (40.7% vs 28.4%, $P < .001$) or die (4.7% vs 1.3%, $P < .001$). There were no significant differences in the distribution of final medical disposition between helmeted and unhelmeted moped riders (Table 2). Among motorcyclists, however, unhelmeted riders were significantly more likely to be admitted to the hospital (44.1%), compared to helmeted motorcyclists (37.3%, $P = .02$), or to ultimately die (7.0% versus 2.4%, respectively, $P = .001$).

When principal diagnoses were reviewed, the incidence of fractures was statistically comparable between helmeted and unhelmeted riders of both vehicle types. However, the incidence of skull fractures was nearly 3 times greater for unhelmeted moped riders, and more than 6 times greater for unhelmeted motorcyclists.

Table 1. Demographic characteristics of motorcycle/moped riders injured in traffic crashes in Hawai'i, by helmet usage, 2007-2009			
	Helmeted	**Unhelmeted**	**Total**
All riders, n (%)	644 (32.8%)	1,321 (67.2%)	1,965
Age, mean (SD), y	35.3 (14.2)	36.2 (14.3)	35.9 (14.3)
Sex, n (%)			
Male	541 (84.0%)	1,022 (77.4%)*	1,563 (79.5%)
Female	103 (16.0%)	299 (22.6%)*	402 (20.5%)
Residence status, n (%)			
Hawai'i resident	559 (86.8%)	1,095 (82.9%)*	1,654 (84.3%)
Non-resident	84 (13.0%)	223 (16.9%)*	307 (15.6%)
Unknown	1 (0.2%)	3 (0.2%)	4 (0.2%)
Principal payer, n (%)			
Dept. of Defense	114 (17.7%)	44 (3.3%)*	158 (8.0%)
Private insurance	404 (62.7%)	791 (59.9%)	1,195 (60.8%)
Income-qualifying/Medicaid	32 (5.0%)	178 (13.5%)*	210 (10.7%)
Self-pay	63 (9.8%)	255 (19.3%)*	318 (16.2%)
Other	31 (4.8%)	53 (4.0%)	84 (4.3%)
Motorcycle riders, n (%)	544	544	1,088
Age, mean (SD), y	34.8 (13.7)	39.0 (13.8)*	36.9 (13.9)
Sex, n (%)			
Male	481 (88.4%)	468 (86.0%)	949 (87.2%)
Female	63 (11.6%)	76 (14.0%)	139 (12.8%)
Residence status, n (%)			
Hawai'i resident	475 (87.3%)	499 (91.7%)*	974 (89.6%)
Non-resident	68 (12.5%)	45 (8.3%)*	113 (10.4%)
Unknown	1 (0.2%)	0	1 (0.1%)
Principal payer, n (%)			
Dept. of Defense	108 (19.9%)	26 (4.8%)*	134 (12.3%)
Private insurance	339 (62.3%)	341 (62.7%)	680 (62.5%)
Income-qualifying/Medicaid	27 (5.0%)	71 (13.1%)*	98 (9.0%)
Self-pay	46 (8.5%)	86 (15.8%)*	132 (12.1%)
Other	24 (4.4%)	20 (3.7%)	44 (4.0%)
Moped riders, n (%)	100	777	877
Age, mean (SD), y	37.9 (16.7)	34.2 (14.3)	34.6 (14.6)
Sex, n (%)			
Male	60 (60%)	554 (71.3%)*	614 (70.0%)
Female	40 (40%)	223 (27.7%)*	263 (30.0%)
Residence status, n (%)			
Hawai'i resident	84 (84%)	596 (76.7%)	680 (77.8%)
Non-resident	16 (16%)	178 (22.9%)	194 (22.1%)
Unknown	0	3 (0.4%)	3 (0.3%)
Principal payer, n (%)			
Dept. of Defense	6 (6.0%)	18 (2.3%)*	24 (2.7%)
Private insurance	65 (65.0%)	450 (57.9%)	515 (58.7%)
Income-qualifying/Medicaid	5 (5.0%)	107 (13.8%)*	112 (12.8%)
Self-pay	17 (17.0%)	169 (21.8%)	186 (21.2%)
Other	7 (7.0%)	33 (4.3%)	40 (4.6%)

*Indicates statistically significant difference ($P < .05$), compared to helmeted riders.

Table 2. Disposition and injury-related diagnoses of motorcycle and moped riders in Hawai'i, by vehicle type and helmet usage, 2007-2009				
	Moped riders		Motorcyclists	
	Helmeted (n=100)	Unhelmeted (n=777)	Helmeted (n=544)	Unhelmeted (n=544)
Disposition				
discharged from ED	75 (75.0%)	542 (69.8%)	328 (60.3%)	266 (48.9%)*
admitted to hospital	24 (24.0%)	225 (29.0%)	203 (37.3%)	240 (44.1%)*
died	1 (1.0%)	10 (1.3%)	13 (2.4%)	38 (7.0%)*
Principal diagnosis				
fractures	23 (23.0%)	250 (32.2%)	193 (35.5%)	217 (39.9%)
fracture of skull	3 (3.0%)	69 (8.9%)*	10 (1.8%)	64 (11.8%)*
dislocations	1 (1.0%)	15 (1.9%)	12 (2.2%)	9 (1.7%)
sprains and strains	8 (8.0%)	41 (5.3%)	40 (7.4%)	17 (3.1%)*
internal	14 (14.0%)	110 (14.2%)	86 (15.8%)	81 (14.9%)
intracranial (no skull fracture)	14 (14.0%)	95 (12.2%)	48 (8.8%)	68 (12.5%)*
open wound	16 (16.0%)	140 (18.0%)	42 (7.7%)	63 (11.6%)*
contusion/superficial	29 (29.0%)	157 (20.2%)*	122 (22.4%)	91 (16.7%)*
other/unspecified injury	5 (5.0%)	42 (5.4%)	34 (6.3%)	34 (6.3%)
non-injury	4 (4.0%)	22 (2.8%)	14 (2.6%)	28 (5.2%)*
Any diagnosis				
any head injury	35 (35.0%)	392 (50.5%)*	127 (23.4%)	291 (53.5%)*
fracture of skull	7 (7.0%)	103 (13.3%)	19 (3.5%)	92 (16.9%)*
intracranial (no skull fracture)	18 (18.0%)	161 (20.7%)	81 (14.9%)	126 (23.2%)*
concussion	12 (12.0%)	121 (15.6%)	69 (12.7%)	85 (15.6%)
open wound	17 (17.0%)	225 (29.0%)*	30 (5.5%)	169 (31.0%)*
contusion/superficial	1 (1.0%)	9 (1.2%)	1 (0.2%)	10 (1.8%)*
traumatic brain injury	22 (22.0%)	273 (35.1%)*	115 (21.1%)	225 (41.4%)*
spinal cord injury	1 (1.0%)	3 (0.4%)	5 (0.9%)	6 (1.1%)

*Indicates statistically significant ($P < .05$) difference in proportion, compared to helmeted riders, within each vehicle type.

When all diagnoses were considered, the risk for any type of head injury was significantly higher for unhelmeted riders of either type of vehicle. Approximately half of the unhelmeted motorcycle (53.5%) or moped riders (50.5%) sustained a head injury, compared to 35.0% of the helmeted moped riders and 23.4% of the helmeted motorcycle riders. The incidence of traumatic brain injury (TBI), which includes the spectrum from concussion to intracranial hemorrhage, was also significantly higher among unhelmeted riders of either type of vehicle. For moped riders, the incidence of TBI among unhelmeted riders was 60% higher (35.1% versus 22.0% for helmeted riders, $P = .009$). For motorcyclists, the incidence was nearly double (41.4% versus 21.1% for helmeted riders, $P < .001$).

Charges

Average medical charges were approximately 50% higher for unhelmeted riders of both vehicle types (Table 3). More than one-third (35.1%) of medical charges to unhelmeted motorcyclists were paid by income-qualifying plans or self-pay, compared to only 13.7% of the charges to helmeted motorcyclists. Medical charges among unhelmeted moped riders were also more likely to be paid by income-qualifying plans or self-pay, compared to helmeted riders (37.9% vs 15.2%, respectively).

Approximately one-quarter (23.3%) of the 1,965 riders had medical charges of $25,000 or more, although this proportion was significantly higher among motorcyclists (28.5%) than moped riders (16.9%, $P < .001$). Unhelmeted motorcyclists were almost 50%, and unhelmeted moped riders almost 40%, more likely to incur $25,000 or more in total charges compared to helmeted riders (Table 3). Unhelmeted riders were about 3 times as likely to have an income-qualifying plan as the principal source of payment for these higher charge totals. They were also more likely to self-pay. As a result, unhelmeted riders in both motorcycles and mopeds had more than double the incidence of accruing $25,000 or more in total charges, combined with an income-qualifying payer plan or self-pay status.

Adjusted Outcomes

After controlling for age and gender by multivariate logistic regression, unhelmeted motorcycle riders had significantly higher odds of hospital admission (1.54, $P = .001$), and nearly three times the odds of a fatal injury (2.85, $P = .001$), compared

Table 3. Total charges for injured motorcycle and moped riders in Hawai'i, by vehicle type and helmet usage, 2007-2009				
	Moped riders		Motorcyclists	
	helmeted (n=100)	unhelmeted (n=777)	helmeted (n=544)	unhelmeted (n=544)
Total charges	$1,411,877	$16,382,380	$14,783,792	$21,878,109
Average charges	$14,119	$21,084	$27,176	$40,217*
Percent of charges, by principal payer category (average amount[a])				
Private insurance	76.1% ($10,747)	52.9% ($11,150)	62.2% ($16,896)	57.6% ($23,149)
Dept. of Defense	3.6% ($506)	1.7% ($351)	20.3% ($5,508)	3.1% ($1,254)
Medicaid/QUEST	1.2% ($167)	20.6% ($4,333)	6.8% ($1,841)	18.1% ($7,264)
Self-Pay	14.0% ($1,978)	17.3% ($3,652)	6.9% ($1,869)	17.0% ($6,829)
Other**	5.1% ($721)	7.6% ($1,597)	3.9% ($1,062)	4.3% ($1,720)
Charges of $25,000 or more	12 (12.0%)	136 (17.5%)	132 (24.3%)	178 (32.7%)*
Medicaid/QUEST	0	17 (2.2%)	13 (2.4%)	28 (5.2%)*
Self-Pay	3 (3.0%)	32 (4.1%)	12 (2.2%)	29 (5.3%)*
Medicaid/QUEST or Self-Pay	3 (3.0%)	49 (6.3%)	25 (4.6%)	57 (10.5%)*

[a]Calculated by multiplying the average charge by the proportion associated with each payer category. Example for helmeted moped riders with private insurance: $14,119 multiplied by 76.1% equals $10,747. *Indicates statistically significant ($P < .05$) difference in proportion, compared to helmeted riders, within each vehicle type. **Other includes Medicare or similar, and person's with worker's compensation.

Table 4. Adjusted* odds ratios for adverse medical and financial outcomes among unhelmeted motorcycle and moped riders in Hawai'i, by vehicle type, 2007-2009 (95% confidence interval given in parenthesis)			
Adverse outcome	**Moped riders**	**Motorcyclists**	**Total**
Final disposition			
Hospital admission or death	1.3 (0.8-2.1)	1.5 (1.2-2.0)	1.5 (1.2-1.9)
Death	1.0 (0.2-18.4)	2.9 (1.5-5.7)	2.8 (1.6-5.4)
Injury-related diagnoses			
TBI, any diagnosis	1.8 (1.1-3.1)	2.8 (2.1-3.6)	2.5 (2.0-3.2)
Skull fracture, any diagnosis	1.9 (0.9-4.7)	5.7 (3.5-9.8)	4.5 (2.9-7.1)
Head injury, any diagnosis	1.9 (1.2-2.9)	3.9 (3.0-5.1)	3.2 (2.5-4.0)
Total charges and principal source of payment			
Charges of $25,000 or more	1.6 (0.9-3.1)	1.5 (1.1-2.0)	1.5 (1.2-1.9)
Charges of $25,000 or more, and income qualifying or self-pay	2.1 (0.7-8.6)	2.4 (1.5-4.0)	2.4 (1.5-3.8)
Income qualifying payer	3.0 (1.3-8.6)	3.1 (2.0-5.1)	3.0 (2.0-4.6)
Self-pay	1.3 (0.8-2.3)	2.1 (1.5-3.1)	1.9 (1.4-2.6)
Income qualifying or self-pay	1.9 (1.2-3.1)	2.8 (2.1-3.9)	2.5 (1.9-3.3)

*All models adjusted for rider age and gender. Models for the total sample additionally adjusted for rider type (motorcyclist or moped rider). Helmeted riders served as the reference group with an odds ratio set to 1.0.

to helmeted riders (Table 4). There were no significant differences in either hospital admission or risk of fatal injury among moped riders.

Unhelmeted riders had significantly higher odds of TBI (2.49, $P < .001$), skull fracture (4.48, $P < .001$), or any head injury (3.18, $P < .001$), compared to helmeted riders, independent of age or gender. The disparity in outcomes was greater among motorcyclists, although unhelmeted moped riders also had significantly higher odds of TBI or head injury, compared to helmeted moped riders. Similar associations were found if only the principal diagnosis was considered.

The odds of incurring $25,000 or more in total charges were nearly 50% higher among unhelmeted motorcyclists, compared to helmeted riders. The former were also about 3 times as likely to have an income-qualifying plan as principal source of payment and twice as likely to self-pay. As a result, unhelmeted motorcyclists had more than twice the odds (2.82, $P < .001$) of accruing $25,000 or more in total charges, combined with an income-qualifying plan or self-pay as the principal source of payment.

Discussion

Multiple prior studies have characterized motorcycle and moped crashes, but few have compared and contrasted outcomes by vehicle type. Patient outcomes might be predicted to be different, as other investigators have reported differences between the populations of moped versus motorcycle riders. Matzch, et al, noted older age and a higher proportion of females in moped compared to motorcycle accidents.[19] Similarly, our study showed a higher percentage of females in moped crashes (30% versus 13% of motorcyclists) but no difference in age between the two groups. Others have identified operator factors associated with lethal moped crashes. Alcohol use is prevalent, with rider blood levels above the legal limit at the time of injury in up to 49% of lethal crashes.[11,12,20]

This study confirms the deleterious associations between non-use of helmets and adverse medical dispositions of injured riders. McSwain, et al, studied motorcycle riders from twelve states and five countries to show that the fatality rate was almost four times higher in unhelmeted compared to helmeted riders.[9] Braddock, et al, in 2,361 hospital discharges and 112 deaths from motorcycle accidents, revealed that non-helmeted motorcycle riders were 3.4 times more likely to die than helmeted riders.[21] While many studies report the injuries and fatality of motorcycle riders, no known study compares the impact of helmet use in motorcycle vs moped riders. Similar to motorcyclists, our data demonstrates that helmets have a significant protective effect for moped riders, with nearly a two-fold lower risk of overall head injury and TBI, and a three-fold lower risk of skull fractures.

An increase in skull fractures and head injuries in unhelmeted riders ultimately results in longer hospitalizations, greater disability, and increased cost. This has been well documented for motorcyclists, with acute care hospital charges for unhelmeted riders up to three times higher than helmeted riders.[3] Orsay, et al, in a study of 1,231 motorcycle riders, demonstrated that unhelmeted motorcycle riders were more likely to sustain serious head-related injuries, which resulted in longer ICU stay and a three-fold increase in hospital charges.[22] Max, et al, studied 11,163 motorcycle injuries and found patients with head injuries averaged $18,527 in hospital costs, compared to $10,350 in patients without head injuries.[23] Belavadi, et al, studied 1,900 motorcycle accidents. Acute care costs for unhelmeted motorcycle riders was three times that of a helmeted rider.[24] Our study confirmed that average hospital charges for unhelmeted riders (both moped and motorcycle) were approximately 50% higher than for helmeted riders. Importantly, these increased charges were seen to the same extent in unhelmeted moped as well as motorcycle riders.

The economic and social impact of the increased rate of TBI in unhelmeted riders (35% of moped and 41% of motorcyclists) may be underestimated if we consider only direct acute care medical charges. Compared to thoraco-abdominal and extremity injuries, TBI may have prolonged disability, incomplete recovery, and diminished performance status or ability to return to work. The disability and loss of productivity may go unrecognized and undocumented, particularly in a patient population that is underinsured and does not seek regular medical care.

The direct cost of crashes involving unhelmeted riders is borne disproportionately by the taxpaying public. Nationwide, state governments absorb nearly $5 billion in hospitalization for unhelmeted riders without medical insurance.[9] Riders in Hawai‘i had a similarly unfavorable distribution of principal insurance policies: one-third used income qualifying plans or self-pay, compared to only 15% of helmeted riders. These outcomes have important implications when considering the public burden in caring for injured unhelmeted riders. For example, unhelmeted motorcyclists accounted for 79% of the $3.2 million average annual medical charges associated with income qualifying insurance plans or self-payment, although they made up only 50% of injured motorcyclists in Hawai‘i.

Conclusions

In summary, motorcycle riders are almost 50% more likely than moped riders to be hospitalized, and over 3 times more likely to suffer from a fatal injury. The mortality rate for helmeted motorcyclists is reduced by nearly 3-fold, but there is no significant impact of helmet use on mortality in moped riders, suggesting that the protective effect of helmets is augmented in higher speed crashes.[1]

A protective association with helmet use is evident for both motorcyclists and moped riders, with a reduced rate of skull fracture (nearly 6-fold and 2-fold, respectively) and TBI. These higher rates of injury are reflected in hospital charges, which are doubled for unhelmeted moped and motorcycle riders. The public burden of these charges is augmented by the unfavorable payer status of unhelmeted riders, with over 35% having income-qualifying (government-assisted) coverage or self-pay. The odds ratio for high cost (>$25,000) and underinsured hospital stays are more than doubled for unhelmeted versus helmeted riders. This data provides direct economic incentive for universal helmet laws covering mopeds as well as motorcycles.

Limitations

Limitations of this study are the inclusion of only injured riders who were attended to by EMS personnel, and the limited sample size of moped riders. Hospital records could not be located for approximately 7% of the injured riders who were transported to hospitals by EMS. However, the exclusion of these riders probably did not bias the results of multivariate logistic regression models, since these riders were more likely to have worn helmets and had a more favorable distribution of pre-hospital injury severity. Another limitation is the availability of only acute care charges in the initial hospitalization. Therefore, medical charges we report may underestimate the true financial burden of long-term injuries. It should be noted that we only had access to medical charges, and not the actual medical costs that were ultimately paid after insurance adjustments. Finally, diagnostic data may be less accurate than the original medical records because HHIC data systems is generated for billing reimbursement.[1]

Strengths

This study includes statewide data collection which was possible through uniform data collection for all EMS providers in Hawai'i, and the existence of HHIC, a central repository of billing data from hospital medical records in the state. The capability of HHIC to track individuals transferred across medical facilities improved the ascertainment of final medical dispositions and reduced loss to follow-up. Finally, this study had a comprehensive comparison of demographics, injury, mortality, cost, and insurance information in four different groups: motorcycle riders with and without helmets, and moped riders with and without helmets. This is the first study with detailed analysis of helmet use between the two vehicle types.

Future Impact

Our study shows that unhelmeted riders are much more likely to suffer serious injury or death and to incur higher hospital charges. Furthermore, these higher hospital charges are more likely to be absorbed by public funds or the hospitals that provide them medical treatment. This is true for both motorcycle and moped riders, a distinction that was previously unstudied. These are important findings for those advocating for legislative policies requiring helmet use. Our study supports that implementing mandatory helmet laws for both motorcycle and moped riders would decrease severity of injury, medical charges, and cost to society.

Conflict of Interest

None of the authors identify any conflict of interest.

Acknowledgments

The data linkage activities were supported by a Highway Safety grant from the Hawai'i Department of Transportation.

Authors' Affiliations:
- EMS & Injury Prevention System Branch, Hawai'i Department of Health, Honolulu, HI (DJG)
- Department of Surgery, John A Burns School of Medicine, University of Hawai'i, Honolulu, HI (NAC, LLW, SS)

Correspondence to:
Daniel Galanis PhD; Injury Prevention Program, EMS & Injury Prevention System Branch, Hawai'i Department of Health, Leahi Hospital, Trotter Annex, 3675 Kilauea Ave., Honolulu, HI 96816; Email: daniel.galanis@doh.hawaii.gov

References

1. Galanis DJ, Ly CL, Wong LL, Steinemann S, and Rosen L. Helmet Use Among Motorcycle and Moped Riders Injured in Hawaii: Final Medical Dispositions from a Linked Database. *J Trauma.* 2014;77(5):743-8.
2. Brown CV, Hejl K, Bui E, Tips G, and Coopwood B. Risk Factors for Riding and Crashing a Motorcycle Unhelmeted. *J Emerg Med*. 2011;41(4):441-6.
3. Heldt KA, Renner CH, Boarini DJ, and Swegle JR. Costs Associated with Helmet Use in Motorcycle Crashes: The Cost of Not Wearing a Helmet. *Traffic Inj Prev*. 2012;13(2):144-9.
4. Brandt MM, Ahrns KS, Corpron CA, Franklin GA, and Wahl WL. Hospital Cost Is Reduced by Motorcycle Helmet Use. *J Trauma*. 2002;53(3):469-71.
5. O'Keefe T, Dearwater SR, Gentilello LM, Cohen TM, Wilkinson JD, McKenney MM. Increased fatalities after motorcycle helmet law repeal: is it all because of lack of helmets? *J Trauma*. 2007;63:1006-1009.
6. Croce MA, Zarzaur BL, Magnotti LJ, Fabian TC. Impact of motorcycle helmets and state laws on a society's burden: a national study. *Ann Sur*g. 2009;250:390-394.
7. Abbas AK, Hefny AF, Abu-Zidan FM. Does wearing helmets reduce motorcycle-related death? A global evaluation. *Accid Anal Prev*. 2012;49:249-252.
8. MacLeod JB, DiGiacomo CJ, Tinkoff G. An evidence-based review: helmet efficacy to reduce head injury and mortality in motorcycle crashes: EAST practice management guidelines. *J Trauma*. 2010;69:1101-1111.
9. McSwain NE Jr., and Belles A. Motocycle Helmets- Medical Costs and the Law. *J Trauma*. 1990;30(10):1197-9.
10. State of Hawaii, Department of Health. Injury Prevention and Control Section: Motorcycle and Moped Safety. Available at: http://health.hawaii.gov/injuryprevention/home/traffic-safety/motorcycle-and-moped-safety/. Accessed June 7, 2015.
11. Christmas AB, Brintzenhoff RA, Schmeizer TM, Head KE, and Sing RF. MOPEDS- Motorized Objects Propelling Ethanol Drinking Subjects. *Am Surg*. 2011;77(3):304-6.
12. Brintzenhoff RA, Christmas AB, Braxton VG, Janulis KE, Huynh TT, and Sing, RF. Mopeds: The Legal Loophole for Repeat Driving While Intoxicated Offenders. *Am Surg.* 2011; 202(6):697-700.
13. Blackman RA, and Haworth NL. Comparison of Moped, Scooter, and Motorcycle Crash Risk and Crash Severity. *Accid Anal Prev*. 2013;57:1-9.
14. Matzsch T. Injuries in Moped and Motorcycle Accidents, a Five-Year Series. *Laekartidningen.* 1983;80(24):2514-7.
15. Hawaii Health Information Corporation (HHIC). About. Available at: http://hhic.org/. Accessed March 9, 2015.
16. Centers for Disease Control and Prevention (CDC). State Injury Indicators Report. Instructions for Preparing 2010 Data. Available at: http://www.cdc.gov/injury/pdfs/2010_State_Injury_Indicator_Instructions-a.pdf. Accessed January 20, 2014.
17. Centers for Disease Control and Prevention (CDC). The Barell Injury Diagnosis Matrix, Classification by Body Region and Nature of the Injury. Available at: http://www.cdc.gov/nchs/data/ice/final_matrix_post_ice.pdf. Accessed January 20, 2014.
18. JMP. Software. Available at: http://www.jmp.com/en_us/software.html. Accessed March 9, 2015.
19. Matzsch T, and Karlsson B. Moped and Motorcycle Accidents-Similarities and Discrepancies. *J Trauma.* 1986;26(6):538-43.
20. Miggins M, Lottenberg L, Liu H, Moldawer L, Efron P, and Ang D. Mopeds and Scooters: Crash Outcomes in a High Traffic State. *J Trauma.* 2011;71(1):217-22.
21. Braddock M, Schwartz R, Lapidus G, Banco L, and Jacobs L; A Population-Based Study of Motorcycle Injury and Costs; *Annals of Emergency Medicine*. 1992;21(3):273-8.
22. Orsaw E, Holden JA, Williams J, and Lumpkin JR. Motorcycle Trauma in the State of Illinois: Analysis of the Illinois Department of Public Health Trauma Registry. *Ann Emerg Med*. 1995;26(4):455-60.
23. Max W, Stark B, and Root S. Putting a Lid on Injury Costs: The Economic Impact of the California Motorcycle Helmet Law. *J Trauma*. 1998;45(3):550-6.
24. Shankar BS, Ramzy AI, Soderstrom CA, Dischinger, PC, and Clark CC. Helmet Use, Patterns of Injury, Medical Outcome, and Costs Among Motorcycle Drivers in Maryland. *Accident Analysis & Prevention.* 1992;24(4):385-96.