A Comparison of Skeletal Injuries Arising from Moped and Motorcycle Collisions

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Abstract

Motorcycle and moped injuries remain a significant cause of motor-vehicle related morbidity and mortality. There is a paucity of literature describing the skeletal injuries of moped riders and how these compare to those of motorcyclists, however. This study seeks to examine the skeletal injuries sustained in such incidents and determine if there are significant differences. Hospitalized riders injured on powered two-wheeled vehicles (PTW) between 2004 and 2007 were entered into a registry along with their presentation and clinical course. This registry was sorted by PTW type. Riders with injuries of the appendicular skeleton, bony pelvis, and spine were extracted. Injuries were categorized by bone location. Demographic data, helmet use, head injury, facial fracture, Injury Severity Score (ISS), and mortality were extracted. Overall, 406/578 motorcyclists, 197/357 moped riders, and 62/92 dirt-bike riders sustained fractures of the appendicular skeleton, pelvis and/or spine. Motorcyclists had a significantly higher ISS upon presentation and had increased first-hospital-day mortality in addition to more skeletal injuries, more fractures of the upper extremity, and more fractures of the spine, pelvis, and foot. Moped riders had a significantly lower rate of helmet use and higher rate of head injuries and facial fractures. In summary, while both moped and motorcycle riders share a risk for injuries of the lower extremity, their overall pattern of injury differs. Motorcyclists appear to be at increased risk for more severe injuries and injuries of the upper extremity, spine, and pelvis, while moped riders are at increased risk for significant head and facial injury.

Keywords

powered two-wheeled vehicle, skeletal trauma, moped, motorcycle

Introduction

Powered two-wheeled (PTW) vehicle accidents account for a large percentage of admissions in orthopedic surgery as well as hospital admissions generally. Two of the highest risk groups for traffic injuries and fatality accidents are motorcycle and moped riders. Injuries sustained in PTW accidents are often more severe than those sustained in automobile crashes.[1] In the United States (US) as a whole, motorcycle accidents contribute to roughly 12% of motor vehicle related deaths.[2] This is an even greater concern for Hawai‘i, where motorcycle and moped accidents caused an average of 27% (20%-34%) of traffic fatalities over the ten years from 2008-2018.[3] Some studies have documented that the risk of injury for moped riders per distance traveled is up to 100 times than that of automobile drivers.[4]

A motorcycle is defined as a two- or three- wheeled powered vehicle with an engine larger than 50cc. This study separates motorcycles into general motorcycles designed primarily for on-road use and dirt bikes, which are motorcycles designed primarily for off-road use.[5] A moped is defined as a two- or three-wheeled powered vehicle that can only carry one person with a maximum of two horse power, an engine size of 50cc or less and a top speed on a level surface of 30 miles per hour.[6] Mopeds are typically equipped with a device designed to prevent them from exceeding 30 mph, however many vehicles have been suspected to have had these devices removed or modified.[7] In the state of Hawai‘i, mopeds hold special appeal to some users because they do not require a special motorcycle license and do not require insurance if they are privately owned, making them comparably inexpensive, they have less stringent licensing requirements, they are more compact, allowing for easier parking in urban areas, and they are typically less expensive to purchase than motorcycles, dirt bikes, or automobiles.[6]

Previous studies have evaluated the factors that influence the occurrence of PTW accidents and PTW fatalities. These include age,[1,8] length of time the individual has held a motorcycle license,[9] gender,[10] personality traits,[11] alcohol intoxication,[9,12,13] helmet use,[14,15] presence or absence of up to date motorcycle license,[9,16] presence or absence of a passenger, speeding,[7] time of day, road design and road conditions.[17]

The federal government does not make a distinction between moped and motorcycles in their reports and there is a gap in understanding the risks and injury type differences. Significant resources are invested in the prevention and treatment of PTW injuries, making it critical to better understand these injuries. Examination of the differences in injuries sustained in motorcycle accidents compared to moped accidents is important given that these vehicles generate different types of traffic interactions than cars and trucks and are often not factored into traffic design.[18] Although previous studies have examined moped related injuries, much of the literature is dated or specifically looks at injuries in children and teenagers, particularly because some European countries allow moped use at age 14.[19,20] The state of Hawai‘i has only a partial helmet law, similar to 27 other states in the US. This partial helmet law is lenient, only requiring helmets for PTW riders and passengers under 18. Those 18 and older are currently not required to wear a helmet in the state of Hawai‘i.[21]

The purpose of this study is to describe injuries sustained in moped and motorcycle accidents and examine the differences based on powered two-wheeled vehicle type, gender, age, and helmet use on injury type, fracture location, head injury, facial fracture, injury severity score (ISS), and mortality.

Methods

The data were collected prospectively in the IRB-approved trauma registry from all patients who presented with trauma activation and arrived alive at The Queen's Medical Center, in Honolulu, Hawai'i, USA with an injury involving a powered two-wheeled vehicle between 2004 and 2007. This registry included such data as: age, gender, use of helmet, type of vehicle, mortality, and hospital stay in addition to a free text description of their presenting injuries. First, the trauma registry was sorted by vehicle type. Demographic information was collected on each group including gender, age at time of injury, use of helmet, and mortality. Next, we coded the free text description of all orthopaedic injuries into injury type, boney location of the fracture, and the presence or absence of open fractures.

The severity of injuries sustained in traumatic incidents are often described using scoring systems. One such system is the Injury Severity Score (ISS).[22,23] This score is the sum of squares of the highest three scores obtained from the Abbreviated Injury Scale (AIS) which describes the severity of injuries of six anatomical regions (head and neck/cervical spine, face, chest & thoracic spine, abdomen and lumbar spine, extremities, external) from one (minor) to six (not survivable). The score goes from 1-75. Any injury resulting in an AIS of 6 (unsurvivable) for that region is automatically scored as 75. This score is widely used and has been found to correlate with measures of severity such as mortality, morbidity, and hospital stay.[23] ISS was noted for each group and ISS of those with fractures of the appendicular skeleton, spine or pelvis were extracted for each group.

Statistical analyses using ANOVA with post-hoc Tukey's HSD were performed to evaluate ISS on presentation, both overall and in patients with factures of the appendicular skeleton, pelvis, or spine. Fisher's exact test was used to evaluate proportions of motorcycle and moped riders sustaining injuries. Chi square testing was used to compare proportions of riders from all three vehicle types. All statistical analyses were performed using Microsoft Excel (Microsoft, Redmond, WA).

Results

We examined the records of 578 trauma-presenting motorcyclists, 357 trauma-presenting moped riders, and 92 trauma-presenting dirt bike riders. Overall, 406 of the 578 motorcyclists, 197 of the 357 moped riders, and 62 of the 92 dirt-bike riders sustained fractures of the appendicular skeleton, pelvis, and/or spine. The majority of patients were male in all groups (88.9% motorcycle, 81.5% moped, 97.8% dirt bike) (data not shown). The mean age of motorcycle riders was 35.8 ± 13.3 years, 35.1 ± 13.4 years for moped riders, and 25.8 ± 11.9 years for dirt bike riders (data not shown). There was no significant difference in the proportion of open fractures between moped and motorcycle riders who had sustained fractures. In comparison to moped and dirt bike riders, motorcyclists had a significantly higher ISS score upon presentation and were more likely to die within the first hospital day as shown in Table 1 and Table 2. Dirt bike riders showed the lowest ISS, with an average ISS of 12.9 compared to an average ISS of 14.5 for moped riders and an average ISS of 16.6 for motorcycle riders.

This study also found that motorcyclists sustained significantly more skeletal injuries than moped riders (P <.0001), as well as more fractures of the upper extremity (hand, radius, ulna, scapula) and significantly more fractures of the spine, pelvis, and foot as seen in Tables 3, 4, 5, and 6. In contrast, moped riders were more likely to sustain significant head injuries and facial fractures (Table 2). There was also a significantly lower rate of helmet use among moped users (9.5% compared to 48.8% among motorcycle riders).

Table 1. Injury Severity Score (ISS) Segregated by Vehicle Type.

	ISS	Standard Deviation	ISS of Those with Skeletal Injury	Standard Deviation
Motorcycle Riders	**16.6**	± 13.04	18.77	± 12.89
Moped Riders	14.5	± 10.78	17.15	± 11.72
Dirt Bike Riders	12.9	± 8.42	**14.10**	± 8.47
P-Value (ANOVA)	.0030		.0125	

Values with P <.05 by Tukey's HSD are in bold.

Table 2. Mortality Rates, Helmet Use and Head Injuries Sustained Segregated by Vehicle Type.

	Motorcycle Riders n (%)	Moped Riders n (%)	*P*-Value
Mortality at Hospital	29 (5.0%)	16 (4.5%)	.7555
Death Upon Presentation/HOD #1	**24 (4.2%)**	4 (1.1%)	.0091
Lung/Hollow Viscus/Solid Organ Injury (Including PTX, Pulm Contusion)	**181 (31.3%)**	81 (22.6%)	.0044
Head Injury	259 (44.8%)	**230 (64.4%)**	.0001
Facial Fracture	96 (16.6%)	**89 (24.9%)**	.0023
Helmet Use	**282 (48.8%)**	34 (9.5%)	<.0001

Values with P <.05 are in bold.

Table 3. Location of Upper Extremity Fractures Segregated by Vehicle Type.

	Motorcycle Riders n (%)	Moped Riders n (%)	*P*-Value
Scapula	**50 (12.3%)**	13 (6.6%)	.0113
Clavicle	76 (18.7%)	30 (15.2%)	.0917
Humerus	34 (8.4%)	11 (5.6%)	.1426
Radius	**67 (16.5%)**	17 (8.6%)	.0013
Ulna	**53 (13.1%)**	17 (8.6%)	.0445
Hand	**66 (16.3%)**	20 (10.2%)	.0101

Values with *P* < .05 are in Bold.

Table 4. Differences in Spinal Fractures and Fracture Location in Motorcycle Versus Moped Riders.

	Motorcycle Riders n (%)	Moped Riders n (%)	*P*-Value
Overall spine	**112 (27.6%)**	35 (17.8%)	.0006
Cervical spine fractures	37 (9.1%)	16 (8.1%)	.4525
Thoracic spine fractures	47 (11.6%)	16 (8.1%)	.0929
Lumbar spine fractures	**49 (12.1%)**	11 (5.6%)	.0039

Values with *P* < .05 are in Bold.

Table 5. Percentage and Location of Fractures to the Sacrum and Pelvis Segregated by Vehicle Type.

	Motorcycle Riders n (%)	Moped Riders n (%)	*P*-Value
Fractures of the Sacrum	**32 (7.95)**	4 (2.0%)	.0010
Fractures of the pelvis excluding the acetabulum	**64 (15.8%)**	18 (9.1%)	.0058
Acetabular fractures	32 (7.9%)	11 (5.6%)	.1858

Values with *P* < .05 are in Bold.

Table 6. Location of Lower Extremity Fractures Segregated by Vehicle Type.

	Motorcycle Riders n (%)	Moped Riders n (%)	*P*-Value
Fractures of the femur	72 (17.7)	39 (19.8)	.3330
Fractures of the patella	15 (3.7)	12 (6.1)	.3112
Fractures of the tibia	122 (30.0)	59 (29.9)	.3455
Fractures of the fibula	102 (25.1)	48 (24.4)	.7604
Fractures of the foot	**48 (11.8)**	15 (7.6)	.0496

Values with *P* < .05 are in Bold.

Discussion

This is one of the first reports to examine the differences in injury severity and fracture location differentiated by PTW type. This is critical to understanding injuries sustained in PTW accidents and the crucial differences between those sustained by motorcycle riders versus moped riders versus dirt bike riders.

Our findings mirror and expand on the results of prior literature in the field. As seen in some previous studies of other populations,[9,24] the ISS was highest in hospitalized motorcycle riders, with an average score of 16.6 compared to an average ISS of 14.5 in moped riders and an average ISS of 12.9 in dirt bike riders. This contrasts with observations of very similar levels of injury severity between moped riders and motorcyclists.[25] We found a significantly higher rate of head and facial injury in moped riders, as compared to motorcycle riders. As is reflected in Table 2, this study also found a statistically significant difference in the use of helmets between those who came in following a moped crash (9.5% had worn a helmet) and those who presented following a motorcycle accident (48.8% had been wearing a helmet), which may explain the increased levels of head injuries and facial fractures among moped riders in this study. Lower extremity injury was common and not significantly different between injured moped and motorcycle riders. Upper extremity injuries distal to the elbow were significantly more common in motorcyclists, as were spinal injury and thoracic injury. We also found pelvic fracture to be more common in motorcyclists.

One of the first reports on moped injuries was a relatively small (N=42) prospective study of moped riders presenting at their trauma center published in 1984.[26] Like our study, they noted a high proportion of head injuries and orthopedic injuries—nearly 1/3 of patients had each. Similar findings were noted in a 2002 study of primary diagnoses in a retrospective analysis of Swedish health service data.[27] Unfortunately, in contrast to the >90% helmet use in the Swedish study, only 9.5% of Hawai‘i moped riders admitted wearing a helmet at the time of the accident. This may explain Hawaii's nearly double rate of head injury in moped riders compared to the other two groups.

In previous studies, we noted that about a third of Hawaii's population had lower extremity fractures, with the tibia being the most common location of fracture.[10] Among patients in an 8-month duration prospective study of moped riders admitted to a South Carolina ED and trauma center, 100% presented with soft tissue injuries, 33% with head injury, and 24% with fractures.[26] This study also saw a low rate of helmet use (5%). By contrast, a retrospective review of 4716 moped riders using records from a Swedish Hospital Discharge Registry (1987-1999) found 28% with a head injury despite 90%-95% reported helmet use. In that study less than one third of moped riders had fractures of the lower extremity (most common tibia/fibula).[10]

Another study in 2002 reported that over one third of moped riders had fractures of the lower extremity as the primary diagnosis.[27] In addition, 28% had some sort of head injury. Unlike our study, however, patients reported high helmet use (90%-95%). Also, this group only evaluated percentages of diagnoses and used combined body regions, so the true percentage of riders with injuries and the specific fractured bone is unclear.[27]

Limitations of this study are that it only includes patients who arrived at the institution alive, and therefore excludes those who expired prior to arrival. This study also only includes injuries noted in the patients' initial hospitalization and does not include long term follow up outcomes. This study also excluded patients who did not seek medical care or received care at other institutions. The authors also had to rely on trauma activation to identify potential patients for inclusion in the retrospective database analysis. We know from past studies that many accidents are not reported in official statistics.[8] Future studies would test the robustness of these findings in different populations and under different variable conditions. To further elucidate the differences in moped and motorcycle injuries, a statewide trauma registry would provide a more robust data set for future studies. Additionally, collecting injury data starting at the time of police report would capture a greater percentage of all powered two-wheeled vehicle collisions. Advantages of this study include one of the largest moped cohorts to compare to motorcycle riders, with one of the largest series of moped injuries published so far. These data were collected at the time of hospitalization and is the only moped rider injury study to date to examine fracture location by specific bone. Additionally, this facility is the primary tertiary referral center in Hawai'i with the highest-level trauma designation in the state with a catchment area including the entire state, allowing this study to present a representative sample of riders of powered two-wheeled vehicles in Hawai'i with injuries.

Based our findings, some recommendations can be put forth for further consideration and testing. This includes requiring helmets for all moped and motorcycle riders to reduce the number of facial and cranial injuries. Many previous studies have demonstrated a reduction in head injuries, facial fractures, and fatality accidents after the adoption of mandatory helmet laws.[28] In addition to helmets, white or reflective clothing has been found to reduce accidents in previous studies.[29] Requiring basic moped training may also be considered, although previous research on this has been inconclusive.[30-32]

Conclusion

Motorcycle and moped riders are amongst the highest risk groups in traffic. This study found several novel patterns in injuries when comparing moped and motorcycle accident trauma data. One is that moped and motorcycle riders had a similar risk of injury to their lower extremities. Moped riders were found to have an increased risk of head injury and facial fractures, likely due to lower levels of helmet use. Motorcyclists were found to have an increased risk of injury to the upper extremities, spine, pelvis and injury to the thoracoabdominal region. Both motorcycle and moped riders had similar injury scores and mortality even though their injury pattern differs. Our data demonstrate a vital need for safety improvements to reduce the incidence and severity of PTW accidents. The most effective safety improvement based on this study and previous studies would be the implementation of a mandatory helmet law for all PTW operators and passengers.

Conflicts of Interest

None of the authors identify a conflict of interest.

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