Epidemiology of Aquatic and Recreational Water Sport Injuries: A Case-Control Analysis

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abstract

The purposes of the current investigation are to evaluate the epidemiology of water sport injuries at a coastal tertiary trauma center and to determine the association of these activities with spinal column injury and to determine whether aquatic trauma injuries differ significantly from those that occur terrestrially. A retrospective review of a consecutive series of 105 patients with aquatic-based mechanisms of injury admitted to a Level II trauma center over a 3-year period, as well as a matched control cohort with terrestrial-based mechanisms of injury, was conducted. Patients were treated at a Level II trauma center from January 1, 2008, to December 31, 2010. All patients received a full trauma work-up on arrival. Patients were identified retrospectively from a prospectively collected database (N=5298). Eligible patients were identified from billing/coding data as having mechanisms of injury related to an aquatic setting. Patients were evaluated using standard trauma protocols. Spinal column and cord injury occurrence and differences between groups were reviewed. Personal watercrafts accounted for the majority of injuries (n=39). Cervical (33.3%), closed-head (25.7%), and thoracolumbar (21.9%) injuries accounted for the majority of injury types. The cervical spinal column and the spinal cord were at an increased risk of injury in the aquatic injury cohort (P<.0001). The current data show the high incidence of spinal column and cord injuries in this patient population relative to controls. Practitioners who care for trauma patients near an aquatic environment should be aware of the high prevalence of these injuries, with proper spinal cord preservation protocols in place to optimize outcome. [Orthopedics. 2015; 38(9):e813-e818.]
Several studies have been conducted on fracture epidemiology in the setting of specific risk factors, such as bicycling,\(^1\)\(^2\) motor vehicle collision,\(^3\) and even airplane injuries.\(^4\) A large-scale evaluation has not been done for the epidemiology of water-based recreational injuries occurring over several years at a populated coastal city. Summer in a coastal region is often accompanied by a surge of unique traumatic incidents associated with the aquatic environment and related recreational activities.\(^5\)^6 There is an increase in tourism to these regions and many of the incoming ocean-goers are less familiar with the risks and dangers associated with water-based recreational activities compared with individuals who encounter them more often. By examining the epidemiology of injuries arising from this seasonal-specific setting, it is believed that more favorable patient outcomes can be obtained through efficient injury management.

Spinal cord injuries in particular are devastating injuries that can result in permanent impairment of function and loss of quality of life, and in some instances can be fatal.\(^7\) Optimum outcome is often achieved when the health care team caring for these injured patients is well seasoned in caring for these injuries with current spinal protocols and treatments (eg, American Association of Neurological Surgeons guidelines\(^8)\), including spinal immobilization and nonoperative vs operative stabilization.

Spinal cord injuries are most common following high-energy mechanisms, which are involved with numerous recreational activities.\(^9\)^-^\(^1\)\(^5\) These include contact sporting activities,\(^16\)^-^\(^1\)\(^8\) motorized vehicle operation, and falls.\(^19\) On coastal waters, a variety of recreational activities exist that carry a predisposition to spinal cord and other traumatic injuries.\(^20\) These include surfing, personal motorized watercraft operation (ie, riding a wave-runner or boating), swimming, kayaking, and bodysurfing. Injuries often occur following these activities due to the high-force nature of these mechanisms combined with the possibility that the event may occur in shallow water near the shoreline, which can lead to headfirst encounters with the ocean floor.

The purpose of the current investigation was to evaluate the nature and mechanisms of injury of recreational water sports in a coastal environment. In addition, the authors sought to determine whether the risk of spinal cord and column injury or other types of bodily injury were more significantly associated with water-based activities relative to those that occur on land in a defined trauma population.

**Materials and Methods**

Institutional review board approval was obtained for this study. All patients were retrospectively identified from a prospectively collected database of patients admitted to the trauma service at the authors’ local tertiary trauma center located on the East Coast. This trauma database and registry are maintained by the admitting trauma service and collect patient demographic data relating to mechanism of injury, injury severity score (ISS), length of stay (LOS), complications encountered, transfusion requirements, surgical procedures performed, age, gender, and medical comorbidities.

Patients enrolled from January 1, 2008, to December 31, 2010, served as the cohort population of patients. This represented 5298 patients admitted as an alert during this time frame. Patients for the case group were eligible for inclusion if they were admitted/injured in the context of water-based activity or recreational sport (eg, swimming, surfing, boating, personal watercraft use). This led to 105 patients eligible for inclusion. For comparative analysis, a control group of patients (matched by age, gender, and ISS) were also obtained from admissions during the same time frame and from the same larger cohort (Table 1). Patients in both cohorts were analyzed in similar fashion and compared using Fisher’s exact tests, Wilcoxon rank sum tests, and a Bonferroni correction.

**Results**

During the study period, there were 5298 trauma admissions, 1672 of which occurred during the summer months. Trauma patients were then excluded from the case group (n=5193) if they did not meet the criteria of having a mechanism of injury originating from a recreational water sport. In the aquatic injury group, there were 75 men (mean age, 37.19 years) and 30 women (mean age, 34.50 years), with a mean ISS of 8.89. Mean LOS was 5.41 days, with a mean LOS in the intensive care unit (ICU) of 5 days.

Twenty-eight (26.7%) patients required surgical stabilization. Mechanisms of injury included 24 (22.9%) wave-runner accidents, 15 (14.3%) boating accidents, 14 (13.3%) bodyboarding injuries, 13 (12.4%) falls, 11 (10.5%) diving accidents, 9 (8.6%) body-surfing accidents, 9 (8.6%) surfing accidents, 8 (7.6%) hits by a wave, 1 (1.0%) tubing accident, and 1 (1.0%) explosion.

Complications included 9 (8.6%) infections, 6 (5.7%) cases of pneumonia/atelectasis, 2 (1.9%) pre-hospital cardiac arrests (traumatic arrests, not due to occlusion of coronary arteries), 2 (1.9%) incidences of deep venous thrombosis.

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**Table 1**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Aquatic (Case)</th>
<th>Terrestrial (Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male, No. (%)</td>
<td>75 (71.4)</td>
<td>75 (71.4)</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>37.19</td>
<td>38.85</td>
</tr>
<tr>
<td>Female, No. (%)</td>
<td>30 (28.6)</td>
<td>30 (28.6)</td>
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<tr>
<td>Age, mean, y</td>
<td>34.50</td>
<td>36.30</td>
</tr>
<tr>
<td>ISS, mean</td>
<td>8.89</td>
<td>9.30</td>
</tr>
<tr>
<td>LOS, mean, d</td>
<td>5.41</td>
<td>6.02</td>
</tr>
</tbody>
</table>

Abbreviations: ISS, injury severity score; LOS, length of stay.
and 1 (1.0%) myocardial infarction. There were 27 (25.7%) concussions, of which 7 (6.7%) had significant closed-head hematomas (epidural hematoma, subdural hematoma, subarachnoid hematoma, intraparenchymal hematoma, or intraventricular hematoma). There were 57 (54.3%) spinal column injuries, of which 20 (19.0%) were significant spinal cord injuries that resulted in neurological deficits. Ten (9.5%) patients required a blood transfusion.

The control group consisted of an equivalent distribution of gender and similar mean ages and ISS. Mean LOS was 6.02 days and mean ICU LOS was not recorded. Nineteen (18.1%) patients required surgical stabilization. Mechanisms of injury included 51 (48.6%) motor vehicle collisions, 31 (29.5%) falls, 14 (13.3%) pedestrians struck, 5 (4.8%) gunshot wounds, 3 (2.9%) falling objects, and 1 (1.0%) assault.

Complications included 12 (11.4%) infections, 9 (8.6%) retroperitoneal hematomas, 2 (1.9%) cases of pneumonia/atelectasis, 1 (1.0%) pulmonary embolus, and 1 (1.0%) embolization. There were 23 (21.9%) concussions, of which 2 (1.9%) were significant closed-head hematomas. There were 11 (10.5%) spinal column injuries of which 1 (1.0%) had a significant spinal cord injury resulting in neurological deficits. Three (2.9%) patients required a blood transfusion (Table 2).

In the aquatic injury group, the spinal column injuries occurred in the cervical region in 35 (33.3%) patients, lumbar region in 13 (12.4%), thoracic region in 10 (9.5%), and sacral region in 2 (1.9%); spinal cord injuries occurred in the cervical region in 19 (18.1%) and the thoracic region in 1 (1.0%). In the terrestrial cohort, the spinal column injuries occurred in the lumbar region in 8 (7.6%) patients, thoracic region in 3 (2.9%), and cervical region in 2 (1.9%); the spinal cord injury occurred in the lumbar region in 1 (1.0%) patient (Tables 3-4).

**DISCUSSION**

These data indicate that, in a coastal environment, recreational aquatic injuries are a common cause of morbidity. Spinal column injuries were more common following aquatic injuries (54.3%) than following terrestrial injuries (12.4%) (Figure 1). Spinal column injuries were also significantly more likely (P<.0001; odds ratio: 24.21) to involve a spinal cord injury in the aquatic injury cohort compared with the terrestrial cohort (19.0% vs 1.0%, respectively).

Cervical injuries represented a large risk among the aquatic injury cohort, with 33.3% of patients sustaining a cervical injury compared with the terrestrial group, which included 1.9% of patients who sustained cervical injuries. This difference was found to be significant (P<.0001;
Figure 1: Bar graphs showing spinal injuries.

Figure 2: Bar graphs showing head injuries.

The observed injury distribution among the groups was consistent with what was expected by the research team. Aquatic spinal cord injuries most often occurred in shallow waters that allowed for the patient’s head to strike the ground under the water in a flexed position. In addition, the lack of restraining equipment present on personal watercrafts combined with the high speeds that these watercrafts are able to achieve makes an ejection off the vehicle following a sudden deceleration a highly likely scenario. These ejected individuals are traveling at a high rate of speed when striking the water, leading to a head-on collision with the ground. It is possible that with a larger sample size the rate of traumatic closed-head hematomas could be found to be significantly greater, but this was not found to be the case during the time frame of this study.

The use of alcohol and other recreational substances also contributed to the observed pattern of injury. The number of intoxicated patients in the aquatic injury cohort was greater than the terrestrial cohort (13.3% vs 7.6%, respectively) but was not significantly greater ($P=0.2596$). This increased rate is consistent with the vacation atmosphere, which led to the seasonal increase in aquatic injuries in this setting. Intoxicated vacationers are less inhibited and less coordinated, which could have led to the occurrence of the injury and to additional compromise of the spinal cord.

When examining the incidence of infections, it was found that among the 9 patients who had a positive culture documented during admission, there was also an extended average LOS in the ICU compared with the rest of the cohort (12 vs 5 days, respectively) in these patients. Two of those patients had their first positive cultures more than 1 week after admission and were likely nosocomial in origin. Of the 5 patients who required surgical stabilization, only 1 used an intrawound antibiotic infused substance (multiple antibiotic impregnated beads) and none used intra-wound vancomycin powder. Three infections occurred in patients also experiencing a spinal cord injury and 2 occurred in patients with closed-head hematomas. Most of the infections, with the exception of the likely nosocomial ones, were the result of aspiration or wound contamination.

The majority of aquatic injuries were due to personal watercraft (wave-runner and boating) accidents (37.2%) followed by bodyboarding (13.3%), falls into water (12.4%), diving (10.5%), bodysurfing (8.6%), surfing (8.6%), and being struck by waves (7.6%). This shows that within this population, personal watercrafts represented the most common mechanism for injury. Personal motorized watercrafts can achieve speeds equivalent to cars and other land-based motor vehicles traveling on a highway; therefore, it is not surprising that collisions and other forms of sudden deceleration events are often associated with trauma center criteria injuries.

Bodyboarding resulted in cervical injuries 57.1% of the time and was not associated with injuries to any other segment of the spinal column. Bodysurfing accidents were always associated with an injury to the spinal column, with 88.9% of injuries to the cervical spine and 11.1% to the thoracic spine. Diving injuries almost always resulted in injury to the spinal column, with 63.6% resulting in cervical injuries. Being struck by a wave commonly resulted in spinal column injuries, with 50% of injuries to the cervical spine and 25% to the thoracic spine. Surfing was most often associated with cervical injuries (44.4%), and personal watercraft (wave-runner) injuries were most commonly associated with lumbar spine injuries (29.2%). Falls and boating were less likely to result in a spinal trauma and did not favor any specific region of the spinal column. Personal watercraft (wave-runner) accidents were also associated with torso-visceral injuries in 25% of patients, which seems consistent with the observed risk to the lower spinal column.

It is worth noting that the difference in LOS was close to being significantly different ($P=0.008028$) after correcting the $P$ value for error with a Bonferroni’s Correction ($P=0.00385$ needed for significance). The median LOS was 3 days for the aquatic injury cohort and 5 days for the terrestrial cohort. The difference ap-
pears to arise from several outlier patients who required an extended hospital stay due to numerous other factors, including injury care, continuing health management, and inability to obtain placement in an appropriate care facility. Therefore, it is unclear whether this value reflected the care necessary for the presenting injuries.

Although there are no known large-scale epidemiologic studies of coastal water sport injuries published, there have been studies that tangentially touched on the issue. A study of male patients who sustained spinal injuries related to water-based incidents related diving and alcohol use to the likelihood of injury. Individual mechanisms have been examined and their epidemiologies reported. Recreational boating and the risks and injuries associated with that activity was the subject of a recent epidemiologic study, which showed that the most likely cause of death on the water was human error. Another study examined canoeing, kayaking, and rafting and the injuries associated with participation in these activities.

Waterskiing and personal watercraft-related injuries were examined and showed a high increase in injuries related to personal watercraft use and guidelines for safer recreational uses were suggested. Skimboarding injuries were also examined for their prevalence to result in lower extremity injury; however, there were no trauma admissions following a skateboard accident during the time frame that was examined in the current study, suggesting that these injuries tend to not qualify for admission to a trauma center. Wave-related injuries were examined and showed a high risk for the elderly due to preexisting cervical spondylosis resulting in central cord syndrome following hyperextension of the neck, as well as the ocean-goer with weak swimming skills. Other studies have looked at water-based injuries and deaths without the context of engagement in a water sport. These studies include an examination of pediatric injuries in relation to any source of water and all water-based fatalities based on autopsy information.

A limitation of this study was the retrospective nature of the analysis. Retrospective studies may be more susceptible to selection bias. Although all data were collected prospectively, it was not recorded with the current study in mind and it is possible that pertinent data may have been overlooked. Patients who expired at the scene of the accident would not have been included, making it reasonable to assume there is some degree of survivorship bias present. It was surprising to the investigators that neither group included any fatalities from the time emergency medical services assumed care of the patients until discharge. Although this is an encouraging scenario, it is not the typical situation experienced while dealing with as many high-velocity mechanisms of injury as were included in this study.

**CONCLUSION**

To the authors’ knowledge, this is the largest epidemiologic series to date on aquatic and water sport injuries. The data show the high incidence of spinal column and spinal cord injuries in this patient population relative to controls. Practitioners who care for trauma patients near an aquatic environment should be aware of the high prevalence of these injuries, with proper spinal cord preservation protocols in place to optimize outcome. Awareness of the associated risk of closed-head injuries should also be taken into account during the workup of patients involved in these high-risk activities. Future strategies aimed at preventing these injuries in seasonal visitors and native coastal inhabitants should be a critical part of any comprehensive regional trauma program.

**REFERENCES**


