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Research article

A comparison of wakeboard-, water skiing-, and tubing-related injuries in the United States, 2000-2007

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Abstract
The purpose of the study was to compare tubing-related injuries to wakeboarding- and water skiing-related injuries. Data was collected from the 2000-2007 National Electronic Injury Surveillance Survey for 1,761 individuals seeking care at an emergency department due to a tubing-, wakeboarding, or water skiing-related injury. Data included patient age and sex, as well as injury characteristics including body region injured (i.e., head and neck, trunk, shoulder and upper extremity, and hip and lower extremity) and diagnosis of injury (e.g., contusion, laceration, or fracture). Case narratives were reviewed to ensure that a tubing-, wakeboarding-, or water skiing-related injury occurred while the individual was being towed behind a boat. Severe injury (defined as an injury resulting in the individual being hospitalized, transferred, held for observation) was compared among the groups using logistic regression. Wakeboard- and tubing-related injuries more commonly involved the head and neck, while water skiing-related injuries were likely to involve the hip and lower extremity. Tubing-related injuries, compared to water skiing-related injuries, were more likely to be severe (OR 2.31, 95% CI 1.23-4.33). Like wakeboarding and water skiing, tubing has inherent risks that must be understood by the participant. While tubing is generally considered a safer alternative to wakeboarding and water skiing, the results of the current study suggest otherwise. Both the number and severity of tubing-related injuries could be prevented through means such as advocating the use of protective wear such as helmets while riding a tube or having recommended safe towing speeds prominently placed on inner tubes.

Key words: Water tubing; water skiing; wakeboarding; epidemiology; injury.

Introduction

Water skiing, wakeboarding, and inner tubing are common recreational activities on many waterways in the United States. Water skiing, an adaptation from snow skiing, has been around since the 1920s (Banta, 1979), and wakeboarding, a more recent sport, was adapted from snowboarding (Hostetler, 2005). Inner tubing, commonly known as tubing, became popular in the 1970s. All three involve hydroplaning behind an engine-powered marine vessel while being tethered to a tow cable that is, for both water skiing and wakeboarding, hand held or, for tubing, attached. While skiers or wakeboarders are able to maneuver voluntarily in and out of the wake of the pulling vessel (Hostetler, 2005), tubers' movements are largely involuntary and controlled by the driver of the pulling vessel (Parmar, 1998).

Water skiing related injuries have been well documented and can range from small contusions and lacerations to fractures and spinal cord damage (Hostetler, 2005). Injuries related to wakeboarding include ACL and PCL tears, fractures, cardiac rupture, intracranial hemorrhage, and lacerations (Carson, 2004; Chia, 2000; Hostetler, 2005; Narita, 2004; Su, 2007; Takakashi, 2004). A 2005 study that compared water skiing-related and wakeboarding-related injuries from 2001-2003 concluded that the number, diagnosis, and body region varied by sport (Hostetler, 2005). However, injuries related to tubing are limited to two case reports. One report describes a penetration of the occipital skull with a carabiner (Carter, 2001), while the other describes a range of serious injuries (Parmar, 1998).

To our knowledge no study has compared injuries associated with these three recreational activities. Herein we present the characteristics of injuries treated in U.S. emergency departments from 2000 to 2007 while participating in water skiing, wakeboarding, and tubing.

Methods

The 2000-2007 National Electronic Injury Surveillance System (NEISS) was used to acquire data for this study. The NEISS was created in 1971 by the U.S. Consumer Product Safety Commission and is used to monitor injuries associated with consumer products. NEISS is a probability sample of approximately 100 hospitals with 24-hour emergency departments arranged by location and size of the hospitals involved. The sampling procedure used by the NEISS and the statistical basis for the calculation of national estimates based upon the NEISS data are described in detail elsewhere (Schroeder, 2001; CPSC, 2000). Used by government agencies and researchers, the NEISS database is constantly accessed and its selection procedure and derivation of sampling weights is well established. Weights were applied to the NEISS probability sample data to account for selection, number of annual emergency department visits for a hospital, and for hospitals that don't respond. After being weighted, the data gives the estimates for the total number of specific consumer product-related injuries in the United States. NEISS staff is located on-site in most of the participating emergency departments to gather data from medical re-

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cords that includes patient's sex, age, race, diagnosis of injury, injured body part, treatment, and product(s) involved and to assign product-related codes to selected injuries. To account for sampling errors (CPSC, 2000), 95% confidence intervals (CI) were calculated using the standard error of the national estimate.

Water skiing-, wakeboarding-, and tubing-related injuries were identified using the consumer product codes for water skiing/wakeboarding (1264) and tubing (3200), which includes injuries related to knee boarding/skim boarding. The narratives associated with these codes were reviewed to ensure that the injury occurred while being pulled or towed by a boat. Narratives that included knee boarding, skim boarding, and bare-foot skiing or were related to tubing at water parks were excluded. Additionally, narratives that didn't specifically state or infer that the tuber was being pulled by, or was tubing behind a powered vessel were excluded. Narratives that included injuries sustained while "water boarding" were marked as wakeboarding injuries.

The 2000-2007 U.S. Census was used for calculating the rate of injuries sustained for each water-sport. Injury rates were estimated according to age, race, and gender. To describe the anatomical location of the injuries, four body regions were designated: head and neck, trunk, shoulder and upper extremity, and hip and lower extremity. The types of injuries distributed within each region (e.g., fracture or laceration) were also compared. Odds ratios (OR) and associated 95% confidence intervals (95% CI)—calculated using logistic regression adjusted for age and gender—estimated the association between severe injury (defined as an injury that was required the patient to be hospitalized, transferred, or held for observation) and type of water sport. All analyses were performed using SAS 9.1, and standard errors for significance tests were adjusted by the provided statistical weights.

Results

Between 2000-2007, an estimated 11,045 tubing-, 18,967 wakeboarding-, and 52,399 water skiing-related injuries occurred in the U.S. (Table 1). Wakeboarding-related injury rates increased from 2000 (0.60 per 100,000) to 2007 (1.33 per 100,000); water skiing injury rates decreased from 3.32 per 100,000 in 2000 1.51 per 100,000 in 2007; and tubing-related injury rates have remained relatively stable from 2000 (0.53 per 100,000) to 2007 (0.57 per 100,000). All three sport types have higher injury rates for males compared to females (0.35 per 100,000 vs. 1.29 per 100,000 for wakeboarding, 1.13 per 100,000 vs. 3.39 per 100,000 for water skiing, and 0.40 per 100,000 vs. 0.55 per 100,000 for tubing). For both wakeboarding and water skiing, injury rates peaked at ages 20-29 (2.62 and 4.59 per 100,000, respectively), although tubing-related injury rates peaked at ages 10-19 (1.33 per 100,000). While rates declined with increasing age after peaking for wakeboarding- and tubing-related injuries, rates remained relatively stable across ages for water skiing-related injuries through ages 40-49.

The head and neck was the most common body region area injured for both wakeboarding- (47.9%) and tubing-related (34.7%) injuries and the second most common body part injured for water skiing-related (24.6%) injuries. Laceration was the most common diagnosis for head and neck injuries for both wakeboarding- (51.3%) and water skiing-related (46.3%) injuries, while tubing-related head and neck injuries were mostly diagnosed as strains/sprains (21.6%), lacerations (15.4%), concussion (15.2%), or contusions/abrasions (15.2%) (Table 2).

The hip and lower extremity was injured in 26.5% of wakeboarding- and 19.0% of tubing-related injuries but was the most common injury among water skiers (35.9%). Of hip and lower extremity injuries, strains and sprains were the most common diagnosis for all three water sports. Lacerations and contusions/abrasions were more commonly diagnosed for tubing-related hip and lower extremity injuries (14.9% and 15.5%, respectively) compared to wakeboarding (4.5% and 7.2%, respectively) and water skiing (8.7% and 9.9%, respectively); however,

Table 1. Estimated Number of Water-Sports Related Injuries and Rates* (Per 100,000 Persons) and 95% Confidence Intervals (CI) by Selected Demographic Characteristics, 2000-2007. * Based on the U.S. census population

		Wakeboarding		Water skiing		Tubing	
		Estimate	Rate (95%CI)	Estimate	Rate (95% CI)	Estimate	Rate (95% CI)
Overall		18,967	0.81 (0.39-1.24)	52,399	2.24 (1.74-2.75)	11,045	0.47 (0.33-0.62)
Year	**2000**	1,703	0.60 (0.23-0.98)	9,370	3.32 (2.43-4.20)	1,502	0.53 (0.25-0.82)
	2001	1,355	0.48 (0.14-0.81)	8,977	3.15 (2.21-4.09)	1,660	0.58 (0.34-0.83)
	2002	2,112	0.73 (0.23-1.24)	7,268	2.52 (1.71-3.34)	1,234	0.43 (0.24-0.62)
	2003	2,189	0.75 (0.20-1.31)	6,938	2.39 91.71-3.06)	477	0.16 (0.04-0.29)
	2004	1,483	0.51 (0.10-0.91)	4,808	1.64 (1.15-2.13)	957	0.33 (0.16-0.50)
	2005	1,953	0.66 (0.34-0.98)	5,137	1.74 (1.20-2.27)	1,324	0.45 (0.24-0.65)
	2006	4,157	1.39 (0.22-2.56)	5,347	1.79 (1.23-2.35)	2,183	0.73 (0.35-1.11)
	2007	4,014	1.33 (0.68-1.98)	4,555	1.51 (1.07-1.95)	1,707	0.57 (0.32-0.81)
Age	**Mean (Range)**	23.4 (5-50)		31.6 (4-82)		24.7 (2-69)	
	0-9	137	0.04 (0.00-0.10)	600	0.19 (0.06-0.31)	409	0.13 (0.00-0.25)
	10-19	6,499	1.95 (0.84-3.06)	9,774	2.94 (2.10-3.77)	4436	1.33 (0.83-1.83)
	20-29	8,403	2.62 (1.30-3.94)	14,744	4.59 (3.41-5.78)	2650	0.83 (0.56-1.09)
	30-39	3,001	0.90 (0.38-1.41)	11,941	3.57 (2.53-4.60)	2311	0.69 (0.37-1.01)
	40-49	911	0.26 (0.02-0.49)	10,825	3.04 (2.27-3.81)	691	0.19 (0.07-0.31)
	50-59	15	0.01 (0.00-0.02)	3,515	1.24 (0.79-1.69)	393	0.14 (0.01-0.27)
	60+	0	0	1,000	0.26 (0.11-0.40)	156	0.04 (0.00-0.09)
Gender	**Female**	4,143	0.35 (0.14-0.56)	13,412	1.13 (0.81-1.45)	4,694	0.40 (0.26-0.53)
	Male	14,824	1.29 (0.62-1.96)	38,987	3.39 (2.64-4.15)	6,351	0.55 (0.36-0.75)

Table 2. Characteristics of water-sports related injuries* by Sport, 2000-2007.

Body Location and Diagnosis	Wakeboarding Estimate†	%	Water skiing Estimate†	%	Tubing Estimate†	%
Overall‡	**18882**		**51923**		**11045**	**18882**
Head and Neck	**9081 (3623-14529)**	**47.9**	**12736 (9336-16135)**	**24.6**	**3830 (2140-5520)**	**34.7**
Concussion	2261 (939-3583)	24.9	1239 (578-1900)	9.7	583 (186-836)	15.2
Contusion/Abrasion	300 (45-555)	3.3	654 (274-1034)	5.1	583 (80-1085)	15.2
Fracture	261 (18-504)	2.9	595 (227-964)	4.7	380 (126-633)	9.9
Laceration	4660 (1235-8086)	51.3	5901 (4036-7767)	46.3	588 (0-1229)	15.4
Strain/Sprain	197 (0-396)	2.2	1550 (960-2140)	12.2	867 (448-1286)	21.6
Other	1402 (349-2454)	15.4	2323 (1799-3675)	21.5	900 (475-1324)	22.6
Hip and Lower Extremity	**5009 (2573-7445)**	**26.5**	**18644 (14215-23072)**	**35.9**	**2104 (1109-3099)**	**19.0**
Contusion/Abrasion	362 (74-650)	7.2	1850 (1089-2611)	9.9	327 (47-606)	15.5
Dislocation	84 (0-223)	1.7	164 (0-419)	0.9	0	-
Fracture	1065 (346-1785)	21.3	1990 (1169-2811)	10.7	101 (0-249)	4.8
Laceration	227 (4-450)	4.5	1618 (704-2533)	8.7	313 (0-742)	14.9
Strain/Sprain	2870 (1208-4531)	57.3	10444 (8034-12855)	56.0	1130 (465-1796)	53.7
Other	402 (43-760)	8.0	2578 (1450-3706)	8.7	233 (0-504)	11.1
Shoulder and Upper Extremity	**2802 (823-4781)**	**14.8**	**9479 (6287-12672)**	**18.3**	**2666 (1490-3842)**	**24.1**
Contusion/Abrasion	711 (0-1598)	25.4	1772 (1001-2543)	18.6	398 (80-716)	14.9
Dislocation	945 (174-1716)	33.7	950 (55-1843)	10.0	195 (0-415)	7.3
Fracture	366 (76-656)	13.1	964 (345-1584)	10.2	783 (276-1289)	29.4
Laceration	35 (0-104)	1.2	590 (180-999)	6.2	6 (0-18)	0.2
Strain/Sprain	582 (204-959)	20.8	3109 (1971-4247)	32.8	927 (433-1421)	34.8
Other	164 (0-375)	5.9	2094 (1204-2984)	22.1	282 (0-826)	10.6
Trunk	**1990 (860-3119)**	**10.6**	**11064 (8352-13777)**	**21.3**	**2445 (1432-3457)**	**22.1**
Contusion/Abrasion	703 (195-1210)	35.3	3138 (2128-4147)	28.4	928 (366-1490)	38.0
Dislocation	35 (0-104)	1.7	87 (0-230)	0.8	71 (0-213)	2.9
Fracture	216 (0-435)	10.9	1594 (927-2261)	14.4	103 (0-249)	4.2
Internal Injury	16 (0-47)	0.8	74 (0-210)	0.7	95 (0-256)	3.9
Sprain/Strain	722 (258-1186)	36.3	4273 (2730-5816)	38.6	800 (282-1318)	32.7
Other	298 (17-580)	15.0	1832 (1095-2569)	15.9	370 (121-774)	15.1

* Estimates based on weighted data. † Weighted estimates <1200 cases may be statistically unstable. ‡ Estimates differ from those reported in Table 1 due to missing information for injury characteristics.

fractures were less commonly diagnosed for tubing-related injuries (4.8%) compared to wakeboarding-related injuries (21.3%) and for water skiing-related injuries(10.7%).

Table 3. Crude (cOR) and adjusted* odds ratios (aOR) and associated 95% confidence intervals (95% CI) for the association between severe injury and type of water sport.

Sport	Number of severe injuries† (%)	cOR (95% CI)	aOR (95% CI)
Water skiing	1,764 (3.4)	Reference	Reference
Wakeboarding	336 (1.8)	.52 (.20-1.34)	.56 (.21-1.52)
Tubing	854 (7.7)	2.40 (1.19-4.85)	2.31 (1.23-4.33)

* Adjusted for age and gender. † Number of serious injuries based on weighted data.

Injuries to the shoulder/upper extremity and trunk body regions were proportionately similar for wakeboarding- (14.8% and 10.6%, respectively), water skiing- (18.3% and 21.3%, respectively) and tubing (24.1% and 22.1%, respectively). For tubing-related shoulder and upper extremity injuries, the most common diagnosis was a strain or sprain (34.8%), followed closely by fractures (29.4%). For water skiing-related injuries, shoulder and upper extremity injuries were more commonly diagnosed as sprains or strains (34.8%), followed by contusions or abrasions (18.6%). Dislocations were the most common diagnosis for wakeboarding-related shoulder and upper extremity injuries (33.7%), followed by contusions or abrasions (25.4%) and strains or sprains (20.8%).

Compared to water skiing-related injuries, there was no statistical difference in the risk of severe injury for wakeboarding-related injuries (OR 0.52, 95% CI 0.20-1.34), although the risk was estimated to be half of that of water skiing-related injuries (Table 3). Conversely, tubing-related injuries were more than twice as likely to be severe (OR 2.40, 95% CI 1.19-4.85). Adjusting the models.for age and gender did not appreciably alter the measures of association.

Discussion

The results of the current study suggest that, while tubing-related injuries are less common compared to wakeboard- and water skiing-related injuries, they are often more severe. To our knowledge, this is the first study to directly compare tubing-, wakeboard- and water skiing-related injuries; however, previous research has compared water skiing- to wakeboard-related injuries (Hostetler, 2005). Both studies report that the most common wakeboard-related injuries were lacerations to the head and the most common water skiing-related injuries were strains and sprains to the lower extremity. To put the currently reported injury rates and distributions into perspective, the estimated rate of personal watercraft-related injuries (i.e., jet skis) from previously reported numbers is approximately 2.14/100,000 (Branche, 1997) compared to the currently reported rates of 0.47/100,000, 0.81/100,000,

and 2.24/100,000 for tubing-, wakeboarding-, and water skiing-related injuries, respectively. Additionally, the distribution of the body part and diagnosis of injury is similar between personal watercraft-related injuries and wakeboarding-, water skiing-, and tubing-related injuries. More specifically, most of the injuries occurred to the head and lower extremities and were either fractures or soft tissue injuries (i.e., contusions, lacerations, and abrasions) (Branche, 1997; Haan, 2002; Hamman, 1993; White, 1999).

The age distribution of tubing-related injuries was similar to that of wakeboarding-related injuries, with a peak in late-adolescence to early adulthood followed by a decline with increasing age. As has been suggested previously, this is more than likely due to the increased participation of these sports among younger individuals (Hostetler, 2005). Interestingly, the rate of wakeboarding injuries has remained relatively stable despite a 33% decrease in the number of individuals six years of age or older who reported participating in wakeboarding at least once a year (SGMA, 2007). This could be due to the fact that those who continue to participate in wakeboarding take more risks than those who discontinue the sport (Hostetler, 2005), resulting in this group constituting the majority of burden of injury among participants. In contrast, the rate of injuries due to water skiing—which does not typically involve performing tricks (Hostetler, 2005)—decreased, possibly due to a 39% decrease in the number of participants during the same time period (SGMA, 2007). While there is no available data for the number of tubing participants, given the decreases in related sports (e.g., wakeboarding, water skiing, and jet skiing) (SGMA, 2007), there is no reason to believe that the trend in tubing participation is any different.

The distribution of the body part injured and diagnoses of tubing-related injuries are similar to the distribution for water skiing-related injuries. This could be due in part to the increased speed at which both boats pull water skiers and tubers compared to wakeboarders (Carson, 2004). Suggested boat speeds for tubing vary by age with suggestions of under 16 kph for children 12 and under, under 32 kph for teens aged 13-16, and under 40 kph for persons aged 17 or older. Comparatively, the recommended boat speed for wakeboarding ranges from 25 to 40 kph, and for water skiing—depending on the type of activity (i.e., slalom, shaped, or combo skiing)—ranges from 32 to 56 kph.

Previous research of tubing-related injuries has been limited to either a case report (Carter, 2001) or a case-series (Parmar, 1998), and while limited, has suggested that the lower extremities are more frequently injured. The current study, however, observed a preponderance of head and neck injuries followed by similar proportions of other body regions injured. Differences between the previous reports, however, can be attributed to differences in population (i.e., the previous study included only tubing-related injuries among children) and the fact that larger sample size using nationally representative data of the current study provides a more generalized observation of tubing-related injuries. Like wakeboarding-related injuries, the increased proportion of tubing-related head and neck injuries could be due to the flipping over of the tube while being pulled, causing the occupant's head and neck to be the first part of the body to contact the water (Carson, 2004). Additionally, unlike wakeboarders and water skiers who remain standing while being pulled, tubers lay flat on the inner tube. This could predispose tubers to head, neck, shoulder, and upper extremity injuries, as their forward momentum after falling from the inner tube could cause these body regions to contact the water before other regions such as the hip and lower extremities. The results of the current study support this notion, as increases in proportions of head, neck, and shoulder and upper extremity injuries were observed for tubers compared to wakeboarders and water skiers, who more commonly suffered hip and lower extremity injuries. The increase in hip and lower extremity injuries related to wakeboarding and water skiing could be due to the fact that these sports require more use of the hips and legs compared to tubing.

The observed increases in concussions and fractures may explain the increased likelihood of severe tubing-related injuries compared to water skiing-related injuries, as these may require more medical attention compared to lacerations, contusions, and abrasions. However, this does not fully explain this finding as adjustment for fracture and concussion in the statistical models did not meaningfully alter the observed associations. While information regarding multiple injuries was not available in the NEISS data (only the most severe injury is included), it is also possible that tubers may more often suffer multiple injuries compared to water skiers or wakeboarders. These more severe injuries may also be attributed to the fact that, unlike most waterskiing and wakeboarding, tubing can be done with more than one person (either on a single tube or multiple tubes). Thus, riders may experience more serious injuries by experience collisions with other riders than simply from contact with the water.

These results should be viewed in light of certain strengths and limitations. The current study was strengthened by the use of a nationally representative dataset that allowed for the estimation of national incidence of injuries related to water skiing, wakeboarding, and tubing. Inspection of the narratives describing each injury decreased the likelihood of misclassification of the type of sport involved in the injury, particularly for tubing-related injuries, which could have occurred while being towed in a boat or in other instances such as at a water park or floating down a river. The narratives, however, did not contain details on whether multiple individuals were on a single tube being towed or a single individual is on multiple tubes, both of which can increase the risk of tubing-related injury. While inclusion of multiple years of data allowed for a greater sample size to be included than in previous studies (Carson, 2004; Hostetler, 2005; Parmar, 1998), there still was not sufficient sample size to provide more detailed analysis such as likelihood of hospital admission or transfer by injury diagnosis, which could help to explain why tubing-related injuries are more severe. While we were able to compare types of injuries by body region injured, this fine an examination of the data resulted in many strata having small samples sizes. With NEISS data, weighted estimates less than 1200 cases are

generally viewed as being statistically unreliable. As a result, we caution against making definitive conclusions regarding injury types by water sport. Additionally, detailed information regarding severity of the injury was not available. While hospitalization, transferal, or being held for observation was used as a proxy for severe injury, the use of measures of severity such as the Injury Severity Score would have been preferable to allow for a more direct comparison of severity among water sport types.

As noted in previous research (Hostetler, 2005), the current results may not reflect all water sport-related injuries in the United States, as those that are less severe either do not require care or are cared for in non-ED settings such as physicians' offices or primary care centers. Also, while the U.S. census population was used as the rate denominator, this assumes everyone is at risk of water sport-related injury; however, only those who participate in a water sport are at risk of injury. As a result, the reported rates are an underestimate of the true rates. Additionally, since there are more individuals who report participating in water-skiing than other related water sports (SGMA, 2007), the rates are differentially biased among wakeboard-, water skiing-, and tubing-related injuries.

Conclusion

Like wakeboarding and water skiing, tubing has inherent risks that must be appreciated. Unlike the aforementioned sports, tubers have little control, which may predispose them to injuries, particularly those related to running into shallow water or becoming airborne off of the wake created by the pulling boat. Prior research suggests the distribution of tubing-related injuries encourages consideration for the use of protective equipment such as helmets to potentially attenuate the severity and incidence of these injuries. Both persons riding the tubes and those operating the towing boat should be aware of the risks associated with the sport and ensure the safety of all involved.

While tubing is generally considered as a safer alternative to other water-related activities such as water skiing and wakeboarding, particularly for younger individuals, the results of this study imply that this is not the case. It is not realistic to suggest placing age restrictions on water tubing, particularly since the injuries are generally among younger individuals. Instead, prevention efforts should be aimed at safety measures to take while tubing. For instance, given the increased likelihood of head and neck injuries, tubing participants should consider the use of protective equipment such as helmets to decrease injury risk. Additionally, participants should be educated on the proper towing speeds based on the age of the tube rider, perhaps by prominently placing recommended towing speeds on the tube. While these measures will not prevent all related injuries, they would help to decrease the severity of injuries.

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Key points

- Increase annual injury rate trend in wakeboard injuries.
- Wakeboard- and tubing-related injuries more often to head and neck, waterskiing-related injuries more often to hip and lower extremity.
- Tubing-related injuries over 2-times as likely to be severe compared to waterskiing-related injuries.

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