The "weekend warrior": Fact or fiction for major trauma?

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Background: The "weekend warrior" engages in demanding recreational sporting activities on weekends despite minimal physical activity during the week. We sought to identify the incidence and injury patterns of major trauma from recreational sporting activities on weekends versus weekdays.

Methods: We performed a retrospective cohort study using the Alberta Trauma Registry comparing all adults who were severely injured (injury severity score [ISS] ≥ 12) while engaging in physical activity on weekends versus weekdays between 1995 and 2009.

Results: Among the 351 identified patients (median ISS 18; median hospital stay 6 d; mortality 6.6%), significantly more were injured on the weekend than during the week (54.8% v. 45.2%, p = 0.016). Common mechanisms were motocross (23.6%), hiking or mountain/rock climbing (15.4%), skateboarding or rollerblading (12.3%), hockey/ice-skating (10.3%) and aircraft- (9.9%) and water-related (7.7%) activities. This distribution was similar regardless of the day of the week. Most patients were injured as a result of a ground-level (21.9%) or higher fall while hiking, mountain climbing or rock climbing (25.9%); motocross-related incidents (24.2%); or collision with a tree, person, man-made object or moving vehicle (14.0%). Injury patterns were similar across both groups (all p > 0.05): head (55.8%), spine (35.1%), chest (35.0%), extremities (31.1%), face (17.4%), abdomen (13.1%). Surgical intervention was required in 41% of patients: 15.1% required open reduction and internal fixation, 8.3% spinal fixation, 7.4% craniotomy, 5.1% facial repair and 4.3% laparotomy.

Conclusion: The weekend warrior concept may be a validated entity for major trauma.

Contexte : Le « guerrier du dimanche » s'adonne à des activités sportives récréatives la fin de semaine, malgré un degré minime d'activité physique durant la semaine. Nous avons voulu mesurer l'incidence des blessures et les types de traumatismes majeurs consécutifs à des activités sportives pratiquées la fin de semaine plutôt que les jours de semaine.

Méthodes : Nous avons procédé à une étude de cohorte rétrospective à partir du registre de traumatologie de l'Alberta pour comparer tous les adultes victimes d'une blessure grave (score de gravité des traumatismes ≥ 12) lors de la pratique d'activités physiques la fin de semaine plutôt que les jours de semaine, entre 1995 et 2009.

Résultats : Parmi les 351 patients recensés (score médian 18, séjour hospitalier médian 6 j, mortalité 6,6 %), un nombre significativement plus grand se sont blessés la fin de semaine plutôt qu'un jour de semaine (54,8 % c. 45,2 %, p = 0,016). Les activités les plus souvent en cause étaient : motocross (23,6 %), randonnée/alpinisme/escalade (15,4 %), planche à roulettes ou patins à roues alignées (12,3 %), hockey/patin sur glace (10,3 %) et activités pratiqués dans les airs (9,9 %) et sur l'eau (7,7 %). Cette distribution est demeurée similaire, indépendamment du jour de la semaine. La plupart des patients ont subi leurs blessures par suite d'une chute au niveau du sol (21,9 %) ou de plus haut lors de randonnées, d'alpinisme ou d'escalade (25,9 %), d'un accident de motocross (24,2 %) ou d'une collision avec un arbre, une personne, un obstacle artificiel ou un véhicule en mouvement (14,0 %). Les types de traumatismes étaient similaires dans tous les groupes (tous, p > 0,05) : tête (55,8 %), colonne vertébrale (35,1 %), thorax (35,0 %), membres (31,1 %), visage (17,4 %), abdomen (13,1 %). Chez 41 % des patients, il a fallu intervenir chirurgicalement : 15,1 % réduction ouverte avec fixation interne, 8,3 % fixation vertébrale, 7,4 % craniotomie, 5,1 % intervention au visage et 4,3 % laparotomie.

Conclusion : Le concept de « guerrier du dimanche » pourrait être une entité valide associée à des traumatismes majeurs.

Given that physical activity is associated with personal and public health benefits, both the Centers for Disease Control and Prevention (CDC) and the American Heart Association recommended in 1995 that "every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week."[1–5] Unfortunately, a subsequent 2003 CDC follow-up study reported that only 45.9% of the US population met this recommendation.[6,7] A lack of time to exercise is commonly cited as the primary reason, possibly because the average time spent at work increased by approximately 163 hours per year between 1969 and 1987.[8,9]

As a result, many people compress their weekly exercise volume into long periods of physical activity on the weekend. This intensity gave rise to the colloquial term "weekend warrior."[7,8,10,11] Anecdotal reports have suggested that weekend warriors are not uncommon and that even sporadic physical activity may reduce mortality among those without major cardiovascular risk factors.[8,10,11] Data from 2 recent surveys reported that approximately 1%–3% of adult Americans are weekend warriors (defined as those "who engage in irregular patterns of [physical activity] (1–2 d/wk) with a total duration of ≥ 150 min/wk[1] spent in moderate- and vigorous-intensity activity), with a substantial proportion participating in sports/exercise-related activities.[7]

Because long periods of intense physical activity on weekends is physically demanding, especially among unfit individuals, weekend warriors may be at an increased risk of injury.[7] Given a lack of available data on this cohort, the purpose of this study was to identify the incidence and injury patterns of major trauma secondary to various recreational sporting activities on the weekend versus weekdays over a 14-year period.

Methods

We conducted a descriptive retrospective cohort study using the Alberta Trauma Registry. This registry contains prospectively collected data on all trauma patients with an injury severity score (ISS) of 12 or greater who are admitted to the Foothills Medical Centre (FMC) or who die in the hospital's emergency department (ED). The FMC is the only adult level I tertiary care trauma hospital and serves as the principal referral centre for all major injuries in southern Alberta, southwestern Saskatchewan, and southeastern British Columbia (population of approximately 1.2 million).

We identified all adults (≥ 16 years) who were severely injured (ISS ≥ 12) on weekends or weekdays while participating in physical activity or recreational sports between Apr. 1, 1995, and Mar. 31, 2009. A weekend was defined as the time period between 5 pm on Friday and 8 am on Monday. As the trauma epidemiology associated with bicycling, horseback riding and rodeo sports, and downhill skiing have already been well described, we excluded patients who were injured as a result of these sports. The University of Calgary Conjoint Health Research Ethics Board approved the study.

We collected data on patient demographics, mechanism and anatomic pattern of injury, specific injuries, ISS, mode of transport to hospital, transport time (i.e., the time from injury to arrival at our trauma centre) and surgical interventions. Injuries to the liver, spleen and kidney were graded according to the American Association for the Surgery of Trauma (AAST) organ injury scale.[12] To determine whether temporal factors influenced the incidence of injury related to physical activity, we also collected data on the time of day (early morning [12:01 am to 8 am], morning/afternoon [8:01 am to 4 pm], evening [4:01 pm to 8 pm] or night [8:01 pm to midnight]) that the injury occurred. Patient outcomes of interest included mortality, and length of stay in hospital (LOS) and in the intensive care unit (ICU).

Statistical analysis

Statistical analyses were conducted using Stata software version 12.0 (Stata Corp). Continuous or measured data are described using means ± standard deviations for normally distributed data or medians with interquartile ranges (IQR) for non-normally distributed data, and count data are summarized using proportions. We compared means using the Student *t* test and medians using the Mann–Whitney *U* test. We analyzed proportions using the Fisher exact test or the 2-sample comparison of proportions. All tests were 2-sided, and we considered results to be significant at $p < 0.05$.

Results

Between 1995 and 2009, 11 772 patients with an ISS of 12 or greater were admitted to the FMC or died in the hospital's ED. Of these patients, 351 (3.0%) were injured as a result of physical activity or recreational sports during weekdays ($n = 159$) or on the weekend ($n = 192$). We observed no differences in characteristics of patients injured on the weekend versus weekdays (Table 1). Eighty-five percent of the patients were men, the median age was 33 (IQR 24–45) years, and the median ISS was 18 (IQR 16–25).

A significantly higher number of patients were injured as a result of physical activity or recreational sports on the weekend versus weekdays (54.8% v. 45.2%, $p = 0.016$). Although slight variations were observed, there was no difference in the number of yearly admissions for recreational sporting injuries throughout the study period. The time of day at which injury occurred was similar for patients admitted on the weekend versus weekdays (all $p > 0.05$), with most injuries occurring in the morning/afternoon (27.4%) or evening (24.8%).

The mode of transport to hospital was also similar among patients admitted on weekends versus weekdays (all $p > 0.05$), with most patients being transported by ground (62.7%) or air (28.8%) ambulance. The mean transport

time was 61 (IQR 25–104) minutes. The median LOS was 6 (IQR 3–14) days and was similar for patients admitted on weekends versus weekdays. Admission to the ICU was required in 22.8% of patients; the median LOS in the ICU was 4 (IQR 1–11) days.

The categories and specific types of physical activity that resulted in injury are described in Table 2. Although motocross-related injuries were more common among patients admitted on weekends versus weekdays (30.2% v. 15.7%, $p = 0.002$), the occurrence of injuries associated with the remaining recreational sporting types did not significantly depend on the day of the week (all $p > 0.05$). Common physical activities associated with injury included hiking and mountain climbing (15.4%); winter (13.4%) and extreme (12.3%) sports; and parachuting, paragliding, and personal plane usage (10.0%). Less common injury-associated activities included water sports (7.7%), indoor or outdoor ball (1.7%), aerobic activities (1.7%), hunting and fishing (1.1%), gymnastics (1.1%), curling (1.4%), boxing or martial arts (0.85%), and even lawn bowling (0.28%) and table tennis (0.28%).

Mechanisms of injury are presented in Table 3, and the anatomic injury distribution is shown in Fig. 1. Aside from an increased number of motorbike-related injuries (30.7% v. 14.5%, $p < 0.001$) and a decreased number of aircraft-related injuries (1.0% v. 5.0%, $p = 0.048$), mechanisms were similar (all $p > 0.05$) between patients who were injured on the weekend versus weekdays. Most patients were injured as a result of ground-level (21.9%) or higher (range ≤ 25 to 486 feet) falls while hiking, mountain climbing or rock climbing (25.9%); a motocross-related fall, faulty jump or collision (24.2%); or a collision with a tree, another person, a man-made object or a moving vehicle (14.0%). These mechanisms of injury culminated in similar anatomic injury patterns across both groups (all $p > 0.05$), with trauma to the head (55.8%), spine (35.0%), thorax (35.0%), extremities (31.1%), face (17.4%) and abdomen (13.1%) being common.

Several uncommon, but severe recreational sporting injury mechanisms also occurred. One patient sustained multisystem thoracoabdominal and extremity injuries after falling 486 feet when his parachute failed (base jumping). Another patient suffered multiple lung contusions, an intercostal artery transection and a cardiac contusion after sliding 300 feet down a glacier while climbing. Two other patients perforated the small bowel after colliding with a tree while riding a golf cart or tripping while playing lawn bowling. Finally, 1 patient suffered a C2–C6 incomplete spinal cord injury after running into a wall while playing table tennis.

Surgical intervention was required in 41.0% of patients, and was similar (all $p > 0.05$) for patients who were injured on weekends versus weekdays (Table 4). Common interventions included extremity open reduction and internal fixation (ORIF; 15.1%), craniotomy and/or craniectomy and evacuation of hematoma (7.4%), spinal surgery for correction of a

Table 1. Characteristics and outcomes of patients injured during the weekdays or on the weekend

Characteristic or outcome	Group; no. (%)*			*p* value
	Overall, *n* = 351	Weekday, *n* = 159	Weekend, *n* = 192	
Age, median [IQR] yr	33 [24–45]	33 [23–47]	33 [24–45]	0.65
Sex, male	299 (85.2)	134 (84.3)	165 (85.6)	0.76
Time of injury				
Early morning (12:01 am to 8 am)	8 (2.3)	5 (3.1)	3 (1.6)	0.48
Morning/afternoon (8:01 am to 4 pm)	96 (27.4)	45 (28.3)	51 (26.6)	0.72
Evening (4:01 pm to 8 pm)	87 (24.8)	42 (26.4)	45 (23.4)	0.54
Night (8:01 pm to 12 am)	14 (4.0)	9 (5.7)	5 (2.6)	0.18
Unknown	146 (41.6)	58 (36.5)	88 (45.8)	0.08
Mode of transportation to hospital				
Private vehicle	30 (8.5)	9 (5.7)	21 (10.9)	0.09
Ground ambulance	220 (62.7)	103 (64.8)	117 (60.9)	0.51
Air ambulance	101 (28.8)	47 (29.6)	54 (28.1)	0.81
Transportation time, median [IQR] min.	61 [25–104]	60 [31–105]	62 [24–97]	0.54
Injury severity score, median [IQR]	18 [16–25]	17 [16–25]	19 [16–25]	0.38
Outcomes				
ICU admission required	80 (22.8)	37 (23.3)	43 (22.4)	0.90
LOS, median [IQR] d	6 [3–14]	7 [3–14]	6 [3–12]	0.78
Length of ICU stay, median [IQR] d	4 [1–11]	3 [1–9]	4 [1–11]	0.95
Mortality	23 (6.6)	10 (6.3)	13 (6.8)	> 0.99

ICU = intensive care unit; IQR = interquartile ratio; LOS = length of stay in hospital.
*Unless otherwise indicated.

fracture or instability (8.3%) and facial fracture repair (5.1%). In addition, 2 patients (< 1%) underwent a thoracotomy for resuscitative purposes or to repair an intrathoracic airway injury, and 15 patients (4.3%) underwent a trauma laparotomy. Indications for trauma laparotomy included 3 AAST grade V renal injuries, 7 AAST grade IV–V spleen or liver injuries, 1 ruptured thoracoabdominal aorta, 2 small bowel injuries, 1 colonic injury and a complete avulsion of the gallbladder from the cystic duct.

In total, 93.4% of injured recreational athletes survived until hospital discharge. Of those who died from their injuries, 17 had a severe traumatic brain injury, 2 had a blunt aortic injury with free hemorrhage into the mediastinum (1 as a result of a parachute failure after a jump from a plane at an unknown height and the other from colliding with a steel railing while rollerblading), 1 had a tracheal perforation (from a motocross-related head-on collision), 1 presented in cardiac arrest secondary to a significant

Table 2. Types of physical activity or recreational sports that resulted in injury

	Group; no. (%)			
Sporting type	Overall, *n* = 351	Weekday, *n* = 159	Weekend, *n* = 192	*p* value
Aerobic	6 (1.7)	3 (1.9)	3 (1.6)	> 0.99
Dancing	2	0	2	
Running	3	2	1	
Track and field	1	1	0	
Aircraft	35 (10.0)	15 (9.4)	20 (10.4)	0.86
Parachuting	11	3	8	
Paragliding	14	4	10	
Personal plane	10	8	2	
Extreme	43 (12.3)	25 (15.7)	18 (9.4)	0.08
Rollerblading	21	13	8	
Skateboarding	22	12	10	
Game catching	4 (1.1)	3 (1.9)	1 (0.52)	0.33
Fishing	1	1	0	
Hunting	3	2	1	
Gymnastic	4 (1.1)	2 (1.3)	2 (1.3)	> 0.99
Gymnastics	2	2	0	
Trampoline	2	0	2	
Indoor or outdoor ball	6 (1.7)	2 (1.3)	4 (2.1)	0.69
Basketball	2	0	2	
Soccer	3	1	2	
Tennis	1	1	0	
Outdoor ball	27 (7.7)	15 (9.4)	12 (6.3)	0.32
Baseball	14	8	6	
Football or rugby	7	3	4	
Golf	6	4	2	
Hiking and mountain or rock climbing	54 (15.4)	31 (19.5)	23 (12.0)	0.06
Water	27 (7.7)	11 (6.9)	16 (8.3)	0.69
Boating or watercrafting	7	3	4	
Swimming, bodyboarding or surfing	14	6	8	
Waterskiing or tubing	6	2	4	
Winter	47 (13.4)	21 (13.2)	26 (13.5)	> 0.99
Bobsledding	1	1	0	
Hockey or ice-skating	36	16	20	
Sledding or tobogganing	10	4	6	
Other				
Auto racing	1 (0.28)	0 (0)	1 (0.52)	> 0.99
Boxing or martial arts	3 (0.85)	1 (0.63)	2 (1.0)	> 0.99
Chuck wagon riding	1 (0.28)	0 (0)	1 (0.52)	> 0.99
Curling	5 (1.4)	2 (1.3)	3 (1.6)	> 0.99
Lawn bowling	1 (0.28)	0 (0)	1 (0.52)	> 0.99
Mechanical bull riding	1 (0.28)	0 (0)	1 (0.52)	> 0.99
Motocross	83 (23.6)	25 (15.7)	58 (30.2)	0.002
Table tennis	1 (0.28)	1 (0.63)	0 (0)	> 0.99
Walking stilts	1 (0.28)	1 (0.63)	0 (0)	> 0.99
Weightlifting	1 (0.28)	1 (0.63)	0 (0)	> 0.99

femoral artery laceration (subsequent to a fall from 200 feet during an avalanche while rock climbing), and 1 succumbed to physiologic exhaustion from a combined AAST grade IV splenic and grade V liver injury.

Discussion

Although sporadic physical activity may produce personal health benefits,[8,10,13] this study reveals that many common recreational sporting activities can result in severe and even fatal injuries. Between 1995 and 2009, recreational activities accounted for 3.0% of all severely injured patients admitted to our trauma centre. The severity of these injuries was significant (median ISS 18, ICU admission 22.8%, median LOS in the ICU 6 d).

Trauma to the head, spine, thorax, extremities, face and abdomen were common among these recreational athletes, with 41.0% receiving emergent or urgent surgical intervention. Although 20.2% required only an ORIF or facial fracture repair, 7.4% underwent emergent craniotomy and/or craniectomy, and 8.3% required spinal surgery. Moreover, 2 patients required immediate thoracotomy, and 15 patients received a laparotomy.

Among the 6.6% of recreational athletes who died, traumatic brain injury was the most common cause of death. Two additional patients had blunt aortic injuries associated with free hemorrhage despite seemingly benign mechanisms of injury (e.g., collision with a steel railing while rollerblading). Finally, 1 patient had a significant tracheal injury, and 2 others died as a result of organ or peripheral vascular hemorrhage.

In support of previous anecdotal reports suggesting weekend warriors may be at higher risk of injury, we observed that those who participated in physical activity on weekends had a higher rate of severe injury than patients who exercised on weekdays.[7] One wonders if this is a result of fatigue secondary to physically demanding and prolonged exercise on the weekend beyond one's inherent exercise tolerance. Another possibility may be that weekend warriors are more inexperienced at various sporting activities than daily or more regular recreational athletes.

In support of this hypothesis, the majority of injury

Table 3. Mechanism of injury distribution

Mechanism of injury*	Group; no. (%)			*p* value
	Total, *n* = 351	Weekday, *n* = 159	Weekend, *n* = 192	
Ground-level fall	77 (21.9)	42 (26.4)	35 (18.2)	0.07
Collision	49 (14.0)	27 (17.0)	22 (11.5)	0.16
Tree	12	8	4	
Another person	22	10	12	
Man-made object	10	4	6	
Moving vehicle	5	5	0	
Hit	23 (6.6)	13 (8.2)	10 (5.2)	0.29
Head by baseball or hockey puck or stick	19	9	10	
Head by overhead falling object (e.g., rock)	3	3	0	
Abdomen by hockey stick or ball	1	1	0	
Crushed under dumbbell while weightlifting	1 (0.28)	1 (0.63)	0 (0)	0.45
Hiking, mountain and rock climbing, and others	91 (25.9)	42 (26.4)	49 (25.5)	0.90
Fall ≤ 25 ft	37	23	14	
Fall 26–50 ft	20	5	15	
Fall > 50 ft (range 60–486)	31	13	18	
Caught in avalanche	3	1	2	
Motorbike-related	85 (24.2)	23 (14.5)	59 (30.7)	< 0.001
Fall	47	12	32	
Faulty jump	34	10	24	
Collision with an object	4	1	3	
Loss of control of aircraft or aircraft systems failure	10 (2.8)	8 (5.0)	2 (1.0)	0.048
Water-related	24 (6.8)	9 (5.7)	15 (7.8)	0.53
Collision of one watercraft with another	4	2	2	
Struck by large wave	4	2	2	
Fell while waterskiing or watercrafting/tubing	5	1	4	
Near-drowning	3	1	2	
Struck head on pool/lake bottom while diving	8	3	5	
Upset golf cart	2 (0.57)	0 (0)	2 (1.0)	0.50
Collision of toboggan or sled with object	10 (2.8)	4 (2.5)	6 (3.1)	> 0.99

*Several patients had more than 1 mechanism of injury (e.g., hit by a moving car and then fell 30 feet), thus the number of listed mechanisms exceeds the column totals.

mechanisms in this study were accidental. Most patients were injured as a result of ground-level or higher (range ≤ 25 to 486 feet) falls while hiking, mountain climbing, or rock climbing; a motorbike-related fall, faulty jump, or collision; or a collision with a tree, another person, a man-made object, or a moving vehicle. Moreover, in 25 patients, falls were secondary to parachute deployment or paragliding failures. Other mechanisms that appeared to be accidental included a 486-foot fall while base jumping, a collision with a tree while riding in a golf cart, and tripping while playing lawn bowling.

It should be noted that the observation of an increased proportion of recreational sports-related injuries on the weekend appears to be largely driven by a significantly higher number of motocross injuries. Although previous investigations have described the trauma epidemiology of motocross riders in detail, to our knowledge, none have analyzed the injury epidemiology of severe motocross-related injuries with an associated ISS of 12 or greater.[14–16] Despite this discrepancy, a previous retrospective cohort study reported that 69.6% of off-road motorcycle-related injuries occurred in the summer between Friday and Sunday, whereas only 30.4% were observed from Monday to Thursday ($p = 0.60$).[16]

Limitations

Our study has several limitations. First, the results should be interpreted with caution given the descriptive nature of this study. We were also unable to characterize the precise skill level of the injured recreational athletes. Moreover, while some may argue that the examined recreational sporting types are not all truly characteristic of a weekend warrior, our findings are consistent with data from a previous study reporting that household/transportation- and sports/exercise-related activities were most common.[7] Finally, although other variables were well described, alcohol and drug use are poorly captured in the Alberta Trauma Registry, and the exact geographic location of injury (i.e., mountain, street, road) is not recorded. Thus,

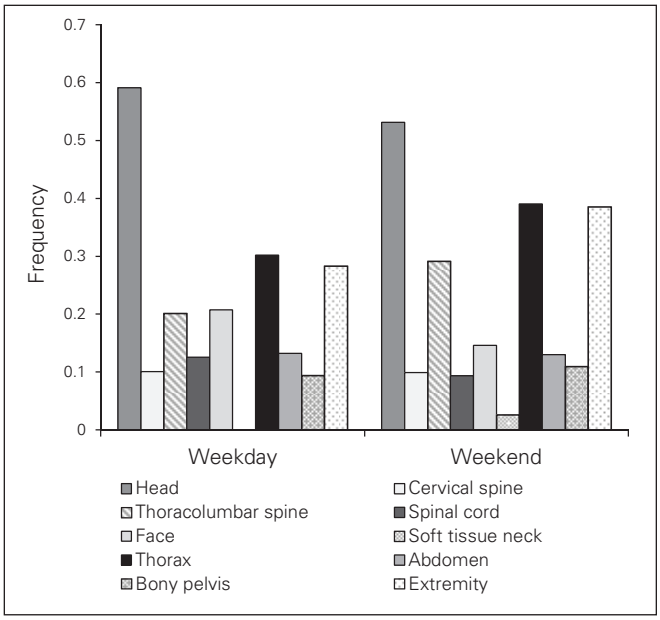

Fig. 1. Anatomic injury distribution of patients injured on weekdays versus weekends.

Table 4. Surgical interventions performed and associated indications

Intervention	Group; no. (%)			*p* value
	Overall, *n* = 351	Weekday, *n* = 159	Weekend, *n* = 192	
Craniotomy and/or craniectomy and evacuation of hematoma	26 (7.4)	12 (7.5)	14 (7.3)	> 0.99
Repair of facial fracture(s)	18 (5.1)	7 (4.4)	11 (5.7)	0.63
Spinal procedure for fracture or instability	29 (8.3)	17 (10.7)	12 (6.3)	0.17
Thoracotomy for resuscitation or repair of intrathoracic airway injury	2 (0.57)	0 (0)	2 (1.0)	0.50
Laparotomy for	15 (4.3)	6 (3.8)	9 (4.7)	0.79
AAST grade V renal injury	3	1	2	
AAST grade IV–V splenic or liver injury	7	4	3	
Ruptured thoracoabdominal aorta	1	0	1	
Small bowel perforation or laceration	2	1	1	
Multiple colonic tears	1	0	1	
Complete avulsion of the gallbladder	1	0	1	
Nontherapeutic reasons	3	0	3	
Extremity open reduction and internal fixation	53 (15.1)	19 (11.9)	34 (17.7)	0.18
Vascular repair for	1 (0.28)	0 (0)	1 (0.52)	> 0.99
Crush injury to brachial artery	1	0	1	
Wound suturing and/or débridement	22 (6.3)	11 (6.9)	11 (5.7)	0.67
None	207 (59.0)	94 (59.1)	113 (58.6)	> 0.99

AAST = American Association for the Surgery of Trauma.

our ability to comment on the potential utility of specific injury prevention efforts, including the introduction of warning signs or regional traffic regulations, is limited.

Conclusion

Although sporadic physical activity may produce personal health benefits, common recreational sporting activities may also result in severe and possibly fatal injuries. In support of previous anecdotal reports suggesting that weekend warriors may be at higher risk of injury, we confirm that those who participated in physical activity on the weekend had a higher rate of severe injury than those who exercised on weekdays.[7] Thus, all weekend warriors should be aware of the risk of severe injury associated with intense and sustained weekend recreation. Moreover, protective equipment, such as padded vests, helmets, gloves and boots, should be recommended for motocross bikers.[16] In addition to analyzing the association between alcohol and drug use and the incidence of recreational sporting injuries, future studies should attempt to characterize the exact geographic location of these injuries (possibly using geometric mapping techniques) in order to guide injury prevention efforts.

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