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Increasing Trend in Pediatric Brazilian Jiu Jitsu Injuries Presenting to US Emergency Departments and an Injury Profile – A 10-Year Analysis.

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Abstract

*Brazilian Jiu Jitsu (BJJ) is an increasingly popular martial arts discipline. Yet, BJJ injuries remain understudied in light of increasing popularity. In particular, pediatric injuries have a dearth of literature examining epidemiologic trends and injury profiles. As such, this study's purpose was to evaluate trends in pediatric Brazilian Jiu Jitsu (BJJ) injuries over a 10-year period and formulate an injury profile. The US Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS) database was queried for martial arts related injuries from January 1, 2012, to December 31, 2021. Codes, and narratives were examined to compile data for patients 18 years of age or younger sustaining BJJ-related injuries. In the study period there were 7722 recorded martial arts related injuries (national estimate [NE]= 282 315) , with 264 (NE= 8357) pediatric BJJ related injuries identified. In all, 70.4% of the patients were male, and the average age was 11.6 years of age (range 4-18).There was a statistically significant increasing linear trend in pediatric BJJ injuries from 2012 to 2021 (*P< .001*). Most injuries were treated in emergency departments without admission. The most common diagnoses weresprains/strains (28.3%), fractures (20.1%), and the most injured body parts were head (14.2%), shoulder (9.8%), and lower arm (8.9%). This study presents novel data concerning pediatric BJJ injuries epidemiology and injury profile, providing useful information for health care professionals to treat these patients.*

Acronyms

BJJ = Brazilian Jiu Jitsu
CPSC = Consumer Product Safety Commission
ED = Emergency Department
NEISS = National Electronic Injury Surveillance System
NE = national estimate

Introduction

Martial arts are popular sports and activities amongst the pediatric population with more than 6.5 million participants in the United States (US).[1] In particular, Brazilian Jiu Jitsu (BJJ), is an increasingly popular form of grappling and martial arts. BJJ is a modification of traditional Japanese Jiu Jitsu and Kodokan Judo, formulation and refinement attributed to the Brazilian Gracie family in the early 20th century.[2] BJJ utilizes takedowns, submission attacks, and positional control to submit, and subdue opponents. Prior studies have established injuries, which often involve elbows, shoulders, knees, hands, and fingers, though literature specific to pediatric populations is lacking.[3-5] There has been increasing pediatric BJJ participation, attributable to increasing gyms, classes and media exposure, as well as developmental benefits in strength, flexibility, cognitive function, self-esteem, and self-defense.[6] However as mentioned, there is a paucity of epidemiological literature, stemming from inherent population and study design challenges.[7,8] With BJJ expected to continue increasing in popularity, it stands to reason there is benefit investigating pediatric BJJ related injuries.

The US Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS) has been utilized to identify epidemiologic trends associated with sports-related musculoskeletal injuries presenting to US emergency departments (EDs).[9-16] In a study by Stephenson et al, authors profiled injuries amongst several martial arts disciplines, including BJJ.[14] However, the authors did not specify pediatric injury trends. Yard et al reported epidemiological trends in pediatric martial arts injuries presenting to US EDs, although the authors did not delineate BJJ-specific injury patterns.[1] In a recent study by Hasegawa et al, the NEISS database was queried to compile an injury profile of all BJJ injuries over a 10-year period, without stratification of pediatric injuries, which represents just one of few studies utilizing national databases for these injuries.[17] As such, the current deficiency in nationally collected pediatric BJJ injury data may precluding understanding of epidemiologic and injury patterns.[3,18] Subsequently, the purpose of this study is to identify trends, etiologies, and diagnoses of pediatric BJJ-related injuries presenting to US EDs over a 10-year period.

Materials and Methods

Data Collection

The NEISS database from the CPSC for sports-related injuries is a national public database containing information from 100 hospital EDs with a minimum of 6 beds and

24-hour services that is a representative sample of all 5000 EDs in the US. The collection base allows for a national estimate (NE) based on data collected from participating EDs and has been validated for epidemiologic studies involving sports related injuries.[19,20] Data is input into the database by both codes indicating diagnosis, disposition, injuries, and other categories, as well as narrative data in which additional descriptors can be freely typed into the database. All martial arts related injuries (product code 3257) were queried from January 1, 2012 to December 31, 2021 to identify patients who suffered an injury resultant from martial arts activity. Patients were considered pediatric if age 18 years or younger. BJJ injuries were coded under *martial arts* injuries, narratives within martial arts injuries were examined for mention of BJJ as activity during injury. Researchers also utilized searches for potential misspellings of BJJ within narratives to capture patient encounters (eg, "Jujutsu," "Jitzu," "Brasilian," "jui jitsu").

Body Region and Diagnosis of Injury

NEISS data incorporates numeric codes to signify body part injuries and a specific injury diagnosis. All available anatomic regions on NEISS database were queried, using the appropriate database dictionary. Additionally, the narrative section was used to determine if participants had sustained specifically a strain or sprain, as these are categorized under the same injury code (product code 64). Narratives were also used to differentiate specific anatomic structures involved in injuries coded for a broad anatomic area, such as acromioclavicular joint within shoulder injuries (product code 30). For some participants, multiple diagnoses of injury were coded, with each injury being included in the evaluation of anatomic regions affected and diagnosis of injury.

Mechanism of Injury

Narratives for each injury were reviewed to determine the mechanism of injury and designated into1 of 9 potential groups. Mechanisms included falling onto ground or opponent falling onto participant without clear designation if the event occurred during an intentional move, contact while standing, contact while on the ground, contact without specifying standing or on the ground, during a submission attack, during a takedown maneuver, overuse injuries, or non-contact injuries such as dermatologic diagnoses or injuries occurring during a warm up or non-contact activity. Narratives that did not specify mechanism of injury were classified as not listed.

Exclusion Criteria

Patients older than 18 years of age were excluded. Narratives were examined for injuries that did not specify martial arts discipline during time of injury, non-BJJ martial arts, and injuries that may have occurred near an adjacent BJJ facility but did not involve BJJ related activities (eg, tripping and falling out of car in parking lot of BJJ facility). These patients were excluded from final analysis.

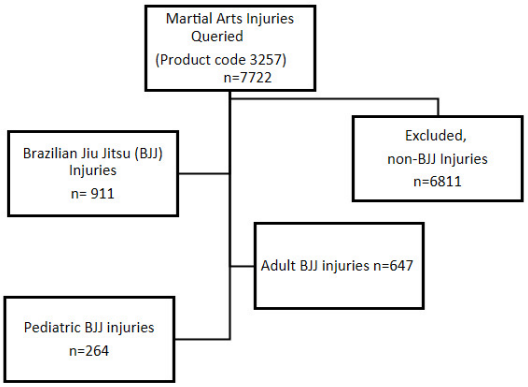


Figure 1. US Pediatric Brazilian Jiu Jitsu Injuries Study Participant Selection Criteria, National Electronic Injury Surveillance System, 2012-2021

Statistical analysis

Statistical analysis was accomplished using Microsoft Excel version 16.78.3 (Microsoft Corp., Redmond, WA). A linear regression was performed to determine injury trends over time. Statistical significance was set at $P < .05$. The NEISS database is comprised of raw values based on a weighted scale determined by the institution's characteristics (ie, size, volume etc.), the CPSC recommends against using raw values for statistical comparisons, as the database is formulated to provide national estimates. As such, in line with their recommendations, national estimate (NE) values used for statistical evaluation and comparison.

Results

Epidemiologic Data

From January 1, 2012 to December 31, 2021, there were 7722 (NE= 282315) ED-diagnosed martial arts-related injuries. After reviewing narratives and using inclusion and exclusion criteria, 911 (NE= 36023) BJJ-related injuries were included for analysis with 264 pediatric patients identified (NE=8357) (**Figure 1**). Yearly results for injuries due to BJJ participation per year can be seen in **Table 1**.

Of the included patients, 170 (NE=5886, 70.4%) were male and 94 (NE= 2471, 29.6%) were female. The average age was 11.56 years old (Range 4-18 years). Race not stated made up 47.4% of patients, and White patients made up 42.1%. Full demographic data can be found in **Table 2**.

Linear regression during the study period demonstrated an increasing trend in annual incidence of BJJ injuries presenting to the ED (R^2= 0.85; SE= 2.30: $P < .001$) (coefficient = -3364.20; 95% CI: [-4541.30 to −2187.10]) (**Figure 2**).

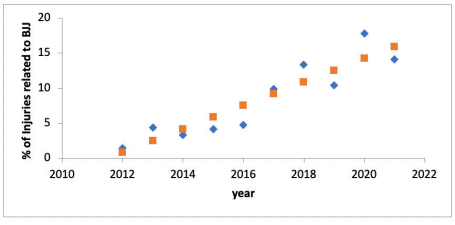
With respect to patient disposition, 94.2% (NE=7873) of patients were treated, examined, and subsequently released from the ED. Patients leaving without being seen comprised 2.5% (NE= 208) of patients. Patients treated and transferred comprised 1.6% (NE=136) of patients. Patients being treated and admitted made up 1.5% (NE=123) and pa-

Table 1. Raw Number, National Estimate (NE) and Percent of Pediatric Martial Arts Injuries Related to Brazilian Jiu Jitsu (BJJ) Participation by Year National Electronic Injury Surveillance System, 2012-2021

Year	Raw total BJJ injuries	NE BJJ injuries	% Injuries related to BJJ
2012	7	206	4.4
2013	11	619	5.9
2014	13	429	6.9
2015	16	462	6.8
2016	16	528	10.6
2017	27	1236	16.2
2018	48	1427	19.3
2019	47	1098	22.2
2020	30	1003	20.0
2021	49	1348	24.7
Totals	264	8357	

Table 2. Demographic Data of Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

	Raw	NE	
Male	170	5886	70.4%
Female	94	2471	29.7%
Average age (years)			11.6
Range (years)			4-18
White	110	3957	47.4%
Not Stated	116	3517	42.1%
Black/African American	15	404	4.8%
Other	15	335	4.0%
Hispanic	10	297	3.6%
Asian	5	57	0.7%
Unknown	3	28	0.7%
Multiracial	2	10	0.7%
Native American/Native Alaskan	1	55	0.7%
Native Hawaiian/ Polynesian	2	32	0.4%



Regression Statistics	
Multiple R	0.92
R^2	0.85
Adjusted R^2	0.83
Standard Error	2.30
P value	< .001
Observations	10

Figure 2. Regression Analysis of Brazilian Jiu Jitsu (BJJ) Injuries Related Injuries, National Electronic Injury Surveillance System, 2012-2021

Table 3. Injury Diagnosis Type for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Injury diagnosis	Raw	NE	%
Strain, Sprain	76	2626	28.3
Fracture	67	1866	20.1
Other/Not Stated	66	1678	18.1
Laceration	7	982	10.6
Internal Organ Injury	19	672	7.2
Concussions	12	512	5.5
Contusions, Abrasions	17	509	5.5
Dislocation	8	259	2.8
Hematoma	7	159	1.7
Nerve Damage	1	17	0.2

tients held for observation comprised 0.2% (NE=17) of patients (*data not shown)*.

Injury Diagnosis

The 2 most common diagnoses were strains/sprains and fractures, at 28.3% (NE=2626) and 20.1% (NE=1866), respectively. Other/Not Stated was the diagnosis for 18.1% (NE=1678) of patients, and lacerations 10.6% (NE= 982) of patients. Internal organ injury, concussions, and contusions/abrasions were the diagnosis 7.2% (NE=672), 5.5% (NE=512), and 5.5% (NE=509), respectively. Full summary of injury diagnoses, and less commonly diagnosed injuries can be found in **Table 3**.

Body Parts Injured

The most affected body part was the head, which comprised 14.2% (NE=1183) of all body parts injured. Shoulder, lower arm, and neck injuries comprised 9.8% (NE=816), 8.9% (NE=744), and 8.8% (NE=736), of involved body parts, respectively. Elbow, knee, and ankle injuries comprised 7.7% (NE=642), 7.4% (NE=619) and 7.2% (NE=604), of injuries, respectively. Finger, toe, and wrist injuries comprised 7.0% (NE=587), 5.1% (NE=430), and 4.8% (NE=404), of injured body parts, respectively. Full summary of affected body parts, and less commonly injured regions of the body can be found in **Table 4**.

Fracture Regions

Lower arm was the most common anatomic region fractured, at 23.3% (NE=434) of all fractures. Shoulder fractures made up 12.7% (NE=238) of all fractures, which when narratives examined all of these fractures were specified as clavicle fractures. Finger, toe, and upper arm made up 12.2% (NE=228), 11.2% (NE=210), and 8.0% (NE=149), respectively. Wrist, face, and lower leg comprised 7.3% (NE=136), 5.4% (NE=100), and 4.9% (NE=91) of fractures, respectively. Elbow, and ankle fractures comprised 4.8% (NE=90) and 4.0% (NE=74) respectively. Full summary of

Table 4. Body Part for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Body part	Raw	NE	%
Head	32	1183	14.2
Shoulder	29	816	9.8
Lower Arm	17	744	8.9
Neck	20	736	8.8
Elbow	25	642	7.7
Knee	22	619	7.4
Ankle	18	604	7.2
Finger	16	587	7.0
Toe	19	430	5.1
Wrist	12	404	4.8
Upper Trunk	17	355	4.3
Ear	4	223	2.7
Lower Leg	4	195	2.3
Foot	8	176	2.1
Upper Arm	5	149	1.8
Face	7	142	1.7
Lower Trunk	8	114	1.4
Pubic Region	3	92	1.1
Hand	3	89	1.1
Upper Leg	2	19	0.2
Mouth	1	18	0.2
Eyeball	3	14	0.2
Not Stated	1	5	0.1

Table 5. Fractures by Body Part for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Fractured body part	Raw	NE	%
Lower Arm	11	434	23.3
Shoulder/Clavicle	12	238	12.7
Finger	8	228	12.2
Toe	10	210	11.2
Upper Arm	5	149	8.0
Wrist	6	136	7.3
Face	3	100	5.4
Lower Leg	2	91	4.9
Elbow	2	90	4.8
Ankle	1	74	4.0
Foot	3	65	3.5
Hand	2	33	1.8
Upper Leg	1	14	0.8
Upper Trunk	1	5	0.2

fractures, and less commonly fractured regions of the body can find in in **Table 5**.

Table 6. Dislocations by Joint for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Dislocated body part	Raw	NE	%
Elbow	5	180	69.6
Toe	1	55	21.4
Shoulder	1	18	7.1
Knee/Patella	1	5	1.9

Dislocations

Elbow dislocations were the most affected boy part, comprising of 69.6% of all dislocations (NE=180). Toe dislocations comprised 21.4% (NE=55) of dislocations. Shoulder dislocations made up 7.1% (NE=18). Knee dislocations comprised 1.9% (NE=5) with all of those being identified as patella fractures in the narrative section. These results are summarized in **Table 6**.

Sprains/strains

Within the code assigned for strains/sprains, narratives specifically designating a sprain injury comprised 56.8% (NE= 1491) of all injuries. Strains and either other/not signified/both listed comprised 38.5% (NE= 1010) and 4.8% (NE= 125) of injuries, respectively (*data not shown*).

The neck was the most affected body part (NE=554 with 41.1% of these diagnoses as sprains and 58.9% as strains. The ankle was the second-most affected body part (NE=434), with 92.4% sprains and 7.6% strains. The shoulder was the third-most affected body part (NE=354), with 4.0% sprains and 96.0% strains. The remaining distribution of sprains and strains are summarized in **Table 7**.

Mechanism of Injury

The most common mechanism of injury was fall/contact with ground/player fall on participant which comprised 28.1% of injuries (NE= 2349). Injury not being listed made up 26.1% (NE= 2181) of injuries. Contact but no designation of standing or ground made up 17.2% (NE= 1441) of injuries. Further summary and less common mechanisms of injury can be found in **Table 8**.

Discussion

In this study, a statistically significant trend of increasing ED admissions due to pediatric BJJ-related injuries was established. Several reasons may account for this finding. A possible theory may be concomitant increase in popularity and participation during the study period, thus increasing the sample population of children recreationally and competitively participating in BJJ.[21-23] This would naturally result in an increase in more injuries as well. An increasing number of gyms and children's specific class/training options have increased accessibility for a pediatric BJJ participants, which would increase both total amount of people at risk for injury and number of exposures. Another poten-

Table 7. Distribution of Sprains, Strains, and Other Injuries for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Body part	Raw Total	NE Total	Sprain (%)	Strain (%)	Other/Not listed/both listed (%)
Neck	12	554	41.1	58.9	0
Ankle	14	434	92.4	7.6	0
Shoulder	8	354	4.0	96.0	0
Wrist	6	269	100.0	0	0
Elbow	13	205	34.0	20.3	45.7
Knee	8	162	0	100.0	0
Lower Arm	1	78	100.0	0	0
Lower Trunk	1	77	0	100.0	0
Upper Trunk	3	26	0	100.0	0
Foot	1	5	0	100.0	0

Table 8. Distribution of Mechanisms of Injury for Pediatric Brazilian Jiu Jitsu (BJJ) Injuries, National Electronic Injury Surveillance System, 2012-2021

Mechanism	Raw	NE	%
Fall/ Contact with ground or player	77	2349	28.1
Not Listed	66	2181	26.1
Contact without designation standing or ground	47	1441	17.2
Take down	25	960	11.5
Submission attempt	14	536	6.4
Non-contact	20	429	5.1
Contact while standing	7	269	3.2
Overuse	5	165	2.0
Contact while on ground	3	28	0.3

tial reason an increase in injuries was observed is an increased awareness of BJJ as an identifiable sport amongst health care providers. The permeation of BJJ into the general public's awareness would increase the likelihood health care professionals and NEISS coders specifically input BJJ as cause of injury. Another possibility is increased skill of pediatric participants. This study took place over a 10-year period, and it is feasible that many participants by the study's end had been practicing BJJ for 5 or more years, thus supposing the frequency and skill at which they were training also increased. These factors could also increase risk of participant injury over the study period.

Current literature demonstrates BJJ-related injuries are common. Lopes et al, reported 37.5% of athletes sustained an injury within the prior 12 months, with an incidence of 0.44 injuries per athlete.[24] Though, similar data in a pediatric population is lacking. The most common diagnosis in this study was strains/sprains, constituting 31.4% of all injuries. This finding is similar to Petrisor et al and Hasegawa et al who established sprains/strains as the most common diagnosis in samples, though without pediatric stratification.[4,17] The high percentage of fractures in this study was similarly highlighted by Stephenson et al. The high rate of these injuries is understandable, as BJJ frequently involves contact with opponents and the ground, as well as maintaining control of opponents through grips, holds, or body position.[14] All of these increase risk of supraphysiologic forces applied to participants, leading to strains/sprains and fractures. The most commonly affected body parts in this study were head, shoulder, and lower arm, respectively. High prevalence of upper extremity injuries have also been shown by Lopes et al and Scoggin et al, who identified the shoulder, elbow, and forearm as the most commonly injured body parts in adult cohorts.[2,24] Head injuries were also reported to be common by Moriarty et al in less experienced adult practitioners.[3] The consistent finding of these anatomic regions being injured, in both adult and pediatric populations, suggests foundational BJJ movements, concepts, and patterns may render the head and upper extremity susceptible to injury. Additionally, preferential utilization of the upper extremity to execute positional control, take downs, submissions, or escapes would be expected in a pediatric population. Incorporating more lower extremity movements and patterns requires more coordination and experience, which may be lacking in a generally less coordinated and physically developed group such as youth BJJ practitioners.

A novel aspect about the current study is an expansion on fractures and dislocations in the pediatric population. Lower arm, shoulder, and finger were the most commonly fractured regions. This is likely due to aforementioned preference of upper extremity use, in lieu of more balanced use between lower and upper extremities seen in adult practitioners. Additionally, the predominant mechanisms of injury in this population, which were some sort of contact, either from falling, contact with the ground, contact with the opponent, or takedown attempts, could be responsible for higher rates of fractures or dislocations in these regions. It is well-known that common mechanisms of upper extremity fractures are from falling onto an outstretched hand or direct blows, which appear to occur frequently as well within a BJJ context. The high distribution of upper extremity fractures in this study would make sense then, as children are falling onto outstretched upper extremity limbs to

brace their fall.[25] In regard to dislocations, the elbow was the most commonly affected joint. Somewhat surprisingly, there is little research on commonly dislocated joints in BJJ injuries. The high rate of elbow dislocations described in this study could be attributed to the common mechanisms of injury, such as direct blows or falling onto outstretched hands. Additionally, many upper extremity submission attacks utilize the elbow as a fulcrum or hinge point to gain a submission against an opponent. Common upper extremity submission attacks involve hyperextending the elbow joint, or manipulating the arm while the elbow is in 90 degrees of flexion and shoulder is in 90-degree abduction position applying either an internal or external rotation (eg, arm locks, Kimuras, or Americanas). Naturally, these may be contributing to risk of elbow dislocation. Likewise, these submissions are less technically demanding and ideally suited to be taught in a children's or youth class setting, which too could increase the rate they are being utilized in sparring or competition matches.

The most common mechanisms of injury were in line with Hasegawa et al findings, in which some sort of contact with the opponent, the ground, or during a takedown attempt were identified.[17] This tends to be in agreement with other survey based studies, though these studies found more overuse or non-contact mechanism injuries.[24,26,27] The repeated consistency of contact, in varying forms, as the most common mechanism points to an environmental and inherent risk of BJJ as a discipline. Basic movements, and concepts necessitate contact with the opponent and ground, thus exposing participants to risk of injury. As such, the accordance of the most common mechanisms of injury between a pediatric and adult population should come as no surprise.

In regard to future trends, it may be assumed youth participation will continue to increase with further media exposure and increasing gym access. Likewise, as many of these youth BJJ participants gain more experience and develop physically, the complexity of movement patterns, submissions, takedowns, and strategy will also increase. This will likely affect the injury risk profile of pediatric BJJ participants. In contrast, some factors which may mitigate a continued rise in pediatric BJJ injuries include improved neuromuscular coordination, defensive techniques, and cross-training, as well as heightened awareness of common injuries and efforts on behalf of coaches or parents to educate participants on how to avoid or prevent these injuries.

Inherent limitations in this study arise from methodology and national database utilization. Specific information in regard to type of martial arts, mechanism of action, and subdividing anatomic regions (eg, shoulder into clavicle vs humerus) was dependent on narrative information, which could be absent or ambiguously defined. This undoubtedly resulted in unidentified patients listed as broad or vague *martial arts injuries*, or patients with incomplete injury specifics. Patients without specific narrative indication of Brazilian Jiu Jitsu injuries could not be included, but patients with Brazilian Jiu Jitsu injuries who had narrative insufficiencies were included in the final analysis, as omission could detract from the validity and accuracy of the overall findings. Additionally, because this database examines data from EDs, patients who elected to pursue treatment at urgent care centers would not be included and their inclusion could potentially alter findings. Overall, this study examined 3.4% of all martial arts related injuries during the study period, which means there is likely a large margin of error around estimates in the study, and were not presented in this study due to database limitations, and is something which should be addressed in future research. Finally, it is important to understand the modern evolution of BJJ has become a synthesized composite of concepts, moves, and aspects from many other martial arts disciplines with an expanding participating demographic base. Cognizant understanding of this by health care professionals in turn will improve care for this growing subset of pediatric athletic injuries.

Conclusion

In this study, there was a statistically significant trend in annual pediatric BJJ injuries presenting to US EDs over the study period. This may be due to increased participation nationally. Most injuries did not require inpatient admission and were treated acutely in the ED. The most common injury was either sprains or strains. The most commonly affected body parts were the head, shoulder, and lower arm. The most common identifiable mechanisms of injury were contact either between ground or another person. The most commonly fractured and dislocated body parts were the lower arm and elbow, respectively. Given these findings, an improved understanding of current pediatric BJJ injury profiles and patterns may provide valuable information to healthcare professionals to improve care for these patients.

Conflict of Interest

None of the authors identify any conflicts of interest.

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