Neurologic Health in Combat Sports

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KEYWORDS

• Combat sports • Neurologic injuries • Neurologic health • Combat sports clinicians

KEY POINTS

- Neurologic injuries of both an acute and chronic nature have been reported in the literature for various combat sport styles; however, reports of the incidence and prevalence of these injury types vary greatly.
- Combat sports clinicians must continue to strive for the development, implementation, and enforcement of uniform minimum requirements for brain safety.
- These health care providers must also seize on the honor to provide this oft-underserved population with the health care advocacy they very much deserve, but often do not receive.

INTRODUCTION

Because combat sports encourage deliberate blows to the head, much of the world's medical community has spoken out against this genre of sport, including the American Academy of Pediatrics and the American, Canadian, Australian, British and World medical associations.[1–6] Despite this opposition, mixed martial arts (MMA) continues to rapidly gain acceptance as a genuine combat sport, and is currently more popular than boxing, the National Hockey League (NHL), and the National Association for Stock Car Auto Racing (NASCAR) amongst males 18 to 34 years of age.[7] Boxing and MMA alike are both watched by millions of spectators annually in the United States and abroad. The May 2, 2015 "Fight of the Century" bout between Manny Pacquiao and Floyd Mayweather,Jr. generated 4.6 million pay-per-view purchases and generated a revenue of over $400 million; both figures remain all-time records within the world of combat sports. In the summer of 2016, the Ultimate Fighting Championship (UFC) was purchased by a group of outside investors for $4.2 billion, which was remarkable considering its original purchase for $2 million in 2000. Up to one-half of all fights in boxing, karate, and taekwondo result in injury, with a significant number of these injuries being to the head and neck region.[8–13] Despite this elevated public interest, chronic traumatic brain injury (CTBI) remains the most predominant safety

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challenge in modern-day combat sports. With its inevitable association with central nervous system trauma, it is imperative that neurologists maintain an open line of communication and understanding with its combatants.

Boxing and other combat sports are different than other sporting pursuits due to the head being an intended and targeted place of contact. Despite the inherent goal of attempting to concuss an opponent, the current author suggests that calls to ban this genre of sport overlook the inherent benefit of active medical involvement in the context of combat sports. Sports medicine providers should emphasize the associated risks, insist on adequate safety precautions, and even prevent future participation due to disqualifying medical conditions. I stop short, however, of unwavering opposition due to other associated factors, such as socioeconomic considerations and the benefit of exercise, self-discipline, and familial structure. In a sports genre where a significant portion of participants arrive from humble socioeconomic backgrounds, the value of health care advocacy provided by sports medicine personnel cannot be underestimated.

Combat sports participation is associated with a risk of neurologic injury, both acute and chronic in nature. CTBI includes a number of disorders that are associated with long-term neurologic sequelae, including persistent post-traumatic headache, chronic postconcussion syndrome, post-traumatic Parkinsonism, post-traumatic dementia, dementia pugilistica, and chronic traumatic encephalopathy (CTE). Previous studies have estimated 20% to 50% of former boxers have symptoms of chronic brain injury.[14] Combat sport athletes are exposed to thousands of blows to the head over the course of their careers, with the cumulative endpoint often being that of chronic neurologic impairment. The complex mixture of applied force, induced head movement, and neurophysiological state at the time of injury contributes to the type & severity of brain injury incurred. Furthermore, there may be a time period of increased vulnerability after TBI where the brain is physiologically more susceptible to recurrent injury at a lower threshold. The early identification of high risk fighters is imperative to facilitate primary prevention efforts, such as decreasing the likelihood of reinjury (secondary prevention), and ensuring access to appropriate interventions that may reduce both personal and aggregate costs (tertiary prevention). The precise threshold of force necessary to induce both acute and chronic neuropathology remains unknown; therefore, the accurate and timely detection of neurologic injury in combat sports is of critical importance so that appropriate therapeutic management may be initiated.

ACUTE AND CHRONIC BRAIN INJURY

Issues regarding the neurologic health of fighters are generally divided into three categories: (1) pre-participation exams to assess baseline status (2) return to fight progression after concussion, and (3) serial assessments to evaluate the aptitude for continued sport participation. Most major professional sports leagues within the United States have formal concussion policies in place; however, return-to-fight management in combat sports participants remains much less standardized. Commonly used guidelines for return-to-sport progression after concussion are inconsistently applied, with significant variability being dependent upon the jurisdiction of medical suspension. In MMA and boxing, medical suspensions are generally issued after a technical knockout (TKO) or knockout (KO). During these restricted periods, fighters are prohibited from sparring and competition, but not from other activities, such non-contact risk conditioning. These suspensions range from 30 to 180 days, but vary greatly in criteria, uniformity, and regulation by the various athletic commissions.[15–18] The transient nature of fighters also provides a frequent barrier in delivering

"best practice" medicine, as many competitors often travel to different jurisdictions or even internationally for training camps and competition; subsequently outpatient follow-up with these individuals is inconsistent at best, and nonexistent, at worst.

The frequency of acute traumatic brain injury (ATBI) in amateur boxing is low. The most common type of ATBI is concussion; however, more moderate to severe brain injuries such as diffuse axonal injury, cerebral contusion, subdural hematoma, intracranial hemorrhage, or epidural hematoma may uncommonly be experienced by participants.[19] A realistic aim in combat sports is ATBI risk reduction and minimization of injury, rather than elimination altogether. This goal is accomplished by performing pre-fight examinations to identify individuals predisposed to catastrophic brain injury. In Kentucky, for example, recent changes were instituted by the Kentucky Boxing and Wrestling Commission (KBWC) at the beginning of 2017 with the aim of improved fighter health & safety.[20] Combatants' comprehensive physicals are now required 15 days prior to licensure, so as to allow adequate time for the Commission's Medical Advisory Panel to review license applications.

Historically, most competitors in boxing, kickboxing, or MMA would be licensed on the day of the bout. A recurrent concern with this model, however, was that a pre-fight physical was not as in-depth as a physical conducted in a clinical setting, such as an outpatient physician's office. The doctors who attend these events must screen numerous contestants, so the time spent with each athlete is limited. Recognizing this concern, the KBWC now mandates that boxers, kickboxers, and mixed martial artists be required to have a comprehensive physical performed before the Commission issues a license. For the accuracy of medical history, this physical must be within the 90 days previous of an applicant seeking licensure. The KBWC also now mandates that an applicant for licensure apply for a license at least 15 days in advance of any scheduled bout, whether professional or amateur. This regulation is required to permit the KBWC's Medical Advisory Panel sufficient time to review an applicant's medical records to determine the applicant's fitness for licensure. Under the old model, such review was impossible, as a fighter was licensed and received a physical only hours before the fighter was set to compete. The accessibility of the Commission's Medical Advisory Panel also allows for the prompt review and subsequent approval of licensure applications in those rare, but unavoidable, situations that fight cards are altered within the 15 day pre-fight period.

The KBWC felt this approach was feasible for applicants, as virtually all health insurance plans cover 100% of the cost of a yearly physical. Combatants can, therefore, have their physician complete the Commission's required physical, and not require extensive out-of-pocket expense. Furthermore, pre-fight physicals, that all contestants must undergo, are provided free of charge. Finally, and most importantly, these changes were felt to be medically necessary to ensure the health and safety of all combatants, while drawing an appropriate balance against unnecessary restrictions.

The pathogenesis of fatal sport-related head injury in young athletes remains controversial. In Japan, judo-related fatalities due to brain injury are occurring at increased frequency and have become an issue of significant public concern[21]; however, validated epidemiologic data are less commonly reported. Deaths to boxing participants have been reported in a more comprehensive manner than judo-related fatalities, or any other combat sport type. The majority of deaths from boxing result from a subdural hematoma, and are often associated with an immediate loss of consciousness during a fight.[22,23] Although a small number of deaths in other combat sports have been the subject of a few case reports, rates of death in those sports cannot be accurately determined based upon the available literature.[24,25]

Neuroimaging applications extend far beyond their ability to rule out evidence of diffuse axonal injury or acute blood product formation following head trauma. Preparticipation radiographic screening can prove invaluable in the setting of preexisting intracranial pathology that may predispose to catastrophic outcomes. The primary objective with such imaging is to identify a structural lesion such as subdural or epidural hematoma, vascular malformation or aneurysm, or space-occupying arachnoid cyst, which could further elevate a fighter's morbidity and mortality during competition.[26] If detected, the significance of an abnormality is deferred to the respective commission's chief medical officer or medical advisory panel. Subsequently, a fighter could conceivably be prohibited from obtaining licensure in one state due to intracranial pathology, while concurrently obtaining formal clearance to fight in another jurisdiction. Within the context of combat sports, there is no evidence-based data from which to derive guidelines for optimal frequency of MRI imaging; however, to reduce the likelihood of serious brain injury, serial monitoring of some type is warranted.

In addition to acute injury, chronic neurocognitive impairment is also a considerable concern in modern-day combat sports.[27,28] It has long been recognized that certain individuals exposed to cumulative head trauma may develop persistent, progressive, and even irreversible neurologic impairment despite the cessation of head trauma exposure (**Table 1**).[26] In the absence of reliable screening methods to consistently identify those fighters at high risk for CTBI, a vexing challenge for combat sports physicians and sanctioning bodies alike is determining when it is no longer safe for a participant to continue competitive involvement within the sport. It is possible that serial neuropsychological testing may help objectively identify those with chronic progressive neurocognitive impairment, yet this is but one component of comprehensive neurologic monitoring. Regardless, baseline neuropsychological testing is recommended so that an additional measure of recovery is available for the treating clinician to assist in return-to-fight decision making. Although inherent limitations exist, such testing can be useful in the assessment of cognitive and behavioral impairment following head trauma exposure.

Many states and jurisdictions require a more extensive neurologic evaluation for fighters considered to be "high risk." The determination of what comprises a high risk fighter is typically a confluence of factors; including age, number of rounds fought, or prolonged time period away from competition. Findings from the Professional Fighters Brain Health Study suggest that strictly using the criteria of age or number of rounds fought did not consistently correlate with decreased measures of cognitive function.[29] Instead, a Fight Exposure Index has been employed that combines several factors including age, number of professional fights, average fights per year, and number of KOs. This formula, based on readily accessible information, correlates significantly with standard cognitive performance measures. Thus, the use of a risk index

Table 1
Chronic traumatic brain injury

Long Term Consequences of Traumatic Brain Injury	
Chronic traumatic encephalopathy	Dementia pugilistica
Chronic post-concussion syndrome	Chronic neurocognitive impairment
Post-traumatic dementia	Post-traumatic cognitive impairment
Post-traumatic parkinsonism	Persistent post-traumatic headache

Data from Jordan BD. Brain injury in boxing. Clin Sports Med 2009;28:561–78.

to identify those fighters at highest risk of impairment can consistently be employed. For those fighters suspected of being higher risk, further evaluation with detailed neuroimaging, formal neuropsychological testing, and clinical neurologic evaluation is recommended. Further testing, such as PET imaging or specific MRI modalities (functional, diffusion tensor, or susceptibility weighted) may be indicated at the discretion of the treating neurologist or neurosurgeon.

HEADGEAR

The introduction of mandated headgear was introduced into Olympic boxing at the 1984 Los Angeles games due to an American Medical Association demand out of concern for long-term neurocognitive impairment in boxers. There was no scientific basis for this transition nor were the head guards designed to reduce the risk of head injury. The original use of headgear was designed to reduce the incidence of facial cuts; however, it is theorized that its use could potentially provide added protection due to energy absorption, and a displacement of peak impact to a greater surface area upon localized impact.[30] Since its inception, subsequent neurosurgical and neurotrauma literature specific to the topic has suggested that headgear efficacy is limited to moderate to severe head trauma, rather than mild traumatic brain injury (TBI) such as concussion.[31] More recent evidence also suggests that patients equipped with headgear do not have improved clinical outcome or protection against concussion when compared to an unhelmeted cohort.[32] Despite opportunistic marketing and a public perception otherwise, it remains unclear to what degree helmets are effective in concussion risk reduction.

The combat sports-specific literature within the context of headgear is quite sparse. In 2013, O'Sullivan and colleagues[33] showed that standard taekwondo headgear does not protect against low-energy (50 g) or high energy (150 g) head impacts thought to result in concussion. Two studies on amateur boxing revealed further evidence showing limited protection offered by headgear. A 2013 study by Bianco and colleagues[34] found that mandatory headgear use was associated with an overall increase in "referee stopped contest due to head injury," as well as "referee stopped contest" injuries overall. Bartsch, and colleagues[35] investigated the use of padded headgear and gloves in mixed martial artists. They found a reduction in linear impact dose, but no effect on rotational impact forces. The addition of headgear also led to increased weaponization of the head, as boxers developed a style of fighting with head placement more forward, resulting in an increase in head-to-head contact with their opponents. In 2013, the Amateur International Boxing Association (AIBA) ultimately mandated the banning of headgear in amateur male competition, citing internal data by chairman of the AIBA medical commission, Dr Charles Butler.[36] Dr Butler reported that removal of headgear was associated with reduced concussion rates among amateur boxers. Specifically, 7545 rounds without headgear use resulted in a concussion rate of 0.17%, while 7352 rounds with headgear resulted in an increased concussion rate of 0.38%. Of interesting note, this transition to headgear removal applied to adult-level amateur males only. It remains unclear why these rule changes were not extended to females and youth athletes also, as the mechanism of injury in those populations would be expected to be the same. To date, all female (any level) and all junior level male boxers are mandated to continue the usage of headgear in competition.

A number of other factors potentially increasing neurologic risk were considered during the evaluation of headgear efficacy. There is some concern that headgear decreases peripheral vision, allowing heavier kicks to be landed to the head, while

concurrently slowing the fighter from taking any counter-defensive measure.[37] It is also important to note that increased cranial weight and bulk from headgear may contribute to greater magnitudes of injury via additional surface areas, which ultimately augment the force of contact.[38] In summary, there is little to no convincing evidence in the medical literature showing that mandatory use of headgear is necessary to either prevent head injury or to reduce concussion risk. A limitation of most pertinent published studies, however, is that headgear regulations have often coincided with other rule changes and implementation. For this reason, it is very difficult to definitively state the effects of mandatory headgear use alone.

WEIGHT-CUTTING

Combat sports medicine physicians remain gravely concerned over the increased occurrence and popularity of weight-cutting. There are overt dangers associated with dehydration, including electrolyte imbalance, hypoglycemia, and the danger of over-rehydration. To ensure a fair & competitive balance among participants, as well as guard against preventable injury, match-making for combat sport involves competition within specific weight classes. In attempt to obtain a competitive advantage within their respective weight class, many participants acutely reduce body mass & weight through a process known as "weight-cutting." This potentially provides an advantage by being the larger and stronger combatant while competing against lighter, weaker, and smaller opponents. Subsequently, many combat sports athletes compete in weight classes 5% to 10% below their normal body weight.[39,40] The prevalence of acute weight reduction is very high in certain combat sports, such as judo, wrestling, karate, boxing, jujitsu, and taekwondo.[41] Of significant concern is a population of younger athletes employing aggressive weight reduction measures. Artioli, and colleagues[39] found that approximately 60% of judo participants utilized rapid weight-cutting practices before competitions at very young ages (ie, 12–15 years). Another study found that 33% of high school wrestlers competed during season below minimum wrestling weight. Minimum wrestling weight was defined as a body fat measurement of 5% or less.[42] Evidence suggests that rapid weight cycling during adolescence can be problematic due to its negative impact upon development and growth.[43] Furthermore, it has been suggested that weight-cutting in youth athletes is associated with a higher risk of obesity after ceasing competitive sport participation.[43]

Despite objective evidence on the negative impact of acute dehydration upon various health-related parameters, combat sports have remained steeped in their own tradition and culture of weight-reducing measures. Although data concerning these practices are beginning to accumulate, the specific study of weight-cutting in combat sports is still a largely under-researched space. In instances of strict pre-bout weight monitoring of participants, weight losses of 3 to 4 kg are not uncommon in the week preceding competition.[39,44–47] A 2013 study evaluated thirty-two collegiate wrestlers who had initiated weight-cutting measures a day before pre-practice and post-practice testing.[48] The authors found pre-match decreased performance on both neuropsychometric measures as well as balance testing. A 2015 study of elite wrestlers found that 60.7% were found to be dehydrated (ie, plasma osmolarity of >290 mOsm/L) on the day of competition.[49] These practices of rapid weight loss invariably result in significant discrepancies among competitors. In sports such as wrestling and taekwondo, weight discrepancies of up to 10 kg may exist between weight divisions, whereas weight classes in professional and amateur boxing are separated by no more than 3 to 4 kg.[50] However, after weigh-in has been completed

in competitive boxing or MMA, rehydration in excess of 9 kg by the time of actual competition has been reported.[51] This potentially allows for a significant mismatch within the ring/cage when a fighter rehydrates to 1, or even 2, weight-classes above his opponent by the time of actual competition.

In response to such situations and an overriding concern for fighter health & safety, the California State Athletic Commission in April of 2017 proposed an ambitious plan to address these ongoing concerns in a systematic manner.[52] Among the proposed revisions include: licensing fighters by weight class; the addition of new weight classes; making fighters move up a division if they miss weight more than once; dehydration checks; and 30-day and 10-day weight checks for high-level title fights. Arguably, the most substantial proposed change is a mandatory weight check on fight day to see if the athlete has gained back more than 10% of his or her body weight after weigh-ins. Per the proposal, if the fighter puts on more weight than the 10%, the fighter would be required to increase weight classification (ie, go up in weight) for his or her next bout.

Acute dehydration can also affect brain morphology, which has key implications, particularly in neurologic health. A study of regional brain changes found that rapid dehydration resulted in ventricular dilation, with the largest volume expansion occurring in the left lateral ventricle and an associated relative decrease in total brain volume.[53] Another study in adolescents observed a significant correlation between bodyweight loss and percentage change in ventricular volume, indicating that greater reductions in body mass were proportional with increases in lateral ventricular volumes.[54] The observed lateral ventricular enlargement is thought, in part, due to an osmotic gradient induced by acute dehydration. This gradient results in water leaving intracellular stores, causing a relative volume loss in astrocytes, which are key components of intracellular water & nutrient transport. The relatively subtle, but definite, degree of brain atrophy may manifest as a compensatory increase in ventricular volume.

Several studies have linked acute dehydration with an increased risk for musculoskeletal injuries during practice or competition.[55–57] The concern for acute and chronic brain injury is also heightened in the context of acute dehydration. Dehydration is accompanied by a number of adaptive hormonal responses that are aimed at the conservation of body fluids, including an increase in plasma vasopressin concentration. Vasopressin can substantially reduce blood flow to the choroid plexus, in turn, decreasing cerebrospinal fluid (CSF) formation.[58] CSF acts as a cushion, mitigating the effects of brain movement inside the skull after sudden jarring movements and/or impacts. Dehydration and concussion share a similar symptomatology, including dizziness, headache, and imbalance. It is critical for sports medicine personnel to understand how weight-cutting tactics affect clinical concussion measures in order to provide appropriate care to combat sport athletes. Unfortunately, negative effects of weight-cutting tactics can significantly skew the accuracy of clinical concussion assessments.[48] Furthermore, much like other realms of sports concussion research, there is a tremendous paucity of data investigating any potential link of acute dehydration and increased risk of neurologic injury. Clearly more information is needed to definitively establish an evidence-based association; however, until such data is available, clinicians should continue to utilize “best practices” medicine, and operate under the assumption of acute dehydration lowering the threshold for concussive injury.

Lastly, the psychological component of weight-cutting in combat sports athletes is often minimized or discounted altogether. For some competitors, strict weight regulation propagates the self-image of being, “a real athlete”.[59] Weight-cutting in combat sports has also been intertwined as a long held tradition and culture of the sport;

however, few studies, however, have further explored the assumed mental and physical benefits or shortcomings of acute weight reduction among combat sport athletes. A 2013 study of Swiss Olympic combat sport athletes (wrestling, judo, and taekwondo) revealed the practice of weight-cutting to be a primary component of sport identity through both self-perception of one's standing as an athlete, as well how an athlete was perceived by others.[59] Consequently, the general practice of rapid weight cycling for the purpose of enhanced athletic performance and perceived competitive advantage was openly encouraged by coaches and teammates. Although recent efforts through entities such as the California State Athletic Commission (described previously) are commendable and long overdue, rule changes alone could potentially fail to address the deeply held beliefs and positive psychological effects associated with weight regulation. Psychological counseling provided for these athletes may be a viable adjunct to aid in the transition away from this longstanding practice and its closely held association with sport identity.[59]

PERFORMANCE ENHANCING DRUGS

The practice of performance enhancement via artificial means and/or compensatory substances is as old as competitive sport itself. As early as BC 776, Greek Olympians are rumored to have used substances such as mushrooms, dried figs, and strychnine to increase their athletic prowess.[60] The first death attributed to a performance enhancing drug (PED) occurred in 1896, when a Welsh cyclist, Andrew Linton, overdosed on a stimulant, trimethyl, although there is some dispute regarding the factual accuracy of the case.[61] The first report concerning the use of anabolic-androgenic steroids (AAS) by a competitive athlete dates back to 1954.[62] Reliable testing for anabolic steroids within Olympic sports was finally introduced in 1974. The International Olympic Committee formally added AAS to its list of prohibited substances in 1976.[63] AAS consistently remain the most commonly used PEDs in modern day Olympic competition. Their reach into the world of combat sports is undeniable despite their prohibition due to health concerns and the unfair competitive advantage provided. Their use also often violates federal laws within the United States regarding controlled substances; regardless, speculation suggests that PED use is more prevalent in combat sports today perhaps than ever before, in amateur and professional ranks alike.

Within the United States, drug testing via United States Anti-Doping Agency (USADA) guidelines has long been the ultimate standard for most professional and NCAA sport participants; however, mandatory Olympic-style drug testing in combat sports is present only at the highest levels of competition. Standard USADA testing can reportedly cost up to $50,000 per fighter for 8 weeks of random testing in the time surrounding a bout.[64] Low -level promoters and smaller state athletic commissions are often unable to ensure the testing of all fighters due to inherent financial constraints. Within the United States, state-to-state variations are commonplace, with some states requiring mandatory testing only for title bouts, while others have no formal testing policy whatsoever. Because of this, lower-level fighters can conceivably avoid detection if they were to continue to fight in venues outside certain jurisdictions or promotions. With no federal oversight or national governing body, such practice variations will almost certainly continue to persist, despite its detriment to the competitors in the ring and/or cage.

Boxers and MMA fighters indeed have unique sport-specific risks when stepping onto the stage of competition; however, fighters agree to face their opponents within a specific weight range, in accordance to the rules of their sport, including the working

assumption that their opponent is void of PEDs. The consequences of PEDs extend far beyond what they may do to the offending party. It can be problematic for the unknowing opponent and decrease the threshold for catastrophic injury in this genre of sport where head trauma is routinely encountered. Due to the inherent risks of combat sports, having all fighters, professional or amateur, subjected to mandatory testing, is not unreasonable.

Testosterone remains a mainstay within the world of PED testing. This naturally occurring hormone plays a critical role in neuronal function; however, supratherapeutic levels can have harmful effects within the central nervous system. Estrada and colleagues[65] suggested that increased amounts of testosterone initiate the apoptotic cascade in otherwise healthy neurons. The authors found that elevated testosterone concentrations increased cell death, with these effects having long-term and potentially permanent effects on brain function. How AAS influence the brain's threshold of concussive injury remains largely unknown; however, a 2016 rodent study revealed that AAS exposure significantly exacerbates microgliosis and axonal injury after head trauma.[66] This suggests that AAS exposure likely alters the inherent neuronal response to mild traumatic brain injury (mTBI). An earlier study using a standard acceleration-deceleration model of mTBI, however, revealed no deleterious effect of AAS on the brain following head trauma.[67] Although approximately 20% of CTE cases report a history of substance use, including AAS, it remains uncertain whether a history of AAS use influences the behavioral and neuropathological responses seen with head trauma.[68] Well-designed prospective studies are necessary to better understand how AAS influence the long-term trajectory of post-TBI neurocognitive deficits.

A more recent structural study found negative correlations between AAS use and cortical thickness and brain volume.[69] Specifically AAS users, when compared to non-using controls, had thinner cortex measurements in multiple regions, as well as significantly smaller neuroanatomical volumes, including total gray matter, cerebral cortex, and putamen. Both thickness and volumetric measures remained relatively stable across different AAS subsets representing various degrees of AAS exposure. These findings raise concerns about possible deleterious effects of long-term AAS use on brain health. The cortical effects seem to persist after stopping AAS use. Large-scale longitudinal, and ideally prospective, studies are warranted to address the possible implication of accelerated cerebral atrophy caused by long-term AAS exposure.

SUMMARY

Neurologic injuries of both an acute and chronic nature have been reported in the literature for various combat sport styles; however reports of the incidence and prevalence of these injury types vary greatly. Large scale longitudinal, and ideally prospective, studies, such as the *Professional Fighters Brain Health Study* at the Lou Ruvo Center for Brain Health in Las Vegas, Nevada, are warranted to address the underlying neurologic implications of combat sport participation. Furthermore, newer areas of concern unrelated to direct head trauma exposure, such as the neurologic implications of weight-cutting and PEDs, also warrant systematic surveillance and diligent study by the combat sports medicine community. Concussion and lasting brain damage, however, remains the most significant risk for in this genre of sport, where the aim is, in fact, to deliver a concussive injury to the opponent. Combat sports clinicians must continue to strive for the development, implementation, and enforcement of uniform minimum requirements for neurologic safety. These health care

providers must also seize upon the honor to provide this oft-underserved population with the health care advocacy they very much deserve, but often do not receive. As a whole, we can ensure both the long-term health of the athlete/patient within the ring of competition as well as the long-term viability of the sport itself.

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