



ORIGINAL RESEARCH



Concussion occurrence and recognition in professional boxing and MMA matches: toward a concussion protocol in combat sports

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ABSTRACT

Objectives: Determine, through video reviews, how often concussions occur in combat sport matches, what influence they have on the outcome, and how well non-physician personnel can be trained to recognize concussions.

Methods: This is a retrospective video analysis by an 8-person panel of 60 professional fights (30 boxing and 30 mixed martial arts). Through video review, physician and non-physician personnel recorded details about each probable concussion and determined if and when they would have stopped the fight compared to the official stoppage time.

Results: A concussion was recorded in 47/60 fights. The mean number of concussions per minute of fight time was 0.061 (0.047 for boxers and 0.085 for MMA). When stratifying by outcome of the bout, the mean number of concussions per minute for the winner was 0.010 compared to the loser at 0.111 concussions per minute. The fighter that sustained the first concussion ultimately lost 98% of the time. The physician and non-physician raters had high agreement regarding the number of concussions that occurred to each fighter per match. The physician raters judged that 24 of the 60 fights (11 boxing [37%]; 13 MMA [43%]) should have been stopped sooner than what occurred.

Conclusion: Recognizing that the concussions often occur in combat sport matches, that the losing fighter almost always is concussed first and tends to sustain more concussions during the fight, along with the demonstration that non-physician personnel can be taught to recognize concussion, may guide policy changes that improve brain health in combat sports.

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Background

As our understanding of concussion and its potential lingering neurological effects has increased, there has been a heightened attention to concussion recognition in organized sports. With this improved awareness, numerous policies now exist to decrease the risk of morbidity/mortality following head injury. Most major professional sports leagues in the United States, including the National Football League (NFL), National Basketball Association (NBA), National Hockey League (NHL), Major League Baseball (MLB), Major League Soccer and Ultimate Fighting Championship (UFC) have a formal concussion policy in place [1–4]. Conspicuously absent from this list are state organizations that sanction combat sports.

Combat sport regulatory commissions vary on guidelines regarding concussions and who is authorized to stop a match. Generally, a contest is halted when a referee and/or physician decides an athlete can no longer defend him or herself [5]. In many jurisdictions, the referee is the sole arbitrator authorized to end a fight while taking into consideration recommendations from the ringside physician [6]. However, referees face immense pressure when making quick decisions to end

a contest, especially during matches that can significantly influence the ranking or title of a combatant or their financial gain. During critical moments, referees are limited by visual perspective and their judgments can be indirectly influenced by crowd noise [7,8], coaches' exclamations [9], corner staff, promoters, and fans (both at the arena and the television audience). Yet, a fight stopped too late could lead to serious injuries and even death [10].

The particular challenge in developing concussion policies in combat sports is that concussion itself is one of the determinates of the outcome of the bout. An implicit goal for a fighter is to induce a concussion on his/her opponent that renders the opponent unconscious (Knock Out [KO]) or unable to continue (Technical Knock Out [TKO]). However, the majority of concussions that occur in sports do not result in loss of consciousness [11]. Thus, if a fighter sustains a concussion that does not KO/TKO them (and thus stop the fight), it may still significantly impair their subsequent performance and place them at risk of experiencing greater cumulative injury in the match. This risk for cumulative injury could potentially be reduced if policies could be constructed to stop a fight earlier.

Currently, there are scant data on the frequency and characteristics of concussions that occur during a sanctioned professional fight. There has been significant heterogeneity in the methods that concussion in combat sports has been reported in the literature including medical diagnosis by a ringside physician or presence of KO/TKO [12,13]. These studies assess concussion as a single endpoint that occurred at termination of the match. No prior study has systematically determined the number of concussions that occur throughout a combat sport competition.

As in other sports, retrospective review of videoed professional fights can be a method to acquire important information on the occurrence of concussions and help guide development of concussion policies. Studies of video analysis in other high contact sports, such as professional American football and rugby, have shown that certain observable signs are comparably sensitive to a concussion diagnosis made by in person assessment [14–16]. The visible features that have been reported to correlate with medically diagnosed concussion include loss of consciousness, vacant stares, motor incoordination, and poor balance/ataxia [17,18]. Potentially, non-physician personnel could be trained to recognize these discernable characteristics of a concussion.

In considering how a concussion protocol could be devised in combat sports, further data is needed about concussion prevalence and recognition. The aims of this exploratory study are: 1) identify the rate at which concussions occur in professional combat sport competitions, 2) determine how they may relate to the outcome of the match, and 3) ascertain how well non-physician personnel can be trained to recognize concussions.

Methods

This was a retrospective video analysis study of 60 professional fights (30 boxing and 30 mixed martial arts [MMA]). The videos were reviewed by an 8-person panel consisting of four neurologists who had extensive experience with combat sports and four non-physicians also familiar with combat sports (certified athletic trainer, college student, boxing inspector, combat sport promoter). Each panelist was instructed on the visual signs which would constitute a concussion. These signs had to have cleared before a combatant was judged to have sustained a subsequent concussion. While we use the term, ‘concussion’, we realize that, technically speaking, it is a **suspected concussion**, since no direct examination of the fighter was performed. The reviewers watched each video on their own on a computer screen without the soundtrack to avoid bias by the commentators. Fight review data were recorded on a standard scoring sheet.

The 60 videos in the study were drawn from a consecutive series of professional-televised fights beginning in May 2015. The 30 MMA fights reviewed were in the Ultimate Fighting Championship (UFC), and the 30 boxing fights reviewed were Premier Boxing Champions fights. To be included in the study, the fight must have been scheduled for a minimum of 6 rounds for boxing or a minimum of 3 rounds for MMA and have had a video publicly available of sufficient quality to reliably assess the behavior of the fighters. Because the number of punches thrown (and perhaps the risk of concussion) differ on average between weight classes, we included an equal number of fights

at various weight classes [19]. Among the 30 UFC fights selected, 11 were Lightweight fights (7 ending in TKO/KO; 4 ending by decision), 9 were Welterweight fights (6 ending in TKO/KO; 3 ending by decision), and 10 were Heavyweight fights (7 ending in TKO/KO; 3 ending by decision). Modified boxing weight classes were defined for the purposes of this study. Boxing fights with competitors less than 135 lbs. were placed in the ‘Light’ category, while those with competitors between 140 lbs.–160 lbs. were placed in the ‘Mid’ category and those with competitors over 175lbs in the ‘Heavy’ category. Among the 30 boxing fights selected, 10 were Light category fights (7 ending in TKO/KO; 3 ending by decision), 11 were Mid category fights (7 ending in TKO/KO; 4 ending by decision), and 9 were Heavy category fights (6 ending in TKO/KO; 3 ending by decision).

The set of 60 fights were divided into 4 unique subsets, each with 15 fights. Each subset included 7 or 8 boxing fights and 7 or 8 MMA fights sampled systematically. Each reviewer was given one of the 4 subsets of fights to review, such that exactly one physician and one non-physician reviewed each subset. The fight video reviewers recorded details about each observed concussion sustained by the combatants, including the round and time left in the round when the concussion occurred, the symptoms of concussion, the method of hit, and the location of the hit. The reviewer answered relevant questions about each fight, including whether or not they would have stopped the fight earlier than the official stoppage time, when they would have stopped it, and what the official stoppage time was (Figure 1).

The completed scorecards were sent by e-mail or mail to the Cleveland Clinic Center for Brain Health in Las Vegas Nevada and the data inputted for statistical analysis.

Statistical analysis

In the comparison of number of concussions, mean and standard deviation (SD) were reported for two fighting styles and the outcome of the bout. McNemar’s test was used to test the agreement between physician and non-physician on whether fights should be stopped sooner. For the agreement test, Kappa test was performed to test the agreement among rates [20]. Levels of agreement based on kappa values are defined as: slight agreement (0–0.2), fair agreement (0.21–0.4), moderate agreement (0.41–0.6), substantial agreement (0.61–0.8), and almost perfect or perfect agreement (0.81–1.0). All these tests were two-sided at the alpha level of 0.05. All statistical analyses were performed by using SAS statistical software (Version 9.4; SAS Institute Inc., Cary, NC).

Results

Of the 60 fights reviewed, a concussion was recorded as occurring by one of the physicians in 47 fights, and no concussion was recorded in the remaining 13 fights. The concussion rate is defined as the total number of concussions divided by the total fight time for all fighters (for example, if 2 concussions occurred in a fight that lasted a total of 10 minutes, the concussion rate would be 2 concussions/20 minutes = 0.1). Considering all the fights, the mean number of concussions per minute of fight time was $0.061 = 120/1982.70$ ($0.047 = 60/1278.93$ for boxers and $0.085 = 60/703.76$ for MMA). When stratifying by outcome of the bout, the mean number of

Fight Number _____

Symptom Key	
1	Knocked Down
2	Abnormal gait/balance
3	Vacant Stare/Dazed
4	Delayed motor response (i.e. decreased ability to defend himself)
5	Slurred speech observed between rounds
6	Focal neurological deficit
7	Prolonged period of defensive positioning with no proactive attempts to strike opponent

Fighter 1	Round	Time Left in Round	Symptom(s)	Method	Location of Hit
1			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
2			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
3			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
4			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
5			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
6			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
7			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
8			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face

Fighter 1	Round	Time Left in Round	Symptom(s)	Method	Location of Hit
1			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
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3			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
4			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
5			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
6			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
7			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face
8			1 2 3 4 5 6 7	Jab Upper Cut Kick Hook Choke Hold	Right Temple Jaw Left Behind Ear Face

Questions

1. Would you have stopped the fight earlier than the official stoppage time? **YES / NO**

2. If YES, and concussion / neurologic brain injury was your reasoning for an earlier stoppage, what specific signs and/or symptoms displayed by the fighter led to your decision? (please indicate from symptom key all that are applicable including 8 - Cumulative trauma; 9 - other explain)

3. When would you have stopped the fight? (please specify round and time left)

Round: _____ Time Left: _____

4. What was the official stoppage time?

Round: _____ Time Left: _____

Figure 1. Elements of the reviewer scorecard.

concussion per minute for the winner was 0.010, whereas the loser on average sustained 0.111 concussions per minute (boxers only: 0.009/min for winner, 0.084/min for loser; MMA only: 0.011/min for winner, 0.159/min for loser). There was no statistical difference in the number of concussions per minute in either boxers or MMA fighters related to weight class.

The distribution of concussions fell preponderantly on the loser (Figure 2). While the winner of the fight generally did not sustain a concussion (or if so, rarely more than 1), the loser more frequently was allowed to sustain multiple concussions as depicted in Figure 2. Moreover, in 46 of the 47 fights (98%) where a concussion occurred, the fighter that sustained the first concussion ultimately lost.

There was a substantial correlation between physician and non-physician raters regarding the number of concussions that occurred to each fighter per match with a kappa correlation of 0.634 for total number of concussions, give or take 1 which is considered substantial agreement (Figure 3). Excluding concussions that ended the fights in a KO or TKO, there still remained a moderate level of complete agreement (0.539). Among the

characteristics that identified a concussion, the fighter being knocked down was the most commonly cited symptom, followed by abnormal gait/balance, vacant stare/dazed, and delayed motor response, though the distribution of the later 3 varied slightly from boxers to MMA (Figure 4).

The panel of physician raters judged that 24 of the 60 fights (11 boxing [37%]; 13 MMA [43%]) should have been stopped sooner than what occurred (Figure 5). The mean amount of time the fights was considered to go on too long was 125 s with a wide range extending from 3 to 835 s, the median time was 34.5 s and the interquartile range (IQR) was from 12 to 119 s. Considering fighting disciplines, MMA fights seemed to terminate closer to what the physician reviewers had adjudicated, the mean time being 44.5 s (3–159 s) and the median time being 27 s (IQR: 10–51 s) compared to boxing matches that went on a mean 220 s too long (6–835 s), and a median 110 s (IQR: 13–339 s).

In determining whether a fight should have been stopped sooner than it was, the non-physician raters agreed with the physicians' judgment that the fight was stopped appropriately 85% of the time. On the other hand, the non-physicians only agreed on 63% of the fights that the physician thought went too long. The greatest discordance was with fights that the non-physician thought were stopped appropriately but the physician disagreed (8/50). The agreement index, Kappa coefficient, was 0.503, which is considered as moderate agreement between physician and non-physician (11), and the agreement test by using McNemar's test had the p-value of 0.248.

Discussion

Given the increasing attention to concussion and long-term effects of exposure to repetitive head impacts, there is emerging interest in strategies to improve brain safety in sports. Historically, combat sports have been ripe for criticism since one of the major goals for competitors is to intentionally inflict neurologic trauma upon their opponents [21,22]. Yet, the majority of fights do not end in knock outs, and there may be policy changes that can make combat sports safer in the 21st century [1,23]. Along those lines, this study was aimed at better understanding the frequency of observed concussions in sanctioned competitions, how their timing effects the outcome of the fight, and how well non-physicians can be trained to identify concussion.

Frequency of concussion

Among the most notable findings was that recognized concussions are likely to occur in a fight, averaging about 1 every 12.5 min of fighting time, and not always the terminal event in the match. While this may not be surprising given the nature of combat sports, it does highlight how fighters, unlike athletes in most other sports, are allowed to continue competing despite sustaining a concussion. Moreover, many losing fighters experience multiple concussions in a fight.

Effect of concussion

What perhaps was most striking in our series was that the fighter that sustained the first concussion in a bout/match

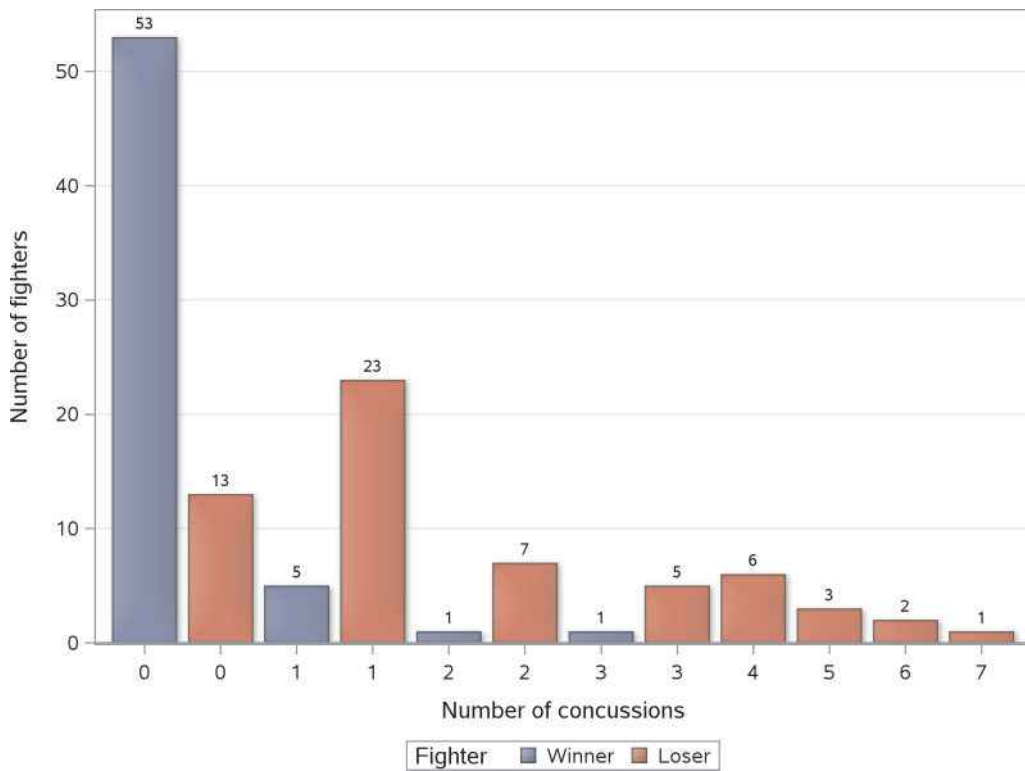


Figure 2. Number of concussions that were sustained by the winner and loser of each fight as judged by the physician reviewer (n = 120 fighters; 60 winners and 60 losers). Number of fighters are listed above each bar.

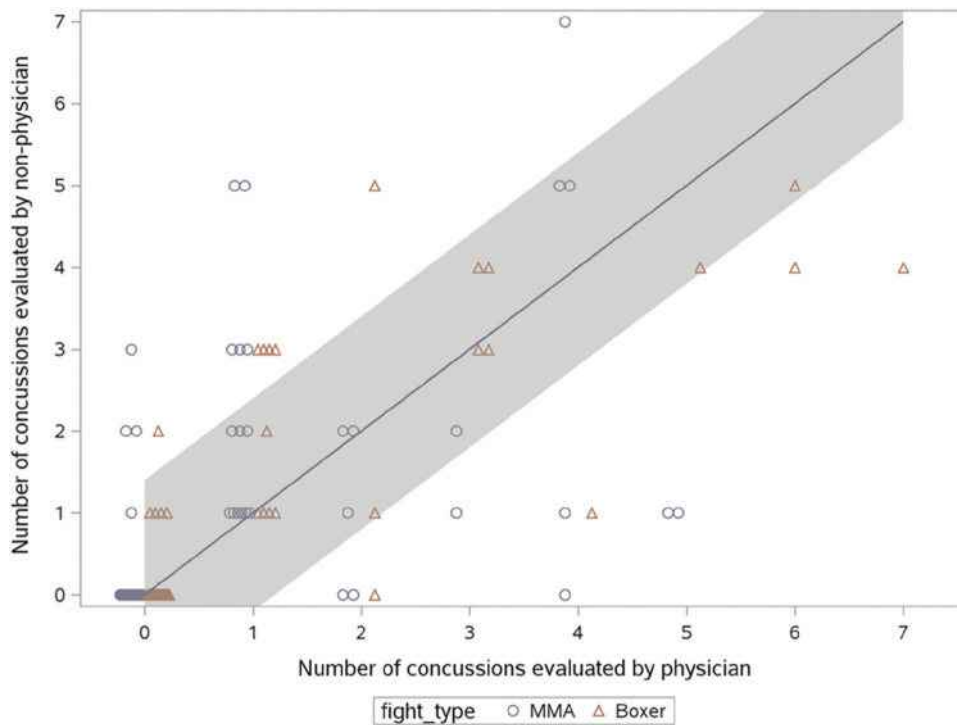


Figure 3. Degree of agreement between physician and non-physician reviewer in determination of number of concussions that occurred per fight. The shaded region indicates the fights where the physician and non-physician rated total number of concussions within 1.

almost always went on to lose. This finding may be due to one or more of the following: sustaining a concussion makes one more susceptible to another, impairs ability to compete as well, or that the inferior fighter is most likely to be concussed

first. A previous case series described three collegiate football players who concealed their concussion and were subsequently judged to have a drop in their performance during the game [24].

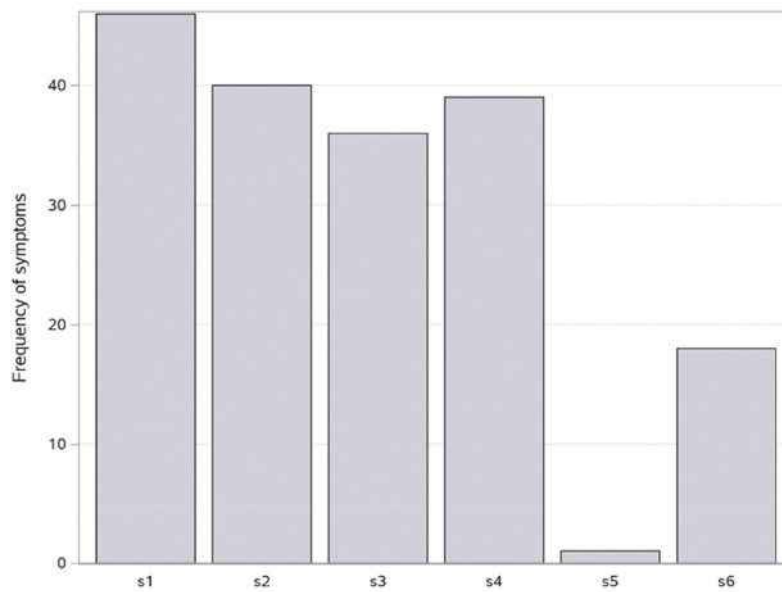
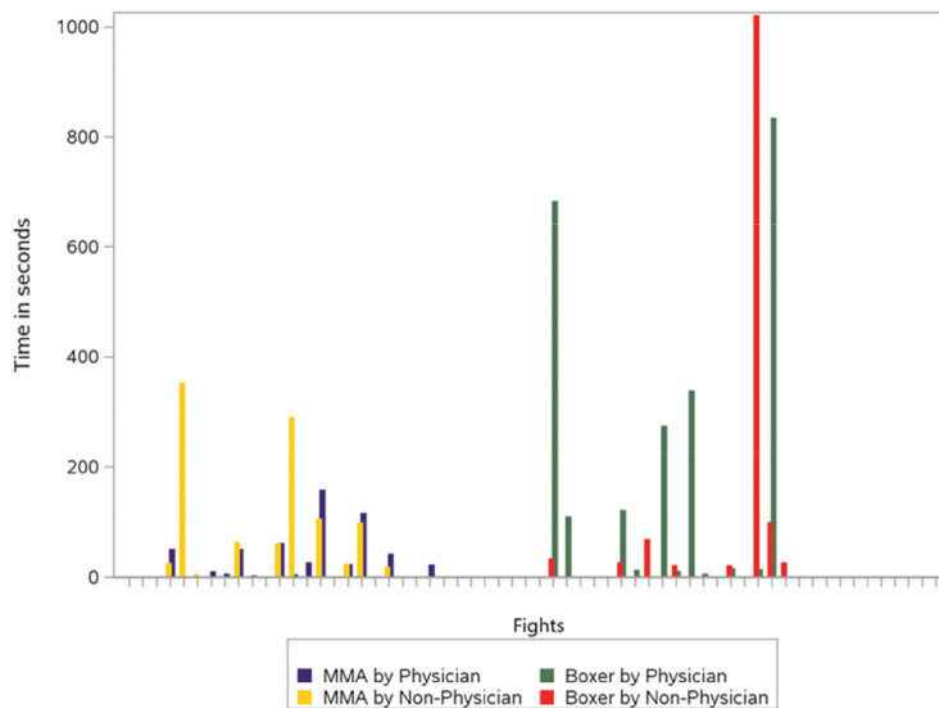


Figure 4. Number of times a specific visual sign was used to identify a concussion. A single concussion could have more than 1 sign. The signs area as follows: s1 Knocked Down, s2- Abnormal gait/balance, s3- vacant stare/dazed, s4- Delayed motor response (decreased ability to defend himself), s5- Focal neurological deficit, s6- Prolonged period of defensive positioning with no proactive attempts to strike opponent.



However, there was no strong correlation between the physician and non-physician's assessment of when the fight should stop. Judging when a fighter is too impaired to continue, short of a fight ending in KO/TKO, is certainly subjective and suggests that perhaps more than a single observer (i.e. referee) should be involved in that decision.

Concussion recognition

While there is an entire industry based on devising techniques and devices to detect concussion, our study suggests that non-physician personnel can be trained to reliably recognize the visual signs of concussion [26]. Previous work has described a group of observable characteristics that are highly correlated with medically diagnosed concussion [17,18]. When non-physician raters familiar with combat sports were specifically trained on these features, we found a high degree of agreement between physician and non-physician identification of concussions in a match. When there was disagreement, more often the non-physician assessed a concussion while the physician didn't. It is possible the non-physicians felt a heightened vigilance to not miss a concussion.

Concussion protocol in combat sports?

How our findings and others can be translated into policies that improve safety in combat sports is challenging. Many of the major promoters already have put into place standards that exceed the minimum requirements by the state regulatory commissions. For example, the UFC requires 4 ringside physicians, along with having their own medical director present at ringside who monitor the fighters during and in-between rounds (Davidson J, personal communication). However, other promotions may have only one physician present, which reduces the ability to scrutinize the ongoing status of both fighters. Furthermore, a referee may be hesitant to stop a fight in mid-round for suspected concussion (particularly early in the fight) unless the fighter is severely impaired. Referees and ring physicians are in the difficult position of balancing the risk of stopping a fight prematurely denying the concussed fighter the chance of possibly coming back and winning (which may have significant financial implications) versus letting that fighter unnecessarily absorb further brain injury. And although, many experienced referees are quite good at assessing the status of fighters, there are a number of external pressures that may exert some influence to allow the fight to go on as long as possible including the stature of the match (championship v. undercard), expectations from paying event attendees, television and pay per view viewers, gaming interests, promoters, and the fighters themselves [7–9].

Yet, one could envision implementing a concussion policy in combat sports. In regard to surveillance, even though there is a physician at ringside during sanctioned matches, it is certainly feasible that all other officials at ringside including referees, judges, and inspectors can be trained in concussion recognition. In addition, in fights where there is only one ringside physician, certified athletic trainers (ATC) who are already familiar with concussion protocols could provide additional monitoring during the match and inspectors could be responsible for observing behavior of fighters in their corner between rounds and alerting the physician or referee if any signs of concussion are noted. If

a concussion is observed, it would trigger a mandatory assessment of a fighter between rounds. The assessment could consist of a brief standardized test in the corner by the ringside doctor; the fight would be stopped if the fighter demonstrated amnesic or psychomotor deficits. In addition, the sport of boxing could decrease the standing 8 count to 4 seconds, which would allow fighters who fell to the ground through a slip or body punch or who can rapidly clear their overt signs and symptoms of concussion to continue, yet protect those who sustain a greater degree of motor or cognitive damage. Nevertheless, the fighter that sustained the first concussion should always have particular scrutiny throughout the match.

Admittedly, it is not known if addressing concussions in combat sports and ending fights sooner would benefit a fighter's overall brain health. A significant amount of the long-term neurological damage has been reported to occur with routine sparring during training [27,28]. However, there are anecdotal cases of fighters who seemingly were allowed to sustain cumulative blows to the head despite overt signs of neurologic impairment; thus, resulting in clear neurological morbidity [29].

Our study has a number of obvious limitations including a relatively small number of fights reviewed. Moreover, each reviewer only adjudicated 15 fights, which reduced the sample size when looking at correlations between physician and non-physician ratings (and whether the background of the non-physician influenced the agreement level with the physician). All bouts reviewed were high level and generally well-matched fights and may not be generalizable to lower level fights in smaller venues. The determination of when a fight should end was simply based on clinical judgment of the reviewer and is not a standardized measurement. The fights were reviewed without sound; it is unknown if the addition of crowd noise or the sound of a blow might influence determination of concussion. Lastly, without actually examining the fighter at the time or being able to review post-fight medical records, we cannot be sure what we assess as a concussion was genuinely a concussion. However, as mentioned previously, prior research has suggested a high correlation between visual characteristics of concussion and in person diagnosis [17].

Recognizing that concussions occur in combat sport matches even in the absence of a KO/TKO, that the losing fighter almost always is the one that is concussed first and tends to subsequently sustain more concussions during the fight, along with the demonstration that non-physician personnel can be taught to recognize concussion, can hopefully help guide policy changes that improve brain health in combat sports.

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Contributors

CB, TH, TS were involved in design of the study; CB, TH, TS, VW, MG, BN, WN assisted in data collection, GS provided statistical analyses for the paper; CB generated the initial draft of the paper; CB, TH, WN, VW, MG, BN, TS, GS revised the subsequent versions of the paper and approved the final version

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Declaration of interest

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Data sharing

Data will be provided upon reasonable request.

Patient consent

None required

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