ORIGINAL ARTICLE

No holds barred sport fighting: a 10 year review of mixed martial arts competition

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Objective: To identify the most salient medical issues that may be associated with mixed martial arts competition by determining the types and proportions of match stoppages.
Methods: Publicly available video footage of 1284 men competing in 642 consecutive televised matches from November 1993 to November 2003 was reviewed to determine the reasons for which matches were stopped. Matches were sanctioned by either a United States or Japan based mixed martial arts organisation.
Results: Of the 642 matches, 182 (28.3 ± 3.4%) were stopped because of head impact, 106 (16.5 ± 2.9%) because of musculoskeletal stress, 91 (14.1 ± 2.7%) because of neck choke, 83 (12.9 ± 2.6%) because of miscellaneous trauma, 173 (27.0 ± 3.4%) because of expiration of match time, and seven (1.0 ± 0.8%) because of disqualification, where the values in parentheses are percentages ± 95% confidence interval.
Conclusions: Blunt force to the head resulted in the highest proportion of match stoppages. Further research is warranted to delineate the morbidity associated with participation in mixed martial arts.

Mixed martial arts (MMA) competition, which is also referred to as no holds barred sport fighting, extreme fighting, and cage fighting, has its roots in 648 BC when pankration was featured at the 33rd Olympiad. Pankration, which is Greek for ''all powerful'', is the hybridisation of boxing and wrestling into a freestyle fighting sport. The sport was revered in ancient Greece and served as the climactic final event of the Olympics for centuries.[1]

Like its pankration predecessor, MMA competition has attracted attention for its sheer violence.[2] Two contestants wearing minimal protective equipment unleash a myriad of full force punches, elbow strikes, knee strikes, kicks, stomps, neck chokes, joint manipulations, body throws, and other grappling techniques against each other. A competitor seeks victory by: concussing an opponent into defencelessness through blunt head trauma; disabling an opponent through joint subluxation, dislocation, or soft tissue trauma; causing syncope by way of a neck choke; or coercing an opponent into submission by any permutation of the preceding.

Despite attempts to ban it by legislators and the medical community,[2 3] MMA metamorphosed in the 1990s from an underground spectacle into an internationally sanctioned sport.[4] This transformation was driven by increased event exposure, more lucrative incentives offered to participants, and modification of rules to make the competition appear safer to athletic governing commissions.[3 4]

Despite exponential growth in the MMA movement, which is epitomised by the proposed return of pankration to future Olympic Games,[5] no known medical literature has elucidated the various outcomes of MMA competition. The aim of this study was to identify the most salient medical issues that may be associated with MMA by determining the types and proportions of match stoppages.

METHODS

Publicly available video footage of 1284 men competing in 642 consecutive televised matches from November 1993 to November 2003 was reviewed to determine the reasons for which matches were stopped. Causes of match stoppage were identified as described below. Data acquisition began with 1993 because this was the first year in which competitions were widely available to the public through pay per view television. Matches were held under the auspices of either a United States or Japan based MMA sanctioning organisation; each organisation produced and distributed its own video footage. The two organisations were chosen because of their readily available video footage of all events, longevity, likeness of match rules, and together they afforded the largest aggregate sample size.

I excluded non-televised matches because they were not subsequently released on video; hence, the outcomes of these matches could not be validated. Non-televised matches were identified by comparing the list of all resulted bouts in the event outcomes section of each organisation's official website with those that were released on video.

Two competitors were generally matched against each other on the basis of similarity in weight and fight record. A match basically consisted of three rounds, each of which had five scheduled minutes of continuous full contact fighting followed by a one minute rest period. Table 1 describes legal techniques and target areas.

Protective equipment consisted of a mouth guard, groin protector, and 113–170 g MMA gloves. The gloves had thin padding to protect the dorsal hand while punching and blocking strikes, yet the palms and fingers were free for grappling techniques. Competitors could fight barefooted or with shoes. Some wore traditional martial arts uniforms, although most wore athletic shorts only.

A referee governed each contest from within the match area. A match was stopped if the scheduled amount of time expired, a competitor was disqualified because of rule infractions, a competitor submitted to his opponent as described below, or a competitor suffered a knockout (KO) or technical knockout (TKO) as defined below.

A match ended by submission if a competitor communicated that he was unwilling to continue because of actual or impending injury. A competitor submitted by (*a*) verbally requesting that the match be stopped while actively engaged with his opponent or (*b*) tapping the ground, his opponent, or

Abbreviations: KO, knockout; MMA, mixed martial arts; TKO, technical knockout

Table 1 Legal techniques and target areas

Legal technique*	Legal target area
Elbow strike	Head, neck, body, and extremities
Punch	Head, neck, body, and extremities
Knee strike	Head, neck, body, and extremities
Kick	Head, neck, body, and extremities
Slam to ground	Head, neck, body, and extremities
Clinching and throws	Head, neck, body, and extremities
Joint lock	Any joint except digits
Choke	Neck
Sweep	Lower extremities

*Head butting, hair pulling, attacking the spine or posterior head, and pinching flesh were legal until the end of 1996. Kicking, kneeing, or stomping the opponent while he was on the ground was allowed in all Japan based matches and variably in United States based matches.

himself repeatedly as a signal for the referee to stop the match.

On the basis of the legal techniques and target areas, I expected four medically salient categories of match stoppage: head impact, musculoskeletal stress, neck choke, and miscellaneous trauma.

Match ending head impact was identified when, immediately after blunt head trauma, a competitor exhibited altered mental status to the extent of defencelessness. Defencelessness was evident when a competitor lost all responsiveness (KO) or partial responsiveness (TKO) immediately after head impact, thereby rendering him prone to uncontested punishment.

The American Academy of Neurology defined concussion as a ''trauma-induced alteration in mental status that may or may not involve loss of consciousness.''[6] This paralleled the above definition for match ending head impact. However, except for matches that ended in KO as discussed below, concussion and loss of consciousness could not be consistently verified on the basis of video analysis alone. Therefore the head impact category was based broadly on match stoppage because of blunt force to the head, rather than a specific diagnosis such as traumatic brain injury.

Musculoskeletal stress was identified when a competitor submitted because of a joint lock, blunt orthopaedic trauma, or other apparent musculoskeletal injury. On the basis of video analysis alone, injury could not be verified in this category. Therefore this category was based broadly on match ending stressors to the musculoskeletal system, rather than specific orthopaedic injuries.

A neck choke was identified as the cause of match stoppage when a competitor submitted or the referee stopped the match because of the apparently inescapable application of such a technique—that is, afflicted competitor appeared to be syncopal or asphyxiating. On the basis of video analysis alone, injury could not be verified in this category. Therefore this category was based broadly on match ending chokes rather than specific episodes of asphyxia and/or cephalic hypoperfusion.

Miscellaneous trauma was distinct from the other mechanisms of match stoppage and therefore given its own category. Matches stopped because of expiration of match time and disqualifications were also recorded.

Age, height, weight, and background fighting style were captured from video footage of each competitor's pre-match introduction. Such data are historically obtained from the competitor's pre-participation physical examination and weigh in.

Standard deviations were calculated for mean values, and 95% confidence intervals were calculated for proportions. This study was approved by the Institutional Review Board of Keesler USAF Medical Center, Keesler, Mississippi, USA.

Table 2 Types and proportions of background fighting styles

Background fighting style	Percentage of competitors ±95% CI (n = 1284 competitors)
Jiu-jitsu	22.2±2.3
Wrestling	20.3±2.2
Submission fighting*	16.2±2.0
Kickboxing	12.9±1.8
Freestyle†	11.1±1.7
Sambo	2.6±1.0
Karate	2.3±0.8
Pitfighting‡	2.0±0.8

Styles with <2% representation each included aikido, boxing, capoeira, jeet kune do, judo, kuk sool won, kung fu, ninjitsu, savate, sumo, and tae kwon do.
*Competitors had a preponderance of grappling skills intermixed with striking capabilities.
†Competitors blended grappling skills with striking skills equally.
‡Competitors were accustomed to illegal, no rules matches.
CI, Confidence interval.

Table 3 Types and proportions of match stoppages because of head impact

Mechanism of match stoppage	Percentage of matches ±95% CI (n = 642 matches)
Punch	16.8±2.9
Various strikes*	5.9±1.8
Knee strike	2.2±1.1
Elbow strike	1.6±1.0
Kick	0.9±0.7
Slam to ground	0.6±0.6
Head stomp	0.3±0.4

*Any assorted barrage of strikes to opponent's head.
CI, Confidence interval.

Table 4 Types and proportions of match stoppages because of musculoskeletal stress

Mechanism of match stoppage	Percentage of matches ±95% CI (n = 642 matches)
Elbow lock*	9.3±2.2
Ankle lock*	2.0±1.0
Shoulder lock*	1.7±1.0
Knee lock*	0.9±0.7
Neck crank†	0.6±0.6

Less than 2% of match stoppages were because of soft tissue trauma and unobserved joint injuries—that is, competitor apparently disabled, but mechanism not captured on video.
*Hypermobilisation of joint through forceful distraction, hyperextension, and/or rotational manipulation.
†Forceful manipulation of opponent's head on neck.
CI, Confidence interval.

RESULTS

The mean (SD) age was 29.2 (4.8) years (range 19–51), mean height was 1.8 (0.1) m (range 1.6–2.1), and mean weight was 96.4 (17.6) kg (range 63.6–272.7). Table 2 gives types and proportions of background fighting styles represented. Fighters who lost because of head impact, musculoskeletal stress, neck choke, or miscellaneous trauma had a mean (SD) age of 30.1 (5.0) years, and those who won by such mechanisms had a mean age of 28.7 (4.6) years (*t* test, $p<0.001$). No other statistically significant differences existed between characteristics and outcomes.

Table 5 Types and proportions of match stoppages because of neck choke

Mechanism of match stoppage	Percentage of matches ±95% CI (n = 642 matches)
Rear choke*	6.5±1.9
Front choke†	4.2±1.5
Leg choke‡	2.3±1.1
Lapel choke§	0.6±0.6
Indistinct choke¶	0.5±0.5

*Locking arm around anterior neck while situated behind opponent.
†Applying forearm across anterior neck while situated in front of opponent.
‡Locking leg around opponent's neck.
§Wrapping lapel of traditional martial arts uniform around opponent's neck.
¶Any obscure combination of arm and/or hand choke around opponent's neck.
CI, Confidence interval.

Of the 642 matches, 182 (28.3±3.4%) were stopped because of head impact (table 3), 106 (16.5±2.9%) because of musculoskeletal stress (table 4), 91 (14.1±2.7%) because of neck choke (table 5), 83 (12.9±2.6%) because of miscellaneous trauma (table 6), 173 (27.0±3.4%) because of expiration of match time, and seven (1.0±0.8%) because of disqualification. Of the 182 matches stopped because of head impact, 62 (34.1±6.8%) involved KO and 120 (65.9±6.8%) involved TKO.

χ^2 analyses revealed no significant differences in outcomes between the two organisations.

DISCUSSION

The proportion of matches stopped because of head impact was higher than that documented in other full contact combat sports. Comparatively, Estwanik *et al*[7] tracked 547 boxing matches, of which 8.8% required stoppage because of head trauma; Gartland *et al*[8] followed 46 kickboxing matches, of which 7.7% were stopped because of concussion.

Although loss of responsiveness as observed in this study does not necessarily translate to a loss of consciousness, both generally exemplify an impaired conscious state. Impaired conscious state and gait unsteadiness, which I observed uniformly among those who lost by KO, are physical signs of concussion.[9] Therefore KO probably signified concussion. Considering that 62 of the 1284 fight participations—that is, 642 matches × 2 competitors per match—were stopped because of KO, it follows that there were conceivably 48.3 concussions per 1000 fight participations in this study. Comparatively, there were 19.2 concussions per 1000 fight participations in a 16 year review of professional kickboxing outcomes.[10]

Table 6 Types and proportions of match stoppages because of miscellaneous trauma

Mechanism of match stoppage	Percentage of matches ±95% CI (n = 642 matches)
Submission because of strikes to the head*	5.9±1.8
Periocular lacerations	3.1±1.3
Submission because of exhaustion, punishment†	2.0±1.1
Thoracoabdominal blunt trauma	1.0±0.8
Epistaxis	0.6±0.6
Ocular blunt trauma	0.3±0.4

*Included any assortment of repetitive elbow strikes, kicks, knee strikes, and punches to opponent's head; definitionally disparate from head impact category (table 3) in that afflicted competitors were sufficiently responsive to submit.
†Involved overtly fatigued competitors unwilling to tolerate further punishment primarily to the body and/or extremities.
CI, Confidence interval.

Matches stopped because of TKO mirrored such instances in amateur boxing whereby the referee stops contest (RSC) because of uncontested punishment. Concussion was not consistently apparent among those who lost because of TKO in this study. However, Moriarity *et al*[11] found that non-concussed boxers who lost because of RSC exhibited significant cognitive impairment at post-match neuropsychological testing. This finding may have implications for neuropsychological testing among MMA competitors.

McCrory *et al*[9] defined concussion as a ''complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces'' and may result in neuropathological changes. Although such changes are often transient, reported sequelae of blunt head trauma include neuropsychological decline, chronic traumatic encephalopathy, seizure disorders, intracranial haemorrhage, and death.[12–15]

After the death of an MMA competitor following a barrage of bare fisted punches to his head,[16] sanctioning organisations mandated that competitors wear MMA gloves. However, Schwartz *et al*[17] found that similar gloves used to punch a viscoelastic dummy head did not mitigate the accelerations that may produce brain injury. The utility of MMA gloves is therefore probably negligible and may protect the attacker's hands more than the defender's head.[17]

Furthermore, concussion may be caused by a blow to the body with transmission of the force to the head,[9] as from a body slam to the ground. Kochhar *et al*[18] found that body slams and hip throws also pose serious risk of causing cervical whiplash injuries. The resultant forces and kinematics from these common MMA techniques rival those generated by rear impact vehicle collisions.[18]

Although the extent of orthopaedic trauma could not be determined in this study, joint locks were the primary cause of match stoppage through musculoskeletal stress. The risk of subsequent joint degeneration may be proportional to the severity of articular surface impact loading, articular surface incongruity after healing, residual joint instability, and age.[19]

Further scrutiny is warranted, as orthopaedic trauma has been documented as the most common type of injury sustained by martial artists, including striking dominant

What is already known on this topic

- Despite the blatantly violent nature of mixed martial arts competition, no known medical literature has elucidated the various, potentially grave outcomes specific to this sport
- Morbidity and mortality data have been documented for other combat sports

What this study adds

- This study identified head impact as a salient medical issue in mixed martial arts competition
- The proportion of matches stopped because of blunt head trauma exceeded that documented in other studies of combat sports, including boxing and kickboxing

kickboxers[20] and grappling dominant judoists[21] alike. On the basis of the results from Birrer's[13] 18 year epidemiological study of the martial arts, 74% of injuries were confined to the extremities.

Although neck chokes may result in syncope,[22] anoxic brain injury,[23] delayed airway obstruction,[24] embolic cerebrovascular events,[25] and death,[26] their transient application and seemingly stringent regulation in MMA probably averts prolonged deficits in cerebral blood flow or neuropsychological status.[27]

Submissions to head strikes were the most common cause of match stoppage because of miscellaneous trauma. Such strikes were not categorised as match ending head impact because an afflicted competitor still possessed sufficient responsiveness to submit. Nonetheless, they often caused facial trauma.

The most common type of facial trauma that prompted match stoppage was periocular lacerations. Documented sequelae include disrupted visual acuity, periocular infections, corneal irritation, and periocular nerve damage.[28] Although facial trauma may occur without apparent concussion, one study found that amateur boxers with epistaxis alone had acute cognitive impairment at post-match neuropsychological testing.[11]

Competitors who lost because of match ending head impact, musculoskeletal stress, neck choke, or miscellaneous trauma were significantly older than their opponents. In other studies of martial arts participation, incidence of injury has been found to be proportional to age.[13 29]

There were no significant differences in outcomes between the two organisations. In light of this and the finding that punches caused more match stoppages because of head impact than all other mechanisms of head impact combined, the rule variation—that is, kicking, kneeing, or stomping a competitor on the ground (table 1)—was probably not a confounding factor.

Excluded, non-televised matches were generally preliminary bouts between competitors transitioning from an intermediate to elite level of competition. Although the preferential televising of elite competitors may be construed as selection bias, inclusion of preliminary bout outcomes could have confounded the results of this study. Nonetheless, novices should be tracked to identify any injury trends that may relate to their experience level.[13]

The primary limitation of this study was that the diagnosis and severity of any injury could not be determined definitively on the basis of video analysis alone. However, this study did identify salient medical issues, of which blunt head trauma may be most concerning. Further research is warranted to delineate the morbidity associated with participation in MMA.

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