Traumatic brain injuries in mixed martial arts: A systematic review

Joel Lockwood1,2, Liam Frape1, Steve Lin1,2,3,4 and Alun Ackery1,2

Abstract

Introduction: Mixed martial arts (MMA), also known as no-holds barred fighting, cage fighting and commonly linked to the brand Ultimate Fighting Championship (UFC), is a combative sport combining traditional martial arts, wrestling, and kick-boxing. Introduced in North America in 1993, MMA was marketed by promoters as a barbarous spectacle designed to find the most effective unarmed fighting style in street-style matches, with a paucity of rules. Due to the lack of regulation and perceived danger to participants and minimal protective equipment, calls for banning the sport have been made by politicians and medical organizations.1

Contemporary MMA has adopted a set of unified rules governing weight classes, with judging similar to other established combat sports. Participants are able to strike opponents with fists, elbows, knees, and kicks in attempt to win matches by a knockout, submission, or judges' decision. Since its legitimization as a mainstream sport, MMA has rapidly increased in popularity and has now been described as America’s fastest growing sport.2 Recently, the UFC has an estimated value exceeding $4 billion USD and has hosted numerous live events with crowds exceeding 50,000 and with over one

1Division of Emergency Medicine, Department of Medicine, University of Toronto, Toronto, Ontario, Canada
2St. Michael's Hospital, Toronto, Ontario, Canada
3Rescu, Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Ontario, Canada
4Institutes of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada

Corresponding author: Alun Ackery, St. Michael’s Hospital, Department of Emergency Medicine, 30 Bond Street, Toronto, ON MSB 1W8, Canada.
Email: ackerya@smh.ca
million pay-per-view purchases.\(^3\) Despite MMA’s increasing popularity and societal acceptance, it remains a violent sport. Studies have reported an injury rate of 28.6 per 100 participations in a group of professional MMA fighters, which is higher than both professional boxing and wrestling.\(^4\) Alarmingly, at least three fatalities have occurred during sanctioned MMA events in North America since 2007, two of which were due to acute traumatic brain injury.\(^5^-^7\)

Of particular concern are the cumulative neurodegenerative effects of repeated head trauma in MMA. In a study of professional MMA matches, 28% of fights ended after head trauma resulted in the losing combatant becoming completely or partially unresponsive.\(^8\) Survey data have shown only 13% of professional and amateur MMA athletes sought medical attention for concussive symptoms sustained in training or matches, and over half returned to active training in less than two days.\(^9\) The long-term effect of repeated brain trauma in boxing has long been associated with premature neurological decline\(^10\); repeated head injuries have been associated with chronic traumatic encephalopathy (CTE), a progressive and irreversible neurodegenerative disorder.\(^11\) More recently, CTE has been verified in American and Canadian football players, ice hockey players, and military veterans, including athletes as young as 28 years old.\(^11^-^15\)

The objective of this manuscript was to systematically review the literature regarding the epidemiology of head injuries sustained in MMA activities, as well as the long-term outcomes associated with repeated head trauma sustained in MMA activity.

**Methods**

**Search strategy**

We conducted a comprehensive systematic review of the literature. A search was performed in the following databases: Ovid MEDLINE, Embase, PsycINFO, EBM Reviews, CINAHL, SPORTDiscus, and Web of Science from 1990 to 2016. Using a search strategy designed by a health sciences librarian to be maximally inclusive and tailored to each database, we used the following keywords: mixed martial arts, ultimate fighting, ultimate extreme fighting, MMA, UFC, cage fighting, and no holds barred. A hand-search of bibliographies from selected articles was also performed. The full search strategy is outlined in Figure 1.

**Study selection**

Two reviewers (JL, AA) independently and hierarchically reviewed the titles and abstracts, and then the full text versions of the search results for inclusion. Disagreements during the article inclusion process were resolved by a third reviewer (SL). Articles were included (a) if they were published in a peer-reviewed journal and (b) if they described acute or chronic head injury sustained in MMA activities. We excluded editorials or studies that were not original research and studies not published in English.

**Evaluation of included articles**

The level of evidence for each included article was evaluated using the GRADE approach outlined by the GRADE working group;\(^16\) the five cohort studies were also assessed for quality using the Newcastle-Ottawa Quality Assessment Scale for cohort studies.\(^17\) The selected articles were evaluated based on the following criteria: participant demographics, type of MMA activity, head injury incidence and prevalence, diagnostics of head injury, history of head injury, and head injury rehabilitation.

This study followed the guidelines outlined in the PRISMA (Preferred reporting items for systematic reviews and meta-analyses) statement.\(^18\) The systematic review was registered with the International Prospective Register of Systematic Reviews.

**Results**

The initial database search yielded a total of 472 citations, including 264 unique citations after duplications were removed. Full text manuscripts were obtained and reviewed for 39 citations. A total of 18 studies (N = 7587) were selected for final analysis, based on the predefined eligibility criteria (Figure 1).

The studies included in the final analysis were heterogeneous in their design, the population studied, and outcomes measured (Table 1). Thirteen observational studies were included, of which eight were retrospective studies describing injuries and injury patterns sustained in MMA competition,\(^4,8,16^-^21\) and five were prospective longitudinal cohort studies measuring structural changes on magnetic resonance imaging (MRI) and behavior;\(^22^-^26\) one cross-sectional study,\(^27\) two survey studies,\(^2,9\) and two case reports\(^28,29\) were also included.

All studies were ranked as very low using the GRADE approach (Table 2). The cohort studies were all assigned a score of 4 (out of a possible 9, using the Newcastle-Ottawa Quality Assessment Scale for cohort studies (Table 3).\(^18,19\)

MMA participants who suffered a head injury were predominantly young (range: 25.2–29.2 years),\(^4,8,9,16,19,22^-^25,27\) male (92.5–100% male participation),\(^2,9,20,22,24,30\) and included both amateur and professional athletes.\(^2^-^4,16^-^18,20\)
Knockouts/technical knockouts

Nine studies\(^2,4,8,9,18–20,22,24\) reported data on knockouts (KOs) and technical knockouts (TKOs), presumably using the unified rules of MMA definitions of a KO occurring ‘when a contestant is rendered unconscious due to strikes or kicks’ and a TKO occurring ‘when the referee stops the contest, or when an injury as a result of a legal manoeuvre is severe enough to terminate a bout’,\(^3\) although this was not explicitly stated.

Survey data from MMA participants recruited from internet forums found 34% of participants had experienced a KO/TKO during MMA participation with only 39% of participants utilizing protective head gear, and 5.3% of respondents reported a ‘head injury’ in their fight careers.\(^2,9\) The same study reported three times the injury rate for professional fighters than for amateurs, but did not report whether head trauma was also proportionally greater for professional fighters.\(^2\)

Five studies presented information on match end-points revealing between 28.3% and 46.2% of matches ended as a result of KO or TKO\(^4,8,18–20\) – two of these studies examined fight outcomes using archived video footage.\(^8,19\) Hutchinson et al.\(^19\) examined competition data and video footage of bouts from one professional MMA organization from 2006 to 2012 and found 31.9% of matches ended due to KO/TKO with 12.7% ended by KO. The losing combatant sustained an...
<table>
<thead>
<tr>
<th>References</th>
<th>Study type</th>
<th>Subjects</th>
<th>Gender (% male)</th>
<th>Mean age (years)</th>
<th>% Amateur</th>
<th>TBI measurement</th>
<th>Concussion definition</th>
<th>HI/TBI incidence or prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banks et al. 22</td>
<td>Longitudinal cohort study</td>
<td>71</td>
<td>100%</td>
<td>28.5</td>
<td>N/A</td>
<td>Self-reported</td>
<td>No</td>
<td>Fighter reported KO mean 0.7 concussion Mean 0.6</td>
</tr>
<tr>
<td>Banks et al. 23</td>
<td>Longitudinal cohort study</td>
<td>76</td>
<td>100%</td>
<td>27.4 SD 7.3</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No data</td>
</tr>
<tr>
<td>Bernick et al. 25</td>
<td>Longitudinal cohort study</td>
<td>131</td>
<td>N/A</td>
<td>28.2</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No data</td>
</tr>
<tr>
<td>Bledsoe et al. 4</td>
<td>Retrospective observational study</td>
<td>342</td>
<td>100%</td>
<td>28.3 SD 4.7</td>
<td>0%</td>
<td>Physician at ringside</td>
<td>No</td>
<td>Bout ended by KO: 6.4% TKO: 39.8% 46.2% of bouts ended with TKO or KO</td>
</tr>
<tr>
<td>Bolelli 16</td>
<td>Retrospective observational study</td>
<td>352</td>
<td>N/A</td>
<td>28</td>
<td>0%</td>
<td>N/A</td>
<td>No</td>
<td>Not reported</td>
</tr>
<tr>
<td>Buse 8</td>
<td>Retrospective observational study</td>
<td>1284</td>
<td>N/A</td>
<td>29.2 SD 4.8</td>
<td>N/A</td>
<td>Video review</td>
<td>Yes</td>
<td>Bout ended by KO: 9.7% TKO: 18.6%</td>
</tr>
<tr>
<td>Fields et al. 28</td>
<td>Case report</td>
<td>1</td>
<td>Single male fighter</td>
<td>40 Year old</td>
<td>N/A</td>
<td>Physician at ringside</td>
<td>No</td>
<td>TKO</td>
</tr>
<tr>
<td>Galetta et al. 27</td>
<td>Observational study</td>
<td>12</td>
<td>100%</td>
<td>25.5</td>
<td>N/A</td>
<td>Physician at ringside</td>
<td>Yes</td>
<td>Head injury 1 of 12 MMA fighters (8.3%)</td>
</tr>
<tr>
<td>Heath and Callahan 9</td>
<td>Survey</td>
<td>119</td>
<td>94%</td>
<td>26.5 SD 7.4</td>
<td>N/A</td>
<td>Self-reported</td>
<td>No</td>
<td>% fighter reporting KO 13.5% TKO 27.7%</td>
</tr>
<tr>
<td>Hutchinson et al. 19</td>
<td>Retrospective observational study</td>
<td>844</td>
<td>100%</td>
<td>29.8 SD 4.1</td>
<td>N/A</td>
<td>Video and score card review</td>
<td>yes</td>
<td>bout end KO 12.8% TKO 21.2%</td>
</tr>
<tr>
<td>Karpman et al. 21</td>
<td>Retrospective observational study</td>
<td>1181</td>
<td>99%</td>
<td>N/A</td>
<td>N/A</td>
<td>Physician at ringside</td>
<td>No</td>
<td>8.3%</td>
</tr>
<tr>
<td>Mayer et al. 26</td>
<td>Prospective cohort study</td>
<td>13</td>
<td>84.6%</td>
<td>28.3 SD 4.9</td>
<td>N/A</td>
<td>Neuropsychologist/self-reported</td>
<td>yes</td>
<td>50%</td>
</tr>
<tr>
<td>McClain et al. 20</td>
<td>Retrospective observational study</td>
<td>1422</td>
<td>92.4%</td>
<td>N/A</td>
<td>female 27.8% male 82.3%</td>
<td>Physician at ringside</td>
<td>No</td>
<td>Bout end TKO/KO 29.1% altered mentation 21.5% of injuries</td>
</tr>
</tbody>
</table>

(continued)
average of 18.5 strikes (location of strikes not described) in the 30 s prior to match termination. Those who suffered a KO were more likely to be above the age of 35 (OR = 1.94, 95% CI: 1.03–3.61, p > 0.05) and suffered previous KOs (OR = 1.30, 95% CI: 1.12–1.50, p > 0.05). Buse examined videos of televised Japanese and American professional MMA matches from 1993 to 2003 and found that 28.3% of matches ended due to blunt force trauma to the head delivered by punch, kick, elbow, or knee, and reported a KO rate of 9.7%.

**Concussion**

Eleven studies provided data on the occurrence of head injuries sustained while participating in MMA activities. McClain et al. retrospectively observed injury profiles documented by a single ringside physician over four years; overall, 21.5% of all injuries were classified as ‘altered mental status’, defined as inability to orient to person, place or time and diagnosed by the ringside physician. A separate study by Scoggin et al. described the injury patterns of 116 professional MMA fights from 1999 to 2006. During 232 fight exposures, 11 participants suffered an acute head injury, noted as ‘concussion’ with four experiencing retrograde amnesia, and all being negative for hemorrhage on computerized tomography of the head. Demographics, head injury protocol, definitions of concussion and long-term outcomes were not described. In a 13-year retrospective study in Edmonton, Alberta, 8.3% of MMA fighters were diagnosed with a concussion after a head injury sustained in a match.

Three studies used competition data and tabulated results of MMA matches to describe injury patterns and compare winning and losing combatants. Ngai et al. examined the data from 1270 professional fight exposures from 2002 to 2007 in the state of Nevada and found that 37% fights were halted due to fighter KO or TKO with a KO incidence of 3.3%. Bledsoe et al. reviewed data from all professional bouts sanctioned in Nevada between 2001 and 2004 with 46% of matches ending in KO/TKO, with a KO rate of 6.4%. Karpman et al. found that 4.2% of fighters suffered a loss of consciousness.

While 11 studies reported data on head injuries labelled as ‘concussions’, only six objectively defined the term concussion, with three studies equating a KO to concussion and one using failure on the Military Acute Concussion Evaluation to define concussion. Three other studies discussed concussion or concussive symptoms without a definition; Heath and Callaghan referring to a post-concussive scale and concussive symptoms, McClain et al. reporting on ‘altered mental state’ and Scoggins et al. reporting concussion as a percentage of injuries. Two studies included data
Table 2. GRADE evaluation of studies evaluating head injuries in Mixed Martial Arts.

<table>
<thead>
<tr>
<th>No. of studies</th>
<th>Quality assessment</th>
<th>Study design</th>
<th>Risk of bias</th>
<th>Inconsistency</th>
<th>Indirectness</th>
<th>Imprecision</th>
<th>Other considerations</th>
<th>Quality</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knockout/technical knock out</td>
<td></td>
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<tr>
<td>5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Single-arm uncontrolled studies&lt;sup&gt;3,8,18–20&lt;/sup&gt;</td>
<td>Serious&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Very serious&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Not serious</td>
<td>Very serious&lt;sup&gt;d&lt;/sup&gt;</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Survey studies&lt;sup&gt;2,9&lt;/sup&gt;</td>
<td>Very serious&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Serious</td>
<td>Very serious</td>
<td>Very serious</td>
<td>Very high probability of bias</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Observational studies&lt;sup&gt;22,24&lt;/sup&gt;</td>
<td>Serious</td>
<td>Not serious</td>
<td>Serious&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Serious</td>
<td>None</td>
<td></td>
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<tr>
<td>Concussion</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Survey studies&lt;sup&gt;2–9&lt;/sup&gt;</td>
<td>Very serious&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Serious</td>
<td>Very serious&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Very serious&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Very high probability of bias</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 Observational studies&lt;sup&gt;8,17–21,22,26,27&lt;/sup&gt;</td>
<td>Very serious</td>
<td>Very serious&lt;sup&gt;g&lt;/sup&gt;</td>
<td>Very serious</td>
<td>Very serious</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Changes in brain imaging and neurological function</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Cohort studies&lt;sup&gt;22–26&lt;/sup&gt;</td>
<td>Serious</td>
<td>Not serious</td>
<td>Serious</td>
<td>Very serious</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Observational study&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Serious</td>
<td>Not serious</td>
<td>Serious</td>
<td>Serious</td>
<td>Very small sample size&lt;sup&gt;h&lt;/sup&gt;</td>
<td></td>
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</tr>
</tbody>
</table>

<sup>a</sup>Head injuries self-reported.

<sup>b</sup>Included self-reported survey studies.

<sup>c</sup>Retrospective studies found variable fight endpoint incidence of KO/TKO.

<sup>d</sup>Little data available.

<sup>e</sup>Subjects recruited from internet forums, MMA gym.

<sup>f</sup>KO/TKO includes, but is not limited to fight endpoints due to head trauma.

<sup>g</sup>Inconsistent definition of concussion.

<sup>h</sup>Total sample of MMA fighters was 12.
on self-reported concussion (1.8%), without a formal definition or diagnosis; two studies relied on clinical experts to acutely diagnose concussion.\(^{21,26}\)

Heath and Callahan’s\(^9\) survey showed that only 13% of the MMA participants recruited sought medical attention post-injury, and the majority returned to activity prior to resolution of concussive symptoms, while McClain et al.\(^{20}\) reported that 24.8% of the 121 injuries recorded in their study were subsequently referred to the emergency room.

**Long-term neurological outcomes**

Five studies measured degenerative neuroanatomical and cognitive changes associated with repetitive blunt head trauma sustained in combat sports.\(^{22–26}\) MMA participants were found to have microstructural brain damage when compared to controls in all five studies. Additionally, one set of studies found fighters with more lifetime bouts tended to have lower cognitive test scores,\(^{23}\) processing speed\(^{25}\) and increased signs of motor impulsiveness.\(^{22}\) The impact on cognitive test scores was more pronounced in fighters who had achieved a high-school education or less.\(^{23}\) In a separate study utilizing a small sample of 12 MMA fighters, one fighter who experienced head trauma was found to have comparatively worse post-fight neurocognitive testing using the King-Devick concussion screening tool.\(^{27}\)

**Discussion**

Within 25 years, MMA has grown from obscurity into a mainstream sport and a multibillion-dollar industry.\(^{32}\) Despite its rapid ascension, little is known

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**Table 3. Quality assessment scale – cohort studies.**

<table>
<thead>
<tr>
<th>Assessment of quality of a cohort study</th>
<th>Banks et al.(^{22})</th>
<th>Banks et al.(^{23})</th>
<th>Bernick et al.(^{25})</th>
<th>Mayer et al.(^{26})</th>
<th>Ngai et al.(^{18})</th>
<th>Shin et al.(^{24})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newcastle Ottawa Scale</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Representatives of the exposed cohort</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>B*</td>
<td>C</td>
</tr>
<tr>
<td>3. Ascertainment of the intervention</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>4. Demonstration that outcome of interest was not present at beginning of study</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Comparability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Comparability of cohorts on the basis of the design or analysis</td>
<td>A*</td>
<td>A*</td>
<td>A*</td>
<td>A*</td>
<td>B*</td>
<td>A*</td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Assessment of outcome</td>
<td>B*</td>
<td>B*</td>
<td>B*</td>
<td>B*</td>
<td>B*</td>
<td>B*</td>
</tr>
<tr>
<td>2. Was follow up long enough for outcomes to occur?</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

**Selection:** I. Representatives of the exposed cohort, A. Truly representative of the average head injured MMA participant *, B. Somewhat representative of the average head injured MMA participant *, C. Select group of users, D. No description.

2. Selection of the non-intervention cohort, A. Drawn from the same community as the intervention cohort *, B. Drawn from a different source, C. No description of the derivation of the non-intervention cohort, or no control.

3. Ascertainment of the intervention, A. Secure record (medical record) *, B. Structured interview *, C. Written self-report, D. Other/no description.

4. Demonstration that outcome of interest was not present at beginning of study, A. Yes*, B. No

**Comparability:** I. Comparability of cohorts on the basis of the design or analysis, A. Study controls for mixed martial arts participation *, B. Study controls for additional factors *


2. Was follow up long enough for outcomes to occur? A. Yes, 25 years *, B. No.

3. Adequacy of follow up of cohorts, A. Complete follow up - all subjects accounted for *, B. small number lost <5% or description of those lost *, C. Follow up rate <90% and no description of those lost, D. No statement.

* Denotes rank of high quality
regarding the incidence, prevalence or sequelae of repeated head trauma sustained in MMA activities. To our knowledge, this is the first systematic review investigating the head injury patterns and long-term outcomes of MMA participants.

In the published data, MMA participants tended to be combatants in amateur and professional bouts and were largely young males. While there was little data that included a medically accepted term for brain injury suffered during MMA activities, the literature suggested that a significant number of bouts ended due to repeated strikes to the head leaving the losing participant partially or completely unresponsive. However, other fight-ending confounders, for example bouts ending in submission, were difficult to exclude due to various study designs. One study showed an average of 18.5 strikes to the head in the seconds preceding head complete unresponsiveness amongst professional MMA athletes. There was no consistent definition of terms related to acute or chronic head injury, one study described using a validated tool to diagnose minor traumatic brain injury but did so in only one MMA participant. No studies outlined a head injury protocol, or return to activity guidelines. There was no description of the use or study of equipment or interventions aimed at minimizing traumatic brain injuries, including restricting blows to the head, mandatory head protection or safer gloves. It is impossible to exclude that the search strategy would have missed articles with no association of head injuries and MMA fighting, although the rigorous methodology included all MMA articles detailing injury patterns and any trauma to the head.

A paucity of high-quality data makes it difficult to compare the incidence or severity of head injuries sustained in MMA to other contact sports. In recent years, however, greater emphasis has been placed on the effects of head injuries sustained in contact sports such as football and ice hockey. This has led to the adoption of head injury protocols, including mandated athlete withdrawal after head injury decided by an independent expert, rule changes to limit direct trauma to the head, the removal body checking in youth leagues, and a greater emphasis on understanding risk factors, management and long-term effects of head injuries. The effect of policy changes in minor hockey has had limited success in reducing head injuries.

Boxing is the most established and best studied combat sport and it remains the cultural benchmark for acceptability regarding violent head injuries to athletes. A lack of well-designed epidemiologic studies in both sports makes it challenging to compare the incidence and long-term outcomes relating to chronic brain injuries.

The most cited evidence from boxing comes from a survey study of 250 retired UK boxers active between 1929 and 1955. In total, 37 (17%) of boxers were found to have lesions in the nervous system based on clinical examination, with limited neuropsychological and radiological assessment. Risk factors for chronic traumatic brain injury included retirement after the age of 28, participation in more than 150 lifetime bouts and over 10 years of boxing experience. This retrospective data may have had confounding factors influencing its comparability with MMA injury patterns.

There are a number of limitations of this study. Among the studies included, there was no uniform or consistent definition of head injury, concussion or traumatic brain injury making it impossible to determine incidence of head injury in MMA activity. Some studies indirectly measured head injuries by the non-medical term ‘KO’ (a fight ending due to fighter disorientation, unconsciousness, or inability to defend oneself). Most data were of very low quality and had significant heterogeneity, thus limiting our ability to perform a meta-analysis and making it impossible to identify possible risk factors including gender, age, head injury history, lifetime bouts or professional status of fighters.

Currently, there is little known regarding the incidence, risk factors or possible long-term sequelae related to head injuries sustained in MMA activity, and currently only poor quality observational research has been conducted on the topic. This is unlikely to change without increased medical oversight and regulation including accurate and consistent head injury assessment and diagnosis by trained medical professionals. In Canada, MMA is regulated provincially, in Ontario the Athletic Commissioner requires a ringside physician to be present (not necessarily ringside) for MMA events and fighters can be licensed by any practicing physician. There is no requirement for specific education or training in head injury assessment or treatment, and in the past, nephrologists, cardiologists and plastic surgeons have been employed as ringside physicians in Canada. Head-injured fighters face a fixed suspension of 60 days regardless of ongoing symptoms and can be cleared by any physician with normal CT, MRI or electroencephalogram. This is in contrast to position statement of the American Medical Society of Sports Medicine which suggests diagnosis, sideline evaluation, standardized neurophysiologic testing and return to sport decisions are made by a healthcare provider familiar with the athlete and knowledgeable in the recognition and evaluation of head injuries.

Little is known regarding the incidence of head injuries or potential long-term neurodegenerative effects of repeated head trauma sustained in MMA. However, the first documented case of CTE was made in a professional 25-year-old male MMA athlete. To improve
knowledge, provincial athletic commissions must mandate MMA head injury protocols led by ringside physicians with training in the diagnosis and treatment of traumatic brain injuries. Further research is required to accurately assess the incidence and severity of head injuries sustained in MMA, as well as the effect of interventions on reducing injury including equipment and rule changes and education of participants and coaches.

Conclusion
MMA has experienced a dramatic increase in popularity. However, head injury patterns sustained by participants, injury prevention strategies, and long-term sequelae of head injuries sustained in MMA activity remain poorly elucidated. Increased medical oversight and study may be required to minimize head injuries sustained in MMA, ensure consistent head injury diagnosis, treatment and reporting are utilized and appropriate return to activity guidelines are developed and enforced.

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