

The Epidemiology of Injuries in Mixed Martial Arts

A Systematic Review and Meta-analysis

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Background: Mixed martial arts (MMA) has experienced a surge in popularity since emerging in the 1990s, but the sport has also faced concomitant criticism from public, political, and medical holds. Notwithstanding the polarized discourse concerning the sport, no systematic review of the injury problems in MMA has been published to date.

Purpose: To systematically review the epidemiologic data on injuries in MMA and to quantitatively estimate injury incidence and risk factor effect sizes.

Study Design: Systematic review and meta-analysis; Level of evidence, 4.

Methods: Electronic searching of PubMed, Scopus, CINAHL, EMBASE, AMED, and SPORTDiscus databases to identify studies reporting on the epidemiology of injuries in MMA. Random-effects models were used to obtain pooled summary estimates of the injury incidence rate per 1000 athlete-exposures (IIR_{AE}) and rate ratios with 95% confidence intervals (CIs). Heterogeneity was evaluated with the I^2 statistic.

Results: A total of 6 studies were eligible for inclusion in this review. The IIR_{AE} summary estimate was found to be 228.7 (95% CI, 110.4-473.5). No studies reported injury severity. The most commonly injured anatomic region was the head (range, 66.8%-78.0%) followed by the wrist/hand (range, 6.0%-12.0%), while the most frequent injury types were laceration (range, 36.7%-59.4%), fracture (range, 7.4%-43.3%), and concussion (range, 3.8%-20.4%). The most notable risk factors pertained to the outcome of bouts. Losers incurred 3 times as many injuries as winners, and fighters in bouts ending with knockout or technical knockout incurred more than 2 times as many injuries as fighters in bouts ending with submission.

Conclusion: Notwithstanding the paucity of data, the injury incidence in MMA appears to be greater than in most, if not all, other popular and commonly practiced combat sports. In general, the injury pattern in MMA is very similar to that in professional boxing but unlike that found in other combat sports such as judo and taekwondo. More epidemiologic research is urgently needed to improve the accuracy of the injury incidence estimate, to determine the injury severity, and to identify more risk factors for injury in MMA.

Keywords: athletic injury; mixed martial arts; incidence; risk factors

Mixed martial arts (MMA) is a term used to describe full-contact combat sport activities utilizing a combination of unarmed Oriental martial arts (eg, karate, judo, jiu-jitsu, and taekwondo), Western combat sports (eg, boxing, Greco-Roman wrestling, and kickboxing), and their derivatives.³⁰ Although fighters have traditionally come from a particular disciplinary background, contemporary MMA athletes

generally adopt a hybridization of striking and grappling techniques, both standing and on the ground. Bouts take place in either a boxing ring or a caged arena and are typically decided by either submission (verbal or physical signal of wish to discontinue), knockout (KO), technical knockout (TKO) due to referee stoppage, or judges' decision after an allotted amount of time has elapsed; however, bouts may also end because of corner or doctor stoppage, fighter retirement or forfeit, or disqualification.³⁵

The international development of combat sports over the past century has been described elsewhere.^{30,35} In brief, modern MMA has been shaped in particular by the influences of Brazilian jiu-jitsu (and its precursor, vale tudo) and Japanese professional shoot wrestling, and can be said to have been properly formed in the 1990s when the hybridization of techniques from different combat sports became extensive. In the early 1990s, 2 notable promotions emerged, namely—K-1 in Japan, a standing-only

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platform closely resembling regular kickboxing, and the all-inclusive Ultimate Fighting Championship (UFC) in the United States. By 1996, the UFC was facing heavy criticism from key political figures in the United States, perhaps most notably from the Senator from Arizona, John McCain, who labeled the events as “human cockfighting” and called for an outright ban across all states.^{21,35} As a result of the campaign, MMA was banned in 40 states in the United States. In response, the UFC increased their cooperation with state athletic commissions by redesigning their rules and rebranding MMA as a sport, and by 2001, the state of New Jersey signed off on a set of codified rules known as the “Mixed Martial Arts Uniform Rules of Conduct” (“Unified Rules”).^{18,35} The Unified Rules, which stipulates a list of 25 prohibited acts to ensure the safety of the participants (eg, head butting, eye gauging, groin attacks, biting, throat attacks, flagrant disregard of the referee’s instructions, and kicking, kneeling, or stomping a grounded fighter), have subsequently been adopted by the vast majority of states in the United States.^{18,35} Today, MMA is regulated in 46 states, and either pending regulation or legal without regulation in the remaining jurisdictions.

MMA has experienced a surging popularity and growth since the early 2000s.^{30,35} This is evidenced by the increase in both spectators and revenue, as well as the emergence of several new MMA promotions (eg, Bellator Fighting Championships, Elite Xtreme Combat, World Extreme Cagefighting, Strikeforce, International Fight League, and DREAM), several of which have since merged with UFC.^{30,35} With the surge in popularity and media coverage, MMA has also attracted the attention of medical associations that have expressed concerns about the safety of the sport, which in turn has contributed to continued polarization of the public and political discourse. For instance, the Canadian Medical Association,² the British Medical Association,⁴¹ and the Western Australia state branch of the Australian Medical Association¹ have all recently called for bans on MMA. This raises questions about how evidence-informed these calls are. How much is actually known about the epidemiology of injury in MMA? Although both Seidenberg³⁴ and Walrod⁴⁰ have authored brief sports medicine reports on injuries in MMA, there have been no systematic reviews or meta-analyses of the epidemiologic injury data in MMA to date. Thus, the main objectives of this systematic review were to describe and evaluate the incidence, severity, patterns, and risk factors of injury in MMA and to provide quantitative summary estimates of the injury incidence rate and risk factor effect sizes.

MATERIALS AND METHODS

This review adhered to guidelines in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement.²⁰

Selection Criteria

Reports from observational studies published in peer-reviewed literature were eligible for inclusion in this

systematic review. Eligible study designs included prospective and retrospective cohort studies, cross-sectional studies, and case-control studies, whereas case reports, case series, commentaries, editorials, letters to the editor, and literature reviews were excluded from this review. No language restrictions were applied. Eligible studies had to report epidemiologic data such as incidence, severity, or risk factors pertaining specifically to injuries in MMA athletes. For the purposes of this review, MMA was defined as a full-contact contest that allows both striking and grappling techniques, both standing and on the ground (contests such as the K-1 kickboxing tournament that only incorporates standing striking techniques were not included). There were no restrictions with regard to the contest enclosure; typical boxing ring enclosures and octagonal and hexagonal cages were all acceptable. No studies were excluded based on sex, age, or any other population characteristics.

Search Strategy

A comprehensive search of the literature was undertaken. This included electronic searching of the PubMed, Scopus, CINAHL, EMBASE, AMED, and SPORTDiscus databases from inception to May 2013. In addition, the bibliographies of included studies and review articles were hand-searched to identify potentially eligible studies not captured by the electronic searches. Keywords used in the electronic searches were *mixed martial arts* (including abbreviations and names of specific MMA contests) in combination with *injury* (including truncation and synonyms).

Study Selection

All the citations from the electronic searches were combined in an electronic spread sheet. Duplicate records were discarded before titles and abstracts were screened to identify and remove citations that were irrelevant or obviously did not meet the selection criteria. Full-text versions of all the remaining, potentially eligible studies were retrieved, and 2 independent reviewers (K.G. and J.W.) evaluated the articles for compliance with the selection criteria. Any disagreement was resolved by mutual consensus in consultation with a third independent reviewer (R.P.L.).

Data Extraction

Data from included studies were extracted and tabulated in an electronic spread sheet. The data of interest were as follows: (1) general study descriptors (eg, authors, year of publication, and study design), (2) description of the study population (eg, sample size, sex distribution, age, and level of play), and (3) main epidemiologic findings (eg, injury and exposure data, distribution of injuries by anatomic location, and type of injury, injury severity, and risk factors for injury). If applicable, the authors of included studies were contacted to provide clarifications or access to raw data.

Data Analysis

Injury incidence rates per 1000 athlete-exposures (IIR_{AE}) and per 1000 minutes of exposure (IIR_{ME}) were extracted from the included studies. One athlete-exposure was defined as 1 athlete being exposed to the possibility of incurring an injury while participating in a single fight. If IIR_{AE} or IIR_{ME} were not specifically reported, they were, if possible, calculated from the available raw data. In an attempt to increase the comparability across the included studies, all injury proportions by anatomic region and injury type were calculated after omitting unspecified injuries from total injury counts, and while adhering to the Orchard Sports Injury Classification System (OSICS), version 10.²⁶ Whenever possible, injury incidence rate ratios per 1000 athlete-exposures (RR_{AE}) and per 1000 minutes of exposure (RR_{ME}) and odds ratios (ORs) were calculated using standard methods²⁹; 95% confidence intervals (CIs) were calculated for all IIR , RR , and OR using standard methods.^{12,29}

Two meta-analytic approaches were undertaken: (1) a quantitative summary estimate of IIR_{AE} was obtained using a random-effects model with the DerSimonian and Laird method and (2) risk factor effect size summary estimates were obtained by pooling RR_{AE} in random-effects models with DerSimonian and Laird procedures. Unlike a fixed-effects model, which is essentially a weighted average of the IIR_{AE} from individual studies with the weight for each study being proportional to the inverse of the within-study variance, a random-effects model allows for between-studies variability in IIR_{AE} by incorporating a random-effects term for the between-studies variability into the weights.^{7,28} Heterogeneity was evaluated using the I^2 statistic, which represents the percentage of total variation across all studies due to between-study heterogeneity.^{13,14} All statistical analyses were conducted using the statistical software R, version 2.15.2 (R Foundation for Statistical Computing, Vienna, Austria)²⁵ and the “metafor” package.³⁸

Risk of Bias Assessment

The risk of bias in individual studies was assessed independently by 2 reviewers (K.G. and J.W.) using the 22-item checklist from the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) Statement.³⁹ Any disagreement was resolved by mutual consensus in consultation with a third reviewer (R.P.L.). The STROBE Statement checklist was not primarily designed to assess the quality of observational studies, but rather to assess the quality of reporting. However, in the absence of a single obvious candidate tool for assessing quality of observational epidemiological studies, the STROBE Statement checklist should suffice as a good starting point for assessing the quality of observational studies.³¹ Moreover, the STROBE Statement checklist has been adopted as a quality assessment tool by a number of authors.^{17,23,24,37} In this review, studies were categorized as either poor, moderate, or good based on the percentage of fulfilled items from the STROBE Statement checklist, that is, <50%, 50% to 80%, and >80%, respectively.

Although there is no standard validated method of assessing risk of bias across studies, examining asymmetry in the funnel plot is typically recommended.^{15,36} This review adhered to recommendations stating that examination of funnel plot asymmetry should be used only when there are at least 10 studies included in the meta-analysis and no significant heterogeneity present.^{15,36}

RESULTS

Figure 1 depicts the PRISMA flow diagram of the study selection process. The electronic searches returned 2380 citations, including 883 duplicate records. After screening titles and abstracts, 1460 records were discarded as irrelevant or obviously not meeting the selection criteria. Hand-searching identified 1 additional potentially eligible study, hence leaving a total of 36 potentially eligible studies. Thirty studies were excluded after retrieving and evaluating full-text versions; thus, a total of 6 studies^{3,5,10,22,27,33} were eligible for inclusion in this systematic review. One included study²⁷ did not report exposure data and could therefore not be included in any of the quantitative analyses.

Table 1 provides a descriptive summary of the characteristics of the included studies. The 6 included studies comprised 4 retrospective cohort studies,^{3,5,22,33} 1 cross-sectional study,²⁷ and 1 prospective cohort study.¹⁰ The vast majority of data were obtained from male professional athletes (age range, 18-44 years). All data were obtained from competitions sanctioned in the United States. The methodological quality of the included studies ranged from poor^{3,10,33} to moderate²² to good.^{5,27} Three studies reported on data derived from the same data source (ie, public records from the Nevada Athletic Commission [NAC]); however, they covered different but overlapping time periods (September 2001 to December 2004,⁵ March 2002 to September 2007,²² and January 2005 to October 2009³). To avoid double reporting of the same data in the quantitative analyses, we obtained the NAC raw data spanning the time period of all 3 studies (September 2001 to October 2009) and combined them into a single data point, hereinafter referred to as “NAC data.”

Figure 2 depicts a forest plot of the meta-analysis of IIR_{AE} . The IIR_{AE} summary estimate was found to be 228.7 (95% CI, 110.4-473.5); however, the total variation across the studies was very high ($I^2 = 97.1\%$). Only the NAC data permitted calculation of IIR_{ME} , which was found to be 54.3 (95% CI, 50.8-57.9). None of the included studies reported on the severity of injuries.

Table 2 provides an overview of the proportions of injury by anatomic region across the included studies. The head was by far the most commonly injured anatomic region, ranging from 66.8% to 78.0%, followed by the wrist and hand, ranging from 6.0% to 12.0%. Table 3 provides an overview of the proportions of injury by type of injury. Overall, the most common type of injury was laceration/abrasion, ranging from 36.7% to 59.4%, followed by fracture, ranging from 7.4% to 43.3%, and nerve injury (ie, concussion), ranging from 3.8% to 20.4%.

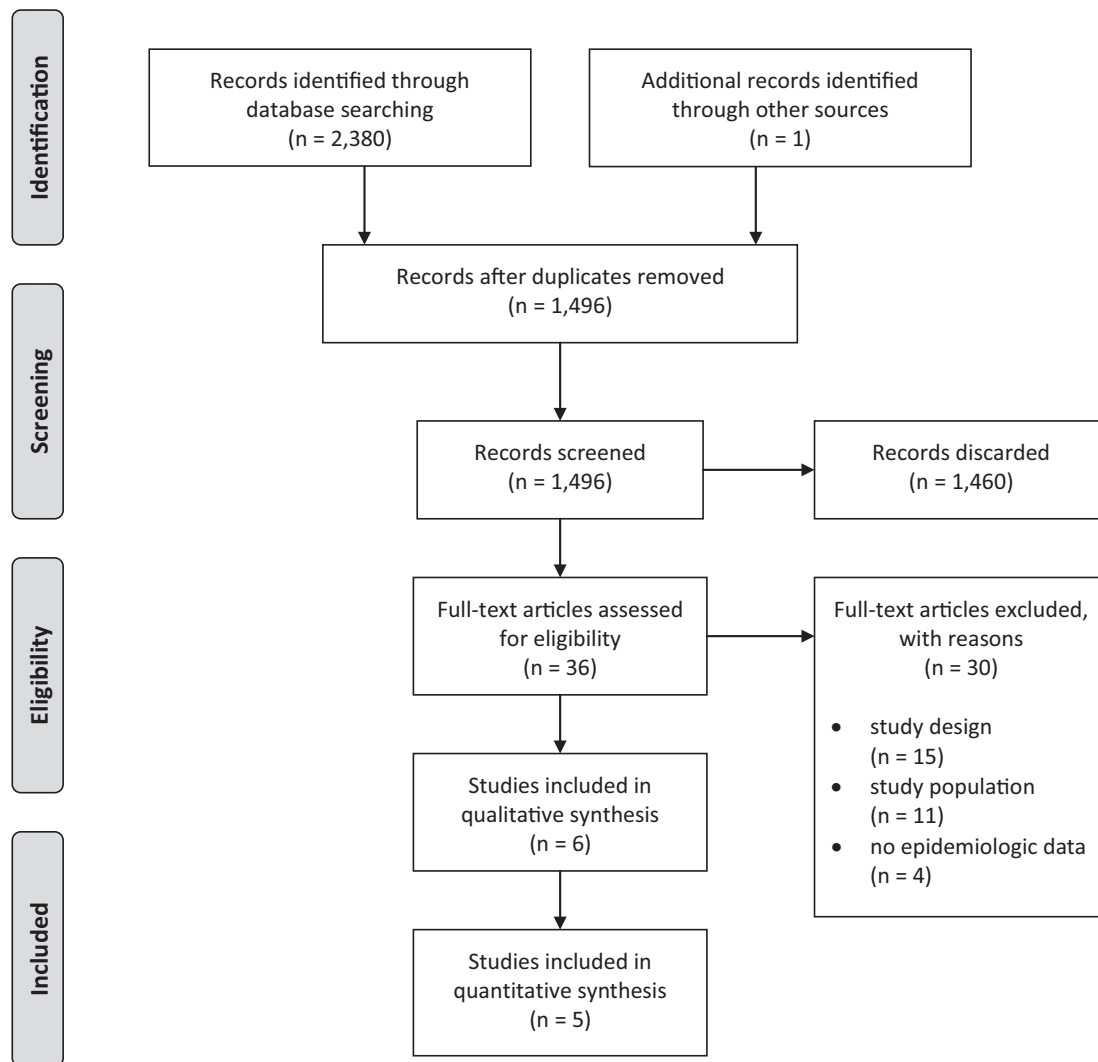


Figure 1. PRISMA flow diagram depicting the study selection process.

Table 4 provides an overview of RR_{AE} , RR_{ME} , and OR calculations of various risk factors from individual studies. Figure 3 depicts forest plots of pooled effect size (RR_{AE}) estimates for risk factors reported in more than 1 study. Several match outcomes were found to be associated with significantly greater IIR_{AE} , namely losing the fight compared with winning the fight (RR_{AE} , 2.99 [95% CI, 2.26-3.95]; $I^2 = 13.6\%$), fight ending with KO or TKO compared with fight ending with submission (RR_{AE} , 2.37 [95% CI, 2.01-2.82]; $I^2 = 0.0\%$), and fight ending with decision compared with fight ending with submission (RR_{AE} , 2.03 [95% CI, 1.27-3.25]; $I^2 = 22.6\%$). In addition, calculations from the combined NAC data revealed that the IIR_{ME} of weight classes heavier than middleweight were significantly greater than the IIR_{ME} of the middleweight division. See Table 4 for individual RR_{ME} calculations. Regarding the variables sex, age, and level of play (professional or amateur), none were found to be significant risk factors; however, very limited data were available.

DISCUSSION

The paucity and methodological shortcomings of published data notwithstanding, this first systematic review of the epidemiology of injuries in MMA highlights that there is a high injury incidence rate in MMA and that the injury pattern is similar to that reported in professional boxing.

The IIR_{AE} in MMA was estimated to be 228.7 (95% CI, 110.4-473.5), which is greater than most, if not all, other popular and commonly practiced full-contact combat sports, including 44.0 in judo,¹¹ 79.4 in taekwondo,¹⁷ 77.7 in amateur boxing,⁹ and between 118.0 and 250.6 in professional boxing.^{6,42-44} However, because there may be significant variability in study methodologies, it is prudent to be cautious when comparing the risk of injury across different sports. For instance, there may be variability in injury definitions, exposure definitions, injury classification system, and demographic characteristics such as age and level of play.

TABLE 1
Characteristics of Included Studies^a

Source	Study Design	Study Population	Study Sample	Setting	Injury Definition	Quality
Bastidas et al ³ (2012)	Retrospective cohort (5 y)	Professional	n = NR (% male NR) Age, mean (SD): NR Age range: NR Location: Nevada, USA	Competition	Determined by ringside physician	Poor
Bledsoe et al ⁵ (2006)	Retrospective cohort (3 y)	Professional	n = 220 (100% male) Age, mean (SD): 28.5 (4.7) Age range: 19-44 Location: Nevada, USA	Competition	Determined by ringside physician	Good
Fields et al ¹⁰ (2008)	Prospective cohort (1 y)	Professional (37%) Amateur (63%)	n = NR (100% male) Age, mean (SD): 24.6 (NR) Age range: 18-42 Location: Indiana, USA	Competition	Determined by ringside physician	Poor
Ngai et al ²² (2007)	Retrospective cohort (5 y)	Professional	n = 636 (% male NR) Age, mean (SD): NR Age range: NR Location: Nevada, USA	Competition	Determined by ringside physician	Moderate
Rainey ²⁷ (2009)	Retrospective cross-sectional	Professional (7%) Amateur (93%)	n = 55 (94.5% male) Age, mean (SD): NR Age range: 18-39 Location: Midwest, USA	Training and competition	Unclear	Good
Scoggin et al ³³ (2010)	Prospective cohort (7 y)	Professional	n = 179 (100% male) Age, mean (SD): NR Age range: 18-40 Location: Hawaii, USA	Competition	Determined by ringside physician	Poor

^aNR, not reported; SD, standard deviation.

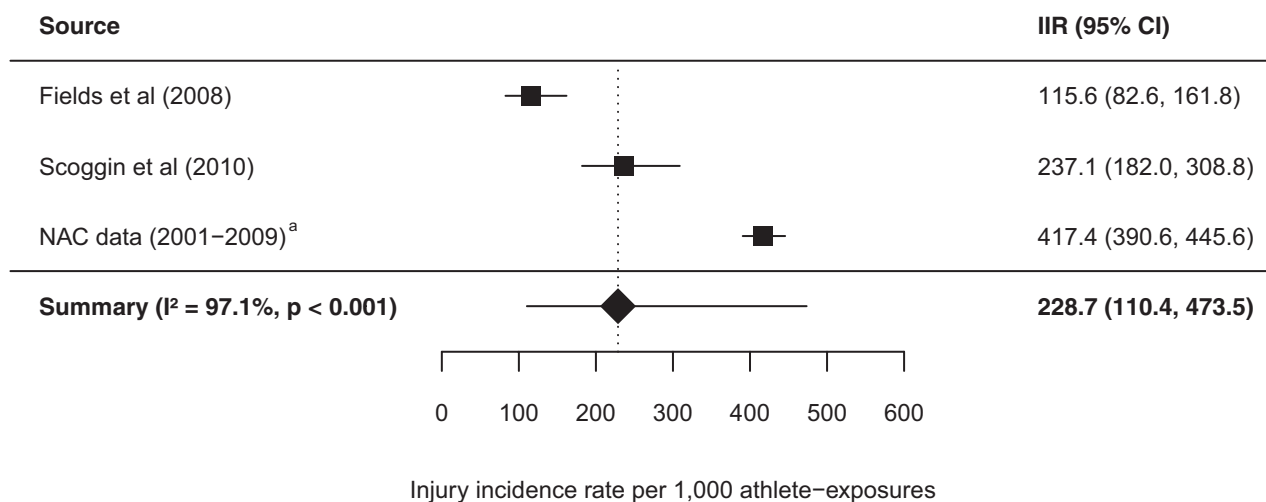


Figure 2. Forest plot of pooled estimate of the injury incidence rate (IIR) per 1000 athlete-exposures with 95% confidence intervals (CIs). NAC, Nevada Athletic Commission. ^aCalculated from Nevada Athletic Commission data (September 2001 to October 2009).

It is important to note that the operational injury definition in all MMA studies to date is unclear, and that in all but 1 study what constituted a reportable injury was at the discretion of the attending ringside physician. In contrast, many, but not necessarily all, of the studies of other combat sports have used a medical-attention injury definition (ie, an injury that results in an athlete receiving medical

attention), which is arguably more inclusive than what has been used in studies of MMA. A further indication of potential underreporting of injuries in MMA studies comes from the observation that surprisingly few contusion/bruising/hematoma injuries were reported at MMA events (1.8%-3.3%). One would expect a combat sport that features a lot of striking techniques to display a relatively greater

TABLE 2
Distribution (%) of Injuries by Anatomic Region

Anatomic Region	Source			
	Fields et al ¹⁰ (2008) ^a	Rainey ²⁷ (2009) ^b	Scoggin et al ³³ (2010)	Nevada Athletic Commission Data (2001-2009) ^c
Head and neck	79.4	38.2	80.0	67.5
Head	76.5	32.4	78.0	66.8
Neck	2.9	5.8	2.0	0.7
Upper limb	11.8	22.8	16.0	19.7
Shoulder	—	6.3	2.0	3.5
Upper arm	—	2.9	—	0.4
Elbow	—	3.4	8.0	3.5
Forearm	2.9	1.0	—	0.4
Wrist and hand	8.8	9.2	6.0	12.0
Trunk	2.9	9.2	—	2.3
Chest	2.9	1.9	—	1.6
Trunk and abdomen	—	0.5	—	0.2
Thoracic spine	—	2.9	—	—
Lumbar spine	—	2.9	—	0.5
Pelvis and buttock	—	1.0	—	—
Lower limb	5.9	29.9	4.0	10.5
Hip and groin	—	1.0	—	0.2
Thigh	2.9	3.4	—	—
Knee	—	5.8	—	5.6
Lower leg	—	4.3	—	0.4
Ankle	—	4.8	2.0	2.3
Foot	2.9	10.6	2.0	2.1

^aCalculated from raw data supplied by the authors.

^bData included both training and competition injuries.

^cCalculated from Nevada Athletic Commission data (September 2001 to October 2009).

TABLE 3
Distribution (%) of Injuries by Type of Injury

Type of Injury	Source			
	Fields et al ¹⁰ (2008) ^a	Rainey ²⁷ (2009) ^b	Scoggin et al ³³ (2010)	Nevada Athletic Commission Data (2001-2009) ^c
Bruising/hematoma	3.3	34.2	1.9	1.8
Laceration/abrasion	36.7	17.9	51.9	59.4
Muscle injury	3.3	18.9	1.9	0.3
Tendon injury	—	—	—	0.3
Joint sprains	6.7	17.3	9.3	2.3
Joint dislocations	—	3.1	3.7	0.5
Synovitis, impingement, bursitis	—	—	1.9	—
Fracture	43.3	6.6	7.4	25.9
Organ injury	—	0.0	1.9	5.8
Nerve injury	10.0	2.0	20.4	3.8

^aCalculated from raw data supplied by the authors.

^bData included both training and competition injuries.

^cCalculated from Nevada Athletic Commission data (September 2001 to October 2009).

proportion of contusion injuries. For instance, in taekwondo, the proportion of contusion injury has been reported to be as high as 72.3%.¹⁶ Thus, there are good reasons to think that relative to other full-contact combat sports, the IIR_{AE} in MMA is probably greater than what is reported above.

Notwithstanding the possible underreporting of injuries in general and underreporting of certain types of injuries in particular, the injury pattern in MMA appears to be very similar to that in professional boxing,⁴²⁻⁴⁴ but unlike that found in other combat sports such as taekwondo^{16,17} and judo.¹¹

TABLE 4
Risk Factors for Injury^a

Risk Factor/Specification	RR _{AE} (95% CI)	RR _{ME} (95% CI)	OR (95% CI)	Source
Sex				
Female (ref. male)	0.87 (0.44-1.72)	0.94 (0.48-1.86)	0.79 (0.32-1.95)	NAC data (2001-2009) ^b
Age				
10-unit change	—	—	1.29 (0.73-2.26)	Bledsoe et al ⁵ (2006)
Continuous variable	—	—	1.02 (0.99-1.06)	Ngai et al ²² (2008)
Weight/body mass index				
Bantamweight (ref. middleweight)	0.73 (0.49-1.08)	0.83 (0.56-1.23)	0.63 (0.39-1.02)	NAC data (2001-2009) ^b
Featherweight (ref. middleweight)	1.11 (0.78-1.57)	1.04 (0.74-1.42)	1.16 (0.73-1.83)	NAC data (2001-2009) ^b
Lightweight (ref. middleweight)	1.00 (0.80-1.25)	0.92 (0.74-1.15)	0.95 (0.71-1.27)	NAC data (2001-2009) ^b
Welterweight (ref. middleweight)	1.11 (0.90-1.36)	1.09 (0.88-1.34)	1.12 (0.85-1.47)	NAC data (2001-2009) ^b
Light heavyweight (ref. middleweight)	1.22 (0.98-1.51)	1.36 (1.09-1.69) ^c	1.31 (0.98-1.76)	NAC data (2001-2009) ^b
Heavyweight (ref. middleweight)	1.37 (1.09-1.73) ^c	1.76 (1.40-2.23) ^c	1.57 (1.14-2.16) ^c	NAC data (2001-2009) ^b
Super heavyweight (ref. middleweight)	1.20 (0.62-2.32)	2.01 (1.04-3.89) ^c	1.58 (0.64-3.90)	NAC data (2001-2009) ^b
10-unit change	—	—	1.03 (0.95-1.11)	Bledsoe et al ⁵ (2006)
Continuous variable	—	—	1.00 (1.00-1.01) ^c	Ngai et al ²² (2008)
Level of play				
Amateur (ref. professional)	1.21 (0.60-2.45)	—	1.12 (0.52-2.43)	Fields et al ¹⁰ (2008)
Match characteristics				
Non-title fight (ref. title fight) ^d	—	—	1.22 (0.81-1.83)	Ngai et al ²² (2008)
Title fight (ref. non-title fight) ^d	0.20 (0.02-1.95)	—	0.18 (0.01-3.08)	Fields et al ¹⁰ (2008)
Title fight (ref. non-title fight) ^d	2.66 (2.29-3.09) ^c	1.22 (1.01-1.46) ^c	2.01 (1.51-2.69) ^c	NAC data (2001-2009) ^b
Rounds fought, n (1-unit increase)	—	—	1.44 (1.11-1.87) ^c	Bledsoe et al ⁵ (2006)
Time, min (1 unit increase)	—	—	1.04 (1.01-1.07) ^c	Ngai et al ²² (2008)
Match outcome				
Loser (ref. winner)	—	—	2.32 (1.36-3.98) ^c	Bledsoe et al ⁵ (2006)
Loser (ref. winner)	4.67 (1.93-11.27) ^c	—	5.05 (2.01-12.67) ^c	Fields et al ¹⁰ (2008)
Loser (ref. winner)	—	—	2.48 (1.89-3.26) ^c	Ngai et al ²² (2008)
Loser (ref. winner)	2.86 (2.46-3.32) ^c	2.86 (2.46-3.32) ^c	4.90 (4.03-5.95) ^c	NAC data (2001-2009) ^b
Decision (ref. submission)	3.75 (1.20-11.70) ^c	—	4.67 (1.22-17.82) ^c	Fields et al ¹⁰ (2008)
Decision (ref. submission)	1.85 (1.53-2.24) ^c	0.57 (0.47-0.69) ^c	2.16 (1.70-2.75) ^c	NAC data (2001-2009) ^b
KO/TKO (ref. submission)	2.05 (0.93-4.52)	—	1.97 (0.83-4.67)	Fields et al ¹⁰ (2008)
KO/TKO (ref. submission)	2.39 (2.01-2.85) ^c	2.11 (1.77-2.51) ^c	3.72 (2.98-4.65) ^c	NAC data (2001-2009) ^b
KO (ref. TKO)	—	—	1.71 (0.97-3.01)	Bledsoe et al ⁵ (2006)
KO (ref. TKO)	1.11 (0.34-3.59)	—	1.22 (0.32-4.65)	Fields et al ¹⁰ (2008)
KO (ref. TKO)	1.08 (0.74-1.58)	1.37 (0.93-2.00)	1.06 (0.58-1.93)	NAC data (2001-2009) ^b

^aBMI, body mass index; CI, confidence interval; KO, knockout; NAC, Nevada Athletic Commission; OR, odds ratio; ref., reference; RR_{AE}, injury incidence rate ratio per 1000 athlete-exposures; RR_{ME}, injury incidence rate ratio per 1000 minutes of exposure; TKO, technical knockout.

^bCalculated from Nevada Athletic Commission data (September 2001 to October 2009).

^cSignificantly different from reference group.

^dTitle fight refers to championship title match scheduled for 5 rounds of combat.

Differences in competition rules undoubtedly explain much of these observed variations in injury patterns; for instance, head injuries are relatively uncommon in judo and taekwondo where punches to the head are disallowed, whereas there is a very high proportion of head injuries in MMA and professional boxing where punches to the bare head are allowed. Moreover, a retrospective review of video footage from 642 consecutive televised MMA fights found that the proportion of bouts stopped because of blunt head trauma exceeded that documented in other studies of combat sports, including boxing and kickboxing.⁸ The high proportion of head injuries in MMA is a cause for concern, especially considering that continued repetitive head trauma (not necessarily limited to clinically observable concussions) is associated with degeneration in brain structures such as bilateral hippocampi, basal

ganglia, and thalamus, which in turn produce measurable changes in cognition.⁴

Overall, there was a paucity of data regarding potential risk factors for injury in MMA. The most notable data available pertained to the outcome of bouts, and unsurprisingly, losers incurred 3 times as many injuries as winners, while fighters in bouts ending with KO or TKO incurred more than 2 times as many injuries as fighters in bouts ending with submission. Furthermore, fighters in bouts ending by judges' decision after the allotted amount of time had elapsed incurred 2 times as many injuries as fighters participating in bouts ending with submission, which is easily explained by the fact that fighters in bouts decided by judges' decision are exposed to risk of injury for longer than fighters in bouts that ended early

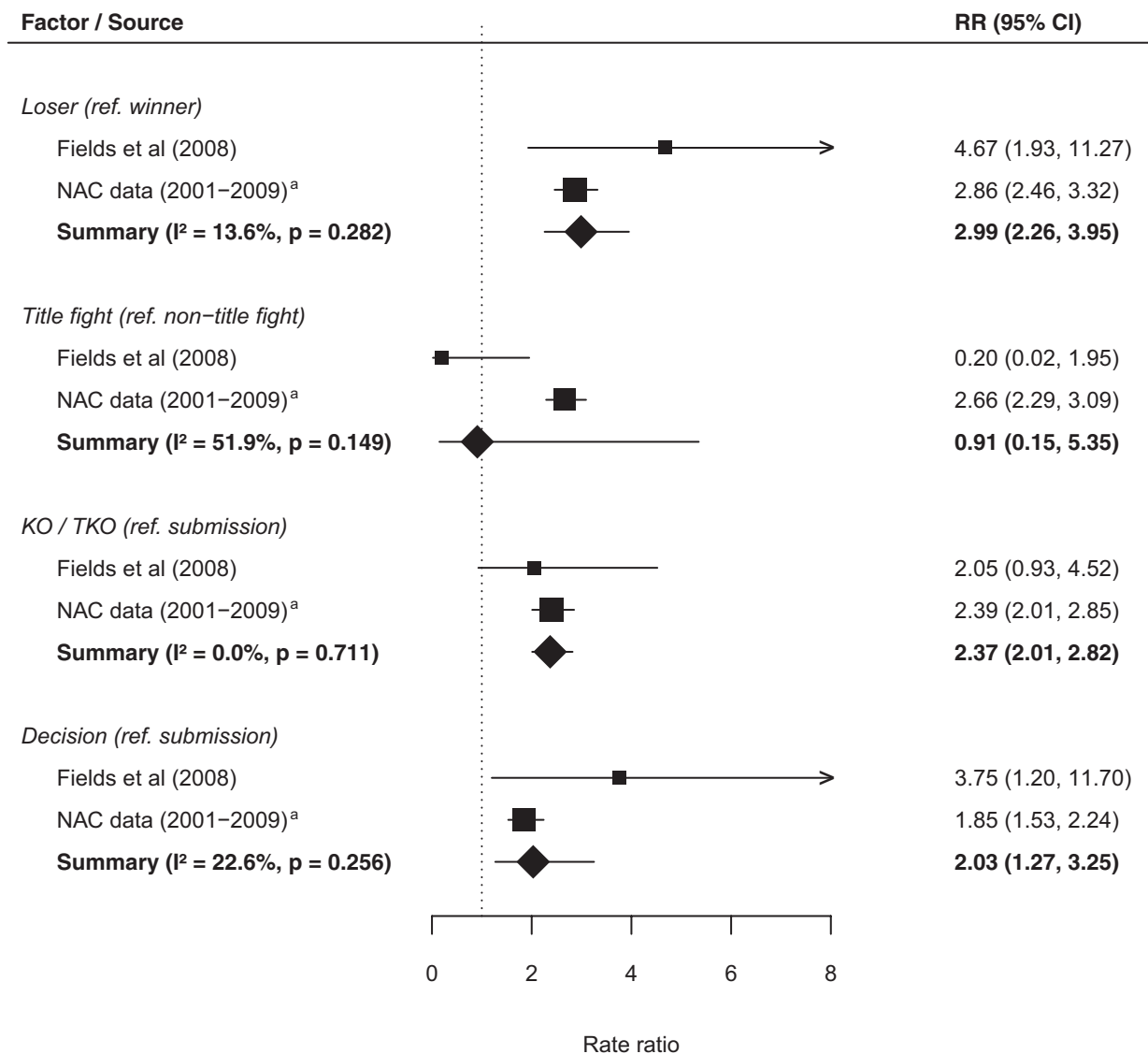


Figure 3. Forest plot of risk factor effect-size estimates (rate ratios [RRs] with 95% confidence intervals [CIs]). KO, knockout; NAC, Nevada Athletic Commission; TKO, technical knockout. ^aCalculated from Nevada Athletic Commission data (September 2001 to October 2009).

due to submission. In fact, when taking exposure time into account, fighters in bouts decided by judges' decision have a significantly lower IIR_{ME} compared with fighters in bouts that ended with submission (RR_{ME}, 0.57 [95% CI, 0.47–0.69]). However, this finding arises from a single data set (NAC data) and needs to be confirmed by independent investigations before drawing any firm conclusions. To inform the adoption and implementation of future injury prevention policies in MMA, future studies are encouraged to increase their efforts to identify potential risk factors for injury.

None of the included studies reported on injury severity, without which it becomes difficult to both assess the actual burden injuries in MMA and subsequently to know where to direct efforts aiming to prevent or mitigate the risk of injury. Thus, it is strongly recommended

that future studies aim to determine the severity of injuries in MMA using objective measurements of actual time lost to participation in training or competition, or preferably, both.

This review is limited by the quality and methodology of the included studies. To facilitate cross-study comparisons and limit ambiguity, future studies are encouraged to adhere to the STROBE Statement guidelines, adopt standard injury definitions, and utilize standardized injury classification systems such as OSICS-10²⁶ or the Sport Medicine Diagnostic Coding System.¹⁹ The generalizability of the findings in this review may be limited because all the reports to date include data from contests sanctioned in the United States (under “Unified Rules”) and predominantly are comprised of professional male athletes. It is conceivable that the injury problem in MMA is different in other

populations, for example, at the amateur level or in other geographical locations, perhaps operating under different rules and regulations. The quantitative analyses were limited by the paucity and large heterogeneity of published data, which in turn precluded any examination of funnel plot asymmetry to assess the risk of bias across studies. Under these conditions, it becomes exceedingly difficult to defend the use of a fixed-effects model; however, it is important to note that compared with a fixed-effects model, a random-effects model will assign relatively greater weights to small data sets.³² Thus, it is likely that the IIR_{AE} summary estimate above is skewed toward the smaller included data set, potentially underestimating the IIR_{AE}. Furthermore, it is important to note the distinction between fixed- and random-effects models in regard to the inference they are able to provide when attempting to estimate effect sizes.³² Whereas the fixed-effects model provides inferences about the size of the average effect within the set of included studies, the random-effects model provides conclusions about the average effect in the entire population of studies from which the included studies are assumed to be a random selection.³⁸ The findings herein should be interpreted in light of these limitations.

CONCLUSION

MMA has experienced a surge in popularity since emerging in the 1990s; however, the sport has also faced concomitant criticism from political and medical holds, including calls for an outright ban. This systematic review reveals a paucity of epidemiologic data on injuries in MMA, which in turn raises questions about how evidence-informed the political and medical discourse and decision-making regarding MMA has been to date. Notwithstanding the paucity of quality data and the likelihood of underestimation in the current analysis, the injury incidence in MMA does appear to be greater than most, if not all, other popular and commonly practiced combat sports. In general, the injury pattern in MMA is very similar to that in professional boxing (ie, a very high proportion of facial lacerations and fractures and concussion injuries) but unlike that found in other combat sports such as judo and taekwondo. However, to date, the severity of injuries in MMA has not been measured. The most notable identified risk factors for injury in MMA pertain to the outcome of bouts, such as losers incurring 3 times as many injuries as winners and fighters in bouts ending with KO/TKO incurring more than 2 times as many injuries as fighters in bouts ending with submission. More epidemiologic research is urgently needed to improve the accuracy of the injury incidence estimate, to determine the injury severity, and to identify risk factors for injury in MMA.

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