

The Effects of Head Trauma on Athletes who Participate in Mixed Martial Arts (MMA)

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Naim Zaga

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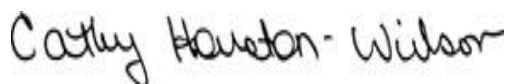


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Abstract

As Mixed Martial Arts (MMA) continues to grow in popularity, the importance of conducting studies on the health and safety of the athletes is imperative. Previous studies on the topic of MMA have revealed the common risks for participating in MMA. It has been suggested that athletes and coaches, as well as MMA organizations need to do a better job of improving the safety of the sport. These promotions are being advised by researchers to look into ways to make the sport safer while also aiding in the research processes. As athletes are constantly putting their bodies through physical harm, the research suggests that improvements and changes need to be made. The purpose of this synthesis project is to review the literature on the effects of head trauma on athletes participating in Mixed Martial Arts.

Chapter 1: Introduction

Mixed Martial Arts (MMA) is a combat sport that uses many different elements in combination drawn from Boxing, Karate, Tai Kwon Do, Wrestling, Jiu Jitsu and more. “Mixed martial arts has experienced a rapid increase in popularity in North America, which has then spread internationally, resulting in a tremendous global growth of the sport” (Hutchison, Lawrence, Cusimano, & Schweizer., 2014). With the meteoric rise of the sport, the attention to the health implications for Mixed Martial Arts athletes has risen as well. Many health associations such as the American Medical Association (AMA) and British Health Association (BHA), have gone as far as to call for a complete ban on the sport (Hutchison et al., 2014). These organizations argue that Mixed Martial Arts is dangerous and violent and poses a threat to the safety of the athletes who partake in it. Injuries such as head trauma have deemed MMA as unsafe according to these health organizations (Hutchison et al., 2014).

The Ultimate Fighting Championship (UFC) is the biggest MMA promotion in the world (Lockwood, Frappe, Lin, & Ackery., 2018). They have reached the highest levels of success and grown in popularity every year. The UFC has had a huge hand in changing the perception of what MMA is. For years, politicians and communities have barred MMA citing the lack of rules, safety, and disorganization (Hutchison et al., 2014). The UFC changed many rules and safety procedures and has since dominated the MMA world. Over the last 10 years, MMA has been one of the fastest rising sports in the world with the UFC leading the way (Curran-Sills & Abedin, 2018). With the rise of the sport, the rise of superstars has occurred as well. MMA fighters such as Anderson Silva, Georges St. Pierre, and Conor McGregor helped to grow and pioneer the sport with their success and charisma (Bleacherreport.com). They increased the popularity of the sport with their quick knockouts and dominant performances.

In MMA, one of the ways in which a match/fight is over is when one person is knocked out (KO) or technically knocked out (TKO) from blows to the head. There is a general understanding that when an athlete is knocked out, they lose consciousness (McCrory et al., 2012). A technical knockout has more grey area than a traditional knock out. A technical knockout is when the match/fight is stopped by the referee's professional opinion that the athlete can/should no longer continue. This occurs when an athlete is "Defenselessness, secondary to repetitive strikes to the head can be the result of a loss of awareness and responsiveness, thus meeting the criteria for a concussion" (McCrory et al., 2012). A study conducted by Fogarty et al. (2019) concluded that rotational head acceleration, particularly in the axial plane, is strongly associated with transient loss of consciousness. When an athlete suffers this in a match/fight the potential for health issues can occur.

McCrory et al. (2012) pose some potential risks due to head trauma in MMA resulting from knockouts, which include concussions and traumatic brain injury. These potential outcomes vary based on sex and weight. In MMA, athletes engage in competition according to their sex and weight class. If a male is fighting another male there has to be a set weight requirement that must be met the day before the bout (Bernick et al., 2020). Both athletes must be within the limits of the weight class. 155 pounds is an example of one weight class that is in MMA promotions such as the UFC.

Statement of the Problem

There are a plethora of potential serious brain injuries as a result of head trauma in MMA. "Each previous concussion seems to be associated with an increased risk of a future similar event" (Hutchison et al., 2014). As athletes get concussed, some of them go right back to training even if they are not allowed to compete in matches for a set period of time. For example,

if an athlete loses a fight by knockout and is deemed to have a concussion by the doctors, the athletic commission that hosted that event can suspend the fighter from competition for a period of time based on the doctor's advice (Follmer, Dellagrana, & Zehr., 2019). The athletes still however, go back to training and can do more harm to themselves. This occurs because "To date, there is no study showing whether MMA athletes and coaches actually possess any level of knowledge of aspects related to head trauma, brain injury, or concussion, which could potentially affect the long-term health status of these athletes" (Follmer et al., 2019).

Repetitive head trauma may be a risk factor for Alzheimer's Disease and is considered the primary cause of chronic traumatic encephalopathy (CTE) according to Bazarian, Jeffrey, Blyth, Mookerjee, He, and McDermott (2010). As athletes are constantly training while having concussions, they risk their long term health. Another potential long term injury is described in a study by Bernick et al. (2015) in which "lower scores on tests of processing speed were correlated with lower brain volumes and increasing levels of exposure." The more the athlete gets hit in the head, the higher the risk of significant long-term injury. There are many implications of long-term health issues for these athletes as a result of repetitive head trauma.

Schlegel, Novotny, Valis, and Klimova (2021) describe how prevalent knockouts are in MMA. The majority of fights end in either a TKO or KO. With prior studies conducted on the sport of boxing and hockey, it is well known that repetitive head trauma is dangerous (Fares et al., 2020). This brings a call to action to conduct more research on an already under researched field in MMA (Curran-Sills & Abedin., 2018).

Purpose of Synthesis:

The purpose of this synthesis project is to review the literature on the effects of head trauma on athletes participating in Mixed Martial Arts.

Operational Definitions:

1. Head Trauma- Damage to the scalp, skull or brain caused by injury (news-medical.net, 2021).
2. Mixed Martial Arts- is a combat sport that uses many different elements in combination drawn from Boxing, Karate, Tai Kwon Do, Wrestling, Jiu Jitsu and more (Hutchison et al., 2014).

Research Questions:

The following research questions will be the primary focus explored for this literature review:

1. Are the risks for head trauma dependent on sex and/or weight?
2. What long-term and short-term risks do MMA athletes face from head trauma?
3. What is the risk of an athlete being concussed and what are the effects of one?

Delimitations:

1. The articles used in the literature review of the synthesis were peer reviewed.
2. The review included articles between 2010-2021.
3. Peer reviewed scholarly articles focused on the different complications, risks, and effects of head trauma on amateur and professional athletes participating in Mixed Martial Arts.

Chapter 2: Methods

The purpose of this synthesis project is to review the literature on the effects of head trauma on athletes participating in Mixed Martial Arts. In order to obtain the proper information needed to conduct this paper, an exhaustive search of past research was completed. This chapter will detail the necessary steps taken to complete the research process.

The literature obtained for this project began with a search using the Drake Memorial Library. The topic of MMA is unique, which initially led to no specific database being used. Anticipating that there would be limited research in this field, a general search was conducted on the Drake Memorial Library search bar. This however, produced over a thousand pieces of literature that needed to be narrowed down further. The EBSCO database was then used as a way to limit the amount of literature in the results. From there, the subject of Kinesiology, Sport Studies & Phys. Ed produced the literature used in this synthesis.

Keywords were needed to help focus the results of the research. Keywords/phrases such as *head trauma*, *mixed martial arts*, and *athletes* were used, based on the relevancy to the purpose statement. Once these results were in, more key words referring to the research questions were applied. These key words included *concussions*, *sex*, *weight*, *long-term*, and *short-term risks*. This allowed for a focused search that resulted in a more appropriate list of literature.

The first search in the EBSCO database used the initial keywords. *Head trauma* in MMA athletes produced 234 results. A limiter was then applied to focus only on peer reviewed scholarly journals. Another limiter was implemented which produced only results from 2010-2021. This only shaved off a few results and the total number of journals found were 196. A look

at the top ten results produced literature that fit the criteria for four of the articles used in the synthesis paper.

The second search conducted on the EBSCO database was done with more specific key words which targeted the research questions. The key words searched were *head trauma*, *MMA*, *athletes*, *sex*, and *weight*. The limiters were the same as the first search which included peer reviewed journals as well as a data frame of 2010-2021. This produced 22 results, of which three were used for the synthesis paper.

The third search used the same limiters as the first process. 2010-2021 were the years, and scholarly peer reviewed journals was the other limiter. This time the keywords included were *head trauma*, *MMA*, *athletes*, *long-term risks*, *short-term risks*. The search produced a result of 72 articles with three duplicates. Of the articles found, two were found appropriate for the synthesis paper.

One final search was conducted using the same limiters as previously mentioned. The key words included *head trauma*, *MMA*, *athletes*, *concussions*. This search produced 97 results with three being duplicates. One article was deemed fit to use for the synthesis.

For the articles to be selected it was important that they met the right conditions. The articles needed to be studies done of MMA athletes and their fights. There had to be a focus on head trauma endured by the athletes. This head trauma was then looked at for possible effects on the athletes. Another condition had to be the distinction between which type of athletes were used in the studies, either based on sex or weight. Some of the articles explained the need for more research to be done for the sake of the athlete's health.

Articles were produced from journals such as, *PubMed*, *BMJ Open Sport and Exercise*, *SAGE Premier*, *The Physician and Sports Medicine*, *Gale Academic Sports Journal*, *American Journal of Sports Medicine*, and *British Journal of Sports Medicine*.

The articles selected for the synthesis used a majority quantitative approach with eight quantitative and two qualitative. The quantitative method allowed for reviews and statistics from previous fights that involved head trauma. This information was used to determine the prevalence of head trauma in MMA competitions. The information collected from these articles used data collection from surveys, previous studies, article reviews, and analysis. There was an epidemiological study done in one of the studies as well.

The most challenging aspect when conducting this research were the lack of studies with a causal link between head trauma and MMA. Most of the studies were similar and used previous data. There is a growing interest in this topic based on the discussions from these articles. Most of the authors ask for more health care and studies to determine the exact risk of participating in MMA.

Chapter 3: Review of Literature

The main goal of this chapter is to review the literature on the effects of head trauma on athletes who participate in MMA. More specifically, the following topics will be explored: the risks for head trauma on MMA athletes depending on sex and weight, the long-term risks for MMA athletes as a result of head trauma, the short-term risks for MMA athletes, and the likelihood of these MMA athletes being concussed and what that means for their health. An analysis of the literature found these key points to be imperative for understanding the implications of head trauma on athletes who participate in MMA.

There was a time when female athletes weren't allowed to participate in MMA. With time, women were included and weight classes were formed just as they were for their male peers. As studies are completed on the risks of head trauma on these athletes, research is being done to understand the significance of the risks to the different body types of these athletes. The first part of this topic that will be explored are the comparisons between the risks of head trauma on males and females, and their respective weight classes.

Male vs Female and Their Weight Classes: Who is More at Risk?

What are the risks of head trauma in male athletes compared to female athletes? Follmer, Dellagrana, Rodolfo, and Zehr, (2019) used a descriptive epidemiological study to determine the differences between male and female injury as a result of head trauma. This study looked at recovery time as well as occurrence of concussions in the athletes. Follmer et al. (2019) acknowledges that there has been a lack of research done that included analyzing the risks to female athletes in MMA. Most of the research conducted to this point has been on male MMA athletes. This study looked at 1903 UFC fights from a three year time period (2014-2017). The UFC male weight categories assessed in the present study were flyweight (52.1-56.7 kg),

bantamweight (56.7-61.2 kg), featherweight (61.2-65.8 kg), lightweight (65.8-70.3 kg), welterweight (70.3-77.1 kg), middleweight (77.1-83.9 kg), light heavyweight (83.9-93.0 kg), and heavyweight (93.0-120.2 kg). All statistical analyses were performed using SPSS. The results of the study found that men were more likely to sustain brain injuries due to head trauma. The authors concluded that this was connected to heavier weight classes, which produced more knockouts than lighter weight classes.

For female weight classes, the strawweight (<52.1 kg) and the bantamweight (56.7-61.2 kg) divisions were analyzed in the same study. These were the two weight classes with a considerable amount of data during the evaluated period (Follmer et al., 2019). The results of this study indicated that as the weight classes got heavier, the risk of a knockout increased 80%, 100%, and 206% at the heaviest classes for men and women. Follmer et al. (2019) states that it is reasonable to consider that because of the knockouts increasing with weight, these athletes are more prone to serious brain injuries. The same study revealed that women had more side effects to head trauma, and took a longer period of time to recover. This put women at even greater risks than their male peers for injuries sustained as a result of head trauma.

In a descriptive epidemiological study by Fares et al. (2020) 816 fights in the UFC were examined from 2016-2019, using the medical records of the fighters after the events. The purpose of the study was to find patterns and trends of head injuries in MMA. MMA remains a sport with a high risk of head injury when compared to other sports. “In fact, the amalgamation of fighting disciplines in MMA allows for increased chances of head trauma, either by kicking, punching, striking with knees or elbows, or by using ground and pound” (Fares et al., 2020). Ringside physician reports from UFC fights between 2016 and 2019 were screened. Data was extracted from the Nevada State Athletic Commission (NSAC) database. An independent t-test

was used to determine whether any significant differences existed between the two sexes, and a Joinpoint regression analysis was used to determine the statistical significance of the trends of head injury rates across different weight divisions (Fares et al., 2020). A total of 288 head injuries in 408 fights were recorded during the study period. Traumatic brain injuries (TBI) were the most prevalent injuries that occurred, and they occurred more often in the higher weight classes. This study also noted a difference between male and female fighters in that the males had a head injury rate of 37 per 100 athlete exposure (AE) while the women had 23 per 100 AE. Fares et al. (2020) concluded, using a one-way analysis of variance, that men were at higher risk for brain injury than their female counterparts.

Bazarian et al. (2010) conducted a study on the differences in males and females in regards to the effects of mild traumatic brain injuries (mTBI). mTBI can occur from blows to the head absorbed by the brain according to Bazarian et al. (2010). There are several factors associated with poor outcome after mTBI, but the most controversial is sex (Bazarian et al., 2010). Of the 1,425 subjects who had mTBI, 643 were female and 782 were male. “Pre-injury, injury, and post-injury factors were compared between males and females using t-tests for continuous variables that were approximately normally distributed, and chi-square tests for categorical variables” (Bazarian et al., 2010). These factors included returning to normal activities, days missed from work, and women who sustained mTBI during child bearing years. Three months after mTBI, males had significantly lower odds of being in a higher post-concussive symptoms (PCS) score category. The results showed that females are associated with a significantly higher risk of poor outcome after mTBI in concussion tests. It should be mentioned that the study by Bazarian et al. (2010) did not find any other significant differences between male and female risks from head trauma.

Long Term Risks

“A fundamental question that needs more exploration is the relationship between the amount, or dose, of head trauma and alteration in brain structure and function” (Bernick et al., 2015). Previous studies in boxers have reported frequency and duration of fighting to be associated with cognitive or neurological problems” (Bernick et al., 2015). The same study conducted a series of cognitive tests along with MRIs on MMA and boxing athletes. The goal of the study was to see the relationship between head trauma and long term effects on the brain. 224 fighters (131 MMA fighters and 93 boxers) participating in the Professional Fighters Brain Health Study. Each participant underwent computerized cognitive testing and volumetric brain MRI. Fighting history including years of fighting and fights per year were obtained from self-report and published records. “Statistical analyses of the baseline evaluations were applied cross-sectionally to determine the relationship between fight exposure variables and volumes of the hippocampus, amygdala, thalamus, caudate, putamen” (Bernick et al., 2015). The results of this study indicated that MMA athletes are also at a high risk for CTE and Alzheimer’s Disease (Bernick et al, 2015). The study also found that the although boxers were more at risk than MMA athletes, there was still a decrease in brain volume, specifically in the thalamus and caudate in the MMA athletes. With the decrease in volume in these areas of the brain, the mental processing speed of these athletes also decreased.

Lockwood et al. (2018) conducted a systematic review of literature on head trauma in MMA athletes dating from 1990 to 2016. The purpose of the study was to systematically review the literature regarding the prevalence, severity, and risk factors of head injuries sustained in MMA activities. The articles were taken from Ovid MEDLINE, Embase, PsycINFO, EBM Reviews, CINAHL, SPORTDiscus, and Web of Science. The studies that were used by

Lockwood et al. (2018) were heterogenous in nature. “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” (Lockwood et al., 2018). The results showed that MMA athletes with more lifetime fights had lower cognitive test scores, processing speed, and increased signs of motor impulsiveness. This study called for more research to be done in this field because head trauma in MMA is an under researched topic (Lockwood et al., 2018).

Short Term Risks

A study by Schlegel et al. (2021) examined the effects of head trauma on the cognitive functional abilities of MMA athletes. This systematic review looked at previous research done to identify what effect came post-fight for the athletes. “The popularity trend of mixed martial arts (MMA) is steeply increasing, especially in the very young population. Unfortunately, MMA carries an enormous risk of head trauma (Schlegel et al., 2021). A systematic literature review was performed using articles from Web of Science, PubMed, Springer, and Scopus databases, and a total of 30 studies were identified. The results indicate that the incidence of head traumas ranges between 58% and 78% of all injuries. Schlegel et al. (2021) showed studies that used the King-Devick cognitive test to determine cognitive function. Athletes who just experienced a knockout or technical knockout had significantly worse cognitive functions than the baseline of the same athletes. “It is confirmed that MMA often causes KO/TKO and this moment is almost always associated with loss of consciousness, which in its acute form has various clinical manifestations: confusion, loss of balance, or blurred vision” (Schlegel et al., 2021).

According to Hutchison et al. (2014) “To date, the empirical research of the risk of head injuries associated with this sport is limited.” Youth and amateur participation is growing,

warranting investigation into the burden and mechanism of injuries associated with this sport. Hutchison et al. (2014) examined the risk factors of head trauma in MMA using video analysis and competition data of 844 UFC events from 2006 to 2012. The study used multivariate logistic regression to investigate factors associated with an increased risk of sustaining a KO or TKO. The results indicated that knockouts and technical knockouts were shown to be more prevalent in MMA than other combat or contact sports. “Logistic regression identified that weight class, earlier time in a round, earlier round in a match, and older age were risk factors for both KOs and TKOs secondary to repetitive strikes” (Hutchison et al., 2014). Concussions and TBI have shown to have short term risks such as nausea, vomiting, loss of consciousness, and even difficulty with coordination to the athletes sustaining them. With the substantial amount of head trauma induced in MMA, this makes this sport dangerous for the health of the athletes involved (Hutchison et al., 2014).

Concussions

Bernick et al. (2020) analyzed the prevalence of concussions in combat sports. The goal was to 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 (Bernick et al., 2020). An eight person panel of physicians and non-physicians who are experienced members of the sport, video analyzed 30 boxing and 30 MMA professional fights. “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” (Bernick et al., 2020). Based on the analysis, a concussion occurred once every 12.5 minutes of fighting time in MMA. Unlike other sports, in MMA/boxing, when a fighter sustains a concussion they are allowed to continue fighting

(Bernick et al., 2020). A concussion was recorded in 47/60 fights. This study also revealed that 40% of the matches should have been stopped by the referee sooner. The panel demonstrated this by observing the clear visual impairment of a fighter that had just sustained a concussion.

A retrospective cohort study with case–control design was performed by Curran-Sills and Abedin (2018) to understand risk factors associated with concussions in MMA. “There is limited literature that examines risk factors for injury and mild traumatic brain injury (mTBI) in mixed martial arts (MMA). An examination of previously unstudied bouts and athlete characteristics that may pose health risks while partaking in this sport is warranted” (Curran-Sills & Abedin, 2018). Calgary fights, both professional and amateur, from 2010 to 2015 were used in the study. Univariate and multivariable logistic regression to identify risk factors for injury and mTBI was one method conducted. Descriptive statistics also, determined that the most common type of head injury in the fights examined was a concussion. The concussion rate for (AE) was 14.7 per 100, which is lower than the rates for ice hockey. Athletes whose bout was finished by a knockout/technical knockout were more likely to sustain an injury (Curran-Sills & Abedin, 2018). It should be noted that the MMA numbers in terms of concussions in this study were significantly lower than previous studies done (28.3 per 100) (Curran-Sills & Abedin, 2018).

Fogarty et al. (2019) conducted a study with the purpose of investigating the strike patterns that produce concussions in MMA. “Concussion with transient loss of consciousness (tLOC) is a commonly observed but poorly understood phenomenon with mounting clinical significance” (Fogarty et al., 2019). Using multivariate logistic regression analyses, Fogarty et al. (2019) reviewed fights from the UFC (2013-2015) that were deemed knockouts. “Time of strike, striking implement, strike location, and head motion were recorded for all KO strikes (cases), and for a subset of non-KO strikes” (Fogarty et al., 2019). Characteristics of winners and losers

were compared using 2-tailed t-tests from which 136 fights were identified and 110 videos were included. Results showed that head motion in the axial plane was strongly associated with tLOC. “Analysis of impact profiles revealed that the strongest independent predictor for loss of consciousness “LOC” was axial head rotation” (Fogarty et al., 2019). This type of movement from the head is deemed to cause brain trauma and concussions (Fogarty et al., 2019).

Summary

Research has shown that there has been significant progress in understanding the short and long term risks of head trauma for MMA athletes. There is a plethora of data that is now available to researchers because of the increase in the sport’s popularity and mainstream significance. With that, more research needs to be done to get a clearer picture of the risks of head trauma in MMA.

As more and more female divisions in MMA are being introduced, the research should follow. Women have biological differences apart from men which can pose potentially more risks to them according to some of the research. With the significance of child bearing, it is important to get a better grasp on the risks for the female fighters so they can make informed decisions.

Concussions and TBIs are the most common injuries that come with head trauma in MMA. Researchers continue to call for more and more studies to be done to get the best possible understanding for the risks in MMA. CTE and Alzheimer’s Disease have the potential to drastically change the outlook for fighters. There have been many studies on boxing, and now MMA is starting to catch up with the research. As it currently stands, there are major risks based on the research, that head trauma can cause serious health implications for MMA athletes.

Chapter 4:

Results, Discussion, and Recommendation for Future Research

The purpose of this chapter is to present the results of the review of literature on the effects of head trauma on athletes who participate in MMA. The results of the review aligned and answered the research questions put forth in this synthesis. In addition, recommendations for future research, and what specific steps can be taken to ensure that the connection between MMA and head trauma is better understood.

The results of the review demonstrated mixed results in terms of who is more at risk for injury sustained due to head trauma, men or women. There is however, no dispute that any athlete who participates in MMA is at risk for significant injury as a result of head trauma. The majority of research in this review points to repeated blows to the head as a significant reason for brain injuries such as concussions or mTBI. All of the literature deemed MMA to be dangerous for the athletes who partake in it. Some of the literature pointed to significant long-term risks for the MMA athletes, including Alzheimer's Disease and CTE.

Discussion

Interpretations

There were three research questions posed for this synthesis. The first question was are the risks of head trauma dependent on sex and/or weight? The results of the conducted literature review returned some mix results about sex. For example, Follmer et al. (2019) showed through their epidemiological study, that women had longer recovery times and worse symptoms after obtaining head trauma. This agreed with the study of Bazarian et al. (2010), who found men to have better scores than women on their post-concussive symptoms examination.

Fares et al. (2020) showed in their study that men are more prone to sustaining a head injury in MMA, and that they are also more likely to injure their brain in the process.

All the literature showed an overwhelming amount of data which concluded that weight class is a significant factor for brain injuries as a result of head trauma. The higher the weight class was, the more knockouts occurred in both women and men. This resulted in more brain injuries such as concussions and mTBI. Fares et al. (2020) demonstrated that the percentage of brain injuries increased as the weight classes got heavier. Follmer et al. (2019) also found this to be true as more knockouts were recorded in heavier weight classes for both men and women.

The second research question had two parts to it. The goal was to find what short-term and long-term effects head trauma had on these MMA athletes. The systematic review by Schlegel et al. (2021) displayed the post-fight symptoms of athletes who were just knocked out. This usually resulted in concussions and a combination of blurred vision, confusion, and loss of balance. Hutchison et al. (2014) also found, through video analysis multivariate logistic regression, that athletes experienced short term memory loss, nausea, and lack of coordination. These symptoms were found to be as a result of a brain injury which occurred due to the head trauma absorbed. It can be inferred from these results that if a knockout occurs in a fight, the athlete will need medical assistance and a physical examination.

Long term risks of head trauma were shown in statistical analyses by Bernick et al. (2015). The results of the study indicated that MMA athletes are at a high risk for CTE and Alzheimer's Disease. Lockwood et al. (2018) showed in their study that MMA athletes with more lifetime fights had lower cognitive test scores, processing speed, and increased signs of motor impulsiveness. This can be connected to the Bernick et al. (2015) study because the symptoms for CTE are the same. These results are indicative of a connection between head

trauma and long-term risks. Bernick et al. (2015) also showed that the volume of the thalamus and caudate in MMA athletes decreased over time. The findings both showed that the longer a fighter continues to fight, the more prone to long-term health implications they will be.

The final research question explored the risk of an athlete being concussed, and what are the effects of one? A video analysis panel of 30 MMA fights implemented by Bernick et al. (2020), found that a concussion occurred once every 12.5 minutes of fighting time in MMA. Similarly, descriptive statistics by Fogarty et al. (2019) determined that the most common type of head injury in the fights examined in their study was a concussion. Although this is strong evidence that concussions are very prevalent in MMA, this conflicts with the study by Curran-Sills and Abedin (2018), in which concussions were found at a lesser rate than that of ice hockey. The Fogarty et al. (2019) study also found that axial head rotation was the main cause of loss of consciousness which also results in a concussion. When MMA athletes are sustaining blows to the head over and over again, this is a sure indicator that concussions are occurring.

The effects of concussions are a cause for concern for these MMA athletes. Bernick et al. (2020) shows that fighters that are concussed show signs of physical impairment, loss of balance, short-term memory loss, and confusion. Often times, fighters who have been knocked out wake up not remembering what happened. This is evidence enough by Bernick et al. (2020) to demonstrate the significance of concussions on athletes.

Implications

The previous research done about the effects of head trauma on MMA athletes have shown that the sport is very dangerous to their health and safety. It is clear that men and women share various levels of risks for significant brain injuries. These injuries can be short-term, but when it comes to the brain, the health implications can be term long-term as shown in these

studies. Concussions occur in this sport very often based on most of the research and it is clear that this needs to be taken more seriously.

It can be implied that due to the significant findings from the research in this field, that this matter is more serious than previously thought. These athletes are risking their lives by participating in such a sport. It is within reason to assume that their mortality rates can be affected based on the traumatic injuries they sustain to their brains. The research shows that the health guidelines of promotions such as the UFC, may not be safe enough and need improvement. Research has shown that MMA fighters can be concussed and still continue to fight. It's not enough to simply evaluate fighters' health post-match, as this can be more risky.

Limitations & Recommendations for Future Research

Following a thorough review of the data in the literature used in this synthesis, many limitations were apparent. The studies were limited to the overall data of the sport itself. With the rising popularity of MMA, it has only been in recent years that studies are being conducted to seriously look at the risks of head trauma. Another limitation were certain studies using a particular small sample size of fights. This can be contributed to the rather new data available based on the sport's significance and awareness to the mainstream media. The studies did not differentiate between style of fighters. This could be due to a lack of knowledge of the sport. Some fighters tend to be grappling based, and almost never knock someone out or get knocked out. Some fighters have many fights in their career and the majority of them end in a knockout. This can be used as a parameter for future research.

Another limitation was the video reviews that were used in some of the studies. Using visual judgement to determine if athletes are concussed or suffered some sort of brain injury isn't reliable enough. Referees in MMA make judgement calls on when a fighter is deemed to no

longer be intelligently defending themselves. There can be times where their judgement is incorrect because everyone is prone to mistakes. Further research can focus on the amount of fights where the fighters suffered a brain injury and were still allowed to continue fighting.

One final limitation that was noticed in the literature was the focus on only the UFC. Although the UFC is the main, and most popular MMA promotion, there are plenty of other ones to explore. For example, the UFC uses certain rules and health and safety protocols that some promotions do not. In fact, there isn't even a uniform set of MMA rules in the United States because it varies from state to state. Further research is needed to determine where these fights were located and what rule sets were used, which could impact the results.

Based on these limitations, future research should consider the following recommendations:

1. Based on the prevalence of concussions, fighters should be examined at the end of a round as opposed to the fight. This can provide critical information to be given to these promotions to help them drastically improve their safety protocols. If a fighter is checked by a doctor and deemed to have a concussion, the fight should, and could be over immediately.
2. Video replays to help referees make informed decisions about when to stop a fight can be implemented. If a study was done using this tool, perhaps fighters can be seen on replay showing symptoms of concussions. This would require a panel of doctors similarly to one of the studies in this synthesis.
3. More studies on specific styles of fighters can be conducted to see the risks for brain injury. Are fighters with more knockouts more prone to head injuries or are all the athletes who participate equally at risk?

4. One final recommendation would be to conduct studies from different promotions other than the UFC. This can compare and contrast different protocols and rule sets to determine which are more effective in lowering the health risks of the athletes.

Summary

The purpose of this synthesis was to examine the effects of head trauma on athletes who participate in MMA. An exhaustive search of online databases using delimiters and keywords/phrases produced 11 articles that were selected for the synthesis. The articles were used to determine if being a man or woman, or being at different weight classes, altered the risks of sustaining injuries due to head trauma. The synthesis also determined the long-term and short-term risks for athletes who participate in MMA, as well as the significance and prevalence of concussions in this sport.

Research revealed that there are many factors that go into sustaining a brain injury as a result of head trauma. Women were found to be more at risk for longer lasting effects from head trauma, while men were more prone to getting a brain injury due to their heavier weight classes and prevalence of knockouts. There were significant short-term and long-term risks such as confusion, memory loss, CTE, and Alzheimer's Disease. Concussions occurred very often in MMA, and were the starting point for most significant long-term brain injuries, according to most of the research.

Further research can only help to get more information on this topic. As MMA continues to grow, the research must follow. With more eyes now on the sport, the risks are becoming apparent, which can help begin to change the sport for the better. Safer health procedures such as

post-round fighter checks can help preserve the fighters. More research on the fight style of fighters can also help figure out who is more at risk and what can be done to reduce that risk.

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Appendix A

Synthesis Article Grid

Author	Title	Source	Purpose	Methods & Procedures	Analysis	Findings	Discussion
Bernick, C., Banks, S. J., Shin, W., Obuchowski, N., Butler, S., Noback, M., Phillips, M., Lowe, M., Jones, S., & Modic, M. (2015).	Repeated head trauma is associated with smaller thalamic volumes and slower processing speed: the Professional Fighters' Brain Health Study.	British Journal of Sports Medicine	To explore the relationship between exposure variables, cognition and MRI brain structural measures in a cohort of professional combatants	224 fighters (131 mixed martial arts fighters and 93 boxers) participating in the Professional Fighters Brain Health Study, a longitudinal cohort study of licensed professional combatants, were recruited, as were 22 controls. Each participant underwent computerized cognitive testing and volumetric brain MRI. Fighting history including years of fighting and fights per year was obtained	Repeated measures analysis of variance was performed to test the association between the outcome variables and fight exposure variables.	Increasing exposure to repetitive head trauma measured by number of professional fights, years of fighting, or a Fight Exposure Score (FES) was associated with lower brain volumes, particularly the thalamus and caudate. In addition, speed of processing decreased with decreased thalamic volumes and with increasing fight exposure. Higher scores	The answer to whether brain volumes and performance change over time with, and in the absence of further exposure will hopefully emerge as this cohort is followed longitudinally.

				<p>from self-report and published records. Statistical analyses of the baseline evaluations were applied cross-sectionally to determine the relationship between fight exposure variables and volumes of the hippocampus</p>		<p>on a FES used to reflect exposure to repetitive head trauma were associated with greater likelihood of having cognitive impairment.</p>	
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<p>Follmer, B., Dellagrana, R. A., & Zehr, E. P. (2019).</p>	<p>Head Trauma Exposure in Mixed Martial Arts Varies According to Sex and Weight Class.</p>	<p>PubMed Central</p>	<p>This study aimed at analyzing match stoppages in MMA and the exposure to head trauma distinguished by sex and weight categories.</p>	<p>Publicly available data of 167 MMA events from 1903 fights between 2014 and 2017 were assessed, comprising 8 male and 2 female weight categories. The UFC male weight categories assessed in the present study were flyweight (52.1-56.7 kg), bantamweight (56.7-61.2 kg), featherweight (61.2-65.8 kg), lightweight (65.8-70.3 kg), welterweight (70.3-77.1 kg), middleweight (77.1-83.9 kg), light heavyweight (83.9-93.0 kg), and heavyweight (93.0-120.2 kg). For female weight classes, the strawweight (<52.1 kg) and the</p>	<p>All statistical analyses were performed using SPSS (v 17.0; SPSS Inc). Descriptive absolute and relative data are presented for each weight class as well as the total male and female cases. We applied a previous definition for an athlete-exposure (AE), that is, participation in any competition in which one was exposed to the possibility of an athletic injury (ie, 1 fight with 2</p>	<p>The lightweight division was chosen as the reference for the binary logistic regression analysis of the male categories according to previous literature. Flyweight was the only category that presented significantly diminished risk (-62%) of a KO/TKO due to strikes to the head. In contrast, the middleweight, light heavyweight, and heavyweight categories increased the risk of sustaining a KO/TKO outcome caused</p>	<p>There is a need to consider both sex and weight class when analyzing the incidence of exposure to head trauma in MMA and its severity. The lightest categories were those in which athletes were potentially more susceptible to receive repetitive subconcussive blows to the head. The male middleweight, light heavyweight, and</p>
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				bantamweight (56.7-61.2 kg) divisions were analyzed, since these were the 2 categories with a considerable amount of data during the evaluated period.	competitors yields 2 AEs). Binary logistic regression analyses were performed to verify and compare the odds ratios of a KO/TKO	by strikes to the head by 80%, 100%, and 206%, respectively. The strawweight division was the reference for the female analysis. Fights of the bantamweight category presented a 221% increased risk of a KO/TKO	heavyweight categories presented increased incidence and risk of a match ending with an athlete either unconscious
Hutchison, M. G., Lawrence, D. W., Cusimano, M. D., & Schweizer, T. A. (2014)	Head Trauma in Mixed Martial Arts.	The American Journal of Sports Medicine	To determine the incidence, risk factors, and characteristics of knockouts (KOs) and technical knockouts (TKOs) from repetitive strikes in professional MMA; and (2) to identify the mechanisms of head trauma and the situational factors that lead	Competition data and video records for all KOs and TKOs from numbered Ultimate Fighting Championship MMA events (n = 844) between 2006 to 2012. Analyses included (1) multivariate logistic regression to investigate factors associated with an increased	Scorecard, video, statistical, The MMA-KT contains 20 factors, organized into 2 parts, and codes information on match characteristics and the situational context of the events	Rates of KOs and TKOs in MMA are higher than previously reported rates in other combative and contact sports. Public health authorities and physicians should be cognizant of the rates and mechanisms of	The mechanisms of head trauma in this sport can form the foundation for efforts that make the sport safer for those who insist on competing in jurisdictions

			to KOs and TKOs secondary to repetitive strikes through video analysis.	risk of sustaining a KO or TKO secondary to repetitive strikes and (2) video analysis of all KOs and TKOs secondary to repetitive strikes with descriptive statistics.	preceding KOs and TKOs in addition to evaluating the mechanism of action and subsequent events surrounding a KO	head trauma. Preventive measures to lessen the risks of head trauma for those who elect to participate in MMA are described.	where it is permitted.
Fogarty, A. E., Guay, C. S., Simoneau, G., Colorado, B., Segal, R. G., Werner, K., & Ellenbogen, J. M. (2019).	Head Motion Predicts Transient Loss of Consciousness in Human Head Trauma: Insights From Mixed Martial Arts	Medicine and Science in Sports and	Concussion with transient loss of consciousness is a commonly observed but poorly understood phenomenon with mounting clinical significance.	A case-control design was used. The Ultimate Fighting Championship database was screened for events ending with knockouts from 2013 to 2016. Time of strike, striking implement, strike location, and head motion were recorded for all knockout strikes	Analysis of impact profiles revealed that the strongest independent predictor for LOC was axial head rotation (OR, 45.3; 95% CI, 20.8 - 98.6)	Our study is among the first investigations of directly observed human head trauma and the first to directly link axial head rotation as a major contributing variable for whether trauma causes LOC in humans.	Direct link to how blows to the head induce head trauma
Bernick, C., Hansen, T.,	Concussion occurrence	The Physician	Determine, through video	This is a retrospective video	In the comparison	Among the most notable	Given the increasing

<p>Ng, W., Williams, V., Goodman, M., Nalepa, B., Shan, G., & Seifert, T. (2020).</p>	<p>and recognition in professional boxing and MMA matches: toward a concussion protocol in combat sports</p>	<p>and Sportsmedicine Taylor and Francis: Science and technology library</p>	<p>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.</p>	<p>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.</p>	<p>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</p>	<p>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.</p>	<p>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. Yet, the majority of</p>
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<p>Bazarian, J. J., Blyth, B., Mookerjee, S., He, H., & McDermott, M. P. (2010)</p>	<p>Sex Differences in Outcome after Mild Traumatic Brain Injury</p>	<p>Gale Academic: Journal of Neurotrauma</p>	<p>The objective of this study was to estimate the independent association of sex with outcome after mild traumatic brain injury (mTBI)</p>	<p>We performed an analysis of a subset of an established cohort involving 1425 mTBI patients presenting to an academic emergency department (ED). The associations between sex and three outcomes determined 3 months after the initial ED visit were examined: post-concussive symptom (PCS) score (0, 1–5, 6–16, and >16), the number of days to return of normal activities (0, 1–7,</p>	<p>Bivariate, multivariate</p>	<p>However, our results suggest that female sex, after appropriate control for confounders, is associated with a significantly higher risk of poor outcome after mTBI in humans. Three months after injury, males had reduced odds of being in a higher PCS score category (OR = 0.62; $p < 0.0001$), and of being in a higher missed days of work</p>	<p>These observations raise the question: Do females have worse outcomes than males, or are they simply more willing to report subtle feelings that males would dismiss altogether? Our results may provide some clues to the answer. Increased symptom</p>

				and >7), and the number of days of work missed (0, 1–7, and >7).		category (OR - 0.57 for 0 days versus 1-7 days, and OR = 0.64 for 0 days versus >7 days), although the latter association did not reach statistical significance	reporting would not explain the pattern of disability as a function of age that we observed among females, but not males.
Schlegel, P., Novotny, M., Valis, M., & Klimova, B. (2021).	Head injury in mixed martial arts: a review of epidemiology, affected brain structures and risks of cognitive decline	The Physician and Sportsmedicine Taylor and Francis: Science and technology library	The aim of this article is to provide review of studies on the association between head injuries and cognitive functions in MMA fighters.	A systematic literature review was performed. Web of Science, PubMed, Springer, and Scopus databases were used. A total of 30 studies were identified. The inclusion criteria were as follows: studies with MMA fighters and head injuries and/or	The methodology follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)	In terms of frequency, head injuries are a common part of MMA. Data varies, but the authors report that up to 78% of injuries are associated with face and head. One of the decisive criteria for assessing possible future	The only thing that can be more than recommended at this point is the increased medical supervision of the fighter (during his career, but also after it)

				TKO/KO and/or reduction of cognitive functions in these fighters.		connections with neurodegenerative changes in the brain should be the presence of KO/TKO, respectively loss of consciousness during a match or training.	and the introduction of practical safety instructions for fighters to reduce the risk of developing CTE.
Fares, M. Y., Salhab, H. A., Fares, J., Khachfe, H. H., Fares, Y., Baydoun, H., Abboud, J. A., & Alaaeddine, N. (2020).	Craniofacial and traumatic brain injuries in mixed martial arts.	The Physician and Sportsmedicine Taylor & Francis Science and Technology Library	This study aims to explore the patterns and trends of head injuries in MMA.	Descriptive epidemiological study. : Ringside physician reports of the Ultimate Fighting Championship (UFC) fights between 2016 and 2019 (inclusive) were screened. Data were extracted from the Nevada State Athletic Commission (NSAC) database. Play-by-play video	A one-way analysis of variance (ANOVA) was used to explore any statistically significant differences between injury rates of different locations, types, and types of finishes.	Head injury rate constituted 35 injuries per 100 athletic-exposures (AE) in sanctioned fights. Traumatic brain injuries (TBI) were the most common type of injury, with a rate of 16 per 100AE,	In general, head injury rates were higher as weight divisions increased. : Head injuries are prevalent in MMA.

<p>Lockwood, J., Frappe, L., Lin, S., & Ackery, A. (2018).</p>	<p>Traumatic brain injuries in mixed martial arts</p>	<p>SAGE premier</p>	<p>We systematically reviewed the literature regarding the prevalence, severity and risk factors of head injuries sustained in mixed martial arts activities.</p>	<p>We conducted a comprehensive systematic review of Ovid MEDLINE, Embase, PsycINFO, EBM Reviews, CINAHL, SPORTDiscus, and Web of Science from 1990 to 2016 for studies of any design that reported associations of acute or chronic head injuries in persons participating in mixed martial arts activities.</p>	<p>The studies included in the final analysis were heterogeneous in their design, the population studied, and outcomes measured. Thirteen observational studies were included, of which eight were retrospective studies describing injuries and injury patterns sustained in MMA competition, and five were prospective longitudinal cohort studies measuring structural</p>	<p>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. 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</p>	<p>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</p>
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					changes on magnetic resonance imaging (MRI) and behavior; one cross-sectional study two survey studies.	professional fighters	including accurate and consistent head injury assessment and diagnosis by trained medical professionals
Curran-Sills, G., & Abedin, T. (2018).	Risk factors associated with injury and concussion in sanctioned amateur and professional mixed martial arts bouts in Calgary, Alberta	Pub Med BMJ Open Sport & Exercise Medicine	To determine the incidence of injury and concussion, along with the identification of risk factors that contribute to injury and mTBI in amateur and professional MMA bouts in Calgary, Alberta.	A retrospective cohort study with case-control design. amateur and professional MMA records were examined from 1 January 2010 to 31 December 2015. Descriptive statistics were used to describe the incidence of injury and concussion, along with univariate and multivariable logistic regression to identify risk	Descriptive statistics were used to determine the incidence of injury and concussion; frequencies (percentages) were presented for categorical data, and mean (SD) presented for continuous data. The rate of injury was normalised to 100 AE	There were 151 athletes who sustained an injury, giving a total of 162 injuries. The number of AEs was 686. The total number of scheduled minutes was 4280 and 75.4% of bouts ended early, resulting in 2000 minutes of bout time or 4000 minutes of exposure. The injury rate per 100 AE, the injury rate per	MMA continues to be a sport that requires investigation to generate evidence-informed understanding of the health risks and to create recommendations to modify these risks. Athletes whose bout were

				<p>factors for injury and mTBI</p>	<p>and 100 ME, while the concussion rate was normalised to 100 AE. A case-control design with univariate and multivariable logistic regressions were used to determine if variables associated with the bout (ie, level of competition, bout type, length of the bout, outcome of the bout</p>	<p>100 ME and the concussion rate per 100 AE were 23.6 (95% CI 20.5 to 27.0), 4.1 (95% CI 3.48 to 4.70) and 14.7 (95% CI 11.8 to 17.2), respectively. The most common injury location was the head, followed by the upper and lower extremities. Concussion was the most common injury type.</p>	<p>finished by a KO/TKO, corner stoppage, draw, no contest or physician and those whose country of origin was non-Canadian were more likely to sustain an injury</p>
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