Determinantes e indicadores clave de la conmoción cerebral en atletas de deportes de combate: una revisión sistemática

Determinants and key indicators of concussion in combat sport athletes: a systematic review

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Abstract

Introduction: Combat sport athletes are more likely to suffer concussions because one of the goals is to knock out an opponent and apply blows during the fight.
Objective: To analyze the mechanisms of concussion specific to combat sports and identify the most prevalent signs and symptoms that affect athletes after concussion.
Methods: The PRISMA protocol was applied, searches were performed in electronic databases using the descriptors: Athletes, Fighting, Martial Arts, Combat Sports, Concussion, Brain Concussion, Traumatic Brain Injury, Physical Symptoms and Motivational Symptoms. The identification and peer selection process were performed using the Rayyan software. We then extracted the articles which met the eligibility criteria for qualitative analysis, using the Risk of Bias Used for Surveys tool.
Results: A total of 912 articles were identified, 90 duplicates and 81 bibliographic reviews, leaving 65 articles for reading the abstracts. Of these, 46 were excluded according to the eligibility criteria, including 19 articles. Regarding exposure to concussion, 70.2% were related to the number of fights performed and 29.8% fighters. The sports modalities were 45.5% MMA, 18.2% boxing, 9.1% taekwondo, 9.1% karate and 9.1% kickboxing. The injuries found were divided into 27.2% traumatic brain injury and 72.8% concussion. According to the signs and symptoms identified, 55.2% were physical and 44.8% motivational.
Conclusion: The frequency of fights is a determining factor for the incidence of concussions in combat sport athletes and the post-concussion symptoms showed significant physical and motivational manifestations, which represent barriers to the technical-tactical development of athletes.

Keywords

Combat sports; concussion; mixed martial arts; motivational symptoms; physical symptoms.

Resumen

Introducción: Los deportistas de combate tienen mayor probabilidad de sufrir conmociones cerebrales porque uno de los objetivos es noquear a un oponente y aplicar golpes durante la pelea.
Objetivo: Analizar los mecanismos de conmoción cerebral específicos de los deportes de combate e identificar los signos y síntomas más prevalentes que afectan a los atletas después de la conmoción cerebral.
Métodos: Se aplicó el protocolo PRISMA, se realizaron búsquedas en bases de datos electrónicas utilizando los descriptores: Atletas, Lucha, Artes Marciales, Deportes de Combate, Conmoción Cerebral, Conmoción Cerebral Traumática, Síntomas Físicos y Síntomas Motivacionales. El proceso de identificación y selección por pares se realizó utilizando el software Rayyan. Luego, se extrajeron los artículos que cumplieron con los criterios de elegibilidad para el análisis cualitativo, utilizando la herramienta Riesgo de Sesgo Utilizado para Encuestas.
Resultados: Se identificaron 912 artículos, 90 duplicados y 81 revisiones bibliográficas, quedando 65 artículos para lectura de resúmenes. De estos, 46 fueron excluidos según los criterios de elegibilidad, incluyendo 19 artículos. En cuanto a la exposición a la conmoción cerebral, el 70,2% estuvo relacionada con el número de peleas realizadas y el 29,8% con los luchadores. Las modalidades deportivas fueron 45,5% MMA, 18,2% boxeo, 9,1% taekwondo, 9,1% karate y 9,1% kickboxing. Las lesiones encontradas se dividieron en 27,2% traumatismo craneoencefálico y 72,8% conmoción cerebral. Según los signos y síntomas identificados, el 55,2% fueron físicos y el 44,8% motivacionales.
Conclusión: La frecuencia de peleas es un factor determinante para la incidencia de conmociones cerebrales en deportistas de deportes de combate y los síntomas post-conmociones cerebrales mostraron manifestaciones físicas y motivacionales significativas, que representan barreras para el desarrollo técnico-táctico de los deportistas.

Palabras clave

artes marciales mixtas; conmoción cerebral; deportes de combate; síntomas físicos; síntomas motivacionales.

Introduction

Combat sports are characterized by a variety of attacking and defending techniques such as punching and kicking, hand-to-hand fighting techniques such as chokes and joint locks, or a mixture of techniques involving standing, clinching and ground movements which are divided into striking, grappling or mixed actions (Correia & Franchini, 2010; Barley et al., 2019; Fernandes et al., 2022). There is currently an exponential growth in popularity and professionalism of these sport modalities, which in turn has driven a growing interest in training practices that must be based on scientific evidence to optimize athlete performance (James et al., 2016). However, despite this progress, there remains a significant gap in consensus on the management of concussions commonly induced by the biomechanical forces inherent to these sports (Neidecker et al., 2019).

In terms of frequency, head injuries are very common in combat sports (Neidecker et al., 2019; Schlegel et al., 2021). As in Karate and Taekwondo, a concussion occurs as a result of a blow to the ground, a blow or a kick to the head (Tapajčíková, 2022). The frequency of head strikes in MMA results in cognitive impairments in those who sparring compared to those who do not, due to recurrent concussions. (Fernandes et al., 2024). The grappling combat sport that uses takedowns, there is a potential brain injury risk, such as a concussion (de Carvalho et al., 2022). And concussion impairs executive functions in boxing and MMA (Follmer et al., 2020). In this context, recurrent concussions may be an eminent risk factor for developing neurodegenerative diseases such as Alzheimer's, Parkinson's disease and other dementias (Schlegel et al., 2021). When concussions occur in combat sport athletes, clinical manifestations include motor and physical deficits, affective, motivational and personality changes, as well as impaired cognitive function.

Previous reviews have evaluated concussions in combat sports. Donnelly et al. (2023) analyzed the acute and chronic neurological and neuropsychological effects that boxing causes on the brain, in addition to the safety benefits provided by boxing head protectors. Lota et al. (2022) highlighted those direct impacts to the head in impact sports produced greater rotational acceleration values than impacts from throws or falls in grappling sports, placing athletes at greater risk of traumatic brain injury. Lystad (2014) examined the concussion incidence rate in Taekwondo, finding that it is higher than in other contact and collision sports, but lower than in boxing. Although the existing scientific literature identifies cognitive signs and symptoms associated with concussion (Bernick et al., 2021; Claro et al., 2024; Follmer et al., 2020; Schlegel et al., 2021), it lacks clarity regarding physical and motivational signs and symptoms in combat sports.

This review not only aims to describe the main physical and motivational signs and symptoms in athletes after concussions, as well as understanding these signs and symptoms to determining the best follow-up and treatments, thus ensuring effective recovery and the athlete's health. However, there are still gaps to be filled regarding the inference of protocols on the short- to long-term physical and motivational signs and symptoms of concussion. Therefore, the main objective of this study is to analyze the mechanisms of concussion specific to combat sports and to identify the most prevalent signs and symptoms that affect athletes, whether physical or motivational, after a concussive event. To this end, a systematic review of the literature was conducted, and complemented by analyses of case studies that document the experiences of athletes who suffered concussions during training or competitions. The present study may contribute to develop more effective prevention and treatment protocols, as well as provide valuable insights for coaches, sports physicians and athletes themselves.

Method

The protocol focused on combat sports athletes who sustained concussion and adhered to the PRISMA guidelines for systematic reviews (Page et al., 2021).

Search strategy

Searches were conducted until January 3, 2024, in the PubMed, Conchrane, BVS, SciELO and Google Scholar electronic databases. Searches were limited to the title, abstract and keywords of the articles, the controlled language of the respective Medical Subject Headings (MeSH) and Descriptors in Health

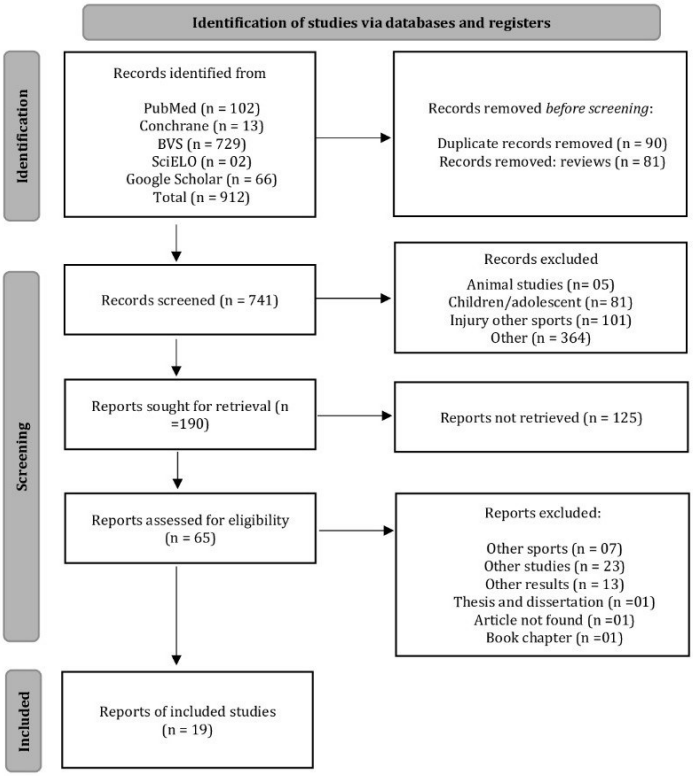
Sciences (DeCS) were queried and combined with the Boolean operators AND and OR. The following search terms were used: (Fighting Athletes OR Martial Arts Athletes OR Combat Sports Athletes) AND (Concussion OR concussion brain OR traumatic brain injury) AND Physical symptoms AND motivational symptoms; for the link with details click here. Filters were used to restrict the results to only scientific articles in Portuguese, English and Spanish. No limits were used for publication years.

Study selection

The following inclusion criteria were adopted for selecting articles: a) Combat sport athletes who have suffered concussion, diagnosed or self-reported (Kicks, head blows, throws, knockouts or technical knockouts); b) young adult participants; c) articles identifying concussion in combat sports including the reported signs and symptoms; d) cross-sectional, longitudinal survey articles. The following articles were excluded: a) studies with low methodological quality; b) unavailable articles; c) off-topic articles; d) studies on contact sports; e) theses, dissertations, abstracts, books; and f) studies which showed insufficient results on concussion.

The process of identifying and selecting relevant articles was carried out by peers who conducted the screening independently. The Rayyan program was used to screen articles, remove duplicates, read titles and abstracts (Ouzzani et al., 2016). The articles were then read and those that did not provide sufficient information on concussion in combat sports to apply the eligibility criteria were excluded. After evaluation, two authors met to reach consensus regarding the inclusion criteria (MAB and JRF), and deletion of each article and disagreements were judged by a third party (BM) author for the final opinion and consensus to be reached for all included articles. The inter-rater agreement was ($k=0.98$, $p<0.001$; agreement = 95%). The description of the study selection is shown in Figure 1.

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.



Source: Page et al. (2021)

Data extraction

For articles that met the eligibility criteria, we extracted the following information for qualitative analysis: a) author and year, b) study design, c) sample, d) type of concussion, e) concussion identification, and f) Signs and symptoms. In case of missing information, contact was established with

the authors of the articles. Eligibility criteria were established according to the PECO question (P = Combat sports athletes; E = Concussion; C = No concussion; O = Signs and symptoms found).

Risk of bias assessment

The risk of bias in each selected article was assessed using the Risk of Bias Utilized for Surveys Tool (ROBUST) (Nudelman & Otto, 2020), that assesses the presence or absence (yes or no) of eight types of risk of bias specific to survey studies. The eight types of biases considered refer to: (1) representativeness of the sample; (2) participant recruitment method; (3) percentage of excluded participants; (4) final sample size; (5) presentation of sociodemographic variables; (6) reliability of the measures used; (7) controlled data collection environment; and (8) data management. As in the previous stages, the instrument was completed by two independent judges, and a third judge was called upon in the event of disagreement between them. The Kappa index showed almost perfect agreement between the judges in relation to the eight items investigated ($k \geq 0.85$, $p < 0.001$; agreement ≥90%). The quality of the analysis in detail is shown in Table 1.

Table 1. Assessment of risk of bias – ROBUST

Study	Evaluation	1	2	3	4	5	6	7	8
Arriaza et al., 2017	Yes	X			X		X		X
	No		X	X		X		X	
Bernick et al., 2015	Yes	X	X		X	X	X		X
	No			X				X	
Bernick et al., 2020	Yes	X	X			X	X	X	X
	No			X	X				
Brown et al., 2020	Yes	X	X	X	X	X	X	X	X
	No								
Bryant et al., 2019	Yes				X	X	X	X	X
	No	X	X	X					
Christopher, 2013	Yes	X	X		X	X	X		X
	No			X				X	
Dretsch et al., 2019	Yes	X	X	X	X		X	X	X
	No					X			
Fares et al., 2020	Yes	X	X	X	X	X	X	X	X
	No								
Follmer, 2019	Yes	X	X	X	X		X		X
	No					X		X	
Hutchison et al., 2014	Yes				X		X		X
	No	X	X	X		X		X	
Khatib et al., 2021	Yes	X	X		X	X	X		X
	No			X				X	
Kirk, 2023	Yes	X		X	X		X	X	X
	No		X			X			
Komatsu et al., 2023	Yes	X	X	X	X		X	X	X
	No					X			
Ohhashi et al., 2002	Yes	X	X	X	X		X	X	X
	No					X			
Pieter et al., 1998	Yes	X					X		X
	No		X	X	X	X		X	
Stephen et al., 2020	Yes	X	X		X	X	X	X	X
	No			X					
Tiernan, 2020	Yes	X						X	X
	No		X	X	X	X	X		
Zazryn, 2002	Yes	X					X	X	X
	No		X	X	X	X			
Warden et al., 2001	Yes	X	X	X	X	X	X	X	X
	No								

Legend: (1) representativeness of the sample; (2) method of participant recruitment; (3) percentage of excluded participants; (4) final sample size; (5) presentation of sociodemographic variables; (6) reliability of the measures used; (7) controlled data collection environment; and (8) data administration.

Results

Figures 1 and 2 show the number of articles present in each stage of the study selection. A total of 912 articles were initially identified by adding up the results in the five databases researched, 90 of which were duplicates and 81 were bibliographic reviews. Soon after, studies involving animals, children/adolescents, and injuries in other sports were excluded by reading their titles; this left 65 articles for reading the abstract, of which 46 were excluded because they clearly did not refer to the topic of interest or because they used other methods (other sports, other studies, other results, theses and dissertations, articles not found, and book chapters). Of the articles that advanced to the eligibility study, only 19 were included in the study.

Risk of bias analysis

For the analysis of the quality of the articles, we observed that 63.2% of the responses demonstrated the quality of the articles and only 36.8% of the data did not match. Therefore, the articles were kept, as they maintained good methodological quality. A total of 19 studies were selected to be analyzed, of

which the study designs were: 54.5% epidemiological, 36.4% observational, and 9.1% pilot. Regarding exposure to concussion, 70.2% are related to the number of fights held and 29.8% fighters. Regarding sports, we found 45.5% MMA, 18.2% boxing, 9.1% taekwondo, 9.1% karate and 9.1% kickboxing. The injuries found were divided into 27.2% traumatic brain injury and 72.8% concussion. The causes of concussions and Traumatic Brain Injury (TBI) found were due to exposure to fights followed by the end of fights by Knockout (KO) and Technical Knockout (TKO); a higher percentage of blows to the head; light heavyweight, heavyweight and bantamweight athletes are more exposed to concussion, as well as older athletes who are more likely to have concussion; elbow strikes, various punches, kicks and throws are more likely to cause concussion; and sparring and competition are more likely to cause concussion.

Table 2. Characterization of selected articles which portray the precursors of concussion risk.

Author	Design	Concussion exposure	Concussion type	Concussion risk
Arriaza et al., 2017	ES	4,625 Karate Ma – 2008 to 2014.	Concussion	Concussion can occur 1:1,156 fights, or 0.43/1,000 per athlete exposure. The concussion rate for men was 1/5,832" per fight, and 1/6,836" for women.
Fares et al., 2021	ES	816 UFC Fts - 2016 to 2019	Concussion	Fighters who suffered head injuries, on average 18 professional fighters, with the average time during M of 9' and 49", absorbed an average of 32 blows to the head. Fights that ended by KO/TKO had the ↑ number of head injuries 60.4% and submission had ↓ number of head injuries 7.3%. Weight division: light heavyweight had 44:100AE, Strawweight 11:100AE.
Follmer et al., 2019	ES	1,903 MMA Ma, 2014 to 2017	traumatic brain injury	KO/TKO rates per 100 AE and probabilities of TBI, involves blows to the head; musculoskeletal injuries, lacerations, and doctor or corner stoppages can lead to TKO. Fight consisting of 2 AE, total of 3,456 and 350 AE for M and F. The flyweight category that presented a ↓ risk of KO/TKO with blows to the head. The middleweight 80%, light heavyweight 100% and heavyweight 206% with a ↑ risk of sustaining KO/TKO by blows to the head. The bantamweight F with a 221% ↑ risk of KO/TKO by blows to the head.
Hutchison et al., 2014	ES	844 MMA Ma, 2006 to 2012	traumatic brain injury	KO rate 6.4:100 AE; TKO rate secondary to RB 9.5:100 AE, combined incidence of TBI at the end of L 15.9:100 AE. For each KO or TKO there was an associated risk of ↑KOs and ↑older Fts. Middleweight or elimination ↓ risk of sustaining a KO. Each additional minute within a round and each additional round in L were associated with a ↓KO risk. For TKO secondary to GR, heavyweight was associated with a ↑ ris.
Khatib et al., 2021	ES	60 MMA Fts, 15 lightweights and 15 heavyweights	Concussion	The HW and LW had an average fight time of 9'53" and 9'36''. The LW sustained much higher frequencies of ↑ and ↓ magnitude MPS impacts than the HW. Regarding the frequency of impacts to the head, the LW suffered a ↑ impact. The large magnitude attacks were the result of punches and kicks in LW fights, elbow impacts to the head caused blows of ↑ magnitude in HW fights.
Kirk & Childs, 2023	PS	MMA Fts (n = 7) - Sparring	Concussion	All experienced multiple direct and indirect head accelerations/decelerations from punches, kicks, and throws per session.
Komatsu et al., 2023	OS	663 Boxers	traumatic brain injury	Older athletes with a history of competition, heavy weights, and ↓defensive and counter-attacking skills tend to have a ↑ probability of being KO'd.
Ohhashi et al., 2002	OS	632 Boxers	Concussion	Clarified that a single punch, rather than damage accumulated by multiple punches, can cause a concussion. Punches: moving the head to the side 38.7%, turning the head 58.5%, unknown 12%. Of the 339 KOs in a fight, 77.3% were KO by one punch, 21.2% passed out after multiple punches.
Pieter & Zemper, 1998	ES	2,407 Taekwondo Fts, 1989, 1990 and 1991	Concussion	M suffered more concussion per 1,000 AE than F. The concussion in 100% F was the result of an unblocked attack receiving the injuring blow. In addition, 87.5% of Concussions in M were an unblocked attack, 91.7% of the cases the injury was post-blow. Fighters get injured while trying to block an attack.
Tiernan et al., 2020	OS	13 MMA Fts	Concussion	451 HI above 10g during 19 sparring and 11 competitive events (13.9 HI per event). The HIs that resulted in C had durations ↑ to those without injury. 4 HIs that resulted in concussion. 57.5% of HIs in sparring and competitive events in the frontal part of the head, 33.9% in the left frontal part of the head.
Zazryn et al., 2003	OS	3,481 Ma Kickboxing - Victoria, 1985 to 2001	Concussion	3,481 AEs, 382 injuries. 109.7:1,000 injury ratio in Ma. 96.5% of injuries in M, 62.9% of FTs involving injury resulted in defeat, 30.1% a win and the remaining 7.0% a draw; 49% of Fts due to injury were decided by points, 49.5% by KO or TKO.

Caption: PS = Pilot study; OS = Observational study; ES = Epidemiological study; M = male; F = female; AE = athlete exposures; Ma = Match; Fts = Fighters; RB = Repetitive blows; LW = Lightweight; HI = head impacts.

Table 3 presents the main signs and symptoms commonly identified in the studies analyzed. The study designs were 77.8% observational, 11.1% experimental and 11.1% epidemiological. There was a total of 3,004 athletes evaluated (65 - female and 2,662 - male), ages ranging from 18 to 47 years. The sports modalities found 45.4% boxing, 44.4 MMA, 11.1 combat sports and 11.1% martial arts. Concussion was identified through 44.4% self-report, 45.4% scales and questionnaires (SCAT2, PCS, TRS and QS), 11.1% medical evaluation, 33.3% cognitive tests (King-Devick), 11.1% magnetic resonance imaging associated with clinical evaluation. Main signs and symptoms identified post-concussion in combat sport athletes were divided into physical symptoms and motivational symptoms. The physical symptoms identified were: 25% headache, 31.3% balance problems, 37.5% dizziness and fainting, 12.5% ringing in the ears, 6.3% gait disturbance, 6.3% lightheadedness, 37.5% motor disturbance, 12.5% neck pain, 37.5% sleep disturbance, 7.8% cervical pain, 25% nausea and vomiting, 12.5% visual disturbance, 18.8% sensory disturbance, 12.5% numbness or tingling, 6.3% back pain, and 6.3% muscle pain. The motivational symptoms included: 53.8% memory impairment, 23.1% processing speed, 46.2% fatigue, 7.8% low energy, 23.1% cognitive impairment, 15.4% inattention, 7.8% perseverance, 7.8% self-control, 7.8% irritability, 7.8% sadness, 7.8% nervousness, 15.4% emotional change, and 7.8% reaction time.

Table 3. Key physical and motivational signs and symptoms of concussion identified.

Author	Design	Sample, Concussion Identification	Signs and symptoms found
Dretsch et al., 2019	OS	PG (n = 98; age = 29.98±4.80); GC (n = 31; age =29.84±3.93). Self-report, KD test and SCAT2 scale	Headache, balance problems, dizziness, memory problems and ringing in the ears.
Bernick et al., 2021	OS	60 fights (30 Boxing and 30 MMA). Medical evaluation	Impaired gait, abnormal balance, vacant gaze, dizziness, and delayed motor response.
Bernick et al., 2015	OS	EG (n= 131 MMA, 93 Boxing and 22 Controls). Cognitive tests and MRI	Verbal memory impairment, Psychomotor speed, Processing speed.
Brown et al., 2021	OS	CS Fts (n= 309) and 13 Coaches; Age (31.4 ±8.8).	Verbal memory impairment, Psychomotor speed, Processing speed.

		Self-report	
Bryant et al., 2020	OS	AFG (n= 442; age= 29.05±5.44) and IFG (n= 64; age= 47.80 ±9.53). Self-report	Cognitive impairments, processing speed, psychomotor speed, lack of attention, cognitive instability, motor perseverance, self-control and cognitive complexity.
Heath & Callahan, 2013	PS	MMA (n= 119); age (n= 26.5 ± 7.4); training per week (n= 2.5 ± 1.4), 60' of sparring (63.3 ± 40). QS; TRS; PCS scales	Headaches, fatigue, dizziness, vomiting, visual problems, nausea, balance problems, difficulty falling asleep, sleeping more, sleeping less, drowsiness, sensitivity to light, sensitivity to noise, irritability, sadness, nervousness, more emotional, numbness or tingling, slowed down, mentally foggy, difficulty concentrating, difficulty remembering.
Ohhashi et al., 2002	OS	632 Boxers (19.2 years old) Self-report questionnaire	Headache, neck pain, back pain, muscle pain, tired or weak, nausea, vomiting, weakness, dizziness, blurred head, shaky legs, fatigue, mental impairment, weak legs, temporary memory loss, fainting, loss of consciousness, double vision, blurred vision, ringing in the ears, difficulty hearing, vertigo, shaky hands, forgetfulness.
Stephen et al., 2020	OS	MA (n= 40), age 27.38±4.81, Boxing (n= 188), age 29.13±5.99 and MMA (n= 279), age 29.00±4.57. Cognitive test and resonance	Processing speed, psychomotor speed and reaction time, language and executive functioning.
Warden et al., 2001	EE	483 Boxing M, age (18.95±0.94) - Cognitive test	Headache, dizziness, balance problems, vision changes.

Legend: CG = Concussion Group; PG = Post-training Group; EG = Experimental Group; CS = Combat Sports; AFG = Active Fighters Group; IFG = Inactive Fighters Group; TRS = Training Regimen Scale; PCS = Post-Concussion Scale; KO = Knockout; TKO = Technical Knockout; MA's= Martial Arts; MMA = Mixed Martial Arts; OS = Observational Study; ES = Epidemiological Study; ES = Experimental Study; SQ = Sociodemographic Questionnaire; KD = King-Devick Test; Fts = Fighters.

Discussion

This study aimed to systematically review the literature to identify predictors of concussion, as well as survey physical and motivational signs and symptoms in athletes after suffering concussions. Most of the studies presented good methodological quality, and a few others were not clearly described, presenting a low risk of bias for the review. A total of 19 studies were selected and composed the database. This methodological diversity allows comprehensive understanding of the indicators of concussion in different contexts within combat sports. Concussion exposure was significantly related to the number of fights carried out. This suggests that fight frequency may be a key indicator of risk, highlighting the importance of monitoring athletes' fight load. Identifying reliable indicators of concussion is crucial for prevention and appropriate treatment, however we can point out possible indicators or facilitators that are related to athlete exposure such as those observed by Curran-Sills & Abedin (2018); Ji (2016); and Karpman et al. (2016). Another factor is related to sports, as we noticed that the possibility of concussion is more common in MMA and Boxing; this distribution indicates that certain practices and rules specific to each sport can influence the incidence, as reported in studies by Karton & Hoshizaki (2018); Schlegel et al. (2021); Donnelly et al. (2023); and Förstl et al. (2010).

The prevalence of concussions reflects the nature of combat sports and the frequent exposure of athletes to impacts to the head, as occurs in MMA and Boxing, which aim to knock out the opponent, and therefore we find a high incidence of KO and TKO submissions. The facilitator of concussion pointed out by the studies (Curran-Sills & Abedin, 2018); (Karpman et al., 2016) and (Bin Zahid et al., 2018) shows that even if there is no diagnosis of concussion, exposure to impacts can be considered an indication. Other factors are important in relation to the profile of the most affected athletes: exposure time to fighting, weight categories (light heavyweight, heavyweight and bantamweight), older athletes and gender, with women being more likely to suffer concussion, as confirmed by the articles by Scalia (2015) and Bennett et al. (2020).

We observed that a strong cause of concussions among the evaluated studies is linked to the actions of fighters. Elbowing, punching, kicking, and throwing are more likely to cause concussion, and sparring and competition are more likely to cause concussion. Combat sports often involve striking, throwing or pinning an opponent, and injuries in general, including concussions, are often caused by punches, kicks, blocks and falls to the mat/ground (Hammami et al., 2018). Furthermore, both sparring training and competitions presented a high risk of concussions, requiring special attention for prevention. The development of sports injuries is closely related to the set of rules, actions developed during combat, the methods used and the physical condition of the fighters. Sports injuries reduce the effectiveness of training, cause disability and loss of competition, and destroy the performance of athletes. Therefore, it is important to identify the characteristics of injuries in combat sports, types, body location, pattern and severity of injuries, and the risk factors associated with age, sex, experience level and weight class.

The main signs and symptoms related to concussion in combat sport athletes are addressed in Table 3, which reveals a complex and multifaceted panorama that is best identified. The design of the studies reflects the intrinsic nature of these sports where direct observation offers valuable insights into the

real conditions faced by athletes. The varied sample offers a broad view of the repercussions of concussion at different stages of adult life, and the sports analyzed are known for their intensity and high risk of physical impact, which justifies the relevance of the study. The variety of concussion assessment methods highlights the complexity of concussion diagnosis, which relies on both high-level assessment and objective tools. Therefore, assessing concussions is not easy, as identifying signs and symptoms is subjective in nature and relies on self-reported information, concussion history, and neuropsychological testing (Jackson & Starling, 2019; McCrory et al., 2017).

After analyzing the articles, the main signs and symptoms identified after a concussion in combat sport athletes were divided into physical symptoms and motivational symptoms. There is still confusion regarding the terms used to describe head injuries among fighters (concussions, blunt force trauma, knockouts, flashes), as well as a lack of understanding of the signs and symptoms of concussion and the desire to return to fighting, which contributes to significant underreporting of symptoms. Proper assessment in observing signs and symptoms can improve the quality of life and safety of athletes, and also highlights the importance of safety protocols and ongoing assessment to prevent and mitigate the effects of concussion in combat sports.

Physical symptoms after concussion, such as headache, balance problems, dizziness and fainting, ringing in the ears, gait disturbance, lightheadedness, movement disturbance, neck pain, sleep disturbance, neck pain, nausea and vomiting, visual disturbance, sensory disturbance, numbness or tingling, back pain, and muscle pain are indicative of the immediate neurological consequences of traumatic brain injury. These symptoms, which affect most athletes who spar and participate in official tournaments, can not only compromise sports performance, but also daily activities, increasing the risk of second impact syndrome and post-concussion syndrome. The presence of nausea and vomiting suggests vestibular and autonomic nervous system dysfunction, while sleep disturbances and motor impairments may both indicate a deeper central nervous system disorder (Claro et al., 2024; Neidecker et al., 2019).

On the other hand, motivational symptoms such as memory impairment, processing speed, fatigue, low energy, cognitive impairment, lack of attention, perseverance, self-control, irritability, sadness, nervousness, emotional changes, and reaction time were reported by more than half of the athletes, and reflect the impact of concussion on cognitive function and energy reserve (Giza & Hovda, 2014). Memory impairment in particular can have devastating implications for learning new techniques and strategies, which are essential for progress in combat sports (Paizante et al., 2024). Fatigue, experienced by many athletes, can significantly reduce training and recovery capacity, prolonging the return to sport period and increasing vulnerability to further concussion (McCrory et al., 2017). Furthermore, these symptoms can easily be underestimated in their severity, affecting the motivation and focus needed for sports practice (Malcolm et al., 2023). Slow information processing can compromise quick decision-making and the execution of complex movements, increasing the risk of errors during competition (Cattaneo, 2021). Understanding these symptoms and their impact on athletes' lives is crucial to developing prevention and rehabilitation strategies. It is imperative that professionals involved in sports health recognize the need for multidisciplinary approaches that integrate neuropsychological, physiotherapeutic and physical conditioning assessments. It will only be possible to guarantee the safety of athletes and the sustainability of their careers in combat sports with this understanding.

According to the studies reviewed, the need for preventive strategies and stricter safety protocols in combat sports is highlighted. It is recommended that measures such as limiting the number of fights, monitoring the health of athletes and educating them about the risks of concussion be implemented. Although this review provides valuable insights, it has limitations, such as the methodological variability of the included studies. Future research should focus on longitudinal studies to follow athletes over time and develop deeper understanding of the long-term effects of concussions.

Conclusions

The data analysis reveals that the frequency of fights is a determining factor for the incidence of concussions in combat sports athletes, highlighting the need for monitoring and regulating fight loads, suggesting a reduction in the frequency of fights, personalized safety protocols, aiming at the protection and longevity of their careers in combat sports.

The investigation of signs and symptoms after a concussion revealed physical and motivational manifestations that go beyond the immediate consequences of the trauma. Headache, balance problems and fatigue are not just symptoms; they represent barriers to the technical-tactical and strategic development of athletes.

The practical implications of these results point to the need to review training and competition protocols, with an emphasis on prevention and appropriate management of concussions, and reinforce the importance of educating athletes and coaches about the risks of concussions and strategies to deal with them.

Multidisciplinary assessments must take place to provide comprehensive care. This will not only facilitate the recovery of athletes, but will also contribute to prevention, ensuring the safety and sustainability of their careers.

Finally, future research should focus on longitudinal studies to follow athletes over time to understand the cumulative effects of concussions, as well as studies with significant female samples, and with homogeneous protocols.

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