ACUTE IMPACT OF MIXED MARTIAL ART BOUTS ON COGNITIVE FUNCTION: A COMPARATIVE STUDY OF REGULAR AND OCCASIONAL SPARRING PRACTITIONERS

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Abstract

The risk of concussion is inherent to the practice of mixed martial arts; therefore, establishing strategies that can protect practitioners is essential to avoid problems associated with brain health. The study compared acute effects on cognition after combat simulation in two groups of MMA practitioners: a) those who spar regularly and b) those who do not. Assessments of executive functions (Mental Processing Speed-MPS; Inhibitory Control-IC; Cognitive Flexibility-CF) and memory (direct-DM and indirect-IM) were performed before and after combat simulation. The results indicated that the SG participants suffered significantly more blows to the head per training (14.0±2.8 vs. 2.4±1.9; p≤0.001). There was a significant effect for MPS the group (p≤0.001) and in time (p=0.006), with the SG presenting higher means in the Pre and Post moments (2.0±1.2 sec. and 1.7±1.5 sec.; p=0.037). There were no significant effects for DM (p>0.05), while IM presented an isolated group effect, with lower means for the SG [-1.3 sec. (-2.2; -0.4); p=0.004]. It is concluded that MMA training which includes sparring twice a week results in cognitive impairments compared to those that do not, possibly due to the frequency of blows to the head. Future studies could conduct chronic follow-ups of athletes to examine potential compromises in the mental and physical health of fighters. Additionally, it would be beneficial to include a larger sample of female participants to provide a more comprehensive analysis.

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Resumen

El riesgo de conmoción cerebral es inherente a la práctica de las artes marciales mixtas, por lo tanto, establecer estrategias que puedan proteger a los practicantes es esencial para evitar problemas asociados a la salud cerebral. Estudio comparó efectos agudos sobre la cognición después de simulación de combate en dos grupos de practicantes de MMA: a) los que practican sparring regularmente y b) los que no lo hacen. Realizaron evaluaciones de funciones ejecutivas (Velocidad de Procesamiento Mental-VPM; Control Inhibitorio-CI; Flexibilidad Cognitiva-FC) y memoria (directa-MD e indirecta-IM) antes y después simulación de combate. Los resultados indicaron que, los participantes de GS sufrieron significativamente más golpes en la cabeza por entrenamiento. Para MPS, hubo un efecto significativo en el grupo, tiempo, presentando el GS medias más altas en los momentos Pre y Post. Para MD, no hubo efectos significativos, mientras que la MI presentó un efecto aislado de grupo, con medias más bajas para el SG. Se concluye que el entrenamiento de MMA, que incluye sparring dos veces por semana, resulta en deterioros cognitivos en comparación con los que no lo incluyen, posiblemente debido a la frecuencia de golpes en la cabeza. Estudios futuros podrían realizar un seguimiento crónico de los atletas para examinar posibles deterioros en la salud física y mental de los luchadores. Además, sería beneficioso incluir una muestra más grande de mujeres participantes para proporcionar un análisis más completo.

Palabras clave: Artes marciales, Deportes de combate, Conmoción cerebral, Cognicion

Introduction

Mixed martial arts (MMA) require complex cognitive demands which involve executive functions related to mental processing speed, inhibitory control, cognitive flexibility and working memory during training and competitions (Cattaneo, 2021; Diamond & Ling, 2016). Thus, athletes are constantly challenged to understand their opponents' movements, attack and defense patterns, as well as to execute technical-tactical actions which are dependent on efficient executive processing (Alarcón López et al., 2017; Romero García et al., 2023).

In this context, sparring is a relevant and essential activity for the technical development of MMA athletes (Esagoff et al., 2023). Sparring training simulates real fighting, is usually carried out twice a week, and enables improving skills, movements, techniques, offensive and defensive actions, and contributes to ideal performance during competition (Coswig et al., 2016). However, caution is advised when sparring, as fighters can suffer many blows to the head, as seen in MMA competitions (Bernick et al., 2021; Brown et al., 2021; Khatib et al., 2021). In fact, the higher frequency of blows fired to the head is justified by the increased chance of victory during a bout, as observed in previous MMA studies (Miarka et al., 2017, 2020). However, a high frequency of attacks suffered to the head can be dangerous for the fighter's health, as it increases the risk of concussion (McCrory et al., 2017; Neidecker et al., 2019).

Concussion is a brain injury caused by an abrupt movement, leading to functional changes related to cognitive, neurological, physical and emotional processes (Bromley et al., 2018; Neidecker et al., 2019). The frontal lobes (modulators of executive functions) are the region most affected by punches, kicks and elbows during a fight (Cristofori et al., 2019). Lesions in the frontal lobe can cause loss of spatial organization ability, changes in behavior, lack of motivation and difficulty in decision making (Chang et al., 2017). Therefore, it is expected that fighters who suffer concussion may have their performance affected (Merino et al., 2023), and in some cases may need to retire from the sport prematurely (Cattaneo, 2021; Paizante et al., 2024).

Repeated concussions can cause acute cognitive impairments, which are mental changes that occur immediately or shortly after a traumatic event (Paizante et al., 2024). These impairments can include temporary memory loss, confusion, difficulty concentrating, and motor coordination problems, and are usually reversible with time and appropriate treatment (Li et al., 2014). In contrast, chronic cognitive impairments develop gradually due to repeated brain trauma over time (Bernick et al., 2021). They can lead to permanent damage to executive functions and cognitive abilities, resulting in conditions such as chronic traumatic encephalopathy. Distinguishing between these two types of impairments is crucial to understanding and appropriately managing the mental and physical health of combat sports athletes (Lim et al., 2019; Schlegel et al., 2021).

The severity of the injury can lead to Chronic Traumatic Encephalopathy, a neurodegenerative disease caused by repetitive concussive and subconcussive injuries. Most confirmed cases have occurred in professional athletes of contact and combat sports. It is believed that participation in these sports increases the risk of disabilities and neurodegeneration in old age. Considering that the practice of weekly sparring favors these injuries, it increases the chance of presenting cognitive impairment (Lee et al., 2020; Montenigro et al., 2015; Ritter et al., 2023).

Regarding the risk associated with MMA, three recent studies (Lim, Ho, and Ho, 2019; Merino, Whelan, and Finch, 2023; Schlegel et al., 2021) indicated that MMA athletes are more exposed to head injuries and greater impairment in cognitive functions when compared to other combat sports. Cognitive losses affect performance and this can occur silently throughout an individual's professional career. Furthermore, concussions can result in several types of changes in executive functioning, which are related to the ability to initiate and perform tasks and are required whenever the individual engages in an unaccustomed situation (Alarcón López et al., 2017; Chang et al., 2017; Vestberg et al., 2017). This is worrying for sports performance, because an

MMA fighter may encounter new situations in each new competition for which the fighter does not have a prior or automated behavioral scheme, which may result in execution errors or difficulty in responding to the opponent's actions (Diamond & Ling, 2016).

Concussion studies with MMA fighters are generally epidemiological and cross-sectional (Bernick et al., 2021; Brown et al., 2021; Khatib et al., 2021). To the best of our knowledge, there is a lack of experimental research comparing athletes exposed to concussion with those not exposed to it and the risk associated with MMA practice. Such comparisons may be necessary to indicate more precise criteria for tracking concussions in a fighter's career and possible interventions to prevent cognitive impairments throughout the professional trajectory. Research in this area can fill gaps in scientific knowledge, providing valuable information for coaches, athletes and health professionals. Therefore, the present study aimed to compare acute effects on cognition after a simulated combat following the official MMA rules in two groups of fighters: a) those who regularly spar (without headgear); and b) those who do not. We hypothesized that athletes who spar regularly will present worse results on cognition tests.

Methods

Experimental design

The protocol was approved by the Research Ethics Committee of the University where the data were collected (protocol no.48167021.5.0000.5257). After approval, we contacted two leading MMA teams (Nova União and Geyber Porfirio Team). The coaches indicated which athletes met the inclusion criteria. Those who agreed signed the Informed Consent Form. The following measurement protocol was performed (Figure 1).

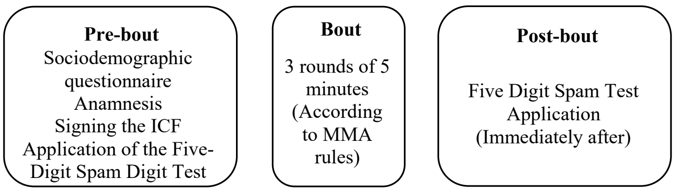

Figure 1. Study design. ICF-Informed Consent Form.

Experimental approach

After receiving approval from the ethics committee, the researchers initiated preliminary procedures by reaching out to coaches for authorization to collect data. The study's aims were then clearly explained during this communication. Once the coaches granted permission, they identified the athletes who met the inclusion criteria. The researchers then convened the selected athletes to outline the study's purpose, potential risks, and the voluntary nature of participation. Each athlete was presented with and signed the Informed Consent Form (ICF). Data collection started on the following day, with all measurements conducted in a consistent environment by the same researcher. The participants remained at the Training Center throughout the data collection and training period. All psychological assessments were administered by a psychologist from the research team.

The experimental protocol was divided into three phases: pre-bout, bout, and post-bout. In the pre-bout phase, a sociodemographic and anamnesis analysis was conducted, collecting data on age (years), weight (kilograms), height (meters), training experience (months), frequency and weekly duration of training (arbitrary units), number of sparring sessions per week, and the average number of head strikes landed per training session (arbitrary units). Following this, cognitive tests, including the Five Digits and Digit Span tests, were administered. Next, a 10-minute warm-up was conducted, incorporating joint movements, stretching, and calisthenics, after which sparring commenced.

The bout consisted of three 5-minute rounds with one-minute intervals, adhering to official MMA rules, in accordance with a previous study (Coswig et al., 2016). The fight could be stopped in the event of a knockout (KO), technical knockout (TKO), or serious joint injuries. Participants were allowed to hydrate during the intervals between rounds. After each bout, the cognitive tests were administered again. Each match was overseen by a professional referee to ensure the athletes' safety and adherence to official rules. The participants were matched based on body weight, age, and technical ability as assessed by their coaches in order to maintain a competitive environment. The athletes received advice from their training partners and coaches during the bouts. Fighters only wore gloves and mouth guards, with no protective equipment such as headgear, shin guards, or chest protectors. All bouts were recorded to quantify the number of head strikes landed. The same cognitive tests were administered post-bout following the same procedure as in the pre-bout phase.

Participants

MMA practitioners were recruited with the following inclusion criteria: a) ≥18 years; b) ≥5 years of practice in MMA; c) ≥60 min per session and ≥3 times per week. In addition to the common criteria, specific criteria were adopted to compose the Sparring Group (SG): a) compete regularly; b) perform ≥2 sparring sessions/week; c) sparring without headgear; d) to not have a recent diagnosis of concussion (≤60 days). The Control Group (CG) was considered as: a) training without sparring; and b) not participating in competition. The exclusion criteria were: a) athletes who self-reported a diagnosis of mental disorder or illness; and b) those who did not complete the protocol steps. Thus, the final group consisted of 51 MMA fighters (SG n=25 with 3♀; CG n=26 with 1♀).

Cognition measurements

Five Digit Test (FDT) – We used a translated and adapted version for Brazilian Portuguese (Sedó et al., 2015). This test aims to measure the speed of cognitive processing, working memory, inhibitory control (IC) and cognitive flexibility (CF), which are components of executive functions. It is a recognized, standardized and validated instrument that evaluates individuals aged between 6-92 years and uses conflicting information about numbers and quantities, presenting them in tables, and its application takes 5-10 minutes. Since the test is expressed by the time in seconds required to complete each stage of the task, cut-off score guidelines are provided with the recommendation that scores be adjusted based on sample characteristics and intended use.

Digit Span-Constructed and validated by Wechsler, (2004), adapted to Brazilian Portuguese by Figueiredo, Vidal, and Nascimento, (2015). This is a verbal working memory test. It aims to measure the extent of memory storage capacity, which is measured by the maximum number of sequences that the person being assessed can reproduce correctly. It can be administered between the ages of 16 and 89. The task occurs in two orders. First, the examiner applies the direct order of the task, and the person being assessed repeats the sequence of digits. Second, the reverse order, the person being assessed must say the sequence in the opposite direction. The number of digits in each item increases progressively.

Statistical analysis

The data were initially grouped into contingence Tables to make comparisons between the pre- and post-periods and between the two groups. Generalized estimating equations were adopted as described by (Paradis & Claude, 2002). The tests were performed using SPSS version 25.0 software, and p≤0.05 was considered significant in all analyses.

Results

Table 1 presents the sociodemographic characteristics of the participants in the SG and CG groups.

Table 1. Characterization of the SG and CG.

Measure	SG	CG
Age (yrs.)	28.5±3.8	32.0±8.0
Weight (kg)	70.4±8.7	79.8±14.8
Height (cm)	1.71±0.1	1.73±0.1
Practice time (months)	44.0±9.5	46.9±5.7
Training per week	10.3±2.2	4.6±1.2
Training duration (minutes)	98.4±28.8	97.1±29.8
Sparring sessions per week	2.0±0.2	0.0±0.0
Average number of blows to the head per training session	14.0±2.8	2.4±1.9#

Table 2 presents the results for the variables indicative of cognitive capacity in the SG and CG groups in the Pre and Post combat simulation.

Table 2. Results for cognition tests in SG and CG at Pre and Post moments.

Cognitive measure	SG	SG	CG	CG
	Pre	Post	Pre	Post
MPS (seconds)	3.7±2.3*	2.4±1.2a	2.0±1.2	1.7±1.5
MPS error (frequency)	0.4±0.8	7.4±1.7 a*	0.5±0.9	0.6±1.5
IC (seconds)	11.4±6.0	8.4±3.3	7.4±3.0	6.0±3.0
IC error (frequency)	3.2±4.7	1.2±3.3 a	3.4±3.1	1.3±3.5 a
CF (seconds)	26.2±8.7	20.6±8.1	16.4±6.0	13.8±5.6
CF error (frequency)	6.5±2.8	3.7±2.0 a	4.1±3.3	4.0±1.5
DM (frequency)	10.2±1.7	9.8±1.2	10.5±2.4	10.6±2.3
IM (frequency)	3.3±1.2	3.9±1.7	5.0±2.3	4.9±2.2

MPS-Mental processing speed; IC-Inhibitory control; CF-Cognitive Flexibility; DM-direct memory; IM-indirect memory. a p≤0.004 vs. Pre for the same group; * p≤0.03 vs. CG for the same moment of measurement.

There was an effect of Group (W=13.985; DfL=1; p≤0.001) and measurement moment (W=7.643; DF=1; p=0.006) for MPS. The SG presented a statistically higher mean than the measurements observed in the Pre- and Post-bout moments [1.3 (0.05; 2.6); p=0.037]. Regarding the comparisons between groups, there was a difference in the Pre-moment [1.7 (0.4; 3.0); p=0.003]. In relation to the MPS Error, there was an Group X Time interaction effect (W=40.508; Df=1; p≤0.001). Differences were observed for the SG between the Pre- and Post-bout moments [7.0 (4.3; 9.7); p≤0.001].

There was no effect of measurement moment (W=1.368; Df=1; p=0.242), group (W=0.625; Df=1; p=0.242), or interaction (W=0.901; Df=1; p=0.342) for IC. Regarding the IC Error, there was an isolated effect of measurement moment (W=22.68; Df=1; p≤0.001), where the post-bout means were statistically lower [2.1 (1.2; 2.9); p≤0.001]. There was no effect of time, group or interaction (W=0.0; Df=1; p=1.0; for all comparisons) for CF. For the CF error, there was a Group X Time interaction effect (W=6.768; Df=1; p=0.009), and the post hoc test indicated a difference between the Post means for the SG [-2.8 (-4.9; -0.7); p=0.003].

Finally, there was no effect of measurement moment (W=0.187; Df=1; p=0.665), group (W=1.757; Df=1; p=0.185), or interaction (W=0.462; Df=1; p=0.497) for DM. There was an isolated effect of Group (W=8.457; Df=1; p=0.004) for IM, in which the means for the SG were statistically lower than the CG [-1.3 (-2.2; -0.4); p=0.004].

Discussion

Combat sports such as MMA are characterized as open activities, so athletes in these sports must be able to respond quickly to the demands imposed by the opponent, whether these are attack, defense or counterattack (Russo & Ottoboni, 2019). In aiming for high-performance, MMA athletes must perform at the best of their cognitive capacity; however, chronic training in this combat sport can affect the fighter's cognition. Thus, our study aimed to compare the acute effects on cognition after a combat simulation following the official MMA rules in fighters who regularly spar versus those who do not. The main results indicated that the SG increased their response time in all measures. Furthermore, there was worsening in MPS, MPS Error, IC Error and CF error when comparing between the pre- and post-bout moments.

These results indicate that SG athletes have slower information processing speed and slower reaction to a stimulus (Campos et al., 2016; Paiva et al., 2015). In fact, previous studies indicate that cognitive ability becomes fundamental for performance during combat (Martínez de Quel & Bennett, 2019). Taken together, these are worrying results regarding SG performance. In line with our results, previous studies have indicated that chronic MMA practice, especially when the fighter suffers many blows to the head, tends to affect cognition (Alevras, Fuller, Mitchell, & Lystad, 2022; Bernick et al., 2021; Schlegel et al., 2021). Finally, it should be noted that, in addition to negatively affecting performance, suffering many blows to the head can put health at risk (Donnelly et al., 2023; Gallo et al., 2020; Schlegel et al., 2021).

The data obtained here are in line with epidemiological studies and will help to expand knowledge about the risk to the cognitive health of MMA fighters. In our understanding, there are previous studies which have measured concussions in fighters and carried out cross-sectional (Bernick et al., 2021) or epidemiological observations (Bromley, Drew, Talpey, McIntosh, & Finch, 2018); on the other hand, few protocols have observed the direct effect of a combat simulation on acute indicators of cognition. Given the broad spectrum of previously published studies, we did not find many that investigated cognitive performance and possible neurological sequelae associated with head injuries in competitors immersed in MMA competitions (Bernick et al., 2021; Galetta et al., 2011; Merino, Whelan, & Finch, 2023; Schlegel et al., 2021).

The National Athletic Trainers Association emphasizes the importance of neuropsychological assessment for sports-related concussions (Broglio et al., 2014; McCrory et al., 2017). They highlight the relevance of neuropsychological testing for baseline assessment and monitoring of sports-related concussions. Consequently, we understand that there is no specific neurophysiological marker for cognitive impairments resulting from concussions, as assessments are essentially clinical. The neuropsychological consequences of concussion vary depending on the severity of the injury and individual factors. Currently, there is no standard treatment for concussion, with individual recovery and management focused on treating symptoms (McCrory et al., 2017).

The SG presented worse results for MPS, as well as a higher number of errors in this measure. In other words, fighters who spar without headgear may have impaired cognitive capacity (Cattaneo, 2021; Merino et al., 2023; Paizante et al., 2024; Schlegel et al., 2021). In this context, it is expected that there will be a relationship between exposure (more bouts or more sparring) and greater possibilities of errors during a combat, since the situations present during fights are immersed in an environment where the athlete is under pressure and must be quick to make decisions (Schlegel et al., 2021).

MPS is an important indicator of performance and can affect the execution of a previously established tactic and decision-making, which are determining factors of performance (Martínez De Quel & Bennett 2016; Schlegel et al. 2021; Vestberg et al. 2017). Our results are in line with those obtained by Schlegel et al. (2021) also in MMA fighters, who presented lower MPS and psychomotor skills when they suffered blows to the head. The increase in MPS errors is an indication of cognitive impairment. Thus, there will be confusion regarding the choices made by the fighter, determining the occurrence of failures and inability to achieve goals.

There was better performance after the fight regarding the IC error, with no difference between groups. Moreover, there was an improvement only in the SG after the bout for the CF error, but it is important to highlight that the CG had a lower frequency in the pre-bout moment and did not have an impaired performance after. The better performance by the SG is possibly linked to behavioral changes and neurophysiological mechanisms; however, there is still no clear definition of how they happen, only indications of a smaller amount of errors after physical exercise, such as those described by Ferrer-Uris et al. (2022). Furthermore, Merege Filho et al. (2014) point out that better performance in terms of CF is due to the increase in cerebral blood flow and consequently improved brain nutrition. These statements are in line with studies by (Li et al., 2014; Vazan et al., 2017) in which a similar test (Stroop) observed a direct association between the physical activity intensity and better cognitive performance.

Our results should be interpreted considering the limitations regarding the female participants' size; limited assessment of the instruments, prior assessment of participants regarding personality, and absence of physiological and physical tests. However, our study presents pairing of groups by training time dedicated to MMA as a strong point (Table 1), thus reinforcing our theory that sparring without headgear is the main culprit regarding the cognitive performance of fighters.

Considering that exposure to concussion is real, it is necessary to organize strategies for baseline assessment, monitoring, and intervention in order to help fighters maintain their health. Considering the popularity of MMA, the findings of this study would have practical applications and could be used by coaches, athletes, and physicians to minimize the risk to fighters. In conclusion, this study contributed to the understanding of the impacts of concussions on combat sports athletes, but it has limitations that should be acknowledged. The sample used consisted of few women, which may limit the generalizability of the results. Future studies should consider a larger and more diverse sample size to improve the external validity of the findings. Furthermore, it is crucial to explore the potential for long-term cognitive effects resulting from regular sparring, an area that remains underexplored. Continued research in these areas will help to deepen our understanding of the neuropsychological consequences of concussions and develop more effective strategies for the protection and treatment of athletes. Based on the objectives we established and the results obtained, we conclude that sparring training with a frequency equal to twice a week does result in cognitive impairments compared to those who do not spar, and these deficits may be related to the frequency of blows suffered to the head.

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