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Cognitive impact of repetitive head blows in combat athletes: A cross-sectional comparison

Running Title: Cognitive profiles in combat sports

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Abstract

Repeated head impacts in combat sports may impair cognitive functions such as memory, processing speed, and executive functioning. This cross-sectional study investigated cognitive performance in 63 athletes (*M* = 25.56, *SD* = 5.46 years, all men) from combat sports with varying levels of head impact. Participants were divided into three groups: professional impact-sport athletes (n = 21; boxing, kickboxing, MMA), amateur impact-sport athletes (n = 21), and a control group practicing low-impact combat sports (n = 21; judo, wrestling, jiu-jitsu). All completed a neuropsychological battery assessing processing speed, attention, memory, executive functions, and visuospatial abilities. Tests included the Auditory Verbal Learning Test, Rey Complex Figure Test, Verbal Fluency, Digit Span and Digit Symbol-Coding (WAIS-III), and the Clock Drawing Test. Results showed that professional impact-sport athletes scored significantly lower in processing speed and verbal learning and memory than the control group. No significant cognitive differences were found between professional and amateur impact-sport athletes. These findings suggest that repeated head impacts, rather than competition level alone, are associated to reduced cognitive performance. Future research should use longitudinal designs, analyze sports separately, include women athletes, and examine emotional and behavioral outcomes to better understand the long-term cognitive impact of combat sports.

Key points – Non-Technical Summary

- Athletes in combat sports with frequent head impacts, like professional athletes, may experience slower processing speed and challenges with memory and verbal

learning, compared to those in low-impact combat sports. This likely stems from repeated hits to the head during training or matches, which can harm brain function over time.

- Protective gear, such as helmets, reduces surface injuries but does not stop deeper brain injuries caused by sudden head movements. Professional athletes face higher risks due to prolonged exposure and intense training, while amateur athletes face lower but still significant risks.
- Despite these risks, professional athletes often adapt through experience and alternative strategies, maintaining performance in some tasks like decision-making and spatial coordination. This shows how the brain can sometimes compensate for injuries.
- The study highlights the importance of protecting athletes' cognitive health by using better equipment, reducing head impact exposure during training, and regularly monitoring cognitive abilities to catch early signs of problems.

Keywords: Cognitive functioning; Combat sports; Executive functions; Memory; Processing speed.

Introduction

Combat sports involve physical confrontation between two athletes, including a range of striking and grappling techniques (Barley & Harms, 2021; Barley et al., 2019). In sports with head impact (striking), athletes are repeatedly exposed to head impacts throughout training and competition — an exposure characteristic that distinguishes these disciplines from grappling-based sports. Cumulative exposure to head impacts, encompassing both concussive and sub-concussive events, has been associated with long-term neurological and cognitive consequences, including increased risk of

dementia and cognitive decline (Batty et al., 2023; McAllister & McCrea, 2017). Evidence shows that athletes in striking sports may present cognitive deficits associated with accumulated exposure to head trauma over time (Bernick et al., 2013; Lim et al., 2019).

Professional and amateur athletes who practice striking combat sports differ in exposure to head impacts, given differences in fight duration and use of protective equipment. However, comparative studies between these groups are scarce. This study addresses this gap by evaluating cognitive differences among professional and amateur athletes in striking combat sports (e.g., boxing, kickboxing, MMA) and a control group in grappling-based, low-head-impact sports (e.g., judo, wrestling, jiu-jitsu).

Increasing evidence suggests that repetitive sub-concussive head impacts (RHIs) — which do not produce immediate clinical symptoms — may play a critical role in long-term cognitive decline, particularly in athletes exposed over many years. These impacts, often experienced during routine practice and competition, may have a cumulative effect on brain health. A recent population-based cohort study and meta-analysis by Batty et al. (2023) supports this view, showing elevated dementia risk in former contact sports athletes, likely associated with sustained exposure to sub-concussive trauma across their athletic careers.

Several recent studies and systematic reviews have contributed to the growing understanding of cognitive and psychological outcomes related to combat sports. For example, a recent study reviewed executive function impairments in combat sport athletes, highlighting consistent deficits in working memory, inhibition, and planning (Barcelos et al., 2024). Others have provided a ten-year epidemiological overview of head impact injuries across multiple martial arts, identifying discipline-specific risk

profiles (Kiehl et al., 2025). Additionally, Thomas and Ornstein (2018) documented the frequency and severity of injuries in karate, drawing attention to head trauma in traditionally perceived "low-contact" disciplines.

Literature on combat sports and psychological well-being is mixed: some studies indicate benefits such as emotional regulation, increased self-esteem, and mental flexibility (e.g., Bojanić et al., 2019; Ciaccioni et al., 2024; Invernizzi et al., 2023; Mînjína, 2014) while others report emotional instability and cognitive decline linked to repetitive head trauma (e.g., Alosco et al., 2020; Bernick et al., 2015; McAllister & McCrea, 2017).

Repetitive impacts can impair higher nervous functions, such as memory, attention, and executive functioning, which are often altered in athletes exposed to cumulative trauma (e.g., McAllister & McCrea, 2017; Safinia et al., 2016; Zazryn et al., 2008). Striking sports have a higher prevalence of head injuries, particularly boxing, MMA, and kickboxing (e.g., McCrory et al., 2008). These sports are strongly associated with CTE symptoms (Safinia et al., 2016; McCrory et al., 2008). By contrast, grappling sports pose lower head trauma risk (e.g., Shadgan et al., 2010; Kim et al., 2015). Multiple factors influence head impact risk in combat sports, including duration of practice, intensity, sparring habits, and inadequate recovery (Daneshvar et al., 2011; Fernandes et al., 2025). Neuropsychological studies highlight deficits in memory, processing speed, and executive functioning among long-term practitioners (e.g., Heilbronner et al., 2009), with cumulative head trauma leading to chronic inflammation and neurodegeneration (e.g., Hay et al., 2016; Lim et al., 2019; McKee et al., 2016). CTE has been linked to tau protein pathology and dementia-like symptoms (e.g., Mez et al., 2017), and former athletes often exhibit long-term cognitive impairment (e.g., Gallo et al., 2020; Hume et

al., 2017). Nonetheless, some studies suggest that young athletes exhibit enhanced functional connectivity, possibly reflecting adaptation or early subclinical damage (Li et al., 2021). Other risks include pituitary dysfunction from repeated head trauma, leading to hormonal deficits that affect cognition (High et al., 2010; Tanriverdi et al., 2007). Distinguishing between impact (striking) and contact (grappling) combat sports is crucial for understanding their specific effects (Kons et al., 2020). Notably, impact sports involve striking techniques, such as punches and kicks, to deliver powerful blows to the opponent, with a significant emphasis on speed and force. For instance, kicking strikes in Taekwondo and Muay Thai can generate impact forces exceeding 9000 N (Corcoran et al., 2024). Contact sports, on the other hand, center around grappling techniques, including holds and throws. The goal is to control or submit the opponent, requiring strength and endurance rather than striking power (James et al., 2016).

Table 1 summarizes the main characteristics of the practice of impact and contact combat sports.

Table 1

Main characteristics of the practice of impact combat sports

Research Groups	Sport	Equipment	Combat
Professional (Impact)	Professional boxing	- Mouth protection - Genital protection - Gloves	4 to 12 rounds of 3 min
	Professional kickboxing	- Mouth protection - Genital protection - Gloves	3 to 5 rounds of 3 min

	Mixed martial arts	- Mouth protection - Genital protection - Open gloves	3 to 5 rounds of 5 min
Amateur (Impact)	Amateur boxing	- Mouth protection - Genital protection - Gloves - Helmet	3 rounds of 3 min
	Amateur kickboxing	- Mouth protection - Genital protection - Shin protection - Gloves - Helmet	3 rounds of 2 to 3 min
	Mixed martial arts	- Mouth protection - Genital protection - Shin protection - Open gloves - Helmet	3 rounds of 3 min
Control (Contact)	Judo	- *Judogi* (trousers, jacket and graduation belt)	4 min
	Olympic wrestling	- *Singlet* (close-fitting suit) - Boots - Ear protection	2 rounds of 3 min
	Jiu-jitsu	- *Kimono* (trousers, jacket and graduation belt) or - *No-Gi* Lycra and shorts.	The time may vary depending on the athletes' graduation belt.

Despite increasing interest in the cognitive risks associated with combat sports, few studies have directly compared professional and amateur athletes or contrasted them with athletes from low-risk disciplines. This gap is especially relevant because professionals typically train more intensely, compete more frequently, and often do so with less protective equipment, potentially increasing cumulative exposure to head impacts. Therefore, given the differing risk profiles, this study aims to compare cognitive performance across athlete groups with varying exposure to head impacts, focusing on domains like memory, processing speed, executive function, and visuospatial skills.

Based on previous literature, we hypothesize that:

H1: Performance on processing speed tasks by professional athletes with a risk of head impact (G1) will be lower than that of amateur athletes (G2), with higher performance expected among athletes with a low risk of head impact (G3).

H2: Performance on learning and memory tasks by professional athletes with a risk of head impact (G1) will be lower than that of amateur athletes (G2), with higher performance expected among athletes with a low risk of head impact (G3).

H3: Performance on executive function tasks by professional athletes with a risk of head impact (G1) will be lower than that of amateur athletes (G2), with higher performance expected among athletes with a low risk of head impact (G3).

H4: Performance on visuospatial organization tasks by professional athletes with a risk of head impact (G1) will be lower than that of amateur athletes (G2), with higher performance expected among athletes with a low risk of head impact (G3).

Method

Study Design

This cross-sectional, observational study aimed to compare the cognitive performance of combat sport athletes with varying levels of exposure to head impacts. The study compared three groups: professional athletes from striking combat sports, amateur athletes from the same sports, and athletes from grappling-based combat sports with low risk of head trauma. Due to the cross-sectional design, this study cannot determine the temporal relationship between exposure and outcome, nor establish causality. The associations identified should be interpreted with caution.

Sample Size Estimation and Justification

An a priori power analysis was conducted to determine the minimum sample size required to detect a meaningful group effect with adequate statistical power. The analysis was performed using G*Power software (version 3.1.9.4; Faul et al., 2007), for a one-way multivariate analysis of variance (MANOVA) with three groups and seven dependent variables. The effect size was set at $f^2(V) = .17$, corresponding to large effect, based on prior literature reporting cognitive differences between athletes with varying levels of head impact exposure (Bernick et al., 2015; Heilbronner et al., 2009). A conventional power of $1 - \beta = .80$ was adopted, consistent with standard practice in psychological and sport science research (Cohen, 2013), and an alpha level of $\alpha = .05$ was used. These inputs yielded a required total sample size of $N = 63$, corresponding to 21 participants per group. No dropout was anticipated, as all participants were recruited and assessed in a single session, and the final sample of $N = 63$ was successfully obtained. This sample size satisfies the a priori requirements and is consistent with the recommendations for transparent reporting outlined by Abt et al. (2025).

Participants and Sample Description

Participants

To carry out this study, we recruited 63 participants ($N = 63$) who met the following inclusion criteria: (1) aged between 18 and 40 years; (2) at least 9 years of education; (3) athletes practicing head-impact combat sports with at least 3 years of experience in the sport, both amateur and professional; (4) athletes practicing combat sports with low head-impact risk with at least 3 years of experience; (5) men (due to the predominance of men in these sports) (Bueno et al., 2022). These inclusion criteria serve to create homogeneity between the groups. The following exclusion criteria were also

considered: (1) diagnosis of cognitive impairment or any medical condition that may interfere with cognitive test performance, such as motor or language impairment; (2) difficulties in understanding the Portuguese language (non-native speakers).

All participants were men. This reflects the gender distribution of competitive athletes in the selected combat sports in Portugal, where participation of men is predominant. The lack of representation of women, limits the ability to explore potential sex differences. Data collection took approximately one year to complete.

A convenience sample was selected by advertising the study at combat academies and on social media. Participants were recruited and allocated to one of the three groups based on their characteristics: Group 1 (G1) – Professional athletes practicing head-impact combat sports, including boxing, kickboxing, and MMA; Group 2 (G2) – Amateur athletes practicing head-impact combat sports, including boxing, kickboxing, and MMA; Group 3 (G3) – Athletes practicing low-risk head-impact combat sports, namely judo, Olympic wrestling, and Brazilian jiu-jitsu.

Sample Description

Our sample consists of 63 individuals ($N = 63$), distributed among three groups categorized by their sport practice and the risk level of head impact (Professional, Amateur, Control), with each group comprising 21 participants. The athletes were aged between 18 and 40 years old. The sample average age was 26 years ($M = 25.56$, $SD = 5.46$), and there were no differences in average age among the groups (Levene's $F(2, 60) = 0.289$; $p = .750$; ANOVA $F(2, 60) = 2.529$; $p = .088$; $\eta^2 = .209$).

Regarding the education level of the sample participants, 5 participants have 9 years of schooling (8%), 37 participants have completed high school (59%), 17 participants hold a bachelor's degree (27%), and 4 participants hold a master's degree

(6%). The groups were also homogeneous in terms of education level (Fisher's Exact Test = 4.464; p = .620).

With respect to years of experience in the sport, the professional group had an average of 11.90 years (SD = 4.70), the control group 9.14 years (SD = 5.26), and the amateur group 4.86 years (SD = 2.58). This resulted in significant differences between groups (Levene's $F(2, 60) = 2.86$; $p = .065$; ANOVA $F(2, 60) = 14.10$; $p < .001$; $\eta^2 = .464$), particularly between professional and amateur athletes (G1 vs G2: 95% CI [3.83, 10.26]; $p < .001$) and between amateurs and the control group (G2 vs G3: 95% CI [-7.50, -1.07]; $p = .006$). No difference was found between the professional athletes and the control group (G1 vs. G3: 95% CI]-0.45, 5.98[; p = .106).

Data Collection Instruments

Sociodemographic and Clinical Questionnaire

This questionnaire includes questions about sociodemographic data (age, education, nationality, and current profession) and clinical aspects (questions regarding the sensory system, nervous system, and other health issues).

Cognitive Test Battery

A cognitive test battery was administered to assess the cognitive functioning of participants. These tests were chosen based on the cognitive abilities that, according to the literature, are most affected in athletes who practice head-impact combat sports (Bernick et al., 2015; Bueno et al., 2022; Heilbronner et al., 2009; Li et al., 2021; Lim et al., 2019). The cognitive domains addressed in this battery, along with the duration of each test, are summarized in Table 2.

Table 2

Cognitive test battery for the study of athletes practicing combat sports

Cognitive tests	**Average time (minutes)**	**Main cognitive domains involved**
Auditory Verbal Learning Test (AVLT)	7	Memory
Rey Complex Figure	6	Visuospatial and perceptual organization Memory
Verbal Fluency Test	4	Executive functions
Digit Span Test (WAIS-III)	4	Memory Executive functions
Coding Test (WAIS-III)	2	Processing speed
Clock Drawing Test (CDT)	2	Visuospatial organization Executive functions
Total time	25	

Auditory Verbal Learning Test (AVLT). This test was used because, according to the literature, verbal memory is shown to be affected in athletes practicing impact combat sports (Bernick et al., 2015). This test assesses the ability to learn and retain verbal information. A list of 15 words is read aloud, and the participant must recall the words in five immediate recall trials (maximum score = 75). After 30 minutes, a delayed recall is administered (maximum score = 15), followed by a recognition task with 50 items (15 targets + 35 distractors; maximum score = 15). The total AVLT_T score ranges from 0 to 105. The average administration time is 7 minutes (Cavaco et al., 2015). The AVLT is a validated measure of verbal learning and memory, characterized

by good internal consistency (Cronbach's $\alpha > 0.80$) and test-retest reliability. Normative data for the Portuguese population are available (Cavaco et al., 2015).

Rey Complex Figure Test. According to the literature, perceptual organization is shown to be affected in athletes practicing impact combat sports (Heppe et al., 2016). This test examines perceptual organization and visual memory. In the first phase, the participant must copy a drawing, and then, after 3 minutes, reproduce the same drawing from memory. For each correct and well-placed element, 2 points are assigned; for each correct but poorly placed element, 1 point is assigned; for each distorted but well-placed element, 1 point is assigned; for each distorted and poorly placed element, 0.5 points are assigned, and for each unrecognizable or absent element, 0 points are assigned. Each of the 18 figure elements is scored based on presence, accuracy, and placement, using a 0–2 scale per element (maximum score per phase = 36). Scores are reported separately for the copy and memory phases (RCF_C and RCF_M, respectively). The average administration time is 6 minutes (Rocha & Coelho, 1988). The RCF demonstrates strong inter-rater reliability (ICC > 0.90) and is widely used for assessing visuospatial construction and memory. It has been validated in the Portuguese context (Rocha & Coelho, 1988).

Verbal Fluency Test. According to the literature, executive functions are shown to be affected in athletes practicing impact combat sports (Heilbronner et al., 2009). This task is sensitive to various cognitive processes, including executive functions, as well as language and memory. In Semantic Fluency, participants are asked to name as many animals as they can in one minute, without repeating variations of the same species. In Phonemic Fluency (letter P), the participant is asked to say as many words as possible starting with the letter P, without using proper names or words with the same

ending. The score is based on the total number of correctly produced words within 60 seconds. The average administration time is 4 minutes (Cavaco et al., 2013). The Verbal Fluency Test is a reliable and valid measure of executive functioning and lexical retrieval. Both phonemic and semantic fluency tasks were used. Portuguese normative data are available (Cavaco et al., 2013).

Digit Span (WAIS-III subtest). According to the literature, memory is shown to be affected in athletes practicing impact combat sports (Li et al., 2021). This task examines verbal short-term and working memory. The participant is asked to verbally repeat a sequence of digits, first in direct order and then in reverse order. Both the direct and reverse sequences have no time limit, and the test ends when the participant scores 0 points in two trials of one element. No feedback is given, and the test begins with the first trial of element 1. Each element is scored 0, 1, or 2 points. The maximum score for direct order is 16 points, for reverse order is 14 points, and for the global test is 30 points. The average administration time is 4 minutes (Wechsler, 2008). The Digit Span subtest assesses verbal short-term memory and working memory. It has shown good test-retest reliability ($r > 0.80$) and internal consistency, and constitutes part of the validated Portuguese version of the WAIS-III (Wechsler, 2008).

Digit Symbol-Coding (WAIS-III subtest). We used this test because, according to the literature, processing speed is shown to be affected in athletes practicing impact combat sports (Heilbronner et al., 2009). This task examines visuospatial processing speed and integrates the Processing Speed Index. The task involves matching symbols to digits, where each digit corresponds to a symbol that the participant must draw beneath the corresponding digit. One point is awarded for each correct match, excluding examples and symbols drawn after the time limit. The maximum score is 133 points.

The administration time is 2 minutes or ends after four complete rows (Wechsler, 2008). The Digit Symbol subtest from the WAIS is a standardized measure of processing speed, with high internal consistency ($\alpha > 0.85$). It is included in the validated Portuguese version of the WAIS (Wechsler, 2008).

Clock Drawing Test (CDT). We used this test because, according to the literature, executive functions are shown to be affected in athletes practicing impact combat sports (Lim et al., 2019). This is a cognitive screening test that assesses visuospatial, visuoconstructive, and executive abilities. The participant is asked to draw a round clock, showing all the numbers and indicating the time 11:10. According to Babins and colleagues' (Babins et al., 2008) scoring system, with normative data for the Portuguese population (Santana et al., 2013), the maximum score is 18 points. The average administration time is 2 minutes. The Clock Drawing Test is a widely used screening tool for visuospatial and executive functioning. It has good inter-rater reliability ($\kappa > 0.75$) and adequate sensitivity for detecting cognitive impairment. Portuguese normative data, stratified by age and education, are available using different scoring systems (Santana et al., 2013; Shulman et al., 2000).

Data Collection

The study protocol was approved by the Committee of the local University (#237_3013) on 9 February 2023. All procedures were conducted in accordance with the Declaration of Helsinki, and informed consent was obtained from all participants prior to their participation. After obtaining ethics approval, combat academies for boxing, kickboxing, and MMA in the Lisbon area of Portugal were contacted. Combat academies for sports with low head-impact, such as Judo and Olympic Wrestling, were

also contacted. This study was also advertised on social media. A non-random snowball sampling method was employed, with matching based on age and other sociodemographic characteristics. Once the sample was defined, a session was scheduled with each participant for evaluation at the academy where they practiced their sport. The assessment protocol included a sociodemographic and clinical questionnaire and a battery of cognitive tests (Auditory Verbal Learning Test, Rey Complex Figure, Verbal Fluency, Digit Span, Digit Symbol-Coding, and Clock Drawing Test). The cognitive battery was administered consecutively in a single session without rest intervals. Two equivalent versions of the battery (Version A and Version B) were used to counterbalance test order across participants. The full assessment lasted approximately 30 minutes. The test results enabled an analysis of the participants' cognitive performance to clarify the research hypotheses. After the data collection, a database was created using IBM SPSS Statistics 29 software for data exploration and analysis.

Data Processing

Statistical Procedure

Statistical analyses were conducted using IBM SPSS Statistics for Mac, version 29. Missing data were inspected and handled using pairwise deletion, as the proportion of missing values was minimal and randomly distributed across variables.

A One-Way Multivariate Analysis of Variance (MANOVA) was performed to assess differences in cognitive test scores across the three groups, followed by univariate ANOVAs. When statistically significant differences were observed, Tukey's Honest Significant Difference (HSD) tests were conducted for post hoc comparisons.

Effect sizes were reported using partial eta squared (η^2 partial), which reflects the proportion of variance explained by group membership while accounting for other sources of variance. According to Cohen's (2013) benchmarks, η^2 partial values of .01, .06, and .14 were considered small, medium, and large, respectively. To further enhance interpretability, we have added Cohen's d for all pairwise comparisons (including both significant and non-significant contrasts). These effect size estimates facilitate a clearer understanding of the observed differences and aid in the comprehensive interpretation of non-significant findings (Cohen, 2013). Compared to repeated applications of univariate analyses of variance (ANOVAs) for each dependent variable, MANOVA has the advantage of controlling Type I error. It is also particularly appropriate when there is a correlation between the dependent variables, as was the case in the present study (Marôco, 2021; Tabachnick & Fidell, 2013). Regarding the independent variable, it allowed the sample to be organized into three groups: a) professional athletes in head-impact combat sports (G1); b) amateur athletes in head-impact combat sports (G2); c) athletes in low-risk head-impact sports (G3). This last group of athletes was included as the control group. The dependent variables were as follows: total score obtained from the adapted version of the Auditory Verbal Learning Test (AVLT_T); total score from the WAIS-III Digit Span subtest (Digits_T); total score from the Verbal Fluency test (Fluency_T); score from the WAIS-III Digit Symbol-Coding subtest (Coding); score from the Clock Drawing Test (Clock); score from the copy of the Rey Complex Figure (RCF_C); and score from the recall of the Rey Complex Figure (RCF_M). Henceforth, these variables will be referred to by their designated abbreviations.

Regarding the assumptions of the One-Way MANOVA, independence of observations was assumed. Mahalanobis distances (MAH) were calculated to identify

any multivariate outliers. The critical Chi-Square value for seven dependent variables was $\chi^2 = 24.32$ ($\alpha = .001$). According to this criterion, no multivariate outliers were observed. The Leverage (LEV) influence measures were calculated, identifying nine cases distributed across the three groups, with values ranging from .20 to .29, which fall within the considered risk range but do not indicate the presence of any multivariate outliers (Marôco, 2021). Given the group sizes, univariate normality was verified using the Shapiro-Wilk test. Normality was violated for some variables and groups, particularly for Clock and RCF_C. However, MANOVA is robust when the absence of normality is due to skewness rather than the presence of outliers (Tabachnick & Fidell, 2013).

To verify the linearity of the dependent variables in each group of athletes, scatterplots were created for the three groups and the seven response variables. A clear linear relationship between the variables was not evident in some scatterplots. Although the absence of linearity reduces test power, it does not increase Type I error, as noted by Tabachnick and Fidell (2013). Bivariate correlations were calculated to assess the potential for multicollinearity between the response variables. The highest coefficient was r = .476. Therefore, all coefficients had values below the threshold suggested by some authors (approximately $r = .60$) for redundancy, avoiding high correlation values (Tabachnick & Fidell, 2013). Lastly, the homogeneity of variance-covariance matrices between groups was validated [Box's $M = 73.694$; $F(56, 10282.900) = 1.093$, $p = .295$].

Results

The One-Way MANOVA revealed a significant effect of sport group (professional, amateur, control) on the response variables [Roy's Largest Root = .416; $F(7, 55) =$

3.272; p = .006; partial η^2 = .294]. In relation to the univariate ANOVA tests, the assumption of homogeneity of variances was met for five of the seven dependent variables [AVLT_T: $F(2, 60) = 2.448$; p = .095; Digits_T: $F(2, 60) = .337$; p = .716; Fluency_T: $F(2, 60) = .806$; p = .452; Coding: $F(2, 60) = 3.797$; p = .028; Clock: $F(2, 60) = 1.200$; p = .308; RCF_C: $F(2, 60) = 3.439$; p = .039; RCF_M: $F(2, 60) = .116$; p = .891]. Only the tests for AVLT_T and Coding showed statistically significant differences (Table 3 and Table 4).

Table 3

Univariate ANOVA F-tests for each dependent variable with df (2, 60)

Variable	*Hyp. Sum of Squares*	*Error Sum of Squares*	*Hyp. Mean of Squares*	*Error Mean of Squares*	*F*	*Sig.*	*Partial* η^2
AVLT_T	497.175	3008.381	248.587	50.140	4.958	**.010****	.142
Digits_T	62.127	1291.619	31.063	21.527	1.443	.244	.046
Fluency_T	13.746	248.476	6.873	4.141	1.660	.199	.052
Coding	2950.222	11641.714	1475.111	194.029	7.603	**.001*****	.202
Clock	18.667	423.333	9.333	7.056	1.323	.274	.042
RCF_C	31.738	628.476	15.869	10.475	1.515	.228	.048
RCF_M	85.024	2360.905	42.512	39.348	1.080	.346	.035

Asterisks indicate levels of statistical significance: *p ≤ 0.05, **p ≤ 0.01, and ***p ≤ 0.001

Table 4

Cognitive measures' outcome scores: Univariate ANOVA F-tests for each dependent variable with df (2, 60)

Variable	*Hyp. Sum of Squares*	*Error Sum of Squares*	*Hyp. Mean of Squares*	*Error Mean of Squares*	*F*	*Sig.*	*Partial* η^2
AVLT_T	497.175	3008.381	248.587	50.140	4.958	**.010**	.142
Digits_T	62.127	1291.619	31.063	21.527	1.443	.244	.046
Fluency_T	13.746	248.476	6.873	4.141	1.660	.199	.052
Coding	2950.222	11641.714	1475.111	194.029	7.603	**.001**	.202
Clock	18.667	423.333	9.333	7.056	1.323	.274	.042
RCF_C	31.738	628.476	15.869	10.475	1.515	.228	.048
RCF_M	85.024	2360.905	42.512	39.348	1.080	.346	.035

AVLT_T: Auditory Verbal Learning Test_Total Score; Digits_T: Digit Span subtest_Total Score; Fluency_T: Verbal Fluency Test_Total Score; Coding: Digit Symbol-Coding test score; Clock: Clock Drawing Test score; RCF_C: Rey Complex Figure Test_Copy test score; RCF_M: Rey Complex Figure Test_Memory test score.

Subsequently, Tukey's HSD multiple comparison tests were applied for AVLT_T, revealing a difference in this variable between professional athletes (G1) and the control group (G3) (95% CI]-11.92, -1.42[; p = .009, Cohen's d = 0.93), with no statistically significant differences in the other comparisons (G1 vs. G2: 95% CI]-7.11, 3.39[; p = .674, d = 0.24; G2 vs. G3: 95% CI]-10.06, .44[; p = .079, d = 0.74). On average, the total AVLT_T score was higher in the control group (M = 53.38, SD = 5.78) compared to the professional athlete group (M = 46.71, SD = 8.27).

Regarding the Coding variable, due to the lack of homogeneity of variances, Games-Howell tests were conducted. Once again, statistically significant differences were found in the comparison between professional athletes (G1) and the control group (G3) (95% CI]-25.22, -8.30[; $p < .001$, $d = 1.49$), with no statistically significant differences in the other comparisons (G1 vs. G2: 95% CI]-19.85, 3.27[; $p = .200$, $d = 0.54$; G2 vs. G3: 95% CI]-19.75, 2.80[; $p = .171$, $d = 0.57$). On average, the Coding score was higher in the control group ($M = 81.67$, $SD = 10.69$) compared to the professional athlete group ($M = 64.90$, $SD = 11.80$).

Discussion

This study was conducted given the lack of comparative research between professional and amateur athletes who practice combat sports with head impact. The literature shows a significant impact on specific cognitive abilities in athletes who engage in impact combat sports, with a pronounced effect on memory, processing speed, and executive functions (Heilbronner et al., 2009). Consistently, we found that professional athletes who practice combat sports with head impact scored significantly lower performance in tasks involving processing speed, verbal learning, and memory compared to athletes practicing combat sports with low risk of head impact. According to the literature, processing speed refers to the time it takes for an individual to perceive, understand, and respond to visual, auditory, or motor stimuli (Salthouse, 2000). In impact combat sports, where repetitive head impacts are common, for example during intensive training sessions like sparring (intensive practice where athletes simulate a competitive fight), this function may be negatively influenced by frequent head impacts. Such impacts have been associated with reduced performance in this cognitive ability due to

microstructural damage in the brain, particularly in white matter (Heilbronner et al., 2009). This reduction can compromise athletes' ability to respond quickly to stimuli, impairing performance and increasing the risk of accidents in daily activities. The observed lower performance in verbal learning and memory may be linked to repeated brain injuries, such as concussions and microtraumas, which affect critical regions like the hippocampus, a key area for these cognitive abilities (Li et al., 2021; Squire & Wixted, 2011).

We also observed that although processing speed, verbal learning, and memory performance in professional athletes tend to be lower on average compared to amateur athletes, the difference in performance for these cognitive tasks is not statistically significant. This may relate to the concept of cognitive reserve, whereby the brain compensates for damage through alternative neural strategies. Professional athletes may develop adaptive mechanisms that maintain performance despite repeated head impacts. Supporting this, Parr et al. (2023) demonstrated that an acute bout of sub-concussive head impacts in soccer produced immediate changes in brain–muscle communication, interpreted as evidence of compensatory neurofunctional reorganization. Although our study does not include neurophysiological measures, these findings suggest a plausible mechanism by which long-term exposure to repeated head impacts may support neural adaptation, potentially helping to explain why differences between professional and amateur athletes in our sample did not reach statistical significance.

Importantly, professional athletes did not show significantly lower performance in executive function or visuospatial tasks compared to amateurs or athletes in low-impact sports. Sustained performance in these domains may reflect cognitive reserve and long-term engagement in cognitively demanding tasks in combat sports, such as

rapid decision-making or hand–eye coordination with moving targets, which mitigate damage from repetitive head impacts (Heppe et al., 2016).

Professional athletes in impact combat sports exhibit impairments in specific cognitive domains compared to athletes practicing combat sports with low head impact, particularly in processing speed, verbal learning, and memory. These differences may be influenced by the limited use of protective equipment during high-intensity impacts, increasing cumulative brain damage (Fernandes et al., 2025). It is important to note that amateurs have partial protection from helmets, which reduce superficial injury but not rotational acceleration of the brain, a major source of neurological damage (Goutnik et al., 2022; Rybak, 2021). Perhaps this explains the fact of no statistical differences between the professional and the amateur groups, and between the amateur and the control groups on both variables, since amateurs exhibited intermediate average values between the other groups. These findings underscore the association between impact combat sports and cognitive impairments and highlight the importance of safeguarding that extends beyond physical and mental health to include cognitive health (Nery et al., 2023). In interpreting these results, it is also important to recognize that differences in physical activity and overall fitness levels may influence the observed cognitive patterns. Regular physical activity is known to improve executive functions, processing speed, and overall cognitive performance, as reviewed by Furley and collaborators (2025). Athletes participating in low-impact combat sports may therefore gain cognitive benefits from consistent training without the destabilizing effects of repeated head accelerations. Rather than presenting competing explanations, we see the cognitive advantages of physical activity and the potential negative effects of repetitive head impacts as complementary. The specific areas where professional impact-sport athletes

tend to perform worse, namely processing speed, verbal learning, and memory, are those most often linked to cumulative head impacts, whereas the general cognitive benefits of regular training may help preserve performance in other areas. This multifaceted interpretation aligns with current evidence showing that physical activity and sport participation can enhance executive functions and cognitive performance (Furley et al., 2025), and offers a more detailed understanding of the complex interaction between impact exposure (Nery et al., 2023), training demands, and cognitive function. Monitoring and preventive measures are critical to protect neurocognitive integrity in athletes. It is not only essential to promote the physical and mental health of athletes, but we also believe their cognitive health should be considered. Thus, the concept of safeguarding should be expanded to encompass not only physical and mental health but also cognitive health. Given the data indicating repeated head impacts and their adverse effects on cognitive abilities, such as memory, processing speed, and executive functions, it is imperative to broaden safeguarding to include the preservation and promotion of neurocognitive health. Preventive monitoring and intervention measures can therefore be implemented to mitigate long-term risks, protecting not only the physical integrity but also the brain function of athletes.

Broader considerations include risk stratification across disciplines to identify higher long-term cognitive risk, and potential benefits of low-impact martial arts, such as judo and jiu-jitsu, for discipline, emotional regulation, and cognitive development. Participation in martial arts may also enhance mental well-being and cognitive vitality in older adults (Ciaccioni et al., 2024). These factors may moderate the effects of repetitive head impacts and warrant longitudinal investigation.

While our findings link head impact exposure to cognitive performance, causal inferences cannot be drawn, as deficits may reflect cumulative impacts, pre-existing factors, or unmeasured variables. These findings should also be interpreted in light of the Portuguese context, where cultural attitudes toward combat sports, training frequency, safety practices, and access to protective equipment may differ from those in other countries. This may impact generalizability and highlights the importance of conducting cross-cultural research. Moreover, in the present study, several pairwise comparisons showed moderate effect sizes despite not reaching statistical significance. This pattern indicates that the absence of statistically significant differences should not be taken as definitive evidence of no between-group differences. Rather, these non-significant results may reflect limited statistical power, given the modest sample size, which may have reduced sensitivity to detect subtle but potentially meaningful effects. This consideration aligns with recommendations to interpret non-significant findings cautiously, particularly when effect sizes suggest effects of practical relevance (Lakens, 2022).

Study Limitations

This study has several limitations. The sample size was relatively small (21 per group), limiting statistical power to detect subtle differences, especially between amateur and professional athletes. Differences in years of experience may have influenced results, as professionals had more years of practice. Snowball sampling introduces potential selection bias, and grouping different sports under broad categories may obscure discipline-specific effects. The cross-sectional design prevents assessment of cognitive changes over time, and lack of detailed quantification of head impact exposure (e.g.,

fights, sparring frequency, knockouts, time since last concussion) limits understanding of dose-response relationships. Finally, the inclusion of only men athletes restricts generalizability; future studies should include women participants to explore sex differences in cognitive and emotional outcomes.

Future Directions

Future research should use longitudinal designs to assess cognitive trajectories and better determine causality. Sport-specific comparisons are recommended to capture protective or harmful effects of each discipline. Expanding recruitment methods and including women athletes will improve representativeness. Emotional and behavioral factors**,** such as impulsivity, emotional regulation, and resilience, should also be considered to understand the broader impact of combat sports on well-being. Objective measures of head impact exposure should be incorporated to clarify dose-response relationships and cumulative effects.

Conclusion

Professional athletes in impact combat sports exhibit lower performance in processing speed, verbal learning, and memory compared to low-impact athletes, possibly associated with repeated head trauma during sparring or competition (Fernandes et al., 2025). Differences between professionals and amateurs were not significant, suggesting that cumulative exposure rather than competitive level alone may influence cognitive outcomes (Brett et al., 2018). Protective equipment, such as helmets, reduces superficial injuries but cannot prevent rotational brain acceleration, a major contributor to neurological damage (Goutnik et al., 2022; Rybak, 2021). Combat

sports may enhance emotional regulation (Bojanić et al., 2019), but repetitive head trauma increases risk for impulsivity and emotional difficulties (McAllister & McCrea, 2017). We recommend regular neuropsychological assessment, tailored cognitive rehabilitation, and careful monitoring of high-intensity impact exposure during training (Daneshvar et al., 2011) to preserve cognitive and emotional health of these athletes.

Due to the cross-sectional design, causal relationships cannot be inferred. Longitudinal studies are essential to track cognitive and emotional outcomes, evaluate protective measures, and inform evidence-based guidelines for safe practice in combat sports.

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Author Contributions:

FR: Conceptualization, Investigation, Writing – Original Draft, Ethical Approval and Compliance.

BR: Validation, Formal Analysis, Data Curation, Writing – Review and Editing, Visualization.

ISF: Methodology, Validation, Writing – Review and Editing, Supervision.

AMA: Conceptualization, Methodology, Validation, Resources, Data Curation, Writing – Review and Editing, Supervision, Project Administration, Ethical Approval and Compliance.

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