



Action-to-recovery and technical-tactical demands across rounds of competitive capoeira

Demandas de acción-recuperación y técnico-tácticas a lo largo de las rondas de la capoeira competitiva

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Abstract

Aim: This study analyzed the technical-tactical performance of competitive Capoeira athletes across competition rounds during the 2018 Men's World Capoeira Championship.

Methodology: A total of 130 matches were analyzed through video recordings using FRAMI 2.0 software to code time-motion and technical-tactical patterns, categorized as Fundamental, Evasive, Unbalancing, Traumatizing, and Flourish actions.

Results: Significant differences were identified across competition rounds, where Fundamental movements (e.g., Ginga) decreased from 45.3% of total action time in the early rounds to 28.4% in the finals ($p < 0.05$, $\eta^2 = 0.21$), whereas traumatizing actions increased from 4.8 to 7.3 per bout between eliminatory and final rounds ($p < 0.01$, $\eta^2 = 0.18$). The action-to-recovery ratio also shifted from 1:2.3 in early rounds to 1:1.4 in finals, reflecting higher intensity and reduced recovery time.

Discussion: These patterns are consistent with previous findings in other combat sports, indicating progressive tactical adaptation and efficiency under competitive demands.

Conclusion: The results highlight the need for adaptive training strategies that incorporate high-intensity exchanges, efficient execution of offensive techniques, and round-specific conditioning. These insights can support coaches and athletes in developing evidence-based training approaches while preserving the cultural and technical identity of Capoeira.

Keywords

Exercise physiology, athletic performance, martial arts, fight, combat sports.

Resumen

Objetivo: Este estudio analizó el rendimiento técnico-táctico de atletas de Capoeira competitiva a lo largo de las rondas del Campeonato Mundial Masculino de Capoeira 2018.

Metodología: Se analizaron un total de 130 combates mediante grabaciones de video utilizando el software FRAMI 2.0 para codificar los patrones de tiempo-movimiento y técnico-tácticos, categorizados como acciones Fundamentales, Evasivas, de Desequilibrio, Traumáticas y de Flourish.

Resultados: Se identificaron diferencias significativas entre las rondas de la competición, donde los movimientos Fundamentales (p. ej., Ginga) disminuyeron del 45,3% del tiempo total de acción en las rondas iniciales al 28,4% en las finales ($p < 0,05$, $\eta^2 = 0,21$), mientras que las acciones traumáticas aumentaron de 4,8 a 7,3 por combate entre las rondas eliminatorias y las finales ($p < 0,01$, $\eta^2 = 0,18$). La relación acción-recuperación también se modificó de 1:2,3 en las rondas iniciales a 1:1,4 en las finales, reflejando mayor intensidad y menor tiempo de recuperación.

Discusión: Estos patrones son consistentes con hallazgos previos en otros deportes de combate, lo que indica una adaptación táctica progresiva y eficiencia bajo las demandas competitivas.

Conclusión: Los resultados destacan la necesidad de estrategias de entrenamiento adaptativas que incluyan intercambios de alta intensidad, ejecución eficiente de técnicas ofensivas y preparación específica por ronda. Estos hallazgos pueden apoyar a entrenadores y atletas en el desarrollo de enfoques de entrenamiento basados en evidencia, preservando al mismo tiempo la identidad cultural y técnica de la Capoeira.

Palabras clave

Fisiología del ejercicio; rendimiento atlético; artes marciales; lucha; deportes de combate.

Introduction

Capoeira is an Afro-Brazilian practice that uniquely integrates martial arts, dance, music, and ritualized play, recognized by UNESCO in 2014 as Intangible Cultural Heritage of Humanity (Monteiro-Junior et al., 2025). Historically, it emerged as a form of cultural and physical resistance developed by enslaved Africans in Brazil (Monteiro-Junior et al., 2025; Salvino et al., 2025). In the 20th century, systematization by figures such as Mestre Bimba transformed Capoeira from a persecuted street practice into a regulated pedagogical and sportive activity, improving motor and cognitive systems (Cruz, & Correa, 2024; Monteiro-Junior et al., 2025). This historical evolution not only consolidated Capoeira as a cultural expression but also enabled its transition into competitive formats under the World Capoeira Federation (WCF) (Cruz, & Correa, 2024; Salvino et al., 2025). Within this paradigm, scientific research has increasingly focused on quantifying its performance characteristics through time-motion analysis, analysing activity and recovery patterns, and technical-tactical analysis, categorizing actions into fundamental, evasive, unbalancing, traumatizing, and flourish movements (Cabraia & Jeronymo, 2014). Such approaches provide a framework for understanding how Capoeira athletes manage intensity, efficiency, and tactical adaptation during high-level competition.

Despite the increasing visibility of competitive Capoeira, scientific research analyzing its technical-tactical performance across competitions remains reduced. In contrast, other combat sports have shown how round-based analysis provides critical insights into tactical adaptations and pacing strategies. For example, in boxing, El Ashker (2017) demonstrated that winners performed more offensive combinations, defensive maneuvers, and effective strikes across rounds compared to losers, underscoring how round progression differentiates performance efficiency. In youth taekwondo, Casolino et al. (2012) analyzed 37 official matches and verified that offensive actions dominated overall ($91.6\% \pm 12.0\%$), yet decreased significantly from the first to the third round (42.3% to 24.5%). This trend highlighted how young athletes progressively reduced their offensive output as fatigue accumulated, while technical execution shifted toward simpler, less coordinatively demanding techniques. Importantly, the study confirmed that round-specific variations are fundamental to understanding combat dynamics, regardless of gender or match outcome.

Building on this paradigm, mixed martial arts (MMA) research has further emphasized round-based technical-tactical changes. Antonietto et al. (2023), analyzing over 1,500 professional rounds, demonstrated that bouts ending in later rounds were characterized by longer preparatory phases and fewer successful strikes, confirming progressive tactical adjustments throughout combat. Together, these findings reinforce the value of considering rounds as natural analytical units to verify the evolving balance between offensive intensity, defensive preparation, and efficiency.

In Capoeira, technical-tactical actions can be systematically classified through validated time-motion patterns, recently operationalized in the FRAMI 2.0 protocol, which demonstrated strong to almost perfect inter- and intra-rater reliability for real competition analysis (ICC = 0.88–0.95; Kappa = 0.70–0.93) (Vianna et al., 2024). The *Ginga* is the fundamental movement, performed continuously throughout the bout, serving as both a preparatory and transitional action that allows athletes to maintain rhythm, regulate distance, and disguise offensive intentions (Cabraia & Jeronymo, 2014, Taylor, 2020). Evasive actions (e.g., *Cocorinha*, *Negativa*, *Esquiva Lateral*) are low-to-moderate intensity movements that extend observation or preparation phases, enabling athletes to avoid direct strikes while simultaneously preparing counterattacks (Cabraia & Jeronymo, 2014, Taylor, 2020). Unbalancing techniques (e.g., *Rasteira*, *Tesoura*, *Vingativa*) are high-intensity movements designed to disrupt the opponent's base, shifting combat toward decisive interaction phases where scoring or dominance is most likely achieved (Taylor, 2020). Traumatizing actions (e.g., *Meia-lua de Compasso*, *Martelo*, *Queixada*) represent direct offensive strikes and, in past research, they were strongly associated with the outcome of matches, as their frequency tends to increase in later rounds when athletes intensify exchanges to secure points (Cabraia & Jeronymo, 2014, Taylor, 2020). Finally, Flourish actions, called *Floreios* (e.g., *Aú Sem Mão*, *Bananeira*, *Mortal*) are acrobatic and expressive maneuvers unique to Capoeira, which appear more frequently in earlier rounds as exploratory tactics but are also used strategically in finals to maintain rhythm and accumulate points (Silva & Souza, 2023, Taylor, 2020).

As demonstrated in recent research, the application of validated technical-tactical protocols in official Capoeira competitions has identified important differences across weight categories. Lighter athletes



tend to perform a greater frequency of traumatizing and unbalancing actions, as well as shorter observation periods, when compared with heavier athletes (Vianna et al., 2024). These findings reinforce the notion that body mass directly influences competitive strategies and the distribution of combat time. However, to date, no investigations have specifically described in detail the technical-tactical actions with effort-to-pause ratio (action-to-recovery) (de Andrade Junior et al., 2025) within Capoeira. This indicator has already proven essential in other combat sports such as kickboxing (de Andrade Junior et al., 2025), judo (Moronta et al., 2025), taekwondo (Zhang et al., 2025), and MMA (Antonietto et al., 2023), where it has been used to characterize the physiological profile of bouts and to guide contextual evaluations, periodization strategies and specific training sessions (Antonietto et al., 2023; de Andrade Junior et al., 2025; Zhang et al., 2025). Therefore, understanding how effort and recovery are distributed across different rounds and weight categories in competitive Capoeira is fundamental not only to prepare athletes for the actual demands of competition but also to improve training quality, allowing coaches to adjust loads, intervals, and strategies based on scientific evidence.

Based on evidence from other combat sports, it is hypothesized that traumatizing and unbalancing actions will increase in frequency across successive rounds, while fundamental and flourish actions will decrease. Furthermore, we expect the action-to-recovery ratio to shift toward shorter recovery times and greater intensity in later rounds, reflecting the progressive tactical and physiological demands of high-level Capoeira competition.

Therefore, this study aimed to analyze the technical-tactical actions and action-to-recovery patterns of male athletes during the Men's World Capoeira Championship held in Baku, Azerbaijan. Specifically, it examined the frequency, duration, and types of movements performed across different phases and rounds (eliminary versus semifinal versus final) to identify how athletes adapt their performance strategies throughout the competition.

Method

This study employed a descriptive, cross-sectional, and quantitative design. The primary objective was to analyze the technical-tactical performance of male athletes during the 2018 Men's World Capoeira Championship (Baku, Azerbaijan). Specifically, the analysis focused on the frequency, duration, and types of movements across distinct competition phases (eliminary, semifinals, third-place dispute, and finals) and rounds (first, second, and third), as defined by the WCF rules.

The unit of analysis was the individual bout, with technical-tactical variables coded through time-motion analysis. A total of 130 official matches were included, ensuring ecological validity by analyzing real competition settings. In addition, the temporal structure of performance was examined at the round level to allow a more detailed characterization of technical-tactical behaviors within bouts.

To improve reproducibility, the study followed key elements, including (i) detailed description of sample characteristics, (ii) operational definitions of movement categories (e.g. fundamental, evasive, unbalancing, traumatizing, flourish), and (iii) the time-motion framework applied. The study protocol was pre-defined before data collection, and data analysis procedures were standardized through the validated FRAMI 2.0 software for coding technical-tactical and time-motion variables. Inter- and intra-rater reliability were assessed on a subsample of matches to minimize observer bias. Because the study used exclusively publicly available data, formal ethical approval by the Brazilian Research Ethics Committee system was not required, in accordance with Article 1, Sole Paragraph, of Resolution No. 510 (April 7, 2016) of the National Health Council, and the investigation adhered to the principles of the Declaration of Helsinki.

Participants

All men's bouts from the World Capoeira Championship, held in Baku, Azerbaijan, were analyzed across the different competition phases and respective rounds. The dataset included: eliminary phase [$n = 74$ bouts; 1st round ($n = 74$), 2nd round ($n = 74$), 3rd round ($n = 26$)], semifinals [$n = 20$ bouts; 1st round ($n = 20$), 2nd round ($n = 20$), 3rd round ($n = 6$)], third-place disputes [$n = 6$ bouts; 1st round ($n = 6$), 2nd round ($n = 6$), 3rd round ($n = 2$)], and finals [$n = 10$ bouts; 1st round ($n = 10$), 2nd round ($n = 10$), 3rd round ($n = 2$)]. The dataset comprised 130 bouts and 354 individual rounds analyzed across the



different phases of the tournament. No athletes were disqualified; therefore, no bouts were excluded. Video data were obtained from the official World Capoeira Federation YouTube channel, which publicly provided the complete matches from all phases of the championship.

Inclusion criteria for video analysis were: (1) complete bouts; (2) full visibility of the competition ring and scoreboard throughout the match; and (4) a minimum video resolution of 720p to ensure accurate identification of movements during frame-by-frame analysis. No bouts needed to be excluded based on these criteria. Exclusion criteria applied only to bouts involving athlete disqualification.

Procedure

To ensure high data quality, each bout was analyzed round by round, given that Capoeira, as a combat sport, involves actions performed predominantly at maximum speed. All videos were obtained from the official channel of the International Capoeira Federation on the YouTube platform.

The coding of technical-tactical actions was performed using the FRAMI 2.0 software (Miarka et al., 2010), which enables synchronized time-motion and categorical analysis. Each round was segmented into discrete actions and recovery periods, and movements were classified into the pre-established categories: fundamental, evasive, unbalancing, projection-type unbalancing, direct unbalancing, traumatizing (lower limbs, upper limbs, intermediate), and flourish. For each action, the following variables were registered: Action type (categorical classification according to Table 1). Frequency (number of occurrences per round). Duration (s), measured as the time from action initiation to completion. Recovery interval (s), defined as the time elapsed until the next effective action.

The procedure to use software allowed coders to insert event markers directly over the video timeline, ensuring precision in quantifying effort and pause ratios. All video analyses were conducted using frame-by-frame playback when necessary to improve temporal accuracy in identifying the start and end of each action. To enhance reliability, a subsample of bouts (10%) was coded by two independent raters. This tool facilitated frame-by-frame coding, allowing precise identification and categorization of movements.

Measures

Key performance variables included:

Total Time per Action: Duration of each movement type executed by athletes, measured in seconds.

Frequency of Actions: Number of times each movement type was performed per round and phase.

Average Time per Action: Mean duration of each movement type.

Action-to-Recovery Ratio: Time spent performing actions relative to recovery periods, mirroring the approach used in studies of taekwondo and muay thai (Del Vecchio, Silva, & Farias, 2015; Menescardi & Royuela, 2016).

Additionally, the relative contribution (%) of each movement category to the total action time was calculated to allow comparisons between competition phases and rounds.

Table 1. Categories and descriptions of each action analyzed, along with the respective movements associated with each category.

Category	Description	Movements
Fundamental Elements	Basic motor structure and displacement, serving as the foundation of the game.	<i>Ginga, Cocorinha</i> (squat defense), <i>Rolê</i> (circular transition), <i>Queda de Quatro</i>
Evasive Movements (Defensive)	Movements aimed at dodging or avoiding attacks, preserving flow and rhythm.	<i>Esquiva Lateral, Esquiva Baixa, Esquiva de Frente, Negativa, Aú, Bananeira, Rolê Evasivo</i>
Unbalancing Movements	Actions that destabilize or sweep the opponent's base through direct contact or leverage.	<i>Rasteira de Mão, Rasteira de Pé, Rasteira Interna, Vingativa, Banda de Costas, Banda Traçada, Cintura Baixa</i>
Projection-Type Unbalancing	Throws where the defender undergoes a flight phase before falling, often involving grips.	<i>Balão de Lado, Balão Cinturado, Cintura Desprezada, Tesoura de Frente, Tesoura de Costas</i>
Direct Unbalancing	Immediate imbalance actions with linear force, without intermediate phases.	<i>Rasteira Frontal, Rasteira Lateral, Rasteira de Tornozelo</i>
Traumatizing Movements, Lower Limbs	Strikes using feet, shins, or knees to cause direct impact.	<i>Meia-lua de Compasso, Martelo, Armada, Queixada, Benção</i> (push kick), <i>Ponteira, Gancho, Joelhada</i>
Traumatizing Movements, Upper Limbs	Strikes with arms, hands, or elbows.	<i>Galopante, Asfixiante</i> (palm strike), <i>Cotovelada, Mão de Vaca, Chapa de Mão</i>



Intermediate Traumatizing Movements	Complex strikes involving spins or aerial components before impact.	<i>Armada Dupla, Meia-lua Solta, Martelo Rodado, Ponteira Voadora, Parafuso</i>
Flourish (Ornamental/Acrobatic) Actions	Movements of high aesthetic value, emphasizing creativity, agility, and cultural expression; often less directly offensive.	<i>Floreio de Mão, Macaco, Parafuso Aéreo, Mortal de Frente, Mortal de Costas, S-dobrado, Pião de Mão, Relógio</i>

Reliability Procedures: The FRAMI 2.0 software further enhanced precision by allowing frame-by-frame slow-motion review and precise temporal markings, ensuring standardized measurement of action-to-recovery patterns. To ensure accuracy and consistency, two independent evaluators analyzed each bout using a predefined coding framework. Both evaluators had prior training in Capoeira-specific technical-tactical analysis, and they were blinded to the study hypotheses to reduce observer bias. Intra-rater and inter-rater reliability were assessed on a random subsample of 10% of bouts.

Cohen's kappa coefficient was applied to categorical variables, yielding values between 0.75 and 0.87, while intraclass correlation coefficients (ICCs) for time variables were ≥ 0.85 .

According to established reliability interpretation guidelines, these values indicate strong to near-perfect agreement between evaluators, supporting the robustness of the coding protocol.

These results indicated strong to near-perfect agreement, supporting the reproducibility of the coding process (Miarka et al., 2010).

Data analysis

Descriptive statistics were initially calculated for all variables, including means, standard deviations (SD), and 95% confidence intervals (CI). Prior to inferential analysis, the distribution of the data was examined through visual inspection of histograms and Q-Q plots, complemented by the Shapiro-Wilk test. Homogeneity of variances was verified using Levene's test. Inferential comparisons were conducted using one-way analysis of variance (ANOVA). Separate ANOVA models were performed to examine differences in total action time (%) across movement categories and competition phases. When a significant main effect was detected, Bonferroni post-hoc tests were applied to identify pairwise differences between phases or rounds. Effect sizes were calculated using partial eta squared (η^2) and interpreted according to conventional thresholds proposed by Cohen: small effect: $\eta^2 \geq 0.01$; moderate effect: $\eta^2 \geq 0.06$, and; large effect: $\eta^2 \geq 0.14$. All statistical results are reported with F-statistics, degrees of freedom (df), p-values, and effect sizes (η^2). The level of statistical significance was set at $p \leq 0.05$ for all analyses.

Results

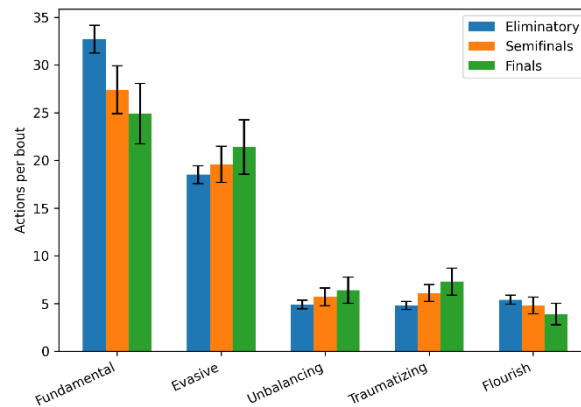
Initial bouts from the 2018 Men's World Capoeira Championship were analyzed. The distribution of matches across competition phases and rounds is presented in Table 2. The eliminatory phase comprised the largest proportion of bouts ($n = 74$), whereas the finals represented the smallest group ($n = 10$). Across all phases, a total of 354 analyzed rounds were coded using the FRAMI 2.0 protocol.

Table 2. Distribution of analyzed bouts and rounds across competition phases.

Phase	Bouts (n)	Round 1	Round 2	Round 3
Eliminatory	74	74	74	26
Semifinals	20	20	20	6
Third-place dispute	6	6	6	2
Finals	10	10	10	2
Total	130	110	110	36

Figure 1 shows total action time by movement category across phases (mean $\pm$ 95% CI).



Figure 1. Total action time by movement category across phases (mean $\pm$ 95% CI).

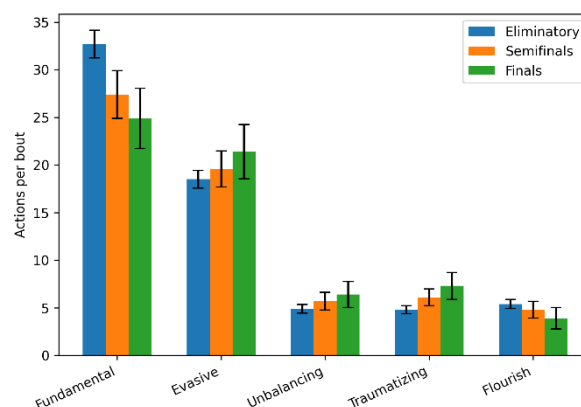
Significant differences were observed in the distribution of total action time across competition phases (Table 3).

Table 3. Total action time (%) by movement category across phases.

Movement category	Eliminary (%)	Semifinals (%)	Finals (%)	F	df	p	η^2
Fundamental	45.3 $\pm$ 6.1	32.1 $\pm$ 5.4	28.4 $\pm$ 4.9	9.84	2,13	0.001	0.21
Evasive	21.7 $\pm$ 4.2	24.6 $\pm$ 4.8	26.3 $\pm$ 5.0	3.12	2,13	0.048	0.07
Unbalancing	11.4 $\pm$ 3.5	14.8 $\pm$ 3.9	17.2 $\pm$ 4.1	5.31	2,13	0.006	0.11
Traumatizing	7.9 $\pm$ 2.4	9.8 $\pm$ 2.6	11.6 $\pm$ 3.0	7.02	2,13	0.002	0.15
Flourish	13.7 $\pm$ 3.8	12.7 $\pm$ 3.5	10.5 $\pm$ 3.2	2.41	2,13	0.095	0.04

Fundamental movements showed a progressive decrease as the competition advanced. In the eliminatory phase, these movements represented 45.3 $\pm$ 6.1% of total action time, decreasing to 32.1 $\pm$ 5.4% in the semifinals and to 28.4 $\pm$ 4.9% in the finals. Statistical analysis confirmed significant differences across phases ($F = 9.84$, $df = 2,127$, $p = 0.001$, $\eta^2 = 0.21$), indicating a large effect size. In contrast, traumatizing actions increased significantly throughout the competition phases. The frequency and relative contribution of these offensive techniques increased from 7.9 $\pm$ 2.4% in eliminatory bouts to 11.6 $\pm$ 3.0% in finals ($F = 7.02$, $df = 2,127$, $p = 0.002$, $\eta^2 = 0.15$). Unbalancing techniques also demonstrated a significant increase toward later stages of competition ($F = 5.31$, $df = 2,127$, $p = 0.006$, $\eta^2 = 0.11$).

Figure 2 demonstrates the frequency of actions per bout across phases (mean $\pm$ 95% CI).

Figure 2. Frequency of actions per bout across phases (mean $\pm$ 95% CI).

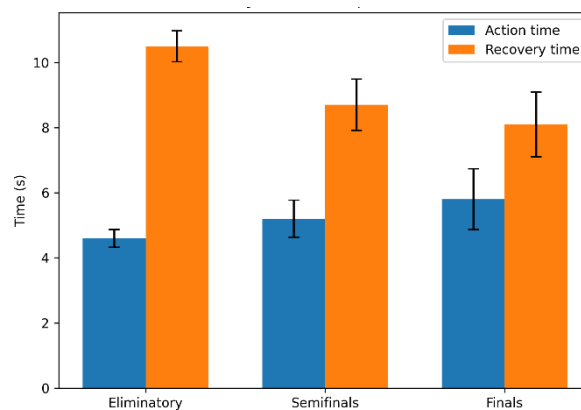
The frequency of technical actions per bout also varied significantly across competition phases (Table 4).

Table 4. Frequency of actions per bout across competition phases.

Movement category	Eliminatory	Semifinals	Finals	F	df	p	η^2
Fundamental	32.7 $\pm$ 6.3	27.4 $\pm$ 5.7	24.9 $\pm$ 5.1	6.92	2,13	0.002	0.14
Evasive	18.5 $\pm$ 4.1	19.6 $\pm$ 4.3	21.4 $\pm$ 4.6	2.96	2,13	0.055	0.05
Unbalancing	4.9 $\pm$ 2.0	5.7 $\pm$ 2.1	6.4 $\pm$ 2.2	4.37	2,13	0.015	0.08
Traumatizing	4.8 $\pm$ 1.8	6.1 $\pm$ 2.0	7.3 $\pm$ 2.3	8.14	2,13	0.001	0.18
Flourish	5.4 $\pm$ 2.1	4.8 $\pm$ 2.0	3.9 $\pm$ 1.8	3.41	2,13	0.036	0.07

Fundamental actions were performed more frequently during eliminatory rounds (32.7 $\pm$ 6.3 actions per bout) compared with semifinals (27.4 $\pm$ 5.7) and finals (24.9 $\pm$ 5.1). This reduction was statistically significant ($F = 6.92$, $df = 2,127$, $p = 0.002$, $\eta^2 = 0.14$). In contrast, traumatizing actions increased significantly as the competition progressed. The mean frequency rose from 4.8 $\pm$ 1.8 actions per bout in the eliminatory phase to 7.3 $\pm$ 2.3 actions per bout in the finals ($F = 8.14$, $df = 2,127$, $p = 0.001$, $\eta^2 = 0.18$). Similarly, unbalancing techniques increased moderately across phases ($F = 4.37$, $df = 2,127$, $p = 0.015$, $\eta^2 = 0.08$).

Figure 3 demonstrates action and recovery time across phases (mean $\pm$ 95% CI).

Figure 3. Action and recovery time across phases (mean $\pm$ 95% CI).

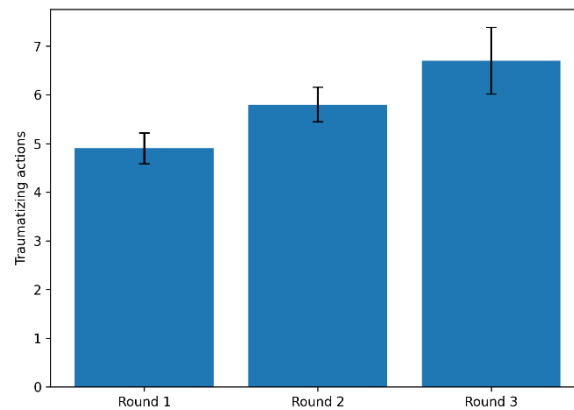
A significant change in the effort-pause structure of bouts was also identified across the different competition phases (Table 5).

Table 5. Action-to-recovery ratio across phases.

Phase	Action time (s)	Recovery time (s)	Ratio
Eliminatory	4.6 $\pm$ 1.2	10.5 $\pm$ 2.1	1 : 2.3
Semifinals	5.2 $\pm$ 1.3	8.7 $\pm$ 1.8	1 : 1.7
Finals	5.8 $\pm$ 1.5	8.1 $\pm$ 1.6	1 : 1.4

The action-to-recovery ratio shifted progressively from 1:2.3 during eliminatory bouts to 1:1.7 in semifinals and 1:1.4 in finals. This pattern indicates a progressive reduction in recovery intervals and an increase in combat density in later phases of the tournament. Statistical analysis confirmed a significant reduction in recovery duration ($F = 7.43$, $df = 2,127$, $p = 0.001$, $\eta^2 = 0.15$).

Figure 4 shows traumatizing actions across rounds (mean $\pm$ 95% CI).

Figure 4. Total traumatizing actions across rounds (mean $\pm$ 95% CI).

Round-based comparisons also revealed statistically significant differences in offensive actions (Table 5).

Table 5. Traumatizing actions across rounds.

Round	Mean actions
Round 1	4.9 $\pm$ 1.7
Round 2	5.8 $\pm$ 1.9
Round 3	6.7 $\pm$ 2.1

The frequency of traumatizing techniques increased progressively from Round 1 (4.9 $\pm$ 1.7 actions) to Round 2 (5.8 $\pm$ 1.9 actions) and Round 3 (6.7 $\pm$ 2.1 actions). Analysis of variance indicated a significant effect of round progression on the number of traumatizing actions ($F = 5.92$, $df = 2,243$, $p = 0.003$, $\eta^2 = 0.09$). Post hoc comparisons showed that Round 3 presented significantly higher values than Round 1 ($p = 0.002$) and Round 2 ($p = 0.041$).

Discussion

The findings of this study reveal meaningful variations in the technical-tactical performance of competitive Capoeira athletes across different competition phases and rounds. Our results demonstrate a progressive modification in action selection and temporal organization of movements as athletes advance from eliminatory rounds to finals. The reduction in total time per action, the increased frequency of traumatizing and unbalancing movements, and the shortened recovery times suggest a shift toward more efficient and decisive exchanges during later competition stages. Rather than indicating simple performance improvement, these changes likely reflect tactical adjustments to the competitive context, opponent level, and scoring dynamics typical of elimination tournaments. Köhler et al. (2025) demonstrated in a review that Capoeira studies demonstrate significant multisystemic impacts, evidenced by improvements in cardiovascular parameters, such as reduced resting heart rate and optimized maximal oxygen uptake in children and young adults, and positive autonomic adaptations following 10-week interventions. These adaptations highlight the importance of conditioning programs tailored to competition phases, ensuring that athletes can maintain technical precision under fatigue while maximizing scoring opportunities (Köhler et al., 2025).

In Capoeira, fundamental movements like Ginga dominated early rounds (45.3% of action time) but decreased to 28.4% in finals, while the frequency of traumatizing actions rose from 4.8 to 7.3 per bout. This tactical shift from preparatory and exploratory movements to decisive, high-scoring actions parallels findings in MMA, where athletes transition from standing preparatory activities to a higher frequency of takedowns and submission attempts in later rounds (Antonietto et al., 2023). Although the specific techniques differ substantially between Capoeira and MMA, both sports show evidence of strategic adjustment across competitive progression. While the specific techniques differ, the underlying principle is consistent: as a match progresses, athletes prioritize actions with the highest

potential to score points or end the contest. In Capoeira, this is driven by a scoring system that awards significant points for takedowns (unbalancing actions) and effective strikes (traumatizing actions). However, these comparisons should be interpreted cautiously because Capoeira competitions incorporate aesthetic, rhythmic, and cultural elements that are not present in most other combat sports. The convergence of our results with theirs underscores the importance of efficiency under competitive pressure, particularly in decisive rounds where prolonged observation may reduce scoring opportunities.

However, despite these parallels, Capoeira maintains a unique technical-tactical identity, largely due to the role of *Floreios* (Flourish actions). In this study, *Floreios* were more prevalent in early rounds (18.7%) before decreasing in finals (9.5%), suggesting a trade-off between expression and efficiency under pressure. Unlike the purely functional movements in sports like MMA or Muay Thai, *Floreios* are acrobatic and aesthetic maneuvers that are scored in competition and serve multiple purposes. As Pasqua and Toledo (2023) describe through interviews with masters, a *Floreio* is not merely an acrobatic flourish but can be a form of expression, a feint, a creative transition, or a way to control the rhythm of the game, representing the "signature" of the capoeirista. Therefore, the reduction of these actions in later competition stages may reflect a tactical prioritization of scoring efficiency rather than a diminished role of creativity in the sport. This integration of aesthetically valued, expressive movements into the competitive framework is a key differentiator from other combat sports, preserving Capoeira's cultural link to dance and ritual play even within a sportive context (Pasqua and Toledo, 2023).

The increase in traumatizing and unbalancing actions across rounds reflects a tactical shift toward offensive strategies designed to secure points. In our study, traumatizing actions rose in finals, with a large effect size. This finding indicates that athletes increasingly rely on actions with higher scoring potential when competitive stakes increase. Such evidence emphasizes the need for training regimens that sustain offensive intensity under fatigue while preserving technical execution (Köhler et al., 2025).

The reduction in time per action for fundamental movements (from 3.5 to 2.1 seconds) illustrates a tactical adjustment toward faster exchanges. Vianna et al. (2024) similarly noted accelerated technical execution among elite Capoeira athletes advancing through competition stages. This reduction in action duration may represent improved decision-making speed and tactical anticipation rather than simply increased movement velocity. This acceleration may be explained by both increased external pressure to score and the physiological necessity of maintaining high output in decisive matches.

Structured capoeira interventions, ranging from large-scale 20-week programs in preschoolers ($N = 1,810$) to targeted sessions for older children ($n = 37$), demonstrate a statistically significant positive impact on the development of high-level cognitive processes (Hirata et al., 2023). Data indicate that consistent practice (40-minute sessions, 3 times per week) yields superior outcomes in inhibitory control and attentional modulation compared to untrained control groups (Hirata et al., 2023). Furthermore, comparative analysis of experimental and control cohorts (ages 8–13) confirms that capoeira training specifically enhances global executive functions, establishing the modality as an effective non-pharmacological tool for neurological and behavioral optimization in pediatric populations (Fernandes et al., 2022).

The progressive reduction in the action-to-recovery ratio (1:2.3 in eliminatory rounds to 1:1.4 in finals) reflects increased intensity and reduced opportunities for passive recovery. This pattern of escalating intensity is a common pacing strategy observed across high-level combat sports. A meta-analysis of MMA bouts by Gonçalves et al. (2024) similarly found a statistically significant increase in high-intensity action time and a corresponding decrease in low-intensity time from the second to the third round, identifying the final round as decisive for the match outcome. Antonietto et al. (2023) also confirmed that MMA athletes increase their frequency of attacks in later rounds to secure a finish. This shared strategy across Capoeira and MMA suggests a universal need to manage metabolic fatigue early in a contest to preserve energy for critical, high-stakes exchanges in the final moments.

In contrast, a study on youth Taekwondo (Casolino et al., 2012) found that offensive actions significantly decreased from the first to the third round, which was attributed to the athletes' not-yet-complete attainment of fundamental coordinative and tactical skills to manage fatigue and maintain output. This



contrast highlights how competitive level, experience, and conditioning may influence pacing strategies and tactical decision-making in combat sports.

The results have direct implications for Capoeira training methodologies. Coaches should incorporate phase-specific conditioning programs that reflect the increased intensity and shorter recovery intervals observed in later competition phases. Training should emphasize the efficiency of traumatizing and unbalancing actions under fatigue, coupled with preservation of technical precision. Moreover, the inclusion of competition simulations, such as structured mock bouts reproducing the tactical progression from eliminatory phases to finals, may better prepare athletes for real competitive demands.

A strength of this study is the use of a validated observational protocol (FRAMI 2.0) applied to official international competition videos, ensuring ecological validity and reproducibility. Additionally, the analysis of a complete championship tournament provides a comprehensive overview of technical-tactical behavior in high-level competitive Capoeira. Another strength lies in the comprehensive categorization of technical-tactical actions, which captures the cultural and sportive specificities of Capoeira.

However, the study has limitations. First, only male athletes were included, preventing generalization to female competitors. Second, physiological variables (e.g., heart rate, lactate) were not measured, which would provide further insight into the internal load associated with observed actions. Third, the observational nature of the study does not allow causal inference regarding the mechanisms underlying the observed tactical adaptations. Finally, the unequal number of bouts across competition phases should be considered when interpreting comparisons between stages. Future research should explore these dimensions and expand to different competitive levels, genders, and age groups to better inform training strategies.

Conclusions

In conclusion, this study provides novel evidence that competitive Capoeira exhibits distinct technical-tactical and physiological patterns across its phases and rounds. The findings indicate that athletes must demonstrate round-specific tactical efficiency and sustain high-intensity efforts despite progressive fatigue, reflecting performance profiles similar to those observed in other combat sports. These results highlight the need for coaches to design training programs that replicate the intermittent and phase-dependent nature of Capoeira matches, integrating tactical decision-making and conditioning components that mirror real competitive demands.

Moreover, the results reinforce the importance of adopting specific strategies and adaptive approaches to optimize performance. Importantly, while pursuing competitive excellence, practitioners and coaches should remain committed to preserving the cultural, expressive, and artistic essence that defines Capoeira as both a martial art and a cultural manifestation.

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