

The Dynamics of Victory: Exploring the Movement Patterns of Female Brazilian Jiu-Jitsu Athletes in Winning and Losing Combats through Time-Motion Analysis

La Dinámica de la Victoria: Explorando los Patrones de Movimiento de Atletas Femeninas de Jiu-Jitsu Brasileño en Combates Ganadores y Perdedores a través del Análisis de Tiempo-Movimiento

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Abstract. In the quest to understand the dynamics of female Brazilian Jiu-Jitsu (BJJ) combats, this research delves into the world of winning and losing. By comparing time-motion analysis based on different outcomes, our objective was to unveil the movement patterns of victory. Our sample included 209 winning (W) versus 209 losing (L) female international BJJ combats, presenting a comprehensive picture of the combat landscape. Through time-motion analysis, we explored various BJJ combat phases, such as approach, gripping, transition, side control, mounting, attack, defense, low-intensity movement, and total time. The statistical results highlight significant differences between winners and losers in key aspects of the combats. Notably, side control (W = 47.7 [27.8; 96.5]s vs. L = 27.3 [20.3; 41.9]s), mount (W = 40.0 [16.6; 85.9]s vs. L = 15.9 [6.1; 25.6]s), attack (W = 50.1 [28.6; 86.7]s vs. L = 16.6 [7.7; 35.7]s), defense (W = 14.6 [6.6; 38.2]s vs. L = 38.8 [17.7; 77.0]s), and low-intensity movement (W = 55.9 [23.4; 132.2]s vs. L = 111.5 [58.7; 225.6]s) revealed differences between the winners and losers. The implications extend to sports psychology and judo training, providing knowledge for enhancing performance, optimizing training programs, and making strategic decisions during combat.

Keywords: sports psychology, technical-tactical analysis, task performance and analysis, judo, martial arts.

Resumen. En la búsqueda por comprender la dinámica de los combates femeninos de Brazilian Jiu-Jitsu (BJJ), esta investigación profundiza en el mundo de ganar y perder. Al comparar el análisis de tiempo y movimiento basado en diferentes resultados, nuestro objetivo era revelar los patrones de movimiento de la victoria. Nuestra muestra incluyó 209 combates internacionales femeninos de BJJ ganadores (W) versus 209 perdedores (L), presentando una imagen completa del panorama del combate. A través del análisis de tiempo y movimiento, exploramos varias fases de combate de BJJ, como aproximación, agarre, transición, control lateral, montaje, ataque, defensa, movimiento de baja intensidad y tiempo total. Los resultados estadísticos destacan diferencias significativas entre ganadores y perdedores en aspectos clave de los combates. Notablemente, el control lateral (W = 47.7 [27.8; 96.5] S vs. L = 27.3 [20.3; 41.9] S), Mount (W = 40.0 [16.6; 85.9] S vs. L = 15.9 [6.1; 25.6] S), Ataque (W = 50.1 [28.6; 86.7] S vs. L = 16.6 [7.7; 35.6; 38.2] S vs. L = 38.8 [17.7; 77.0] S), y el movimiento de baja intensidad (W = 55.9 [23.4; 132.2] S vs. L = 111.5 [58.7; 225.6] s) reveló diferencias entre los ganadores y los perdedores. Las implicaciones se extienden a la psicología deportiva y al entrenamiento de judo, brindando conocimientos para mejorar el rendimiento, optimizar los programas de entrenamiento y tomar decisiones estratégicas durante el combate.

Palabras clave: psicología del deporte, análisis técnico-táctico, ejecución y análisis de tareas, judo, artes marciales.

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Introduction

Time-motion analysis is a research method employed in female combat sports to assess the physical and technical-tactical demands specific to modality (Barreto et al., 2022; Sterkowicz-Przybycień et al., 2017a; Tornello et al., 2014). Within the context of female Brazilian Jiu-jitsu (BJJ), time-motion analysis involves capturing the duration and frequency of various movements during a match, including grappling, ground fighting, and transitions (Dos Santos et al., 2023). Researchers typically utilize video analysis and wearable sensors to conduct time-motion analysis in BJJ (Coswig et al., 2018; Kirk et al., 2020). Video analysis facilitates the identification of specific movements performed by athletes (Brito et al., 2017; Chaabene et al., 2014; Tabben et al., 2018), while wearable sensors, such as heart rate monitors (Øvretveit, 2019; Villar et al., 2018), measure movement intensity and the physiological demands placed on athletes.

During tournament matches, athletes are not permitted to wear sensors that record heart rate, movement patterns,

or velocity data (Coswig et al., 2016; Ghoul et al., 2019; Villar et al., 2018). However, matches can be recorded and later subjected to time-motion analysis (Branco et al., 2013; Miarka et al., 2020). Such analysis yields insights into combat demands, including the duration and frequency of specific movements (Barreto, Aedo-Muñoz et al., 2022; Sterkowicz-Przybycień et al., 2017), movement intensity (Guillen Pereira et al., 2018), and overall physiological demands (Andreato et al., 2022; Campos et al., 2022; Magno et al., 2022). This performance analysis in Brazilian Jiu-jitsu offers valuable insights into the sport's physical and mental demands (Branco et al., 2017; Coswig, Gentil et al., 2018; Spanias et al., 2022), which can inform decisions about training and conditioning programs (Magno et al., 2022; Øvretveit, 2018; Øvretveit & Tøien, 2018; Villar et al., 2018; White & Kirk, 2021). Additionally, this analysis assists in injury prevention (Carvalho et al., 2022; Colonna et al., 2022; Lima et al., 2017; Sędek et al., 2022) and deepens the understanding of combat demands unique to female combat sports (Dos Santos et al., 2023). Key time-motion analysis variables often used in combat sports include total

match time (Coswig et al., 2018), effort time (Brito et al., 2018), rest or pause time (Soto et al., 2020), low-intensity time (Franchini et al., 2019; Miarka, 2016), high-intensity time (Bello et al., 2019), and the respective phase frequencies.

Consequently, time-motion analysis serves as a crucial tool in female Brazilian Jiu-Jitsu (BJJ) training, offering significant benefits across various domains including coaching, sports psychology, and physiology. This multidisciplinary approach enhances training, performance, and overall athlete well-being, integrating physical, psychological, and tactical aspects of the sport. For instance, coaches can develop more effective training programs by understanding the duration and frequency of various combat phases, focusing on areas crucial for success (Andreato et al., 2017; Aedo-Munoz et al., 2019; Branco et al., 2013). The analysis aids in refining tactics and teaching athletes efficient time management in different combat phases, such as transitioning from defense to attack (Miarka et al., 2014). It allows for an objective assessment of female athletes' performance, identifying strengths and improvement areas (Dos Santos et al., 2023). For athletes, women can identify which combat phases require more focus and improvement, like maintaining control in side positions or enhancing attack strategies (Miarka et al., 2016). Understanding combat phase durations aids in effective strategizing, such as energy conservation or intensifying efforts at key moments (Andreato et al., 2016; Coswig et al., 2018).

For sport psychologists, the time spent in various phases can guide psychological training to develop resilience and mental toughness specific to those moments (Barreto et al., 2023). Time-motion data assists in formulating strategies to manage stress and anxiety, particularly in extended high-pressure situations (Férez et al., 2023). Psychologists can help athletes improve focus and concentration during longer combat phases, boosting overall performance (Brito et al., 2022). For Physiologists, insights into the physiological demands of each phase support the design of specific conditioning and training protocols (Andreato et al., 2016; Carvalho et al., 2022). Understanding the physical demands informs injury prevention and effective recovery programs (Miarka et al., 2022). Tailored nutrition and hydration strategies can be developed to meet the energy requirements of athletes in prolonged or intense combat phases, improving performance (Calvo Rico et al., 2018; Maurício et al., 2022).

Finally, given the importance of outcome comparisons in combat sports, this research aims to compare time-motion analysis results for females across different outcomes, further elucidating the tactical and physiological aspects that differentiate winning and losing combats (Adamczyk et al., 2021; James et al., 2019; Slimani et al., 2017; Stellpflug et al., 2022). Studying female BJJ combats is essential for enhancing the understanding of gender-specific characteristics in the sport, improving training and performance (Dos Santos et al., 2023), promoting female participation (Dos Santos et al., 2023), and ensuring the health and well-being of

female athletes (Carvalho et al., 2022a; Brandt et al., 2019). Therefore, the objective of this research is to compare time-motion analysis results for elite BJJ females across outcomes.

Methods

Design and characterizations of the study

The study is characterized as a documental and descriptive applied research. It centers on the development, description, and comparisons of elements in time-motion analysis within the context of female BJJ combats. The research design unfolds in three stages, each aimed at creating the model.

In the first stage, researchers gleaned indicators from prior reports and time-motion analyses related to grappling modalities. These indicators were subsequently integrated into a conceptual model tailored for female BJJ combats.

During the second stage, intra-expert validation of the model was carried out. This process entailed a randomized selection of combat records. Field experts evaluated the model to verify its precision and reliability.

In the concluding third stage, combats were analyzed utilizing the refined model. Statistical examinations were conducted, and outcome comparisons were drawn to pinpoint specific combat phases that notably influenced victorious outcomes.

Through the analysis of combat data and resultant statistical comparisons, the researchers sought insights into the pivotal combat phases instrumental in securing victory in female BJJ combats.

Sample

The sample consisted of 418 international performances in female Brazilian Jiu-Jitsu (BJJ) combats. Participants were categorized based on the outcomes and types of results in their combats. Specifically, the sample included 209 pairs of female international BJJ combats, resulting in 209 winning and 209 losing performances. Additionally, within each outcome category, performances were further segmented by result types: 167 by submission, 227 by scores, and 24 by referee's decision. The fights were randomly selected, ensuring that none involved the same athletes. The breakdown of the combats included forty qualifying matches, eighty-two quarterfinal fights, one hundred and two semifinal matches, and one hundred and twenty-four final matches.

The inclusion criteria for selecting combats were as follows: high-level international female BJJ combats with complete video recordings, staged in conditions optimal for analysis, in line with the criteria previously set by Barreto et al. (2022). However, combats resulting in disqualification ($n = 2$) or due to injury ($n = 2$) were excluded. All analyzed combats took place during the 2020 BJJ Pan American event in Kissimmee, Florida, USA, organized by the International Brazilian Jiu-Jitsu Federation (IBJJF).

To ensure the representativeness of the sample for international female combats, a sample size calculation was conducted following past research (Kadam & Bhalerao, 2010).

This aimed for a 99% confidence level and a 1% margin of error, based on data from 379 ranked athletes in the IBJJF (i.e. target population). All analyzed combats were sourced from a publicly accessible website affiliated with the IBJJF (IBJJF, 2020).

This study conformed to the ethical standards delineated in the WMA Declaration of Helsinki. As the combats are considered public data, approval was secured from the local Research Ethics Committee.

Procedures and measurements

This study aimed to categorize variables within its protocol into a macro group, simplifying the classification of

Brazilian Jiu-Jitsu (BJJ) techniques. The process involved the analyst specifying the technique's group, its definition, its laterality, and whether it resulted in points or submission.

The instrument utilized was based on BJJ combat phases as delineated in a previous protocol using the Frami software (Miarka et al., 2011; Barrientos et al., 2021). Established phases include approach, gripping, attacks, defense, and movement. This study further augmented the protocol by introducing phases like transition, control side, guard, and mounted to encapsulate BJJ combat's unique nuances. The criteria for the variables are listed in Table 1.

Table 1.

The criteria for each time-motion variable analyzed from BJJ female combats, with Cronbach's Alpha Coefficient - CAC.

Variable	Criteria	CAC
Approach Time	This denotes non-contact movements where competitors analyze opponent actions without making physical contact. Also included is pinpointing specific areas on the adversary's kimono (Barreto et al., 2019; Brito et al., 2017; Soto et al., 2020b).	r = .92
Gripping Time	It signifies the onset of physical interaction, emphasizing securing a grip on the opponent's kimono (Dal Bello et al., 2019; Miarka et al., 2016a).	r = .97
Transition Time	This moment is respective to the transition between stand-up and groundwork combats entails executing throws or projections, which, if effectively delivered, can accrue points. Particularly, guard pulling has become more prevalent recently, allowing combat to shift to the ground while minimizing exposure to counters (Coswig et al., 2018; Sterkowicz-Przybycien et al., 2017).	r = .93
Guard Time	Refers to the groundwork position called "guard", where a combatant restricts opponent movement using leg wraps. The primary goal is to sustain control (Del Vecchio et al., 2016; Lima et al., 2017).	r = .93
Side Control	A common groundwork position is a pinning position where the athlete is perpendicular to their opponent and not entangled in their legs, facilitating control and submission over the opponent (Kirk et al., 2015; dos Santos et al., 2023).	r = .95
Mounting Time	This phase sees a combatant achieving a dominant mount position, sitting atop the opponent's torso, making escape challenging (Kirk et al., 2015).	r = .89
Attack/ Defense	The attack encompasses techniques like sweeps, throws, guard passes, chokes, and lock submissions (Kirk et al., 2015; Coswig et al., 2018). In contrast, defense entails countering or safeguarding against opponent attacks, including defensive maneuvers and counter-attacks (Kirk et al., 2015; Miarka et al., 2017).	r = .96 and r = .98
Low-Intensity Movement Time	This phase includes actions not directly influencing scores or dominance, like grip adjustments and stationary movements. Pauses in combat are also considered under this low-intensity moment (Barrientos et al., 2021; Del Vecchio et al., 2011; Tornello et al., 2014).	r = .89
Total time	This is the total combat time (Barrientos et al., 2021; Del Vecchio et al., 2011; Tornello et al., 2014).	r = .93

Reliability testing

A single analyst performed the analysis. This protocol has been validated and was used in previous research (Dos Santos et al., 2023). Therefore, the study's reliability assessment centered on intra-observer agreement and was conducted by an expert possessing over a decade of experience in Physical Education. This expert, referred to as expert A, provided the BJJ time-motion data for the study's analysis.

Procedure for Intra-observer Agreement: Expert A initially analyzed 20 BJJ matches using the FRAMI software (Miarka et al., 2011).

Subsequently, for the intra-observer agreement test, ten BJJ matches (equivalent to 20 performance analyses) were randomly chosen. Expert A then re-analyzed these matches in a randomized sequence to ensure consistency in observation.

Reliability Analysis: The reliability of time-motion variables was gauged using the Cronbach's Alpha Coefficient (CAC). Each variable's frequency distribution was inspected, resulting in the determination of corresponding CAC values.

Agreement strength was categorized based on CAC values, which varied from excellent (.93-.94) to low (.11).

Agreement classifications spanned a range, including (but not limited to) strong, reliable, high, moderate, satisfactory, and low.

Statistical computations were executed with the SPSS software (version 22.0). A significance level was established at $p \leq 0.05$. The time-motion indicators utilized in the study, alongside their specific Alpha values, are detailed in Table 1. Such reliability assessments validate the consistency and precision of the time-motion analysis presented in the study (Miarka et al., 2011).

Statistical Analysis

The present research performed the statistical analysis using SPSS 22.0 for Windows. To comprehensively understand the dataset, descriptive data are reported as median [25th percentile; 75th percentile] values. To compare winning and losing combats, the Wilcoxon test was employed. This non-parametric test is suitable for comparing two related samples and determining if there are significant differences between them. For comparing time-motion seconds and frequencies between BJJ, the Kruskal-Wallis test was utilized. This non-parametric test is appropriate for comparing three or more independent groups and identifying if there are significant differences among them. Subsequently,

Bonferroni post hoc analysis was performed to determine specific group differences. To compare time-motion seconds between different BJJ outcomes, the same Kruskal-Wallis test was applied. This allowed for the evaluation of potential differences among the outcomes. The significance level for all statistical tests was set at $p \leq .05$, indicating that results with a probability of occurring by chance less than or equal to 5% were considered statistically significant.

Results

Table 2 presents a detailed descriptive analysis of the time-motion phases in international female Brazilian Jiu-Jitsu (BJJ) combats.

Table 2 reveals significant differences across various combat phases. Specifically, we observed notable differences in approach times ($H = 11.865$, $p \leq 0.018$), gripping moments ($H = 20.179$, $p \leq 0.001$), transitions ($H = 12.408$, $p \leq 0.015$), guard positions ($H = 19.597$, $p \leq 0.001$), attack strategies ($U = 5895.0$, $p \leq 0.001$; $H = 13.428$, $p \leq 0.009$), low-intensity movements ($U = 20756.0$, $p \leq 0.001$; $H = 23.272$, $p \leq 0.001$), and the overall combat duration (total time: $H = 188.281$, $p \leq 0.001$).

Table 3.

Measures of the times in seconds of the international BJJ fighters in each combat phase, compared according to the outcome of winning combats.

Phase	Submission			Score			Referee's decision			Statistical inferences	
	Med	Q ¹	Q ³	Med	Q ¹	Q ³	Med	Q ¹	Q ³	H	P
Approach	5.5	3.5	8.2 ^a	6.8	3.6	12.8 ^a	4.8	2.7	9.0	11.865	0.018
Gripping	4.7	2.8	10.0 ^b	4.1	2.1	15.5 ^c	18.0	6.2	277.2 ^{bc}	20.179	≤ 0.001
Transition	2.1	1.4	3.2 ^a	2.5	1.7	4.4 ^a	2.5	1.9	4.3	12.408	0.015
Guard	59.6	23.5	124.3 ^{ab}	102.3	44.8	197.8 ^a	131.4	44.3	216.8 ^b	19.597	≤ 0.001
Side control	38.3	24.6	58.8	48.6	26.7	123.9	44.0	44.0	44.0	3.575	0.311
Mount	25.3	11.5	63.0	45.2	18.7	96.8	-	-	-	5.013	0.025
Attack	26.1	10.7	51.5 ^a	43.2	17.3	84.9 ^a	30.8	7.5	52.7	13.428	0.009
Defense	22.4	12.8	49.4	37.9	14.0	74.1	27.7	8.7	41.7	8.871	0.064
Low-intensity Movement	68.6	22.4	109.3 ^a	110.5	44.0	225.4 ^a	84.7	20.9	192.1	23.272	≤ 0.001
Total time	203.8	117.6	283.0 ^{ab}	385.6	342.8	487.5 ^{ac}	355.8	301.8	439.8 ^{bc}	188.281	≤ 0.001

Note: time is in seconds; - = this symbol was used when the action did not occur; Med – Median / Q¹ – First quartile / Q³ – Third quartile / P = P-value (significance) / U - H - statistical test value / ; a = significant difference in Submission and points; b = significant difference in submission and judge's decision; c = significant difference in points and judge's decision; all comparisons considered $p \leq 0.05$.

Moreover, when comparing the outcomes in women's BJJ combats as detailed in Table 3, significant differences become evident. Combats that resulted in submission showed consistently shorter phases compared to those ending in score outcomes, specifically in approach ($H = -27.938$, $p = 0.019$), transition ($H = -22.110$, $p = 0.013$), guard ($H = -47.420$, $p \leq 0.001$), attack ($H = -39.010$, $p \leq 0.001$), low-intensity movement ($H = -55.093$, $p \leq 0.001$), and overall duration (total time: $H = -168.731$, $p \leq 0.001$). Furthermore, submission outcomes were associated with shorter gripping times ($H = -63.900$, $p = 0.018$) and overall combat durations (total time: $H = -118.190$, $p \leq 0.001$) compared to combats concluded by the referee's decision. Additionally, combats ending in score outcomes had shorter gripping times ($H = -72.257$, $p \leq 0.001$) and overall durations (total time: $H = 50.541$, $p = 0.05$) when compared to those finished by the referee's decision.

Table 3 provides a comprehensive descriptive time-motion analysis focusing on the outcomes of elite women's Brazilian Jiu-Jitsu (BJJ) combats.

Table 2.

Measures of the times in seconds of the international BJJ fighters in each combat phase, compared according to the outcome.

Phase	Winning combats			Losing			Statistical inferences	
	Med	Q ¹	Q ³	Med	Q ¹	Q ³	U	P
Approach	5.8	3.4	10.7	5.9	3.6	10.7	19093.0	0.872
Gripping	4.5	2.4	17.5	4.9	2.6	15.9	12922.0	0.586
Transition	2.3	1.5	3.6	2.2	1.6	4.1	5775.0	0.795
Guard	100.6	33.3	155.3	94.9	37.7	186.6	14800.0	0.169
Side control	47.7	27.8	96.5	27.3	20.3	41.9	353.0	0.032
Mount	40.0	16.6	85.9	15.9	6.1	25.6	85.0	0.031
Attack	50.1	28.6	86.7	16.6	7.7	35.7	5895.0	≤ 0.001
Defense	14.6	6.6	38.2	38.8	17.7	77.0	15006.0	≤ 0.001
Low-intensity Movement	55.9	23.4	132.2	111.5	58.7	225.6	20756.0	≤ 0.001
Total time	341.3	232.1	411.9	344.9	244.8	444.3	23433.0	0.349

Note: time is in seconds; - = this symbol was used when the action did not occur; Med – Median / Q¹ – First quartile / Q³ – Third quartile / P = P-value (significance) / U - H - statistical test value / ; a = significant difference in Submission and points; b = significant difference in submission and judge's decision; c = significant difference in points and judge's decision; all comparisons considered $p \leq 0.05$.

Discussion

Our study examined female Brazilian Jiu-Jitsu (BJJ) time-motion analysis concerning different outcomes. The principal results revealed significant differences between winning and losing combats. Female winners exhibited longer durations in side control, mount, and attack phases, while losing combats showed longer defensive actions and low-intensity movements. These findings provide valuable insights into the tactical use of movements and the physiological demands of combat sports (Franchini et al., 2013).

Moreover, analyzing the peculiarities inherent in different outcomes contributes to a comprehensive understanding of BJJ combats (Bello et al., 2019; Falco et al., 2016; Fernández et al., 2020; Miarka et al., 2016; Slimani et al., 2016, 2017; Tabben et al., 2018).

Interpretation of findings

Our research revealed that in international female Brazilian Jiu-Jitsu (BJJ) combats, there is a prevalent use of a sequence of domain-attack-defensive actions, followed by low-intensity movements, at a ratio of 6:1. This contrasts with the ratios in male elite BJJ simulated tournaments and contextual elite training, which are 8:1 (Andreato et al., 2015) and 8.5:1 (Andreato et al., 2017), respectively. Moreover, it is higher than the ratio observed in female judo Olympic combats during the 2016/2020 period, which was approximately 3:1 (Barreto et al., 2022), and in the 2012 female Olympic combats (Miarka et al., 2016). A previous study of female BJJ athletes did not demonstrate significant differences between categories; the longest combat times were in the rooster category, with a median of 408 seconds (302; 482 seconds), and in the light feather category, with a median of 390 seconds (306; 445 seconds) (Dos Santos et al., 2023). Our results showed an average combat time of approximately 343 seconds (238; 428 seconds). A recent publication indicated that the most significant differences in weight categories among female BJJ athletes were in gripping time (Dos Santos et al., 2023). The longest times were observed in the rooster category, with a median of approximately 7 seconds (4; 65 seconds), followed by the middleweights, with a median of approximately 6 seconds (2; 14 seconds), and the heavy category, with a median of approximately 5 seconds (2-29 seconds). In contrast, the super heavy category, with a median of approximately 3 seconds (6-120 seconds), and the light feather category, with a median of approximately 3 seconds (6-15 seconds), demonstrated shorter gripping times (Dos Santos et al., 2023). Additionally, our study found that in female BJJ combats, outcomes determined by scores and judge decisions involved gripping times that were 4.5 times longer compared to other strategies. Despite this, all types of BJJ combat outcomes still had shorter gripping times than those in elite female judo combats (Barreto et al., 2022; Miarka et al., 2016; Miarka et al., 2014). Previous research suggests that female BJJ athletes strategically use these phases to control their opponent's actions until a projection or transition to groundwork combat occurs (Dos Santos et al., 2023; Spanias et al., 2022). Traditionally, BJJ is known for a predominance of groundwork time during combats (Andreato et al., 2015; Andreato et al., 2017; Coswig et al., 2018).

Gripping is a key factor in determining expertise in grappling combats, as indicated by various studies (Barreto et al., 2021; Brito et al., 2021; Calmet et al., 2010; Courel et al., 2014; Dopico-Calvo et al., 2022; Obminski et al., 2015; Miarka, Del Vecchio, et al., 2016; Sterkowicz-Przybycien et al., 2017). Research comparing beginners and experts in judo suggests that while beginners tend to spend more time gripping without significant technical and tactical skill, high-level athletes engage in gripping with breaks (Calmet et al., 2010). These moments are used for recovery, accommodating the higher frequency of actions

seen in advanced competition (Courel et al., 2014; Kajmovic et al., 2022; Barreto et al., 2021).

Our findings are in line with recent studies on the Approach and Gripping Phases in senior-level combats, which show that the Approach phase lasts an average of 5 to 8 seconds, and the Gripping phase 6 to 13 seconds (Calmet et al., 2010; Miarka et al., 2012). These durations underline the importance of experience in judo, as seasoned athletes spend extended periods in displacement without gripping (Calmet et al., 2010; Miarka et al., 2012). This approach serves two main tactical purposes (Calmet et al., 2010; Miarka et al., 2012). Firstly, this approach offers athletes an opportunity to swiftly evaluate their opponent and establish effective gripping interactions. Gripping plays a significant role in influencing combat outcomes (Kajmovic; Radjo, 2014). Secondly, athletes use this time not only to grip but also to defend against their opponent's attacks or attempts to dominate. This strategy helps in controlling the space and striving for dominance over the opponent, setting the stage for sequential BJJ phases (Barreto, Santos, et al., 2022; Miarka et al., 2012).

In terms of Attack Time, our analysis shows a notable difference in the frequency of actions during female ground combat in mixed martial arts (MMA). Specifically, there are approximately 1.3 projections, 0.3 side controls/mounts, and 0.2 advances to the back per round in female MMA (Miarka et al., 2016). This contrasts with female judo combats, where attacks primarily occur while standing, as opposed to Brazilian Jiu-Jitsu (BJJ), which predominantly involves ground fighting. This difference is significant, as attacks in BJJ can't be directly compared to judo projections.

Additionally, our research indicates that BJJ athletes tend to have longer attack durations compared to those observed in judo. For instance, biomechanical analyses of judo report a total attack duration of 1.14 seconds for a specific arm technique, the *Morote-seoi-nage* (Blais & Trilles, 2004; Street et al., 2007). In contrast, our data show that attack times in BJJ exceed those recorded in studies involving state and regional-level athletes, where attacks with projections vary between 0.5 and 3 seconds (Dal Bello et al., 2019). These observations underscore the distinct differences between judo and BJJ, including the execution of techniques (Coswig et al., 2018), the number of attack orientations used in competitions (Calmet et al., 2010), and the variations across different levels of BJJ athletes (Soto et al., 2020; Miarka et al., 2018; Miarka et al., 2016). In present winning BJJ combats, these variations are linked to the time spent on techniques (see Table 2). Longer durations are observed in phases such as side control, mount, attack, and defense, while shorter durations are noted in low-intensity movements (see Table 2).

Limitation, future research and reliability

It is crucial to recognize the limitations of time-motion analysis in combat sports, which include challenges in accurately assessing physiological responses such as heart rate

and lung capacity (Andreato et al., 2016). Due to the unique nature of these sports, integrating such tests into the time-motion framework is often impractical. Consequently, even when conducted by specialists, the analysis tends to be subjective, leading to varying interpretations among analysts. To mitigate this, descriptive and observational analyses of actions can serve as an alternative to better understand the physiological demands and key actions in Brazilian Jiu-Jitsu (BJJ) tournaments (Barreto et al., 2022). Future research should aim to extend these findings to various competition levels and include a wider range of physiological responses.

Compared to existing models in grappling combats, our time-motion model offers a more comprehensive analysis of effortful moments, including gripping, transitions, attacks, defense, and specific BJJ positions. This level of detail surpasses previous BJJ models (Andreato et al., 2015; Coswig et al., 2018) and is similar to methodologies used in earlier judo studies (Branco et al., 2017; Miarka et al., 2015) and wrestling research (López-González et al., 2013). Present study introduces new elements to time-motion structures, particularly emphasizing the duration of the Defense Phase as a key factor in winning BJJ combats following a recent protocol (Dos Santos et al., 2023). This addition builds on prior research highlighting a tendency for defensive behavior among high-level athletes in grappling combat (Boguszewski, 2011; Miarka et al., 2014).

Regarding technique analysis, the consistency of our results with previous studies validates the use of the Frami® software in combat analysis (Miarka et al., 2011). Our study also demonstrated a high level of intra-expert agreement on measured variables, corroborating earlier findings (Barreto et al., 2021; Barrientos et al., 2021; Lima et al., 2022). The intra-expert comparison in our study showed significant agreement, with indices exceeding 0.90 (Barreto et al., 2022; Barrientos et al., 2021; Lima et al., 2022).

Implications and significance

The practical applications of your study's findings in the context of female Brazilian Jiu-Jitsu (BJJ) training and competition are substantial and multifaceted:

Training Focus for Athletes and Coaches: The findings suggest that coaches and athletes should emphasize training in side control, mount, and attack phases (Miarka et al., 2016). This targeted training could lead to improved performance (Vargas-Molina et al., 2023) in combats by focusing on the areas that most often determine winning outcomes.

Enhanced Understanding of Stress and Anxiety Management: The study's insights into the various phases of combat, especially the high-pressure situations like attack and defense, can help athletes understand and manage the stress and anxiety associated with these moments (Contessoto et al., 2021; Fernández et al., 2020; Fernández et al., 2022). By identifying the psychological demands of each phase, athletes can develop better coping mechanisms to maintain

composure and mental clarity during combats (Brandt et al., 2019; Coontessoto et al., 2021).

Targeted Mental Skills Training: With the knowledge of how different combat phases influence performance, sports psychologists can develop tailored mental training programs (Fernández-Rio et al., 2013). These programs can focus on improving concentration, resilience (Slimani et al., 2016), and tactical decision-making (Miarka et al., 2016), particularly in phases where athletes spend most of their time, such as side control or mount positions.

Improved Reaction Time and Situational Awareness: The study's emphasis on the duration of different combat phases can guide training to enhance cognitive functions like reaction time and situational awareness (Brito et al., 2022). Athletes can train to make quicker, more accurate decisions under pressure, an essential skill in fast-paced combat sports like BJJ.

Optimized Recovery and Stress Regulation: Understanding the physiological demands of prolonged attack or defensive phases helps in developing effective recovery strategies (Barreto et al., 2022a). This knowledge can be used to design training sessions that incorporate adequate rest and recovery, optimizing an athlete's ability to regulate stress and fatigue.

Strategic Planning in Competitions: Female athletes and their coaching teams can use the insights from this study for strategic planning in competitions (Barreto et al., 2023). Understanding that extended durations in offensive positions correlate with winning outcomes can guide fighters in making tactical decisions during combats (Barreto et al., 2023).

Physiological Training Adaptations: Knowledge about the physiological demands and the importance of certain combat phases can influence conditioning and fitness training (Andreato et al., 2017; Coswig et al., 2018). Female athletes can work on specific endurance and strength training that caters to the demands of prolonged attack phases and efficient defense.

Performance Analysis Tools: The introduction of unique time-motion structures, such as the Defense Phase duration, provides a new tool for performance analysis (Dos Santos et al., 2023). Coaches and analysts can use these metrics to assess athlete performance more accurately and tailor training regimens accordingly (Silva Batista et al., 2022).

Biofeedback and Physiological Monitoring: The study could encourage the use of biofeedback and physiological monitoring during training to better understand how the body responds to different combat scenarios (Torres Luque et al., 2010). This can include monitoring heart rate, muscle activation, and breathing patterns, which can be critical in developing strategies to manage physiological responses during combats (Andreato et al., 2017; Barreto et al., 2022a).

Rehabilitation and Recovery: Understanding the demands of different combat phases can inform rehabilitation

and recovery protocols (Dos Santos et al., 2023; Norambuena et al., 2021). Female athletes recovering from injuries can focus on regaining strength and endurance in the specific phases most relevant to their combat success (Carvalho et al., 2022; Spano et al., 2019; Dos Santos et al., 2022).

By applying these insights, the study's findings can be instrumental in enhancing the psychophysiological training of female BJJ athletes, focusing on the most impactful areas to enhance performance in combats.

Conclusion

The results of this study have significant implications in the fields of sports psychophysiology and Brazilian Jiu-Jitsu (BJJ) training, presenting practical applications to advance performance and refine training methodologies. Firstly, the insights from our study enable coaches and athletes to formulate targeted training programs. Enhancing skills in side control, mount, and attack phases is crucial, as our findings suggest these are key determinants of success in female BJJ combats. Training sessions should be structured to prioritize these phases, with a focus on specific drills and exercises aimed at honing technique and strategic planning.

Secondly, the study underscores the importance of defensive skills in combat sports. Athletes who find themselves frequently in defensive positions or engaged in low-intensity movements could see substantial benefits from collaborating with sports psychologists. Such collaboration could focus on improving reaction times, enhancing situational awareness, and developing counter-attacking strategies. Mental skills training is also pivotal in helping athletes maintain focus and composure during high-pressure defensive scenarios.

In addition, conditioning and fitness regimens should be customized to meet the unique physiological demands of female BJJ. Athletes need to concentrate on bolstering endurance, strength, and agility to better endure prolonged periods in the critical combat phases. Sports psychologists play a vital role here as well, aiding athletes in cultivating mental resilience and toughness, which are essential for sustaining peak performance during combats.

Lastly, our study highlights the value of time-motion analysis as a tool for performance evaluation and feedback. By systematically recording and analyzing combats, coaches and athletes can gain an objective view of performance, pinpointing strengths and areas for improvement in specific combat phases. This analysis, when combined with the expertise of sports psychologists, allows for the provision of impactful feedback, setting of realistic performance goals, and development of strategies for skill advancement. Therefore, our study not only contributes to the tactical and physical aspects of BJJ training but also underscores the importance of psychological preparedness and strategic analysis in enhancing overall athlete performance.

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