

Mini-review and Meta-analysis of effort ratios in mixed martial arts rounds: key insights for research and coaches

Mini-revisión y Meta-análisis de proporciones de esfuerzo en rounds de artes marciales mixtas: ideas clave para la investigación y entrenadores

Mini-revisão e Meta-análise das proporções de esforço em rounds de artes marciais mistas: insights chave para pesquisa e treinadores

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Abstract. This study investigated the critical aspect of match intensity in MMA bouts and its impact on performance. MMA is a physically demanding sport, and understanding the dynamics of intensity throughout matches is essential for both athletes and trainers. To achieve this goal, we adhered to the PRISMA guidelines for comprehensive and ethical reporting of our findings. We conducted a thorough search of electronic databases, including PubMed, Bireme, CINAHL, SportDiscus, EMBASE, SCOPUS, and Cochrane, to identify relevant articles. Our search terms included "mixed martial arts athletes," "movement time study," "male athletes," "female athletes," "lactate," "heart rate," and "motor action." Our meta-analysis yielded compelling results. We found a statistically significant difference between the third and second rounds ($p=0.0001$) for both total high-intensity and low-intensity time. Additionally, significant differences were observed when comparing the second round to the first round for total high-intensity time ($p=0.52$) and total low-intensity time ($p=0.58$). These findings indicate a progressive increase in intensity throughout the rounds, with the third round significantly affecting the fight's outcome. Our results suggest that trainers and athletes should consider a specific strategy for the third round to address potential metabolic fatigue. Future research should delve deeper into strategies that can effectively manage intensity throughout MMA bouts, with a focus on factors like nutrition, recovery, and psychological aspects, which could provide valuable insights into optimizing performance in this demanding sport.

Keywords: Technical-tactical analysis; Task performance and analysis; Exercise physiology; Martial Arts.

Resumen. Este estudio investigó el aspecto crítico de la intensidad en los combates de MMA y su impacto en el rendimiento. El MMA es un deporte físicamente exigente, y entender la dinámica de la intensidad a lo largo de los combates es esencial tanto para los atletas como para los entrenadores. Para lograr este objetivo, seguimos las directrices PRISMA para un informe completo y ético de nuestros hallazgos. Realizamos una búsqueda exhaustiva en bases de datos electrónicas, incluyendo PubMed, Bireme, CINAHL, SportDiscus, EMBASE, SCOPUS y Cochrane, para identificar artículos relevantes. Nuestros términos de búsqueda incluyeron "atletas de artes marciales mixtas", "estudio del tiempo de movimiento", "atletas masculinos", "atletas femeninas", "lactato", "frecuencia cardíaca" y "acción motora". Nuestro meta-análisis arrojó resultados contundentes. Encontramos una diferencia estadísticamente significativa entre el tercer y el segundo asalto ($p=0.0001$) tanto en el tiempo total de alta intensidad como de baja intensidad. Además, se observaron diferencias significativas al comparar el segundo asalto con el primero en cuanto al tiempo total de alta intensidad ($p=0.52$) y el tiempo total de baja intensidad ($p=0.58$). Estos hallazgos indican un aumento progresivo de la intensidad a lo largo de los asaltos, siendo el tercer asalto el que impacta significativamente en el resultado de la pelea. Nuestros resultados sugieren que los entrenadores y atletas deberían considerar una estrategia específica para el tercer asalto para abordar la posible fatiga metabólica. Las investigaciones futuras deberían profundizar en las estrategias que pueden gestionar eficazmente la intensidad durante los combates de MMA, con un enfoque en factores como la nutrición, la recuperación y los aspectos psicológicos, lo que podría ofrecer valiosos conocimientos para optimizar el rendimiento en este exigente deporte.

Palabras clave: Análisis técnico-táctico; Rendimiento y análisis de tareas; Fisiología del ejercicio; Artes marciales.

Resumo. Este estudo investigou o aspecto crítico da intensidade dos combates de MMA e seu impacto no desempenho. O MMA é um esporte fisicamente exigente, e entender a dinâmica da intensidade ao longo das lutas é essencial tanto para atletas quanto para treinadores. Para alcançar este objetivo, seguimos as diretrizes PRISMA para um relato abrangente e ético de nossas descobertas. Realizamos uma busca minuciosa em bases de dados eletrônicas, incluindo PubMed, Bireme, CINAHL, SportDiscus, EMBASE, SCOPUS e Cochrane, para identificar artigos relevantes. Nossos termos de busca incluíram "atletas de artes marciais mistas", "estudo do tempo de movimento", "atletas masculinos", "atletas femininas", "lactato", "frequência cardíaca" e "ação motora". Nossa meta-análise revelou resultados contundentes. Encontramos uma diferença estatisticamente significativa entre o terceiro e o segundo round ($p=0.0001$) tanto no tempo total de alta intensidade quanto no de baixa intensidade. Além disso, foram observadas diferenças significativas ao comparar o segundo round com o primeiro no tempo total de alta intensidade ($p=0.52$) e no tempo total de baixa intensidade ($p=0.58$). Esses achados indicam um aumento progressivo da intensidade ao longo dos rounds, com o terceiro round impactando significativamente o resultado da luta. Nossos resultados sugerem que treinadores e atletas devem considerar uma estratégia específica para o terceiro round para lidar com a possível fadiga metabólica. Pesquisas futuras devem explorar mais a fundo as estratégias que podem gerenciar efetivamente a intensidade ao longo das lutas de MMA, com foco em fatores como nutrição, recuperação e aspectos psicológicos, que podem fornecer insights valiosos para otimizar o desempenho neste esporte exigente.

Palavras-chave: Análise técnico-tática; Desempenho e análise de tarefas; Fisiologia do exercício; Artes marciais.

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Introduction

The rising popularity of Mixed Martial Arts (MMA) has sparked significant interest in the development of advanced training and assessment methodologies for the sport (Kostikiadis et al., 2018; Vasconcelos et al., 2020). MMA is a complex combat discipline characterized by a multifaceted energy system, involving intermittent patterns of high-intensity actions, low-intensity periods, and pauses in movement or technique. These demands encompass strength, endurance, speed, and various changes in angles, levels, and positions, occurring across three distinct areas of action: movement, clinch, and ground fighting (Fernandes et al., 2018).

Studies on effort ratios in MMA, often referred to as work-to-rest ratio studies, are crucial for enhancing the performance of MMA athletes (Fernandes et al., 2018; Kirk, 2018). A meta-analysis of effort ratios, particularly by round, within the context of MMA training, can provide valuable insights and contribute to improving training methods and overall athlete performance. This research method is integral to the field of scientific MMA research and evidence-based decision-making, involving the systematic analysis of time-motion data from multiple original studies on effort ratios in MMA bouts.

Each MMA bout typically consists of three to five rounds, each lasting five minutes, with one minute of rest between rounds (Kirk, 2018). Given the versatile and physically demanding nature of MMA, precise training management based on physiological tests and analyses is essential (Lisa et al., 2022; Tota et al., 2019). Understanding the specific demands of MMA, including its intermittent nature and the complexity of its techniques, is crucial for effective training planning, using the effort ratio as a guiding principle. This approach ensures that athletes are adequately prepared for the dynamic and physically demanding nature of mixed martial arts (Andrade et al., 2019).

Time-motion analysis, a non-invasive method, offers a comprehensive approach that considers skills, tactics, physiological responses, and energy contributions (Bridge et al., 2018). It involves analysing the time and frequency spent on different types of actions, such as high and low-intensity moments or pauses, during combat (Miarka et al., 2018). This knowledge is vital for designing targeted training programmes that encompass strength, power, and conditioning exercises, as well as enhancing metabolic, tactical, and motor skills (Miarka et al., 2017). Understanding this concept is essential for developing training models that simulate the physical efforts seen in official competitions, incorporating exercises to enhance metabolism, tactics, and motor cognition (Andrade et al., 2019; Kostikiadis et al., 2018; Miarka et al., 2021).

MMA matches can be decided by various methods, including submission, knockout (KO), technical knockout

(TKO), stoppage, or a judge's decision after a specified duration (Fernandes et al., 2018). These actions, particularly submissions and KO/TKOs, significantly influence the outcome of the match, making it imperative for athletes to train and adapt to these scenarios (Miarka, Coswig, et al., 2016; Da Silva Santos et al., 2020). Moreover, the methods of outcome in MMA can affect the effort ratio in combat, with fighters adjusting their strategies based on perceived preferences of judges and the scoring system (Fernandes et al., 2018; Kirk, 2018).

Therefore, this systematic review and meta-analysis aim to describe the ratios of total time spent in high and low intensity during matches consisting of three completed rounds and those that ended in the first, second, or third rounds through submission or TKO/KO methods among professional MMA athletes. This comprehensive information will enhance our understanding of movement timing and physiological responses, providing valuable insights for MMA coaches and athletes seeking to optimise their training and performance strategies.

Materials and Methods

Literature Search Strategy

The systematic literature search for this review involved a thorough exploration of several reputable databases, including PubMed, Bireme, CINAHL, Sportdiscus, EM-BASE, SCOPUS, and Cochrane. To ensure a comprehensive retrieval of relevant studies, a combination of database-specific descriptors was employed, utilising logical operators (AND and OR). The selected keywords for the search covered various aspects pertinent to the study, including "mixed martial arts athletes," "male athletes," "female athletes," "resistance training," "resistance training programme," "time-motion study," "lactate," "heart rate," "high-intensity interval training," and "motor action."

To maintain the relevance and validity of the findings, specific filters were applied, including adult participants, publications in the English language, and a focus on studies within the humanities. Additionally, both non-randomised trials and randomised controlled studies were included in the review. The screening of potential articles was conducted in a sequential manner, involving three stages: title screening, abstract assessment, and full-text examination. In cases of disagreement between the two investigators during the selection process, a third investigator was called upon to independently review the articles and engage in collaborative discussions to reach a consensus. It is important to note that the investigators were not blinded to the manuscript, study title, authors, or associated institutions during the selection process.

For transparency in reporting the selection process, we summarised the findings using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, as illustrated in Figure 1.

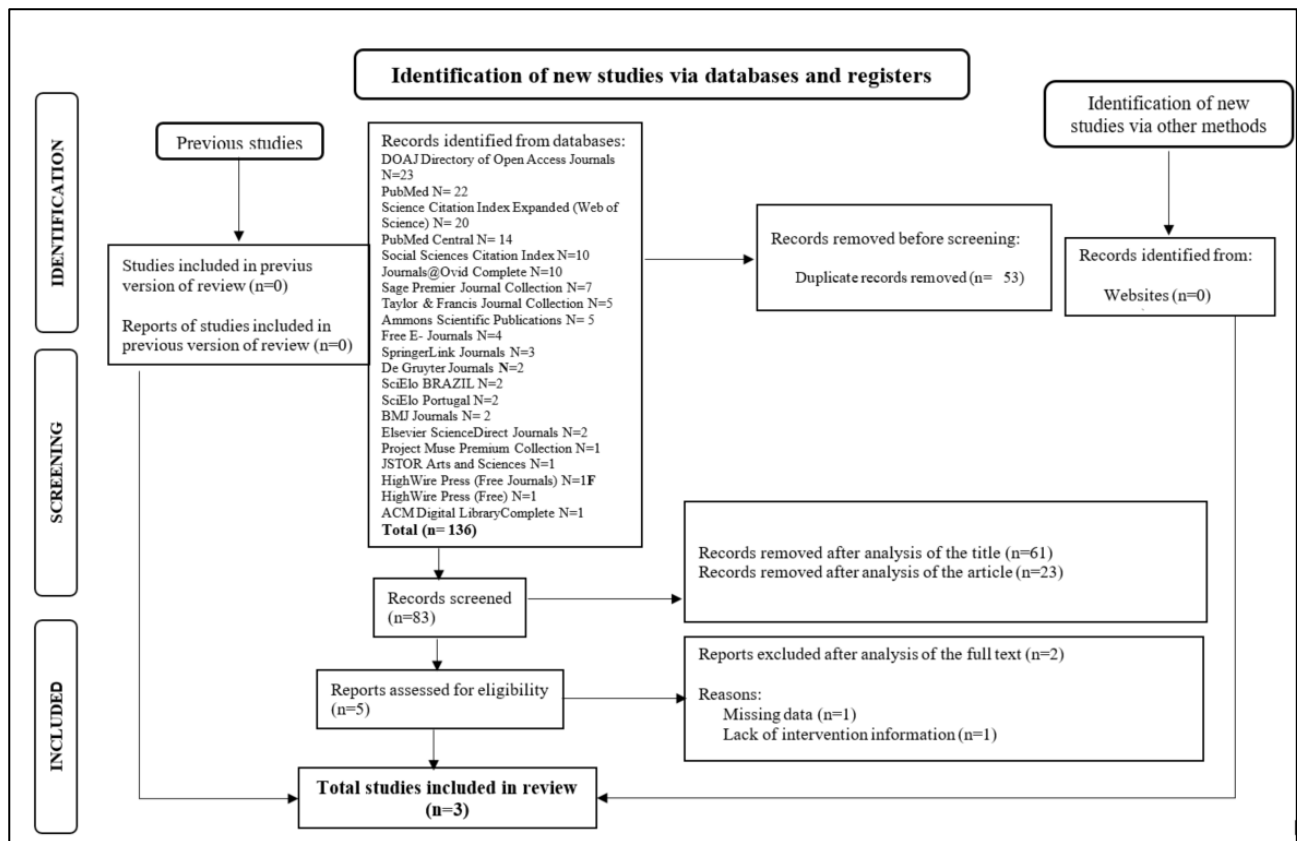


Figure 1. PRISMA flow diagram for study selection.

This systematic approach aims to provide research readers with a comprehensive and unbiased understanding of the literature search and article selection process for this study.

Inclusion and Exclusion Criteria

For this systematic review, articles published in English were included, without any restrictions on the year of publication, to facilitate comprehensive qualitative and quantitative analyses. To maintain data integrity and reliability, studies involving athletes under the age of 18 were excluded, as well as systematic reviews, meta-analyses, abstracts, books, e-books, editorial letters, and commentaries.

Participant Type

To ensure a focused and relevant investigation, only male and female MMA athletes were considered eligible for inclusion in this review. Athletes below the age of 18 were excluded from the analysis.

Data Extraction

The critical information extracted from the included studies was meticulously compiled into tables using Microsoft Word 2016 (Microsoft, WA, United States). These tables provided a structured overview of the relevant data for easy reference and comparison. Additionally, a narrative description was performed to thoroughly analyze and discuss the findings from the selected literature on the subject. In cases where specific study details extended beyond the tabular representation, comprehensive narrative explanations were provided in the "Results" section to enhance readers'

understanding.

Retrieved Data

The data acquired from the included articles focused on the ratios of total time spent in high and low-intensity actions during each round (first, second, and third) of both completed and ended MMA combats, determined by TKO/KO or submission. This systematic approach ensures the presentation of robust evidence to explore the variations in intensity patterns throughout MMA matches, contributing valuable insights to enhance performance strategies and training methodologies in this dynamic combat sport.

Qualitative Analysis

To assess the risk of bias in the selected studies, the "Tool for Assessing Study Quality and Reporting in Exercise Training Studies" (TESTEX) checklist 16 was utilized. This rigorous evaluation aimed to identify any potential methodological limitations that could influence the validity and reliability of the findings. After a thorough examination, the studies were categorized into two groups: "adequate quality" (score ≥ 7 points) and "poor quality" (score < 7 points). Studies with low quality were excluded from the analysis to ensure the inclusion of only robust and reliable research. To minimize biases and ensure accuracy, two authors (J-N and C-A) independently conducted the quality assessment, while any discrepancies were resolved through arbitration by a third author (P-M-M).

Quantitative Analysis

All gathered data were synthesized using the Review Manager 5.3.1 program. The variables under consideration were sports performance indices, specifically reaction time and measures of decision-making. The data consisted of continuous mean (M), standard deviation (SD), and the number of participants (n) from each study. For each study, effect sizes (difference between standardized means) with 95% confidence intervals (CIs) were calculated, representing the difference in mean changes after the intervention (pre vs. post). Effect size interpretations were classified as small (0.2>), moderate (0.5>), and large (0.8>) effects based on predetermined cut-off values. This approach allows us to quantitatively evaluate the impact of the interventions on sports performance.

To gauge the heterogeneity among the included studies, the I2 statistic was employed, providing a quantitative measure of inter-study inconsistency. Studies with an I2 value between 25% and 50% were considered to have low

heterogeneity, between 50% and 75% as moderate heterogeneity, and an I2 value greater than 75% as high heterogeneity. This assessment enables us to ascertain the level of variability among the studies and aids in the interpretation of the meta-analysis results. Through this systematic and evidence-based approach, we aim to provide research readers with comprehensive and reliable insights into the effects of interventions on sports performance indices, fostering a better understanding of their potential impact in this field.

Results

Qualitative Analysis

The methodological quality of the selected studies was rigorously assessed using the TESTEX checklist, a validated tool for evaluating study quality and reporting in exercise training studies. Each study underwent thorough evaluation, and all of them achieved a high score of 10 points, indicating robust methodological rigor and comprehensive reporting (Table 1).

Table 1. Results of quality analysis according to TESTEX

Author (year)	A	B	C	D	E	F	F*	F**	G	H#	H##	I	J	K	M	Total
Miarka et al. (2016)	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	10
Miarka, Brito, et al. (2018)	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	10
Antonietto et al., (2019)	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	10

Note.: Yes = 1 point; No = 0 points; A - Specified eligibility criteria; B - Participants Randomly Assigned; C Allocation hiding; D Similar groups on the baseline; E Accessor blindness; F Measures assessed in 85% of the patients; G Intention-to-treat analysis; H Statistical comparisons between groups reported; I Point measures and reported variability measures; J Monitoring of activities in control groups; K Relative exercise intensity remained constant; M Exercise volume and energy expenditure; * > 85% adherence; **reported adverse effects; *** assistance % notified; # for main results; ##for secondary results.

Table 2 presents a concise summary of the included studies, providing essential details such as the number of

participants, gender distribution, competitive level, specific event, number of fights, and duration of each fight.

Table 2. Studies related to movement time and related aspects (number of participants, gender, competition level, event, number of matches, and duration).

Study	Participant numbers	Gender	Competition level	Event	Number of combats	Duration
Miarka et al. (2016)	4194	Male	Internacional	UFC	2097	3 Round 5' each
Miarka, Brito, et al. (2018)	364	Male	Internacional	UFC	678	Combat not finished by points
Antonietto et al. (2019)	364	Male	Internacional	UFC	678	Combat finished by TKO/KO or Finalization

These crucial parameters aid in contextualizing the findings and understanding the characteristics of the participants and the nature of the studied MMA matches. This comprehensive approach ensures the reliability and validity of the research outcomes and supports evidence-based conclusions for the scientific community.

Meta-analysis

Figure 2 displays the synthesized findings concerning the total time of high intensity in bouts that ended by TKO/submission and rounds won by score, comparing the first vs. the second rounds. The analysis revealed a statistically significant difference between the second and third rounds (p = 0.01).

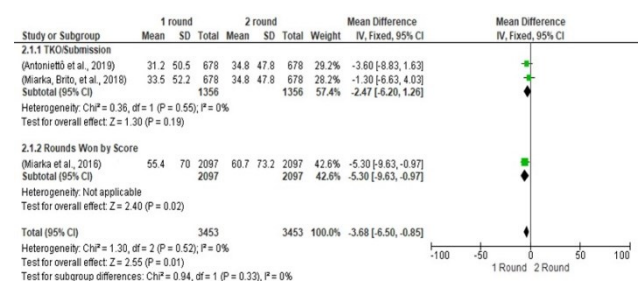


Figure 2. Meta-analysis considering the studies on the total time of high intensity of the first and second rounds in matches and ended via TKO/submission and rounds won by score.

The results presented in Figure 2 visually demonstrate a substantial influence on a higher volume of high-intensity actions during the second round in comparison to the first round, with an average effect of -3.68 (-6.50, -0.85). These effect size values indicate a meaningful impact on performance between the two rounds. Notably, the meta-analysis

did not detect any notable heterogeneity among the studies included in the analysis, suggesting a consistent and coherent body of evidence.

Through this systematic integration of data, the meta-analysis provides valuable insights into the variations in high-intensity actions during the first and second rounds of MMA bouts. These findings contribute to a more comprehensive understanding of the physiological demands and performance dynamics in the sport, potentially informing tailored training strategies and enhancing overall athlete preparation. Figure 3 presents the synthesized findings regarding the total time of high intensity, comparing the second vs. the third round in bouts that concluded by TKO/Submission and judged by score. The analysis revealed a highly significant difference between the second and third rounds ($p = 0.00001$).

Figure 3 shows the meta-analysis considering the studies on the total time of high intensity of the second and third rounds in matches and ended via TKO/submission and rounds won by score.

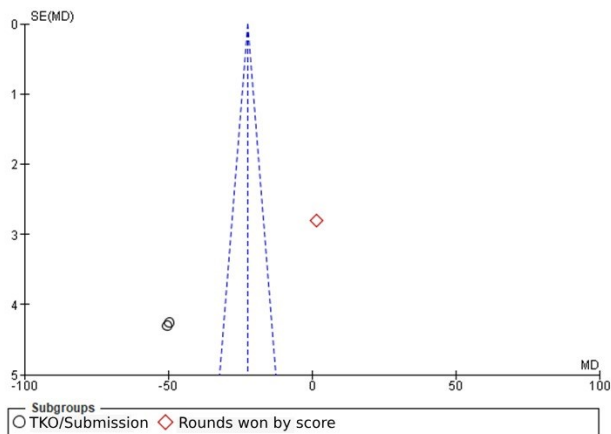


Figure 3. Meta-analysis considering the studies on the total time of high intensity of the second and third rounds in matches and ended via TKO/submission and rounds won by score.

The results depicted in Figure 3 visually demonstrate a substantial impact on a greater volume of high-intensity actions during the third round in comparison to the second round, with an average effect of -19.18 (-22.54, -15.82). These effect size values indicate a substantial and meaningful difference in performance between the two rounds. Notably, the meta-analysis did not detect any notable heterogeneity among the studies included in the analysis, suggesting a consistent and coherent body of evidence. The highly significant difference observed between the rounds underscores the critical importance of effectively managing energy and performance levels throughout the course of a match, especially during the decisive third round. Figure 4 illustrates the combined findings pertaining to the total time of low intensity, comparing the first round vs. the second round in matches concluded by TKO/Submission and finished by score. The analysis revealed a non-significant difference between the second and third rounds ($p = 0.58$).

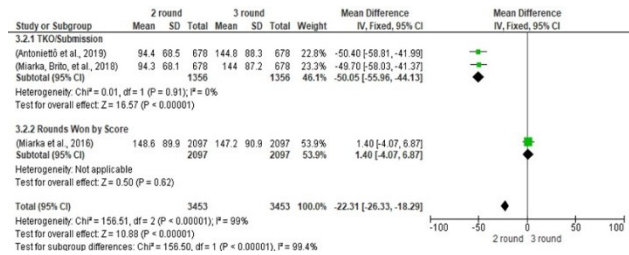


Figure 4. Meta-analysis considering the studies on the total time of low intensity of the first and second rounds in matches and ended via TKO/submission and rounds won by score.

The results visually depicted in Figure 4 indicate a notable impact on a smaller volume of low-intensity actions during the second round compared to the first, with an average effect of -1.07 (-4.86, -2.72). These effect size values indicate a moderate but non-significant difference in performance between the two rounds. Importantly, the meta-analysis detected no significant heterogeneity among the studies included in the analysis, suggesting consistency and robustness in the available evidence.

Through the systematic synthesis of data, this meta-analysis offers valuable insights into the variations in low-intensity actions during the first and second rounds of MMA matches. While the effect size indicates a slight difference, the lack of statistical significance between the rounds emphasizes the need for further exploration and consideration of other influencing factors. The findings contribute to a deeper understanding of the physiological demands and performance dynamics in the sport, guiding coaches and athletes in their training strategies to optimize performance throughout a match.

Figure 5 presents the synthesized findings concerning the total time of low intensity, comparing the second vs. the third round in matches concluded by TKO/submission and rounds won by score. The analysis revealed a highly significant difference between the second and third rounds ($p = 0.00001$).

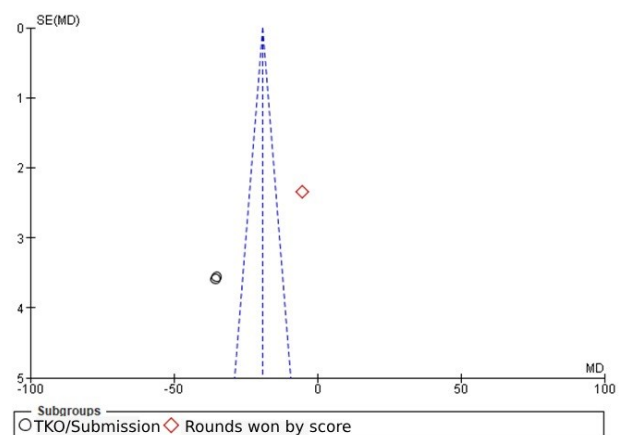


Figure 5. Meta-analysis considering the studies on the total time of low intensity of the second and third rounds in matches and ended via TKO/submission and rounds won by score.

The results depicted in Figure 5 visually demonstrate a

substantial impact on a smaller volume of low-intensity actions during the third round in comparison to the second round, with an average effect of -22.31 (-26.33, -18.22). These effect size values indicate a significant and meaningful difference in performance between the two rounds. Notably, the meta-analysis did not detect any notable heterogeneity among the studies included in the analysis, affirming the consistency and robustness of the available evidence. The highly significant difference observed between the rounds highlights the crucial importance of managing energy and performance levels effectively as the match progresses, especially during the decisive third round.

Discussion

To enhance their performance in MMA, athletes must attain a high level of physical and technical prowess. Understanding the time-motion structure of the sport is crucial for precise training prescription (Franchini 2020; Miarka et al. 2018), which leads to improvements in conditioning through specific training for MMA athletes. Such training aims to simulate the technical and tactical demands of combat while respecting the sport's complexity in terms of spatial and temporal dynamics, which evolve throughout each five-minute round (Kirk et al. 2021; Miarka, Coswig, et al. 2016). Consequently, this systematic review and meta-analysis aimed to describe the ratios of total combat time spent in high and low-intensity actions during matches consisting of three completed rounds and matches that concluded in the first, second, or third rounds through submission or TKO/KO methods among professional MMA athletes.

The primary results of this meta-analysis unveiled a notable difference in effect size between the second and third rounds in terms of total high-intensity time. As the rounds progress, the importance of impressing judges with high-intensity actions, such as takedowns, knockouts, or submissions, becomes increasingly critical (Kirk et al. 2021; Miarka et al. 2018). Remarkably, the majority of fights (59%) concluded in the third round, followed by 13% in the second round and 28% in the first (Del Vecchio, da Silva, et Miarka 2015). Among regional athletes, fights concluding in the third round exhibited a predominant use of high-intensity actions on the ground, with the rear naked choke being the most frequently employed submission method (Miarka, Coswig, et al. 2016). When considering weight categories, rooster weights demonstrated longer high-intensity ground efforts compared to welterweight, light heavy-weight, and lightweight categories (Sterkowicz-Przybycień et al., 2017). Factors that differentiated winning and losing athletes in the third round included half-guard advances, mounting on the side, and taking the back, highlighting the importance of developing these skills for success in MMA (James et al. 2017). Given that the third round often proves decisive for victory, MMA athletes must develop a high physical capacity to sustain grappling and striking throughout all

three rounds (Kirk et al. 2021; Miarka et al. 2018). Understanding the intensity variation in different phases of combat is essential for effective training planning (Bridge et al. 2018).

In contrast, the second round displayed a greater proportion of high-intensity actions compared to the first round. Featherweights demonstrated longer high-intensity ground efforts compared to lightweights, contributing to this difference (Sterkowicz-Przybycień et al. 2017). Athletes tend to engage in more low-intensity actions during the first round, utilizing this time to analyze opponents and gauge the distances necessary for effective strikes or clinch control/takedowns (Kirk et al. 2021; Miarka et al. 2018). Regarding the total time of low intensity, the third round exhibited a greater effect compared to the second round. Low-intensity periods during MMA bouts may serve strategic purposes, such as controlling the opponent, recovering, or receiving feedback from coaches (Kirk et al. 2021; Miarka et al. 2018). Winning athletes may strategically avoid exposing themselves to their opponents during these periods, while losing athletes seek to evade disadvantageous positions that could lead to defeat (Kirk et al. 2021; Miarka et al. 2018). Bouts decided by unanimous and split decisions exhibited a greater total time of low intensity compared to those ending by KO/TKO and submission due to their longer duration (James et al. 2017). Furthermore, specific weight categories, such as flyweights and lightweights, demonstrated longer total time of low intensity compared to roosters and heavyweights (Sterkowicz-Przybycień et al. 2017).

Mixed Martial Arts (MMA) encompasses two distinct athlete profiles: strikers and grapplers, with combat outcomes often associated with TKO/KO or submission finishes, both of which involve high-intensity actions. To optimize fight results, Miarka et al. (2016) proposed a specific training program focusing on quick TKO/KO finishes, employing a particular pace pattern. This strategy involved attempting nine strikes in seven seconds during the first round, 11 strikes in 10 seconds during the second round, and 11 strikes every 20 seconds in the third round, all at high intensity. The pace-based training approach aims to ensure athletes can meet the metabolic demands of the fight before its conclusion, ultimately increasing the likelihood of success (Miarka, Vecchio, et al. 2016).

While this meta-analysis offers valuable insights, it has certain limitations that should be considered. The reliance on video observation for data collection may introduce inherent biases, despite the efforts to minimize them through the use of experienced investigators (James et al. 2017). Video observation can introduce observer bias, where the person collecting the data might interpret actions differently (James et al. 2017). To mitigate this bias, experienced investigators were employed in this study, which is a best practice. Additionally, interrater reliability tests were conducted to ensure consistency among observers (James et al. 2017). The choice of which matches or athletes to include in the analysis can introduce selection bias. To minimize this

bias, clear inclusion and exclusion criteria were established before data collection, and these criteria were consistently applied (James et al. 2017). Additionally, the focus of this meta-analysis was on specific performance indices, and further investigations could explore additional variables to comprehensively understand the dynamics of MMA bouts.

Regarding the variable of the total time of high intensity, our findings indicated a moderate correlation coefficient of 0.69 for the comparison between the first and second rounds and a slightly stronger correlation coefficient of 0.75 for the comparison between the second and third rounds. For the variable of the total time of low intensity, the correlation coefficients were 0.54 for the first and second rounds and a notably stronger correlation of 0.91 for the comparison between the second and third rounds. These correlation coefficients suggest that the patterns of high and low-intensity actions may differ between the rounds, warranting further investigation into the physiological and strategic implications. The meta-analysis sheds light on the importance of pace and intensity management in MMA, particularly in the pursuit of TKO/KO or submission finishes. The proposed training approach and the use of experienced investigators in time-motion analysis contribute to enhancing athletes' performance and understanding of the dynamics of MMA combat. The observed correlation coefficients offer valuable insights into the temporal variations of high and low-intensity actions throughout the rounds, providing a foundation for future research and training strategies in this demanding and multifaceted combat sport.

The findings of this systematic review hold significant practical implications for combat sports science, coaches, athletes, and strength and conditioning specialists. The time-motion analysis results provide valuable insights for adjusting combat simulations and refining athletes' strategies within specific pacing patterns (Miarka, Coswig, et al. 2016). One notable observation is the progressive increase in intensity and key actions throughout the rounds. This emphasizes the importance of gradually increasing the training load over the course of the rounds to replicate the real life demands of a fight. Coaches should design training programs that allow for longer durations of high-intensity actions or reduced recovery time between actions to simulate a state of fatigue and metabolic stress, while addressing the technical-tactical needs of the later rounds. Special attention should be given to the third round, as it has a decisive impact on the outcome of the fight. Therefore, a specific strategy for the third round is recommended, considering the potential for metabolic fatigue (James et al. 2017). Targeted interval training can be developed, incorporating alternating high-intensity actions, such as strikes or takedowns, interspersed with low-intensity actions like spatial displacement or strategic pauses (Miarka, Coswig, et al. 2016). This approach aims to improve athletes' physical capabilities, including oxygen consumption and anaerobic power (Franchini 2020), while enhancing their tactical plans based on both physical and mental capabilities (Miarka, Coswig, et al. 2016).

However, it is essential to acknowledge limitations associated with this research. The reliance on video observation for data collection may introduce biases, despite efforts to minimize them through the involvement of experienced investigators (James et al. 2017). Additionally, the focus of this meta-analysis was primarily on specific performance indices, and further research could explore additional variables to gain a comprehensive understanding of MMA dynamics. The findings of this meta-analysis provide valuable guidance for coaches and athletes in developing effective training strategies for MMA. By understanding the progressive increase in intensity throughout rounds and the critical role of the third round, coaches can tailor training programs to enhance athletic performance and tactical preparedness. However, future research should address the identified limitations to further enrich the knowledge base of MMA and optimize training approaches for combat sports athletes.

Conclusions

This research provides valuable insights into MMA performance; however, it is essential to acknowledge the inherent limitations associated with the study methodology. Caution is warranted when interpreting the results. This meta-analysis focused on specific performance indicators, highlighting the need for future investigations to comprehensively understand all aspects of MMA dynamics. Understanding the progressive increase in intensity throughout rounds and recognizing the critical role of the third round can prompt coaches to adjust their strategies and training programs, ultimately enhancing athletic performance and strategic acumen. Nevertheless, it is imperative that future research addresses the identified limitations to further enrich the knowledge base of MMA and optimize training approaches for combat sports athletes.

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