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Effect of different work-to-rest ratios on physiological and perceptual responses to kickboxing specific high intensity intermittent exercise in elite male kickboxers

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ORIGINAL PAPER

Abstract

This study examined how different rest periods during high-intensity, intermittent kickboxing exercise affect physiological and perceptual responses in nine elite kickboxers. After being informed about the nature of the study, the athletes performed three exercise sessions consisting of kicks and punches with 1:1, 1:2 and 1:3 work-to-rest ratios in a randomised order, with 48 hours between each session. Their heart rate (HR) was measured at rest, immediately after, and six minutes after each exercise protocol. The athletes performed a countermovement jump (CMJ) test before and after exercise. Rating of perceived exertion (RPE) and muscle soreness (PMS) were measured immediately after exercise. The number of kicks and punches performed by the athletes was recorded. Different rest ratios did not affect heart rate ($F_{2,14} = 1.08$, $p = 0.36$). There was no difference in the number of kicks or punches performed by the athletes among different rest intervals ($F_{2,16} = 1.59$, $p = 0.24$; $F_{2,16} = 1.70$, $p = 0.21$). Exercises with different rest periods did not induce changes in CMJ ($F_{2,16} = 0.69$, $p = 0.52$). While the PMS responses of the athletes did not differ among the different rest intervals ($F_{2,16} = 1.27$, $p = 0.31$), the RPE values did differ among the exercises with the different rest intervals ($F_{2,16} = 3.70$, $p = 0.04$). The athletes presented higher RPE values with the 1:1 interval than with the 1:2 and 1:3 intervals ($p < 0.05$). Kickboxing-specific HIIE with different rest intervals did not induce any physiological or performance differences, but led to a higher RPE following a short rest interval than a long one. These findings highlight that perceived difficulty (i.e. RPE) increases as the rest period shortens. Thus, there is a need to optimise HIIE protocols for targeted results and subjective recovery needs in this sport.

Keywords: Martial arts; combat sports; HIIT; HIIE; rest intervals; exercise physiology; kick test.

Efecto de diferentes ratios trabajo/descanso sobre las respuestas fisiológicas y perceptivas al ejercicio intermitente de alta intensidad específico del kickboxing en kickboxers masculinos de élite

Resumen

Este estudio evaluó los efectos de diferentes períodos de descanso durante el ejercicio de kickboxing intermitente de alta intensidad sobre las respuestas fisiológicas y perceptivas en nueve kickboxers de élite. Los atletas fueron informados sobre la naturaleza del estudio y, tras

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Resumo

Este estudo avaliou os efeitos de diferentes períodos de descanso durante o exercício de kickboxing intermitente de alta intensidade sobre as respostas fisiológicas e percetivas em nove kickboxers de elite. Os atletas foram informados sobre a natureza do estudo e, após se

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Contributions: Bayram Ceylan (ABCFGHLM), Furkan Öztürk (AM), Hasan Basri Taşkın (ABF), Ibrahim Ouergui (AMN), Bilgehan Baydil (AMN). Codes according to CRediT (Contributor Roles Taxonomy): (A) Conceptualization. (B) Data curation. (C) Formal Analysis. (D) Funding acquisition. (E) Investigation. (F) Methodology. (G) Project administration. (H) Resources. (I) Software. (J) Supervision. (K) Validation. (L) Visualization. (M) Writing – original draft. (N) Writing – review & editing.

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familiarizarse con las mediciones antropométricas, realizaron tres sesiones de ejercicio que consistieron en realizar patadas y puñetazos con ratios de trabajo-descanso de 1:1, 1:2 y 1:3 en orden aleatorio, con intervalos de 48 horas. Se midió la frecuencia cardíaca (FC) en reposo, inmediatamente y 6 minutos después de cada protocolo de ejercicio, y se realizó una prueba de salto con contramovimiento (CMJ) antes y después del ejercicio. La percepción del esfuerzo (RPE) y el dolor muscular (PMS) se midieron inmediatamente post-ejercicio. Se registraron el número de patadas y puñetazos realizados. Las diferentes ratios de descanso no afectaron a la FC ($F_{2,14}$ = 1,08, p = 0,36). El número de repeticiones de patadas y puñetazos no difirió entre los diferentes intervalos de descanso ($F_{2,16}$ = 1,59, p = 0,24; $F_{2,16}$ = 1,70, p = 0,21). Los ejercicios con diferentes períodos de descanso no indujeron cambios en el CMJ ($F_{2,16}$ = 0,69, p = 0,52). Si bien las respuestas PMS no difirieron entre los diferentes intervalos de descanso ($F_{2,16}$ = 1,27, p = 0,31), los valores de RPE sí difirieron ($F_{2,16}$ = 3,70, p = 0,04), obteniendo valores más altos con 1:1 que con 1:2 y 1:3 (p < 0,05). En conclusión, el HIIE específico para kickboxing con diferentes intervalos de descanso no indujo ninguna diferencia fisiológica o de rendimiento, pero condujo a un RPE más alto tras un intervalo de descanso corto en comparación con intervalos de descanso más largos. Estos hallazgos ponen de relieve que la RPE aumentó a medida que se acortaba el período de descanso. Por ello, es necesario optimizar los protocolos de HIIE para los obtener resultados deseados y atender las necesidades subjetivas de recuperación que presenta en este deporte.

Palabras clave: Artes marciales; deportes de combate; HIIT; HIIE; intervalos de descanso; fisiología del ejercicio; test de patada.

familiarizarem com as medições antropométricas, realizaram três sessões de exercício que consistiram em dar chutes e socos com rácios de trabalho-descanso de 1:1, 1:2 e 1:3 em ordem aleatória, com intervalos de 48 horas. A frequência cardíaca (FC) foi medida em repouso, imediatamente e 6 minutos após cada protocolo de exercício, e um teste de salto com contra-movimento (CMJ) foi realizado antes e após o exercício. A percepção do esforço (RPE) e a dor muscular (PMS) foram medidas imediatamente após o exercício. O número de chutes e socos realizados foi registado. As diferentes proporções de descanso não afetaram a FC ($F_{2,14}$ = 1,08, p = 0,36). O número de repetições de chutes e socos não diferiu entre os diferentes intervalos de descanso (F2,16 = 1,59, p = 0,24; $F_{2,16}$ = 1,70, p = 0,21). Os exercícios com diferentes períodos de descanso não induziram alterações no CMJ ($F_{2,16}$ = 0,69, p = 0,52). Embora as respostas PMS não tenham diferido entre os diferentes intervalos de descanso ($F_{2,16}$ = 1,27, p = 0,31), os valores RPE diferiram ($F_{2,16}$ = 3,70, p = 0,04), obtendo valores mais elevados com 1:1 do que com 1:2 e 1:3 (p < 0,05). Em conclusão, o HIIE específico para kickboxing com diferentes períodos de intervalos de descanso não induziu nenhuma diferença fisiológica ou de desempenho, mas levou a um RPE mais alto após um intervalo de descanso curto em comparação com intervalos de descanso mais longos. Essas descobertas destacam que a dificuldade percebida (ou seja, o RPE) aumentou à medida que o período de descanso foi encurtado. Portanto, é necessário otimizar os protocolos de HIIE para obter os resultados desejados e atender às necessidades subjetivas de recuperação apresentadas neste desporto.

Palavras-chave: Artes marciais; desportos de combate; HIIT; HIIE; intervalos de descanso; fisiologia do exercício; teste de chute.

1. Introduction

Kickboxing is a dynamic combat sport that combines elements of traditional martial arts and boxing. It involves a variety of striking techniques using both the upper and lower body, making it a full-body workout that requires a high level of physical fitness and technical skill (Ouergui et al., 2013). The sport is characterized by its high-intensity acyclic nature, with athletes often engage in bouts that demand quick bursts of energy, agility, and strength (Ouergui et al., 2016).

Time-motion analysis in kickboxing has revealed that the sport consists of intermittent periods of high-intensity activity (i.e., offensive and defensive actions) interspersed with short rest intervals (i.e., during active rest and referee interruptions), resulting into effort to pause ratios varying from 1:1 to 1:2 (Calabrese et al., 2024; Ouergui et al., 2014). This pattern of activity is crucial for understanding the physiological demands placed on athletes during competition. To be able to perform repeatedly high-intensity actions during combats with varying effort:pause ratios according to time-motion analysis during combat sports contests (Vasconcelos et al., 2020), kickboxers should achieve a high level of physical and physiological capacities through the use of diverse specific training strategies (Ouergui et al., 2021).

Among various exercise modalities, the high intensity interval exercise (HIIE) is particularly relevant in kickboxing, as it mimics the nature of the sport, requiring athletes to perform at their maximum during active periods and recover rapidly during rest periods (Hall et al., 2024; Vasconcelos et al., 2020). Additionally, previous research has indicated that kickboxing training regimen should focus on high-intensity interval training modalities, due to their benefits in increasing aerobic fitness which positively influences the recovery of athletes — and increasing anaerobic power and capacity — which impacts scoring actions and their capacity to repeat high-intensity actions (Ouergui et al., 2021). In this consideration, previous research has investigated the effect of sprint interval training program on the recovery and oxygen kinetics of kickboxing athletes

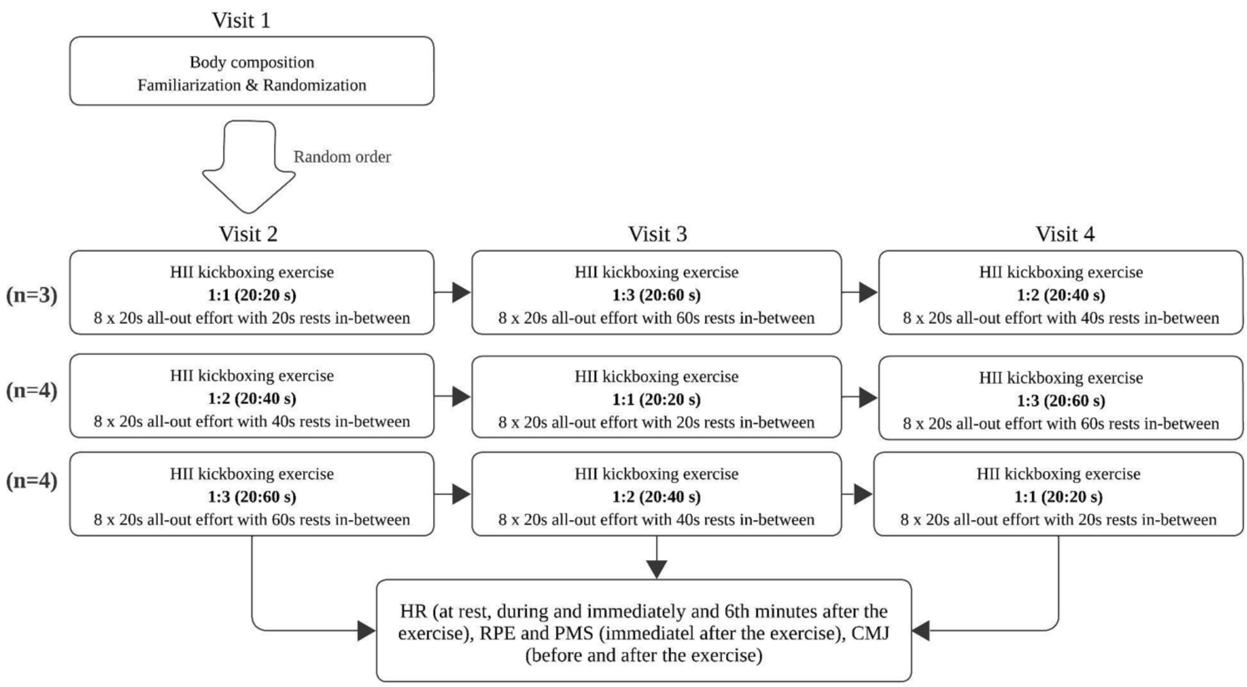
(Hall et al., 2024). The authors indicated enhanced recovery time and aerobic performance adaptations in athletes following a 9-session sprint exercise period. Despite being studied in different combat sports (Ceylan & Balci, 2023; Zhang et al., 2024), the effects of varying rest intervals within HIIE have not been investigated in kickboxing. Moreover, to our current knowledge, no study has investigated the effect of different rest ratios during a specific HIIE using kickboxing techniques on physiological and perceptual responses. Determining these responses could help coaches to arrange their training plans (Gavrlilovic et al., 2016; Ouergui et al., 2016) to make them more effective and productive. Thus, the present study aimed to identify the physiological and perceptual responses to HII kickboxing specific exercise with different rest periods. Specifically, the study focused on measuring changes in heart rate, countermovement jump performance, the number of kicks and punches executed during different exercise protocols, and the athletes' ratings of perceived exertion and muscle soreness. We hypothesized that athletes would present higher physiological and perceptual responses and lower punch and kick repetition numbers following shorter rest interval (i.e., 1:1) compared to longer rest interval (i.e., 1:2 and 1:3).

2. Methods

2.1. Study design

This is a repeated measures randomized cross-over study design in which participants were evaluated in terms of physiological and perceptive responses in three different specific kickboxing exercise protocols. Once athletes being informed about the nature of the study and familiarized with the testing procedure, body composition measurements were performed. Then, athletes were randomly assigned to exercises with different rest ratios during the rest 3 visits with 48h intervals for kickboxing specific HIIE using three different work-to-rest ratios as follows: 20s work and 20s rest, 20s work and 40s rest, and 20s work and 60s rest, respectively. The study design is presented in Figure 1.

Figure 1. Study Design; Athletes were assigned to each exercise with different rest ratios in a randomized order. Although the study started with 11 athletes, it was completed with n = 9.

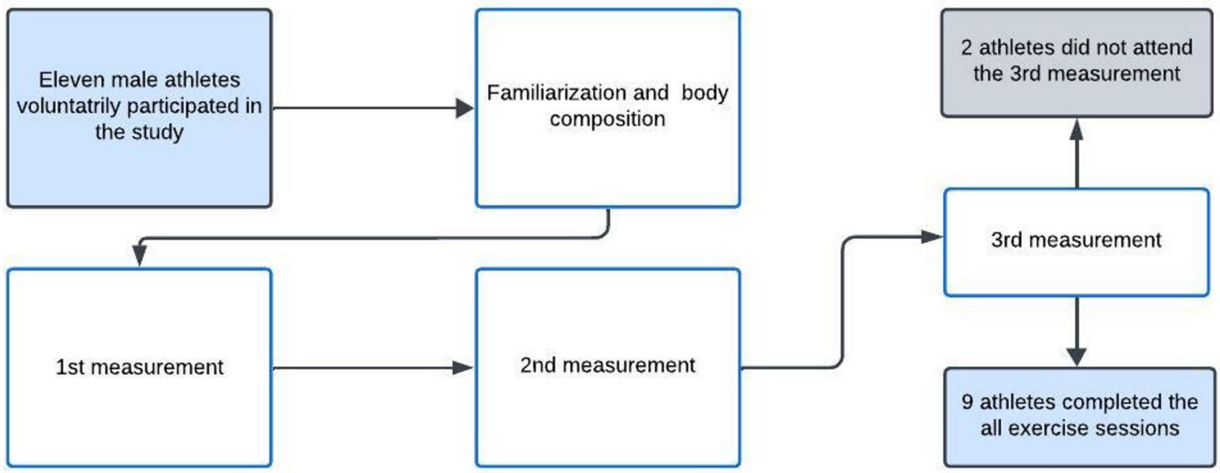


2.2. Participants

Eleven elite male kickboxing athletes voluntarily participated in this study. Figure 2 illustrates the phases and process related to the participants. The sample size was justified via a post-hoc power analysis using G*Power (version 3.1.9.7; Universität Kiel, Kiel, Germany) for a repeated measures ANOVA (within-subjects design). Parameters included a type I error rate of 0.05, an assumed correlation of 0.9 among repeated measures, and an effect size of f=0.40, classified as large (Perugini et al., 2018). Analysis indicated that 9 participants were enough to observe significant, large-sized effects (actual power of 0.99). Athletes had to meet the following criteria in order to participate in the study: having medals at international competitions (including World Championship, European Cups and international tournaments) for the last 2 years, being a weight-stable period and having no musculoskeletal injuries that could adversely affect their regular participation to training sessions.

The participants had an average kickboxing experience of 7.3±1.7 years. As the participants were elite-level athletes, they were familiar with the exercises performed in the study. They also completed a familiarisation session involving one set of each exercise at three different work-to-rest ratios. A written informed consent form was obtained from each athlete before the commencement of the experiment, and the study was conducted in accordance with the latest version of the Declaration of Helsinki. Ethical approval was received from the Kastamonu University Clinical Research Ethics Committee (143-17.01).

Figure 2. The flow chart of the study



2.3. Measures

Body composition: Athletes' body composition was measured with a bio impedance device (BF511, Omron) in the morning in accordance with the suggestions of the manufacturer. Body mass, body fat percentage, muscle percentage, and body mass index (BMI) were recorded for each athlete. Athletes' body height was measured with a stadiometer to the nearest 0.1 cm.

Heart rate measurement: Athletes' heart rate (HR) was measured using HR monitor (Seego, Realtrack Systems, Almeria, Spain) at rest, immediately after each set during the exercise and at the 6th minute following the exercise. Athletes HR was also recorded for HR mean and peak.

Counter-movement Jump Test: Participants were asked to perform quick countermovement without arm swing to a self-selected depth, followed by explosive upward propulsion to achieve maximum jump height movement while maintaining the identical take-off and landing positions. The same researcher filmed the jumps with a mobile phone mounted on a tripod (iPhone Xs, Apple) at a sampling rate of 240 Hz, using the My Jump 2 App, 1.5 m away from the athlete. Athletes performed three trials with 30s rests and the highest jump height was used for the analysis. The application has been demonstrated to be a trustworthy instrument for measuring jump performance (Cruvinel-Cabral et al., 2018; Gençoğlu et al., 2023). The measurements in the current study showed high intraclass correlation (ICC=0.905, 95% CI=0.786-0.974).

Perceptual Responses: Immediately after the exercise, athletes rated rating of perceived exertion (RPE) on 10-point facial scale, ranging from 0 (really easy) to 10 (maximal) (van der Zwaard et al., 2023). They also rated perceived muscle soreness (PMS) of the lower limbs with a scale from 0 (absence of soreness) to 10 (very intense soreness) (Ceylan et al., 2023).

Kickboxing-Specific High Intensity Exercise: HII kickboxing exercise was designed from a kickboxing-specific test developed by Gençoğlu et al. (2023) which mimics the most commonly used punch and kick techniques performed in both international official (Ouergui et al., 2013) and simulated (Ouergui et al., 2016) kickboxing matches. The exercise consisted of performing the straight left punch, right-roundhouse kick, straight right punch, and left-roundhouse kick techniques, respectively. We demanded athletes to perform all strikes all-out (as many as possible in the given duration). Athletes were required to follow the technique sequence as previously determined, which was monitored by a qualified coach. Also, the strike areas were determined for each athlete and they were encouraged to strike those specific areas during each repetition. Athletes performed this exercise 8 sets x 20s work with 20s, 40s, and 60s rest intervals (Ouergui et al., 2021) at each different visit, with the order was determined randomly. Athletes' performance was monitored by one of the researchers during all measurements and the researcher counted the kick and punch repetition numbers for each set.

2.4. Statistical analysis

Statistical analysis was performed using JASP software (version 0.15.0.0). The Shapiro–Wilk test and descriptive methods using skewness and kurtosis coefficients were used to check the normality of data, which were subsequently presented as M±SD. Descriptive statistics and 95% confidence intervals (CIs) were used to present athletes' characteristics. A two-way analysis of variance (ANOVA) with repeated measurements (rest intervals × measurement times) was used to determine changes in HR (3 rest intervals × 9 measurement times), the repetition number of kick and punch (3 rest intervals × 8 sets), and CMJ (3 rest intervals × 2 measurement times). A one-way repeated measures ANOVA was used to determine changes in HR mean and peak, RPE and PMS among exercises with different rest intervals. Assumptions of sphericity were tested using Mauchly's Test, and when violated, Greenhouse-Geisser correction was applied. In case of significant differences, a post-hoc with holm correction was applied. Eta squared (η^2) was calculated to determine the effect size (ES), using the 0.0099, 0.0588, and 0.1379 considered as small, medium, and large (Cohen, 1988). Statistical significance was set at $p < 0.05$.

3. Results

The descriptive data of the athletes' characteristics are presented in Table 1.

Table 1. Descriptive characteristics of the participants (n=9)

Variables	Mean ± SD	95% CI
Age (years)	20.2 ± 2.3	18.5-21.9
Body height (cm)	1.75 ± 0.05	1.70-1.78
Body mass (kg)	73.2 ±12.6	63.5-82.9
BMI (kg/m^2)	24.1 ± 3.9	21.0-27.1
Muscle percentage (%)	41.4 ±4.4	40.0-46.8
Body fat percentage (%)	15.2 ± 7.1	9.7-20.7

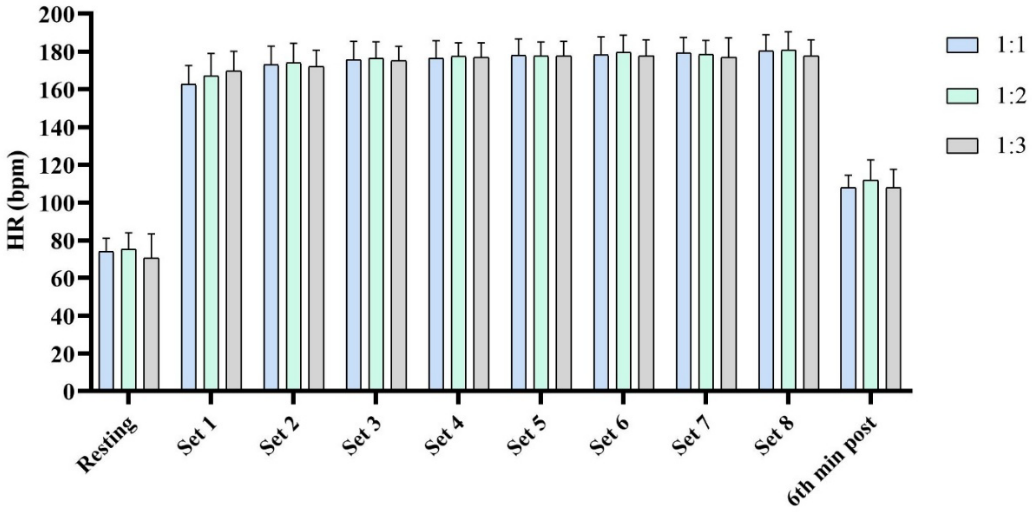
SD=Standard deviation, CI=Confidence interval, BMI=Body mass index

The HR changes during kickboxing specific HIIE with different rest intervals are presented in Figure 3. Repeated measures ANOVA revealed that different rest intervals did not affect HR measured following each set ($F_{2,14}$=1.08, p=0.36, η^2<0.01; ES=Small). Moreover, there was no interaction effect between rest intervals and measurement times on HR ($F_{18,126}$=1.02, p=0.45, η^2<0.01; ES=Small). However, different measurement times resulted in differences in HR ($F_{9,63}$=657.55, p<0.01, η^2=0.98; ES=Large) (Figure 3).

Athletes' HR mean did not differ with different rest intervals ($F_{2,16}$=1.66, p=0.22, η^2=0.17; ES=Large). Athletes' HR mean was 167.33±8.19 beats.min^{-1} during 1:1 work-to-rest ratio, 163.56±8.92 beats.min^{-1} during 1:2 work-to-rest ratio and 161.67±2.35 beats.min^{-1} during 1:3 work-to-rest ratio. Moreover, athletes' HR peak did not change among different rest intervals ($F_{1.10,8.82}$=1.34, p=0.28, η^2=0.14; ES=Large). Athletes' HR peak was 181.33±8.72 beats.min^{-1} during 1:1

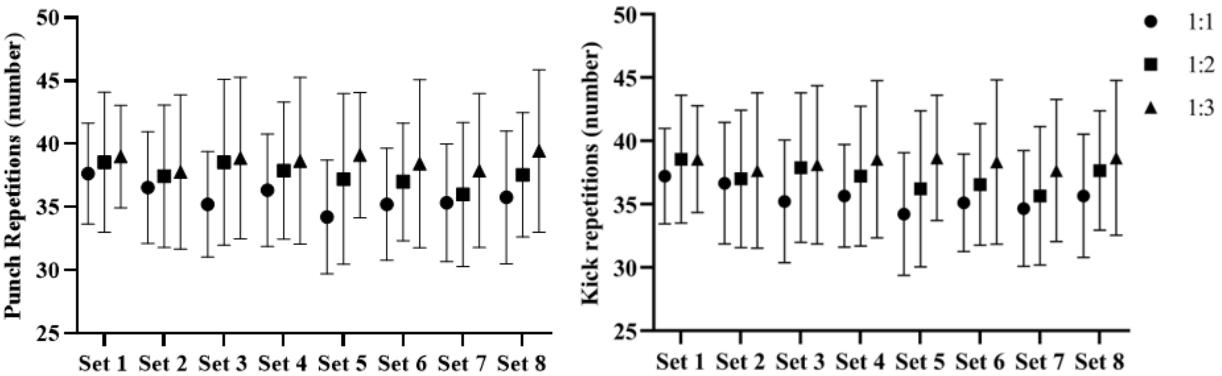
work-to-rest ratio, 182.11±8.75 beats.min^{-1} during 1:2 work-to-rest ratio and 179.11±13.69 beats.min^{-1} during 1:3 work-to-rest ratio.

Figure 3. Athletes' heart rate changes during HII exercises with different rest intervals



Athletes' kick and punch repetition numbers are presented in Figure 4. Different rest intervals did not affect the changes in athletes' kick repetition numbers ($F_{2,16}$=1.59, p=0.24, η^2=0.11; ES=Large). Furthermore, there was no interaction effect between different rest intervals and measurement times on athletes' kick repetition numbers ($F_{14,112}$=1.12, p=0.35, η^2=0.02; ES=Small). Nevertheless, sets significantly affected athletes' kick repetition numbers ($F_{7,56}$=2.22, p=0.04, η^2=0.03; ES=Medium). Athletes' kick repetition numbers showed a downward trend from the 1st to 8th set with 1:1 and 1:2 while they kept the repetition number with 1:3 rest intervals. Additionally, different rest intervals did not affect athletes' punch repetition numbers ($F_{2,16}$=1.70, p=0.21, η^2=0.12; ES=Large). Moreover, rest intervals did not lead to changes in athletes' punch repetition numbers ($F_{7,56}$=1.98, p=0.07, η^2=0.03; ES=Medium). There was no interaction effect of different rest intervals and different sets on athletes' punch repetition numbers ($F_{14,112}$=1.38, p=0.18, η^2=0.03; ES=Small) (Figure 3).

Figure 4. Athletes' kick and punch repetition numbers during HII exercises with different rest intervals



CMJ performance did not differ across different rest intervals ($F_{2,16}$=0.69, p=0.52, η^2=0.04; ES=Small). Measurement times also did not affect athletes' CMJ performances ($F_{1,8}$=1.84, p=0.21, η2=0.03; ES=Small). Moreover, the interaction between different rest intervals and measurement times was not significant ($F_{2,16}$=0.60, p=0.56, η^2=0.03; ES=Small). Athletes' CMJ performances were 32.30±6.20 cm and 32.99±6.84 cm, 32.24±7.75 cm and 33.70±7.70 cm, 33.66±7.11 cm and 33.53±7.28 cm before and after the exercises with 1:1, 1:2 and 1:3 work-to-rest ratios, respectively (Figure 5).

Athletes' RPE responses differed across different rest intervals ($F_{2,16}$=3.70, p=0.04, η^2=0.31; ES=Large). Athletes presented higher RPE following 1:1 work-to-rest ratio (6.55±1.33 a.u) compared to 1:2 (5.56±1.67 a.u) and 1:3 (5.44±1.33 a.u) work-to-rest ratios ($p<0.05$). However, athletes' PMS responses did not differ among different rest intervals ($F_{2,16}=1.27$, $p=0.31$, $\eta^2=0.13$; ES=Large). Athletes classified PMS as 4.11±2.03 a.u, 3.33±1.66 a.u, and 3.67±2.06 a.u following 1:1, 1:2 and 1:3 work-to-rest intervals, respectively (Figure 6).

Figure 5. CMJ performance of the athletes at rest and following the exercise

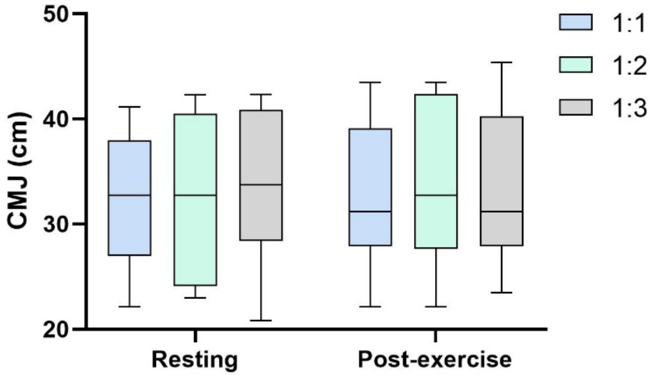
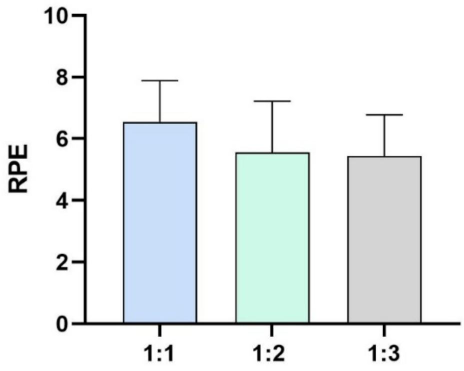


Figure 6. Athletes' rating of perceived exertion responses



4. Discussion

The current study investigated the effect of different rest intervals during HII kickboxing specific exercise on the physiological and perceptual loads. Contrary to our hypothesis, different rest intervals did not induce significant changes in terms of HR, PMS responses and technical performance during the exercises but the effect sizes ranged from moderate to large. However, athletes rated lower RPE following 1:3 and 1:2 work-to-rest ratios compared to 1:1 work-to-rest ratio.

The results demonstrated that different work-to-rest ratios did not significantly affect athletes' HR, with no interaction between rest ratios and measurement times. However, HR significantly varied across measurement times, indicating the influence of exercise progression rather than rest ratio. Average HR was slightly higher during the 1:1 ratio compared to 1:2 and 1:3 ratios, though these differences were not statistically significant (Figure 2). Peak HR also remained stable across all rest conditions. These findings suggest that kickboxing-specific HIIE elicit similar cardiovascular responses regardless of rest interval, with temporal exercise factors being the primary drivers of HR variability.

Previous research by Little and Williams (2007) highlighted that different rest ratios affected perceptual and physiological responses during repeated sprint performance. The authors stated that athletes presented significantly higher HR percentage and RPE with shorter rest period during repeated sprint intervals in soccer players. In a study involving taekwondo athletes, Zheng et al. (2025) found that the RPE increased significantly when the duration of high-intensity exercise exceeded the length of the rest interval. This suggests that athletes are subjected to higher perceptual load at unbalanced work-rest ratios. In the aforementioned study, unlike the present one, the impact of varying rest periods on physical, physiological, and perceptual load outcomes was not investigated. During the course of the study, differences were observed in both rest intervals and work durations across three distinct conditions. It is hypothesized that these variations in work durations may have influenced the results, potentially confounding the effect of different rest periods. In line with this finding, the athletes in the current study presented higher RPE values following short rest period.

In another study, Ceylan and Balci (2023) reported that, during judo-specific HIIE with different rest ratios, shorter rest period (1:1/2) increased HR responses compared to longer rest period (1:3) despite presenting similar change trend during the whole exercise. These phenomenon aligns with the findings showing that HR responses during HIIE tend to plateau after an initial adjustment period, irrespective of rest interval length (Buchheit & Laursen, 2013). This stability might be attributed to the relatively short exercise bouts and the athletes' high fitness levels, which enable them to sustain cardiovascular performance under varying rest conditions (Suzic Lazic et al., 2017). The lack of significant HR differences across ratios may also reflect the nature of kickboxing, where the intermittent and explosive nature of the activity naturally limits excessive cardiovascular drift (Falz et al., 2019).

Athletes' kick and punch repetition numbers were not affected by work-to-rest ratios' variation, suggesting that short-term recovery periods do not substantially influence the ability to maintain performance during repeated HII sets. However, the number of kicks decreased significantly across sets, indicating cumulative fatigue. In contrast, punch repetition numbers remained stable, potentially due to the lower neuromuscular demand (i.e., engaging smaller muscle groups compared to kicks for example) or task-specific adaptations (straight punches are easier to perform compared to kicks even under fatigue). These results are consistent with previous research indicating that performance in short-duration, high-intensity tasks tends to be preserved under varying rest intervals, especially in well-trained athletes (Glaister, 2008). However, in contrast to our findings, Ceylan and Balci (2023) reported that the number of total techniques' repetition was higher with 1:2 and 1:3 work-to-rest ratios compared to 1:1/2 and 1:1 ratios during a judo-specific HIIE. The authors concluded that it may be important to prefer 1:2-1:3 rest ratios in order to keep the performance at the highest level and improve the sustainability of the training in HIIE applied in judo athletes. In another study, the researchers applied judo-specific HIIE with different techniques and work-to-rest ratios (Franchini et al., 2013). The authors stated a decrease in technique repetition from first to last minute and higher technique repetition in the exercise where a technique containing no body rotation was used.

The number of repetitions could not be compared through different studies as each study has different nature in terms of techniques used and work-to-rest ratios. Specifically, in the current study, the exercise used was based on upper and lower body techniques' combination which require greater coordination, balance and apply high cognitive load comparably to isolated techniques. Additionally, due to the high skill level of the athletes, repetition numbers may not have shown significant changes within the different rest ratios (Tomlin & Wenger, 2001). La Monica et al. (2016) implemented repeated high-intensity sprint protocols with varying rest intervals, and reported that total workload and mean power output were significantly higher with long rest intervals compared to short rest intervals. Moreover, the rate of performance decrement was found to be slower when longer recovery durations were provided. These findings highlight the critical role of rest interval duration in optimizing performance outcomes, and underscore the importance of appropriately structuring rest periods in the design of training programs. Furthermore, interval pattern of the HIIE might lead to less afferent feedback, promoting faster recovery during rest periods (Hall et al., 2024).

CMJ performance was unaffected by different rest intervals, with no significant interaction between rest periods and measurement times. These results indicate that the neuromuscular system's ability to perform explosive movements remained stable across all conditions. To the best of our knowledge, there are no previous studies that examined the effect of rest periods on neuromuscular performance. The consistency of CMJ performance before and after exercises suggests that kickboxing-specific HIIE, irrespective of rest ratio, do not induce acute neuromuscular fatigue. The lack of change in CMJ may be explained by the relatively short duration of the sessions and the athletes' training background and thus faster recovery process.

Athletes reported significantly higher RPE scores when the work-to-rest ratio was 1:1 compared to 1:2 and 1:3. This finding highlights the impact of shorter recovery periods on perceived effort during high-intensity interval exercise (HIIE). This can be explained by the fact that the exercise combined upper and lower limb techniques, which may require greater coordination and imply a higher cognitive load (e.g. mental focus). This makes the exercise feel harder and increases RPE, especially when recovery is insufficient. However, perceptual muscle soreness (PMS) scores did not differ among rest conditions, indicating that perceived muscular fatigue was not significantly influenced by varying rest ratios. This is consistent with previous studies showing that soreness is more strongly associated with exercise-induced muscle damage than with acute recovery periods (Cheung et al., 2003). Athletes' high training exposure likely minimised muscle damage (Ehmke et al., 2023), resulting in low, consistent PMS scores across all conditions.

This study has several limitations that should be acknowledged. First, the small sample size (n=9) may limit the generalizability of the findings, despite the post-hoc power analysis indicating sufficient statistical power (actual power of 0.99). Future studies should aim to include a larger and more diverse sample, including female athletes and athletes of varying skill levels, to enhance the external validity of the results. Second, the study only examined acute responses to HIIE, and the long-term effects of different rest intervals on performance adaptations remain unknown. Longitudinal studies are needed to explore how varying rest ratios influence training outcomes over time. Third, the measurement of technical performance (i.e., kick and punch repetitions) was conducted by a single researcher, which may introduce observer bias. Future research should consider using automated or video-based tracking systems to improve the objectivity of these measurements. Additionally, the study did not include blood lactate levels, which could provide further insight into the anaerobic demands of the different protocols. Finally, the lack of a control group or baseline condition limits the ability to compare the effects of HIIE with other training modalities. Future studies should take these issues into consideration, as well as the long-term effects of HIIE with different rest ratios. Despite these limitations, the study provides valuable insights into acute physiological and perceptual responses to kickboxing-specific HIIE with various rest intervals.

5. Conclusion

The present study highlighted that different rest ratios during kickboxing-specific HIIE did not significantly impact HR, technical performance, or neuromuscular responses. However, although statistical significance was not achieved, the observed moderate to large effect sizes (e.g., in HR and kick/punch repetitions) suggest that practically meaningful differences may still exist. Given the limited sample size, these effects may not have reached conventional significance thresholds due to insufficient power. Therefore, the findings should be interpreted with caution, and it is possible that the study was underpowered to detect smaller but meaningful changes. Future research with larger sample sizes is necessary to further explore these potential effects. Shorter rest intervals increased RPE, suggesting potential applications for intensifying training sessions. These findings contribute to optimizing HIIE protocols, balancing performance outcomes and subjective recovery needs in combat sports. In additional, coaches can use RPE scales to optimize high-intensity intermittent exercise interventions with different work-to-rest ratios and to balance, improve and evaluate individually the performance of athletes.

While the different rest ratios did not lead to statistically significant changes in HR, neuromuscular function, or technical performance, the magnitude of the observed effects suggests possible practical relevance. Particularly in applied sport settings, even moderate physiological or technical changes could influence performance over time. Coaches and researchers may consider these trends when designing individualized HIIE protocols, especially in elite athletes with high adaptation thresholds. Thus, future research should explore the longitudinal effects of varying rest ratios on performance adaptations, integrating physiological, psychological, and external factors to provide a comprehensive understanding of HIIE responses in this athletic population and it is also suggested to investigate the differences between different level of athletes and different sexes.

6. Practical applications

Current research findings suggest that perceived difficulty increases as rest periods shorten. Therefore, coaches and athletic performance specialists can develop personalised programmes based on individual rest intervals to accurately evaluate athletes' performance, training efficiency and intensity. While performance outcomes do not differ significantly between HIIT protocols with varying rest intervals for elite athletes, perceived difficulty levels do vary. For this reason, rest intervals can be adjusted both individually and according to team level to differentiate between elite and non-elite athletes. By monitoring parameters such as the optimal work-to-rest ratio, perceived difficulty and heart rate, the most suitable protocol can be determined for each athlete. Thus, optimally designed HIIT protocols are recommended for enhancing athletic performance.

References

Buchheit, M., & Laursen, P. B. (2013). High-Intensity Interval Training, Solutions to the Programming Puzzle. *Sports Medicine*, *43*(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x

Calabrese, J. C., Silva, R. G., Bertuzzi, R., & Lima-Silva, A. E. (2024). Time–Motion and Technical–Tactical Aspects of Glory World Series Matches in the Male Middle-Heavy-Weight Category.

International Journal of Sports Physiology and Performance, *19*(10), 1122–1127. https://doi.org/10.1123/ijspp.2023-0491

Ceylan, B., & Balci, S. S. (2023). The effects of various work-to-rest ratios during high-intensity intermittent exercises on uchi-komi performance and postexercise heart rate and blood lactate in judo athletes. *The Journal of Strength and Conditioning Research*, *37*(6), 1231–1236. https://doi.org/10.1519/jsc.0000000000004386

Ceylan, B., Taşkın, H. B., & Šimenko, J. (2023). Effect of ischemic preconditioning on acute recovery in elite judo athletes: a randomized, single-blind, crossover trial. *International Journal of Sports Physiology and Performance*, *18*(2), 180–186. https://doi.org/10.1123/ijspp.2022-0280

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge.

Cruvinel-Cabral, R. M., Oliveira-Silva, I., Medeiros, A. R., Claudino, J. G., Jiménez-Reyes, P., & Boullosa, D. A. (2018). The validity and reliability of the "My Jump App" for measuring jump height of the elderly. *PeerJ*, *6*, e5804. https://doi.org/10.7717/peerj.5804

Ehmke, A., Binhardi, P. M., Zecchin, A., Aquino, R., & Puggina, E. F. (2023). The effects of high-intensity functional training on muscle damage and recovery capacity in trained individuals. *Revista Andaluza de Medicina del Deporte*, *16*(1-2), 1-7. https://doi.org/10.33155/j.ramd.2023.05.001

Falz, R., Fikenzer, S., Holzer, R., Laufs, U., Fikenzer, K., & Busse, M. (2019). Acute cardiopulmonary responses to strength training, high-intensity interval training and moderate-intensity continuous training. *European Journal of Applied Physiology*, *119*(7), 1513–1523. https://doi.org/10.1007/s00421-019-04138-1

Franchini, E., Panissa, V. L. G., & Julio, U. F. (2013). Physiological and performance responses to intermittent uchi-komi in judo. *The Journal of Strength and Conditioning Research*, *27*(4), 1147–1155. https://doi.org/10.1519/JSC.0b013e3182606d27

Gavrilovic, D., Petrovic, A., Dopsaj, M., Kasum, G., Pajic, Z., & Koprivica, V. (2016). Work and rest peak heart rate variability response during the different technical and tactical situations of elite kickboxers. *International Journal of Performance Analysis in Sport*, *16*(1), 96–110. https://doi.org/10.1080/24748668.2016.11868873

Gençoğlu, C., Ulupınar, S., Özbay, S., Ouergui, I., & Franchini, E. (2023). Reliability and validity of the kickboxing anaerobic speed test. *Research Quarterly for Exercise and Sport*, *94*(3), 715–724. https://doi.org/10.1080/02701367.2022.2048783

Gençoğlu, C., Ulupınar, S., Özbay, S., Turan, M., Savaş, B., Asan, S., & İnce, İ. (2023). Validity and reliability of "My Jump app" to assess vertical jump performance: a meta-analytic review. *Scientific Reports*, *13*(1), 20137. https://doi.org/10.1038/s41598-023-46935-x

Glaister, M. (2008). Multiple-sprint work: Methodological, physiological, and experimental issues. *International Journal of Sports Physiology and Performance*, *3*(1), 107–112. https://doi.org/10.1123/ijspp.3.1.107

Hall, A., Williams, A. K., & Babraj, J. (2024). Training for recovery: Impact of sprint interval training on recovery dynamics and aerobic performance in kickboxing athletes. *Journal of Science in Sport and Exercise*. https://doi.org/10.1007/s42978-023-00273-6

La Monica, M. B., Fukuda, D. H., Beyer, K. S., Hoffman, M. W., Miramonti, A. A., Riffe, J. J., ... & Stout, J. R. (2016). Altering work to rest ratios differentially influences fatigue indices during repeated sprint ability testing. *The Journal of Strength and Conditioning Research*, *30*(2), 400–406. https://doi.org/10.1519/jsc.0000000000001122

Little, T., & Williams, A. G. (2007). Effects of sprint duration and exercise: Rest ratio on repeated sprint performance and physiological responses in professional soccer players. *The Journal of Strength and Conditioning Research*, *21*(2), 646–648. https://journals.lww.com/nsca-jscr/fulltext/2007/05000/effects_of_sprint_duration_and_exercise__rest.63.aspx

Ouergui, I., Benyoussef, A., Houcine, N., Abedelmalek, S., Franchini, E., Gmada, N., Bouhlel, E., & Bouassida, A. (2021). Physiological responses and time-motion analysis of kickboxing: Differences between full contact, light contact, and point fighting contests. *The Journal of Strength and Conditioning Research*, *35*(9), 2558–2563. https://doi.org/10.1519/jsc.0000000000003190

Ouergui, I., Davis, P., Houcine, N., Marzouki, H., Zaouali, M., Franchini, E., Gmada, N., & Bouhlel, E. (2016). Hormonal, physiological, and physical performance during simulated kickboxing combat: Differences between winners and losers. *International Journal of Sports Physiology and Performance*, *11*(4), 425–431. https://doi.org/10.1123/ijspp.2015-0052

Ouergui, I., Hssin, N., Franchini, E., Gmada, N., & Bouhlel, E. (2013). Technical and tactical analysis of high level kickboxing matches. *International Journal of Performance Analysis in Sport*, *13*(2), 294–309. https://doi.org/10.1080/24748668.2013.11868649

Ouergui, I., Hssin, N., Haddad, M., Franchini, E., Behm, D. G., Wong, D. P., Gmada, N., & Bouhlel, E. (2014). Time-motion analysis of elite male kickboxing competition. *The Journal of Strength and Conditioning Research*, *28*(12), 3537–3543. https://doi.org/10.1519/jsc.0000000000000579

Perugini, M., Gallucci, M., & Costantini, G. (2018). A practical primer to power analysis for simple experimental designs. *Revue Internationale de Psychologie Sociale*, *31*(1), 1–23. https://doi.org/10.5334/irsp.181

Suzic Lazic, J., Dekleva, M., Soldatovic, I., Leischik, R., Suzic, S., Radovanovic, D., Djuric, B., Nesic, D., Lazic, M., & Mazic, S. (2017). Heart rate recovery in elite athletes: The impact of age and exercise capacity. *Clinical Physiology and Functional Imaging*, *37*(2), 117–123. https://doi.org/10.1111/cpf.12271

Tomlin, D. L., & Wenger, H. A. (2001). The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Medicine*, *31*(1), 1–11. https://doi.org/10.2165/00007256-200131010-00001

van der Zwaard, S., Hooft Graafland, F., van Middelkoop, C., & Lintmeijer, L. L. (2023). Validity and reliability of facial rating of perceived exertion scales for training load monitoring. *The Journal of Strength and Conditioning Research*, *37*(5), e317–e324. https://doi.org/10.1519/jsc.0000000000004361

Vasconcelos, B. B., Protzen, G. V., Galliano, L. M., Kirk, C., & Del Vecchio, F. B. (2020). Effects of high-intensity interval training in combat sports: A systematic review with meta-analysis. *The Journal of Strength and Conditioning Research*, *34*(3), 888–900. https://doi.org/10.1519/jsc.0000000000003255

Zhang, Z., Xie, L., Ji, H., Chen, L., Gao, C., He, J., Lu, M., Yang, Q., Sun, J., & Li, D. (2024). Effects of different work-to-rest ratios of high-intensity interval training on physical performance and physiological responses in male college judo athletes. *Journal of Exercise Science and Fitness*, *22*(3), 245–253. https://doi.org/10.1016/j.jesf.2024.03.009

Zheng, H., Zhang, G., Zhong, Y., Nassis, G. P., Chen, Z., & Li, Y. (2025). The effects of different work: Rest durations on physiological, neuromuscular, and ratings of perceived exertion responses during taekwondo-specific high-intensity interval training. *Journal of Exercise Science and Fitness*, *23*(2), 141–147. https://doi.org/10.1016/j.jesf.2025.03.002

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