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MONITORING THE SUBJECTIVE INTERNAL LOAD IN ELITE LEVEL KUMITE-KARATE ATHLETES: ROLE OF THE REST PERIODS DURATION, BREATHING TECHNIQUES, AND TRAINING VOLUME

SPREMLJANJE SUBJEKTIVNE NOTRANJE OBREMENITVE PRI VRHUNSKIH KUMITE-KARATE ŠPORTNIKIH: VLOGA TRAJANJA POČITKA, DIHALNIH TEHNIK IN OBSEGA TRENINGA

ABSTRACT

Objectives: Study aimed to investigate interdependent effects of rest periods duration, breathing techniques, and training volume, on the set Rating of Perceived Exertion in elite-level karate athletes. **Equipment and methods:** Nine elite-level athletes (males = 6) participated in this study. We organized six training sessions, each consisting of 200 gyaku-zuki strikes divided into five sets with 40 repetitions per set, with varying rest and breathing techniques (kime, kiai, and without exhalation). The sessions included both short (30 seconds) and long (90 seconds) rest periods, and the training volume was analyzed separately for each of the five sets. Internal load measures were collected from participants during the between-set pauses. **Results:** The three-way within subject ANOVA have showed the that shorter rest ($p = 0.013$, $\eta^2 = 0.561$) and a higher number of sets ($p = 0.000$, $\eta^2 = 0.861$) lead to higher subjective responses compared to longer rest and fewer sets. Contrary, the subfactors of breathing techniques did not show significant effects ($p > 0.05$). **Conclusion:** This study provides insights into the advantages of rest period duration and training volume on subjective load during kumite-karate training sessions for elite-level karate athletes, suggesting that incorporating these factors could be a beneficial approach in designing kumite-karate training.

Keywords: karate training, gyaku-zuki, kime, kiai, World Karate Federation

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IZVLEČEK

Cilji: Študija je bila namenjena raziskovanju medsebojno odvisnih učinkov trajanja počitka, dihalnih tehnik in obsega vadbe na nastavljeno oceno zaznanega napora pri karateistih na elitnem nivoju. **Oprema in metode:** V tej študiji je sodelovalo devet vrhunskih športnikov (moški = 6). Organizirali smo šest treningov, od katerih je vsak obsegal 200 gyaku-zuki udarcev, razdeljenih v pet serij s 40 ponovitvami na serijo, z različnimi tehnikami počitka in dihanja (kime, kiai in brez izdiha). Treningi so vključevali kratke (30 sekund) in dolge (90 sekund) počitke, obseg treninga pa je bil analiziran ločeno za vsakega od petih sklopov. **Meritve notranje obremenitve** so bile zbrane od udeležencev med premori med serijami. **Rezultati:** Tristranska ANOVA znotraj subjekta je pokazala, da krajši počitek ($p = 0.013$, $\eta^2 = 0.561$) in večje število nizov ($p = 0.000$, $\eta^2 = 0.861$) vodita do višjih subjektivnih odzivov v primerjavi z daljšim počitkom in manj nizi. Nasprotno pa podfaktorji dihalnih tehnik niso pokazali pomembnih učinkov ($p > 0.05$). **Zaključek:** Ta študija zagotavlja vpogled v prednosti trajanja časa počitka in obsega treninga glede subjektivne obremenitve med treningi kumite-karateja za vrhunske karateiste, kar nakazuje, da bi lahko bila vključitev teh dejavnikov koristen pristop pri načrtovanju treninga kumite-karateja.

Ključne besede: trening karateja, gyaku-zuki, kime, kiai, Svetovna Karate Zveza

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INTRODUCTION

Monitoring the training load is intricately related to the training configuration variables (intensity, volume, rest duration, etc.) and can be measured through external and internal load indicators. External load involves tracking objective workload measures (i.e., total work), while internal load pertains to the physiological and psychological stress experienced by the athlete in response to the training sessions, ultimately determining both acute and chronic changes in training outcomes (McGuigan et al., 2021; McLaren et al., 2018). Various objective methods, such as heart rate monitoring, blood markers, or maximum oxygen consumption, can be utilized to measure the level of internal load (McLaren et al., 2018). However, despite the demonstrated validity and objectivity of these methods, their practicality is hindered by the need for specific equipment and organizational challenges. Alternatively, a subjective method based on perceived exertion of training (RPE) has been advocated to quantify internal load (McGuigan et al., 2021; McLaren et al., 2018; McLaren et al., 2017). This approach is grounded in notions demonstrating a strong correlation between RPE and physiological (heart rate, lactate, oxygen consumption) as well biomechanical (e.g., kinetic and kinematic variables, electromyography) and psychological (mood state, motivation, mental stress) measures across various types of training (Borg, 1998; Lagally et al., 2004; Milanez et al., 2011; Robertson & Noble, 1997). The use of RPE is based on the idea that athletes can assess their stress levels during exercise, as well as post-training or competition, ensuring a more personalized and nuanced approach to exercise prescription (Eston, 2012). In available literature, there are two types of the RPE, the one collected through training sessions – set RPE, and the one collected > 10 min. after training sessions – session RPE, and it is worth mentioning that the first RPE derivative is much more unexplored (Halson, 2014; Scott et al., 2016).

Karate, renowned globally as an engaging martial art, is defined by explosive, intermittent, and quick movements performed either by the upper or lower part of the athlete's body (Chaabene et al., 2012). Despite the existence of two distinct forms of karate – kumite (sparring) and kata form (technique without an opponent) – a significant portion of research (Beneke et al., 2004; Helmi Chaabène et al., 2014; Iide et al., 2008; Mori et al., 2002) on the physiological and performance analysis of karate athletes has predominantly centered around kumite matches, whether in real competitions or simulations. Results from these studies demonstrate that kumite karate involves brief, high-intensity actions interspersed with extended periods of low-to-moderate-intensity actions, highlighting the involvement of both aerobic and anaerobic pathways in energy production. Consequently, karate can be classified as a sport exhibiting

moderate-intensity interval characteristics (H Chaabène et al., 2015). On the other hand, limited data exist regarding specifics of kumite training and how training configuration affects internal load during training session, especially in elite athletes. Previously, only Milanez and co-workers (2011) explored the correlation between objective (heart rate, blood lactate) and subjective (RPE) measures of internal load during a karate session, noting a strong correlations ($r = 0.91 - 0.96$). However, their study did not exclusively address how interval load is influenced by different training configurations.

Considering the significance of manipulating *training volume* and *rest periods* in designing strength and endurance-focused training, it is logical to presume that such adjustments might influence internal load parameters during skill-based karate training. The available literature on monitoring karate training is very limited, with no studies found that define techniques, sets, and repetitions, or provide clearly structured training regimens. Additionally, it is important to highlight the existence of two distinct *breathing techniques* in karate: kime, involving the firming of the abdominal wall along with a clear and energetic exhale, and kiai, characterized by a brief shout following kime, aiming to channel the martial artist's energy in a specific attack, consequently enhancing levels of strength and speed in the motor action (Kotarska et al., 2019). Although karate coaches frequently underscoring the importance of *breathing techniques* in karate-specific performance, as far as we know, no study has investigated the effects of different karate breathing techniques on internal load parameters to date. Within the experimental sessions, gyaku zuki technique was applied, as the most used technique in the kumite, with 70% and more of the scoring punches are result from this technique (Laird & McLeod, 2009). Therefore, the objective of the current study was to explore the interdependent impacts of the *rest periods duration*, *breathing techniques*, and *training volume*, on the set RPE in elite-level karate athletes. We hypothesized that set RPE will: a) show higher values in short rest periods (rest period duration 30 sec.) compared to long rest periods (rest period duration 90 sec.), b) rise with higher number of the repetitions (i.e., through sets), and, c) to somehow display difference in the different *breathing techniques*, of GZ performance.

METHODS

Experimental Approach to the Problem

This study, employing a within-subjects design, investigated the combined effects of rest interval duration, breathing technique, and training volume on the set rate of the perceived exertion (RPE) assessment during a set and throughout the session. Participants engaged in one familiarization session and six separate randomized experimental sessions, where the *gyaku-zuki* (GZ) technique was performed with manipulations in rest period duration, breathing techniques, and training volume. Subsequently, participants provided data on the RPE in each rest period duration.

The first session involved short rest (30 sec.) and *kime* as the breathing technique. In the second session, the designated breathing technique was *kiai*, with a 30 seconds rest interval between sets (short rest). The third session, in addition to short rests (30 seconds), required the strike to be performed without simultaneous exhalation. The remaining three sessions described long rest between sets, with the fourth session having *kime* as the designated breathing technique, the fifth session featuring *kiai*, and the sixth session executing the strike without simultaneous exhalation.

Sessions were randomized, allowing manipulation of the effects of the rest period duration, breathing technique, and training volume. In all experimental sessions, information on the RPE within the set (set RPE) was collected at a beginning between-set rest period.

Subjects

The subjects in this study consisted of 9 elite karate athletes (males = 6, females = 3). All participants are representatives of Serbia karate team (World Karate Federation association), including medalists in national, Balkan, European, and world competitions, as well as participants in the World Series A events. The characteristics of the participants were as follows: age 20 ± 3.91 years; body height 1.81 ± 0.08 m; body mass 68.44 ± 10.26 kg; body mass index (BMI) 20.98 ± 2.56 kg/m². Participants did not report any health issues, and no injuries were recorded immediately before, during, or after the experiment that could compromise performance. Prior to the experiment, all participants were briefed on the testing protocol and potential risks (which were minimal). They were also required to sign an informed consent document. The study was approved by the faculty of sport and physical education - Institutional Review Board (No. 02 194/20-2, from 18.02.2020).

Procedure

The experimental sessions were conducted over a 12-day period at a beginning of the summer transitional period, with two days of rest between experimental sessions. Experiments were organized during summer Serbia karate team camp in the summer of the year 2022. Besides experimental sessions, in this camp were performed other training sessions, but in nature they were light, because camp took place in the beginning of the between season transitional period. Note that this camp was chosen for experiment realization in counseling with Serbia karate team National coach. Participants executed the GZ strike in all six randomized sessions, consisting of 5 sets of 40 repetitions each (totaling 200 strikes per session). Rest interval duration between sets was manipulated to be either 1) 30 seconds or 2) 90 seconds, along with different breathing techniques: 1) with kime, 2) with kiai, and 3) without exhalation.

Participants performed the GZ technique from the "fudo dachi" stance, involving a simultaneous step forward with the front leg, a strike with the opposite hand, trunk rotation, and the release of the back foot's heel, which remains in the stance. The researchers controlled the rhythm of the GZ strike.

Familiarization Session

This session involved collecting anthropometric measures and familiarizing participants with the research protocol. The research protocol included introducing participants to the RPE CR-10 scale (Table 1) and presenting the type of activity (GZ strike) used during the experiment and its execution method, which is well known technique for athletes of that level. During familiarization with the RPE CR-10 scale, participants were shown the scale with both alphabetical and numerical labels and values, along with an explanation of its use with already described procedures (Sweet et al., 2004).

Table 1. RPE CR-10 scale.

Rating	Descriptor
0	No perceived exertion
1	Very light
2	Light
3	Moderate
4	
5	Hard
6	
7	Very hard
8	
9	
10	Extremely hard

Experimental Sessions

Before the start of each session, all participants had a common warm-up, consisting of 5 minutes of stationary shaping exercises, 5 minutes of running exercises, and 5 minutes of specific karate exercises. Each experimental session involved performing the GZ strike in the air, without a sparring partner, following the rhythm set by the researcher. The strike was performed from the starting position of the "fudo dachi" stance, to which participants immediately returned to execute the next strike promptly. All participants performed the task at maximum intensity. It is very important to stated, that because there were two different experimental rest period durations, two experienced researches carried out all experimental sessions so all participants could simultaneously complete named sessions. The researchers gaved vocal commands to signal the start of testing, execution of strikes, and the end of testing. After each set, at the beginning of each between-set rest period, participants' corresponding internal response (set RPE) to exertion were collected.

Data Collection and Analysis

The experiment was conducted in a sports hall period, between 7:00 AM and 9:00 AM. Experimental sessions were carried out at the begging of the training sessions, so the fatigue couldn't influence on the collected data. The temperature in the hall ranged between 20°C and 23°C. The familiarization session was designed to collect standard anthropometric measures and inform participants about procedures (exercise execution, preferred approach to the test, introduction to the RPE CR-10 scale). Anthropometric measures were taken by the same experienced researcher, following standard procedures recommended by the International

Society for the Advancement of Kinanthropometry (Norton et al., 2000). Body height and weight were measured with an accuracy of 0.5 cm and 0.1 kg, and the Body Mass Index (BMI) was calculated from the obtained data.

Instruments

The instruments used in this research included a stopwatch, used to control the between-set rest period and the rhythm of strike execution (every 2 seconds), and the RPE CR-10 scale, through which participants assessed the subjective response of the perceived exertion.

Statistical analysis

Descriptive statistics were calculated for all experimental data as mean and standard deviation (SD). Normality distribution for all data was assessed by using Shapiro-Wilic test. A repeated measure three-way ANOVA was used to establish effects of applied independent variables (i.e., *rest period duration*: short vs. long; *breathing techniques*: kime vs. kiai vs. without exhalation; and *training volume*: 1st set vs. 2nd set vs. 3rd set vs. 4th set vs. 5th set) on dependent internal load variable set RPE. A Greenhouse-Geisser adjustment was made to the degrees of freedom in case of violation of the sphericity condition. Follow up ANOVAs statistical analysis were processed according to detail explained procedures (Howell & Lacroix, 2012). When the interactions or main effects were revealed, Bonferroni post hoc test with adjustment was applied (Vincent & Weir, 2012).

According to Cohen (Cohen, 2013), the magnitude of difference on the post-hoc test was tested by means of effect size (ES), where difference was considered either very small (0.01), small (0.2), moderate (0.5), large (0.8), very large (1.2) or huge (larger than 2.0) for post hoc test (Sawilowsky, 2009). Percentage differences, along with ES, were calculated in a need of Tables 2 and 3 constructions. On the other hand, the eta squared (η^2) was calculated for the ANOVAs interactions and main effects with the following classification for magnitude effects (Field, 2013): no effect ($\eta^2 < 0.04$), minimum effect ($0.04 < \eta^2 < 0.25$), moderate effect ($0.25 < \eta^2 < 0.64$) and strong effect ($\eta^2 > 0.64$). A significant level of $p < 0.05$ was used for all comparisons. All statistical procedures were analyzed by using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) and Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA).

RESULTS

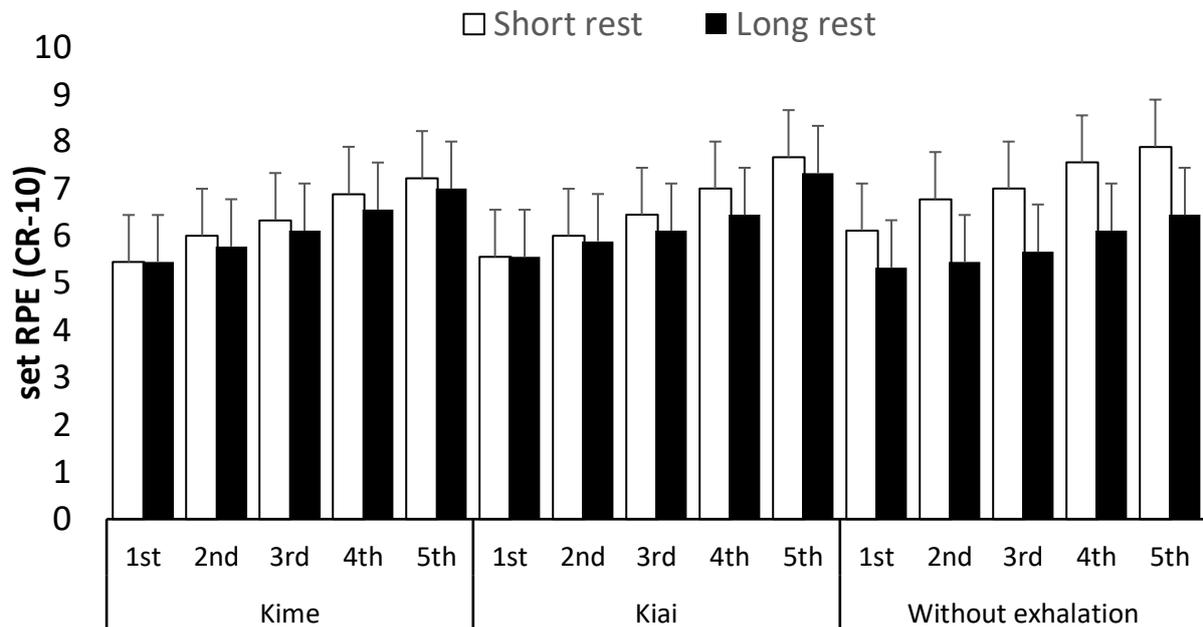


Figure 1. Graphic display of means and standard deviations of the subjective load variable set rating of perceived exertion (set RPE - expressed in values from CR-10 scale), for the rest period duration (short and long rest), breathing technique (kime, kiai, and without exhalation) and training volume (1st, 2nd, 3rd, 4th, and 5th set).

Set rate of perceived exertion (set RPE). The results of this subjective internal load measure are showed in Figure 1. Further, three-way interaction ($p = 0.876$), and two-way interactions *breathing techniques* \times *training volume* ($p = 0.435$) and interactions *rest period duration* \times *breathing techniques* have not reached significance ($p = 0.131$). On the other hand, for two-way interaction *rest period duration* \times *training volume* significance was confirmed ($p = 0.017$), with moderate effect size magnitude ($\eta^2 = 0.351$). Detailed data of the confirmed two-way interaction, which involved percentage differences and effect sizes, highlighted from perspective of training volume and *rest period duration*, are displayed in Tables 2 and 3. Post hoc adjustment Bonferroni have showed that there were no differences between short and long rest sessions on the 1st set ($p = 0.193$). On the contrary, the 2nd set significance was achieved, with short rest sessions showing significantly higher set RPE values than long rest ($p = 0.024$) sessions. Similarly, on the 3rd set set RPE values of the short rest sessions have also showed significantly higher results than on the long rest ($p = 0.008$) sessions. In a case of the 4th set, short rest sessions again confirmed significantly higher values than long rest ($p = 0.014$)

sessions. Further, on the last set (5th), significance was also confirmed in higher values of the short rest, when they were compared with long rest ($p = 0.005$) sessions. Furthermore, on the short rest sessions, 1st set have showed significantly lower set RPE values compared to 2nd set ($p = 0.002$), 3rd set ($p = 0.000$), 4th set ($p = 0.000$), and 5th set ($p = 0.000$) values. Set RPE values of the 2nd set have showed significantly lower values than 3rd set ($p = 0.017$), 4th set ($p = 0.000$), and 5th set ($p = 0.000$) values. In the case of the 3rd set, lower set RPE values were detected compared to 4th set ($p = 0.002$), and 5th set ($p = 0.001$) values. Additionally, 4th set set RPE values were significantly lower than 5th set ($p = 0.016$) values. When examining long rest sessions, significances were observed with the set RPE values of the 1st set lower compared to 2nd set ($p = 0.008$), 3rd set ($p = 0.003$), 4th set ($p = 0.000$), and 5th set ($p = 0.000$) values. Next set (2nd) have showed significantly lower values than 3rd set ($p = 0.023$), 4th set ($p = 0.001$), and 5th set ($p = 0.000$) values. Significantly lower set RPE values of the 3rd set, compared to 4th set ($p = 0.002$), and 5th set ($p = 0.000$) values were observed. Finally, set RPE values of the 4th set were observed as lower, compared to the 5th set ($p = 0.000$) values. Regarding main factor analysis *rest period duration* and *training volume* have showed significance ($p = 0.013$, $p = 0.000$, respectively), with *rest period duration* achieving moderate effect ($\eta^2 = 0.561$), and *training volume* achieving strong effect size ($\eta^2 = 0.861$). On the contrary, the main factor *breathing techniques* failed to reach significance ($p = 0.795$).

Table 2. Presented data through the percentage difference (effect size), and highlighted from perspective of training volume in confirmed two-way interaction rest period duration \times training volume.

Training volume	Rest period duration
	SRP vs. LRP
1 st	4.55 (0.47)
2 nd	8.88 (0.92)
3 rd	9.55 (1.17)
4 th	10.88 (1.04)
5 th	8.78 (1.27)

Notes: SRP - short rest period, LRP, long rest period,
1st – first set, 2nd – second set, 3rd – third set, 4th –
fourth set, 5th – fifth set

Table 3. Presented data through the percentage difference (effect size), and highlighted from perspective of rest period duration in confirmed two-way interaction rest period duration \times training volume.

		Rest period duration					
		SRP			LRP		
Training volume	1 st vs.	2 nd	8.88 (1.49)	1 st vs.	2 nd	4.55 (1.17)	
		3 rd	13.48 (2.67)		3 rd	8.70 (1.37)	
		4 th	20.21 (2.74)		4 th	14.53 (1.88)	
		5 th	24.88 (2.31)		5 th	21.39 (2.34)	
		3 rd	5.06 (1.00)		2 nd vs.	3 rd	4.35 (0.93)
	2 nd vs.	4 th	12.44 (3.08)	2 nd vs.	4 th	10.47 (1.79)	
		5 th	17.56 (2.41)		5 th	17.65 (2.59)	
		4 th	7.77 (1.49)		3 rd vs.	4 th	6.40 (1.47)
	3 rd vs.	5 th	13.17 (1.66)	5 th		13.90 (2.74)	
		4 th vs.	5 th	5.85 (1.01)	4 th vs.	5 th	8.02 (1.92)

Notes. SRP - short rest period, LRP, long rest period, 1st – first set, 2nd – second set, 3rd – third set, 4th – fourth set, 5th – fifth set.

DISCUSSION

This study aimed to investigate the effects of *rest period duration*, *breathing techniques*, and *training volume* on the set RPE in elite-level karate athletes. Specifically, the authors hypothesized that set RPE would: a) be higher in short rest periods (30 seconds) compared to long *rest periods* (90 seconds), b) increase with a higher number of repetitions (i.e., across sets), and c) exhibit differences across the different *breathing techniques* used during GZ performance. Note that these three factors (*training volume*, *rest period duration*, and *breathing techniques*) were observed interdependently. The results showed that *rest period duration* and *training volume* had significant effects both through interaction ($p = 0.017$) and as independent factors (*training volume*: $p = 0.000$, *rest period duration*: $p = 0.013$). However, the *breathing techniques* did not show significant effects in any interaction ($p > 0.05$). The following discussion will focus on understanding and interpreting the main findings related to the subjective internal load variable responses.

Regarding rest period duration, the analysis of set RPE differences between short and *long rest periods* revealed significant effects starting from the 2nd set, with a large effect size ($ES = 0.92$). This large effect size was maintained through the 3rd set ($ES = 1.17$) and the 4th set ($ES = 1.04$), ultimately achieving a very large effect size in the 5th set ($ES = 1.27$), favoring short

rest periods over long rest periods. Another independent variable showed significance – *training volume* and in this case ES magnitudes were higher in short compared to long rest protocols. In the short rest periods, the ES reached a very large magnitude between the 1st and 2nd sets (ES = 1.49). In the following sets, the ES increased and remained substantial compared to the 1st set (1st vs. 3rd: ES = 2.67; 1st vs. 4th: ES = 2.74; 1st vs. 5th: ES = 2.31). The long rest periods demonstrated a different pattern, with a large effect size between the 1st and 2nd sets (ES = 1.17), which then increased to very large between the 1st and 3rd sets (ES = 1.37) and the 1st and 4th sets (ES = 1.88). Finally, the effect size between the 1st and 5th sets reached a huge level (ES = 2.37).

Unfortunately, no studies have compared the independent or interdependent effects of *rest period duration* and *training volume* in kumite-karate training. The closest comparisons are found in resistance training and body-weight power training, due to their similar set structures. Three previous studies analyzed the effects of *rest period duration* and *training volume* on RPE in resistance training (Farah et al., 2012; Larson Jr & Potteiger, 1997; Woods et al., 2004), and one study examined these effects in body-weight power training (Arsenijević et al., 2023). Woods and co-workers (2004) applied resistance exercises with *rest period duration* of 1, 2, and 3 min. Their results showed that the set RPE was similar between groups that executed different rest period duration, performing knee extension exercises in three sets at 70% of one repetition maximum. Similarly, Larson Jr and Potteiger (1997) conducted experiment with different recovery conditions. Each conditions had length of the 3 minutes, with 1:3 work:rest ratio, in a session of four sets of squat exercise at 85% of the 10-repetition maximum that was performed to failure. Again, obtained results showed no differences in the set RPE between the three recovery conditions (i.e., rest period duration). Conversely, a study by Farah and colleagues (2012), where the same *rest period duration* was applied like in our study (30 sec. and 90 sec. interval of rest between sets sessions), had different findings. In both sessions, five exercises (bench press, knee extension, seated row, knee curl, and frontal rise) were executed at 50% of one repetition maximum through three sets. These differences in the set RPE between two protocols of the *rest period duration* was significant only in the third set and responses were similar for all exercises except for the bench press, and it should be highlighted that the rest period duration in the research (Farah et al., 2012) were comparatively shorter compared to other two researches (Larson Jr & Potteiger, 1997; Woods et al., 2004), which might have caused influence on muscle recovery. Final research that has some similarity with our study was by Arsenijevic and colleagues (2023), who analyzed influence of the different rest period

duration sessions (60 sec. and 120 sec. between sets) and different *training volume* (analyzed for first six sets and for the last six sets – total 144 jumps per session) on the set RPE in body-weight vertical jumping sessions. Results have showed that only *training volume* reached significance, with the first six sets (i.e., small volume; 1st to the 72nd jump) showing lower subjective set RPE responses, compared to last six sets (i.e., large volume; from the 73rd to the 144th jump). Compared to our study, the significant differences in set RPE from the 2nd set onward might be due to the nature of the exercise inducing fatigue (i.e., *gyaku-zuki* in our study), which differs greatly in loading from the external resistance (i.e., resistance and body-weight) exercises performed in the aforementioned studies.

The important theoretical implications were carried out through this study. Our findings propose that *rest period duration* have showed influence on the subjective internal load, with long *rest periods* that provided lower levels of subjective fatigue, compared to the short rest periods, when performing GZ strike in elite-level kumite-karate athletes. Likewise, *training volume* (sets and reps) structured in this study, demonstrated gradually enlargement of the set RPE from 1st to 5th set, and normally with higher effect size magnitude in the short *rest periods*, compared to long rest periods. This is very practical finding for strength and conditioning experts while monitoring training load, if they are willing to provoke different training stimulus (e.g., higher or lower fatigue) in the training process. Practitioners than should use shorter rest periods and higher number of the repetitions for higher perceptual fatigue, and longer rest periods and lower number of the repetitions for lower perceptual fatigue. Furthermore, this was the first study, to our knowledge, that explored and confirmed influence of the rest period duration and training volume in elite-level kumite-karate athletes.

Contrary to our third hypothesis, the breathing technique did not significantly affect the RPE levels in participants, suggesting that breathing technique is not necessarily relevant for fatigue induction, at least among elite-level karate athletes. This finding is important because no previous study has explored the effects of breathing variants in martial arts training, making it challenging to directly compare our results with earlier research. Several studies, however, have examined the specifics of voluntary breathing and its effects on sports performance in marathon running, cycling, swimming, and resistance training (Blazek et al., 2021; Inbar et al., 2000; Johnson et al., 2007; Kilding et al., 2010). According to previous meta-analyses (HajGhanbari et al., 2013), specific breathing patterns can improve sports performance for some athletes by increasing respiratory muscle strength and endurance. From our data (see Figure 1) it can be seen that study design was appropriate in leading fatigue to high levels of subjective load

(values of set RPE in short rest session were up to 9 in some cases), so the total external load applied was no limiting factor for *breathing technique*. Therefore, although different breathing variants did not alter RPE levels in this study, it seems reasonable to assume that breathing variants may affect kinetic and kinematic performance, or some other training load variables, during specific karate techniques such as gyaku-zuki (GZ). Lastly, future studies should deal with the exploration of other acute training variables on training load in karate-kumite training, which could promote understanding of this specific dose-response in named training process.

The current study has several strengths. Firstly, the sample consisted of elite-level karate athletes, providing valuable insights into training responsiveness in elite-level combat sports. Additionally, we focused on the gyaku-zuki, the most commonly used strike in karate training and competition (Laird & McLeod, 2009). For the first time, we implemented structured and organized training sessions with defined sets, repetitions (total training volume), and *rest period duration*. Although *breathing technique* failed to show any significance, to our knowledge this was the first study to analyze influence of the kime and kiai, as this specific *breathing techniques* in karate are still unexplored. Note that previous research has examined and monitored internal load in karate training but without strictly defined total *training volume* and *rest periods* throughout the sessions (Johnny et al., 2014; Milanez et al., 2011; Tabben et al., 2013).

Concerning the limitations of the study, it should be stated that inclusion of the objective internal load variables (e.g., heart rate, blood lactate levels, etc.) could strengthened the discoveries of the study, but there a lot of confirmation of the relationships between set RPE and objective internal load indicators (Eston, 2012). Another limitation is number of the participants in the study, and is fair to state that is very hard to have available for experiments athletes of this level.

CONCLUSION

Our study underlines the importance of the rest period duration and the *training load* in kumite-karate training, since the obtained findings clearly suggest that longer *rest period duration* are causing less subjective stress, compared to shorter *rest period duration*. Similarly, independent factor *training volume* have showed that lower sets are perceived subjectively easier in comparison to higher number of sets. Specifically, when performing GZ, the manipulation with these two factors in kumite-karate training is desirable in order to provide decrease/increase of

the subjective internal load. Therefore, it appears that the distribution of *rest period duration* between sets, along with the manipulation with the number of sets, in the applied GZ strike, could provide the aforementioned benefits. Hence, it could be concluded that the rest period duration and *training volume* undoubtedly demonstrated potential for its further application in designing kumite-karate training. Unfortunately, *breathing techniques* that are often used in karate sport, failed to display significance on subjective internal load. It is necessary to further explore its effectiveness with respect to other strikes and kicks and the combinations of these two in kumite-karate sport, and to possibly explore effectiveness of other acute training variables (e.g., set structure, number of reps per set, training intensity, etc.) to provide benefits with respect to the acute training effects.

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