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Effects of Self-Selected Rest Interval between Sets on Resistance Training Session Total Volume

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ABSTRACT

Purpose: To investigate the effects of self-selected and different fixed rest intervals (RI) lengths between sets on the volume-load of upper- and lower-body resistance exercises in resistance-trained individuals. **Methods:** Nineteen resistance-trained males performed six randomized resistance training (RT) sessions separated by at least 72 hours, including bench press and back squat exercises. Each RT session consisted of four sets of maximum repetitions with a 6RM load for both exercises with different rest intervals (RI), 2-min, 5-min, and a self-selected RI length. In the self-selected RI session, subjects started subsequent sets when they indicated perceived readiness (PR) at 4. **Results:** For the back squat exercise, volume-load and repetitions were similar across conditions ($p > 0.05$), whereas self-selected rest intervals were longer than those in the 2-min session across all sets ($p \leq 0.001$). No significant differences in PR scores were observed between sessions ($p > 0.05$). For the bench press exercise, volume-load was higher in both the self-selected ($p \leq 0.001$) and 5-min ($p \leq 0.01$) sessions than in the 2-min session. The number of repetitions performed during the third and fourth sets was lower in the 2-min session than in both the self-selected and 5-min conditions ($p < 0.05$). Self-selected rest intervals were shorter than 5 min during the first two intervals ($p = 0.001$; $p = 0.006$, respectively) but longer than 2 min across all intervals ($p \leq 0.001$). PR scores were significantly higher during the third rest interval than during the first in both the 5-min ($p = 0.045$) and 2-min ($p = 0.010$) sessions. **Conclusions:** Longer or self-selected intervals were beneficial for maintaining volume-load during the bench press but not necessary for the back squat.

Keywords: Perceived recovery, Bench press, Back squat, Performance.

INTRODUCTION

Physical activity practitioners and athletes perform resistance training (RT) with different goals, aiming for maximal strength, power, and/or muscle hypertrophy development [1]. Usually, RT variables (i.e., exercise choice and order, number of sets, number of repetitions, training frequency, intensity, and rest interval) are manipulated to enhance the results according to the desired results [1, 2]. When the training goal is to improve maximum strength and muscle hypertrophy, intensity [3] and volume-load (sets × reps × load) [4], respectively, are key factors to be considered.

The ability to work against high intensity and to perform high training volumes is directly affected by between-set rest interval (RI) length, which must be sufficient to restore the capacity to produce muscle force, while avoiding excessive durations that may result in some cooldown [5, 6]. In this regard, RI between 2 and 5 minutes has been recommended for maximal strength and muscle

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hypertrophy development [5-7]. However, there is a great individual variability and no consensus in the literature regarding the optimum RI [5].

In addition, upper and lower limb RT exercises may require different RI lengths [8-10]. A long (5-min) RI between sets has been shown to allow the completion of higher volume-load when training with high loads (~85% 1RM or ~8RM) compared to short RI (~1-2 min) in both bench press and back squat exercises [8-10]. On the other hand, the sustainability of repetitions against high loads in the bench press exercise seems to be more affected than in the back squat exercise [8]. Willardson and Burkett [8] showed that the 5-minute RI resulted in the highest volume-load in both exercises, followed in descending order by the 2- and 1-min RI. In the back squat exercise however, volume-load was not different between the 1- and 2-min RI. This finding suggests that the lower body muscles possessed greater endurance characteristics than the upper body muscles, and RI should be considered according to the muscles involved.

To optimize recovery, the use of self-selected RI has been investigated [11-13]. The self-selected model postulates that RI self-regulation during RT could result in a better maintenance of the number of repetitions throughout the sets, and consequently in a greater volume-load during RT session [11]. To the best of our knowledge, three studies [11-13] investigated the effects of fixed RI models versus self-selected RI between sets on lower and upper body exercises performance. In two of these studies, self-selected RI allowed subjects to maintain a pre-determined volume-load during high intensity back squat [12, 13]. Another study found no difference in the number of repetitions achieved during the back squat and bench press exercises with self-selected compared to the fixed RI model (2-min) [11]. It is worth noting that the number of repetitions in the bench press declined during the sets, regardless of the adopted rest interval length. However, during the back squat exercise, the number of repetitions performed in the second and third sets decreased when a self-selected RI was applied, which could be explained by a shorter self-selected RI compared to fixed RI, but the difference was not significant between RI modes (~ 1 min and 45 s vs. 2-min; $p > 0.05$). On the other hand, for the bench press the self-selected RI was shorter than the fixed RI between the second and third sets (1 min and 48 s vs. 2-min; $p < 0.05$) but no difference was found between the number of repetitions performed [11].

Edwards et al. [14] proposed a perceived readiness (PR) scale to help individuals self-select the RI during high-intensity interval training. In addition, do Carmo et al. [15] demonstrated the PR scale effectiveness for rest interval self-selection when compared to a fixed RI to elicit post-activation potentiation on countermovement jump performed by strength-trained individuals. In this sense, the PR scale may be a useful psychobiological tool to individualize RI length while maintaining exercise intensity and volume-load.

However, we are unaware of any study that compared RT session volume-load for upper and lower limbs using short, long and self-selected RI. Therefore, this study aimed to investigate the effects of self-selected and different fixed rest intervals (RI) lengths between sets on the volume-load of upper- and lower-body resistance exercises in resistance-trained individuals.

METHODS

Experimental Design

The complete experiment consisted of 11 visits: 3 for familiarization sessions, 2 control sessions to determine the 6RM load for the back squat and bench press exercises, and 6 for experimental trials. A counterbalanced crossover design was used during experimental trials. We compared the effects of different fixed (2- and 5-min) and self-selected (based on PR scale) [14] RI lengths between sets on RT session volume-load [16] in the bench press and back squat exercises. Subjects were submitted to three RT sessions with upper (bench press) and lower (back squat) body exercises (i.e., 6 experimental sessions, Figure 1). All sessions were held at the same time of day for each subject and under similar environmental conditions (~22°C and ~60% humidity).

Subjects

Nineteen resistance-trained males, age between 21 and 30 years (age = 24.4 ± 6.9 years, body mass = 81.1 ± 9.7 kg, and height = 177.0 ± 6.1 cm), volunteered to participate in this study. All subjects had at least two years of RT experience (3.0 ± 0.9 years), and an average of four training sessions per week. In addition, the subjects were free from health problems and neuromuscular disorders that could affect their ability to complete the study protocol and all of them were free of any drug or nutritional

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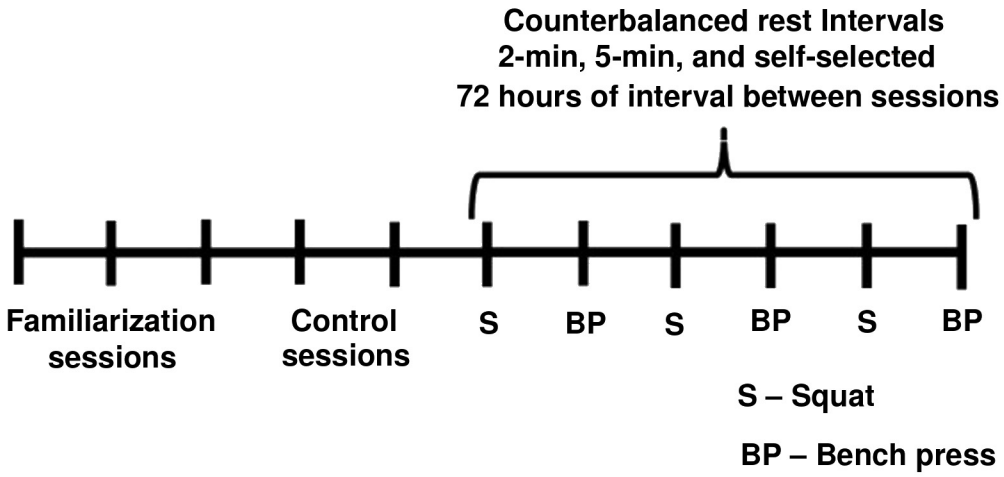


Figure 1. Study overview.

supplement ingestion. They were instructed to refrain from exercises two days before all study sessions to avoid residual fatigue. Subjects were excluded if: (a) they used any alcoholic beverages two days before each experimental session; and (b) they performed any strenuous exercise 24 hours before each experimental session. The study followed the guidelines established in the Declaration of Helsinki for human subjects. All subjects signed informed consent and the experiment gained approval from the Research Ethics Committee of the Escola de Educação Física e Esporte da USP (protocol number: 487509/2011).

Familiarization Sessions

Before the RT sessions, all subjects went through three familiarization sessions with the back squat and bench press exercises (random order), performed at least 72 hours apart (Figure 1). The back squat exercise was performed on a Smith machine using a high-bar position (Cybex®, Massachusetts, USA). Body position and foot placement were registered with measuring tapes fixed on the bar and on the ground, respectively, and reproduced throughout the study. In addition, a wooden seat with adjustable heights was placed behind the subject to keep bar displacement and knee angle (~90°) constant on each back squat repetition. The bench press exercise was executed on a traditional flat bench (Cybex®, Massachusetts, USA) in a supine position with both feet on the ground. Subjects gripped the bar comfortably and lowered the weight until ~90° angle of their elbows. The distance between thumbs was recorded in a measuring tape placed over the bar and reproduced throughout the study.

In the first and second familiarization sessions, the subjects performed four sets of both exercises to get an initial estimation of their 6RM load. There was a 3-min RI between each set and 10-min between exercises. In the third session, a more precise estimation of the 6RM load was obtained for both exercises.

Determination of 6-Repetition Maximum

After the familiarization, two control sessions were performed to determine the 6RM load for the back squat [17] and bench press [18] exercises. After a standard warm-up (see Resistance Training Sessions), each subject performed a maximum of two attempts for each exercise with 5 minutes of RI between attempts and 10 minutes between exercises. The greatest load lifted over the 2 sessions was considered the 6RM load (bench press = 87.7 ± 11.3 kg; back squat = 151.5 ± 26.5 kg). The tests were conducted by two experienced researchers, and strong verbal encouragement was provided during the lifts. Data showed high inter-session reliability for the 6RM in the back squat (ICC = 0.978; 95% CI = 0.938 to 0.992) and bench press (ICC = 0.948; 95% CI = 0.852 to 0.982) exercises. All test and retest procedures occurred 72 hours apart and they were performed at the same time of day for each participant.

Resistance Training Sessions

At least two days after the control sessions, subjects performed six RT sessions. Three alternated sessions were conducted between bench press and back squat exercises, interspersed by at least 72 hours. During these experimental sessions, subjects were required to perform four sets of maximum repetitions with a 6RM load in one of the exercises. The RT protocol was adopted with multiple sets and high load intensity according to previous recommendations for strength and muscle hypertrophy gains in trained subjects [1, 3, 19].

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RI length (i.e., 2-min, 5-min, or self-selected) was balanced and randomized among RT sessions (www.randomization.com). For the self-selected RI, individuals were oriented to rest for as long as necessary until they reached a score of 4 (Adequately recovered - able to exercise at the required intensity) in the PR scale [14].

Before each experimental session, subjects performed a standard warm-up comprised of running for 5 min at 9 km·h^{-1} on a treadmill followed by two warm-up sets. During the first set, the subjects performed eight repetitions with 50% of the estimated 6RM. After a 2-minute interval, the subjects performed the second set with three repetitions at 70% of the estimated 6RM. The time spent between sets, the PR scale score and the number of repetitions performed in each set were recorded in all conditions. Subjects remained seated during the rest interval. Volume-load was calculated as the product of sets × repetitions × load [16].

Perceived Readiness (PR) Scale

The PR scale was designed as a rapid self-assessment tool to determine readiness to resume exercise between bouts. During all familiarization sessions and the self-selected RI session, subjects were instructed to determine their recovery duration based on their perceived readiness to resume exercise at a PR scale value of 4. Standardized instructions were provided to ensure proper use of the PR scale. Specifically, subjects were instructed to rest until they felt "fully recovered – able to exercise at maximal intensity," based on a 7-point categorical Perceived Readiness (PR) scale (1 = fully recovered – able to exercise at maximal intensity; 7 = exhausted – unable to exercise) [14].

Statistical Analysis

Data normality for continuous variables (i.e., volume-load, number of repetitions per set, and RI duration between sets) was confirmed using the Shapiro–Wilk test, and results are expressed as mean ± standard deviation. Differences between RI sessions (i.e., 2-min, 5-min, and self-selected) in volume-load were analyzed using a repeated-measures ANOVA. For the number of repetitions per set and rest interval duration between sets, a repeated-measures ANOVA was performed, with RI sessions (i.e., 2 min, 5 min, and self-selected) and time as factors. Post hoc comparisons were performed using the Bonferroni adjustment whenever a significant F-value was obtained. When the assumption of sphericity was violated, the Greenhouse–Geisser correction was applied. Data from PR scale scores are shown as median and interquartile range [IQR]. PR scale scores were compared across conditions using Friedman's test and additional post-hoc analysis with Wilcoxon signed-rank test and Bonferroni correction. The significance level was set at $p<0.05$. All calculations were performed using IBM® SPSS® Statistics 22 software (IBM Co., USA).

RESULTS

Back Squat Exercise

No significant differences in volume-load were observed between the 2-min, 5-min, and self-selected RI conditions during the back squat exercise (Figure 2A). Similarly, the number of repetitions performed per set did not differ between sessions, and no significant interaction between session and sets was observed (Figure 2B). Regarding rest interval duration, subjects adopted longer intervals during the self-selected session compared with the 2-min condition ($p < 0.05$), whereas no differences were observed compared with the 5-min condition. In addition, rest interval duration progressively increased across sets during the self-selected session (Figure 2C). For the PR scale, no significant differences were identified between sessions following post hoc analysis (Figure 2D).

Bench Press Exercise

For the bench press exercise, volume-load was higher in the self-selected and 5-min sessions compared with the 2-min session ($p < 0.05$), with no differences observed between the self-selected and 5-min conditions (Figure 3A). The number of repetitions performed per set was lower in the 2-min condition compared with both the self-selected and 5-min sessions ($p < 0.05$). In addition, repetition performance progressively declined across sets in the 2-min and 5-min sessions, whereas repetitions were maintained across sets during the self-selected session (Figure 3B). Regarding rest interval duration, subjects selected longer rest intervals during the self-selected session than in the 2-min condition across all intervals ($p < 0.001$), but shorter rest intervals than in the 5-min session during the first two intervals ($p = 0.001$ and $p = 0.006$, respectively), with no difference in the third

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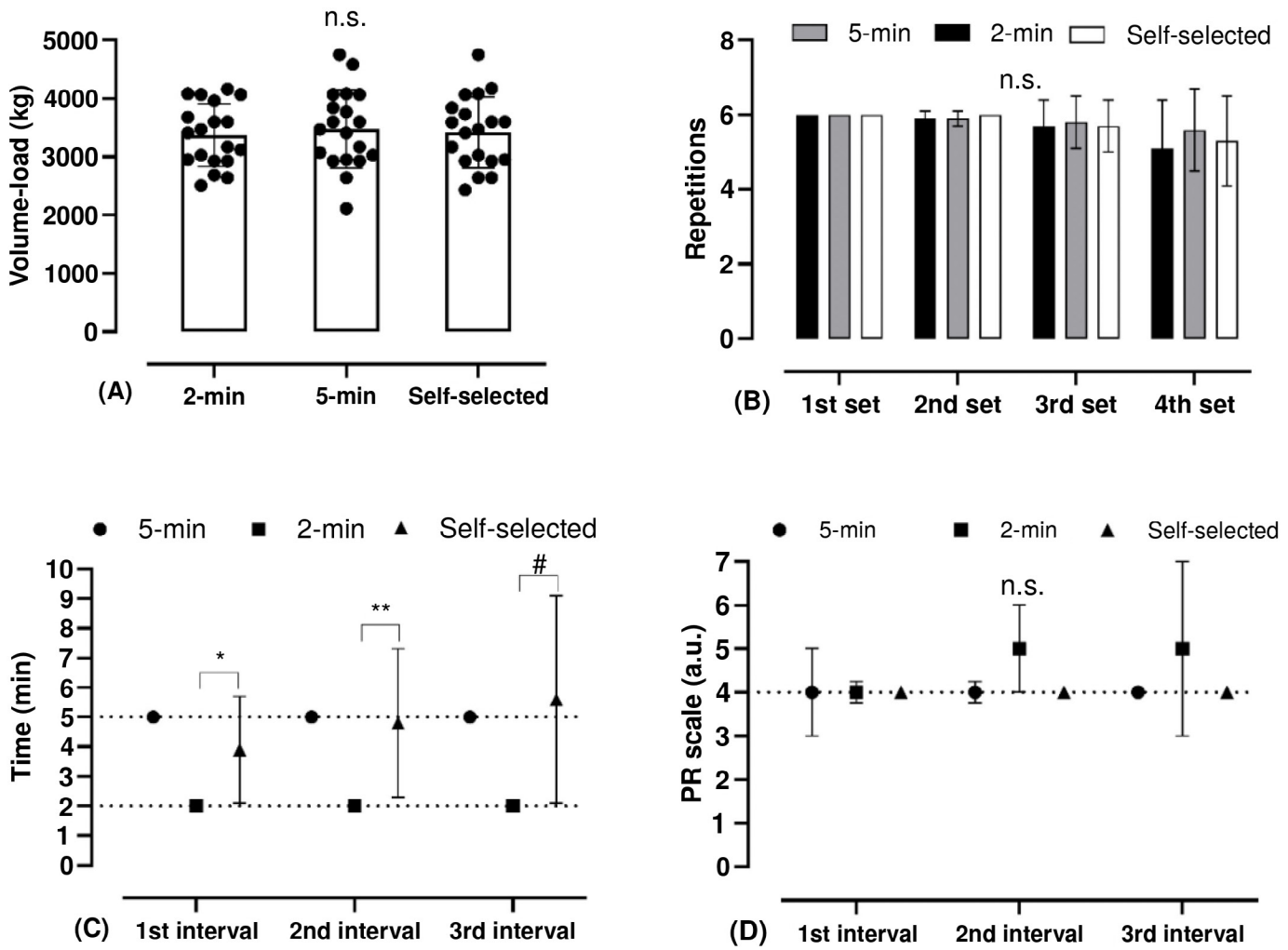


Figure 2. Back squat exercise. Volume-load (A), Number of Repetitions per Set (B), Rest Interval Between Sets (C), and Perceived Readiness (D).
*Legend: n.s. = no significance between sessions; *Self-selected RI session > 2-min session (mean difference = 1.9 ± 0.4 min, p = 0.001); **Self-selected RI session > 2-min session (mean difference = 2.8 ± 0.6 min, p ≤ 0.001); #Self-selected RI session > 2-min session (mean difference = 3.6 ± 0.8 min, p = 0.001).*

interval. Rest interval duration also increased across sets during the self-selected condition (Figure 3C). For the PR scale, higher scores were observed at the third interval compared with the first interval during both the 5-min and 2-min sessions ($p < 0.05$) (Figure 3D).

DISCUSSION

The present study investigated the effects of self-selected and fixed rest interval (RI) durations on volume-load performance during upper- and lower-body resistance exercises in resistance-trained individuals. Overall, the main findings indicated that RI duration influenced performance differently depending on the exercise performed. Specifically, no significant differences in volume-load were observed among RI conditions during the back squat exercise, suggesting that shorter rest intervals may be sufficient to maintain lower-body performance under the tested conditions. In addition, no differences were observed in PR scale scores between sessions, suggesting that an indicator of adequate recovery (i.e., a score of 4 on the PR scale) may be used to maintain volume-load during the back squat exercise. In contrast, for the bench press exercise, both self-selected and longer fixed RIs (5-min) resulted in greater volume-load and higher repetition performance compared to the shorter 2-min RI, indicating that upper-body performance may be more sensitive to insufficient recovery periods. Additionally, subjects naturally selected progressively longer rest intervals across sets, reinforcing the importance of autoregulated recovery strategies during resistance training. Another interesting finding is related to the use of the PR scale. Our results showed increased perceived readiness from the first to the third interval in both the 5-min and 2-min sessions, suggesting that this indicator was not sufficient to maintain volume-load in the bench press exercise.

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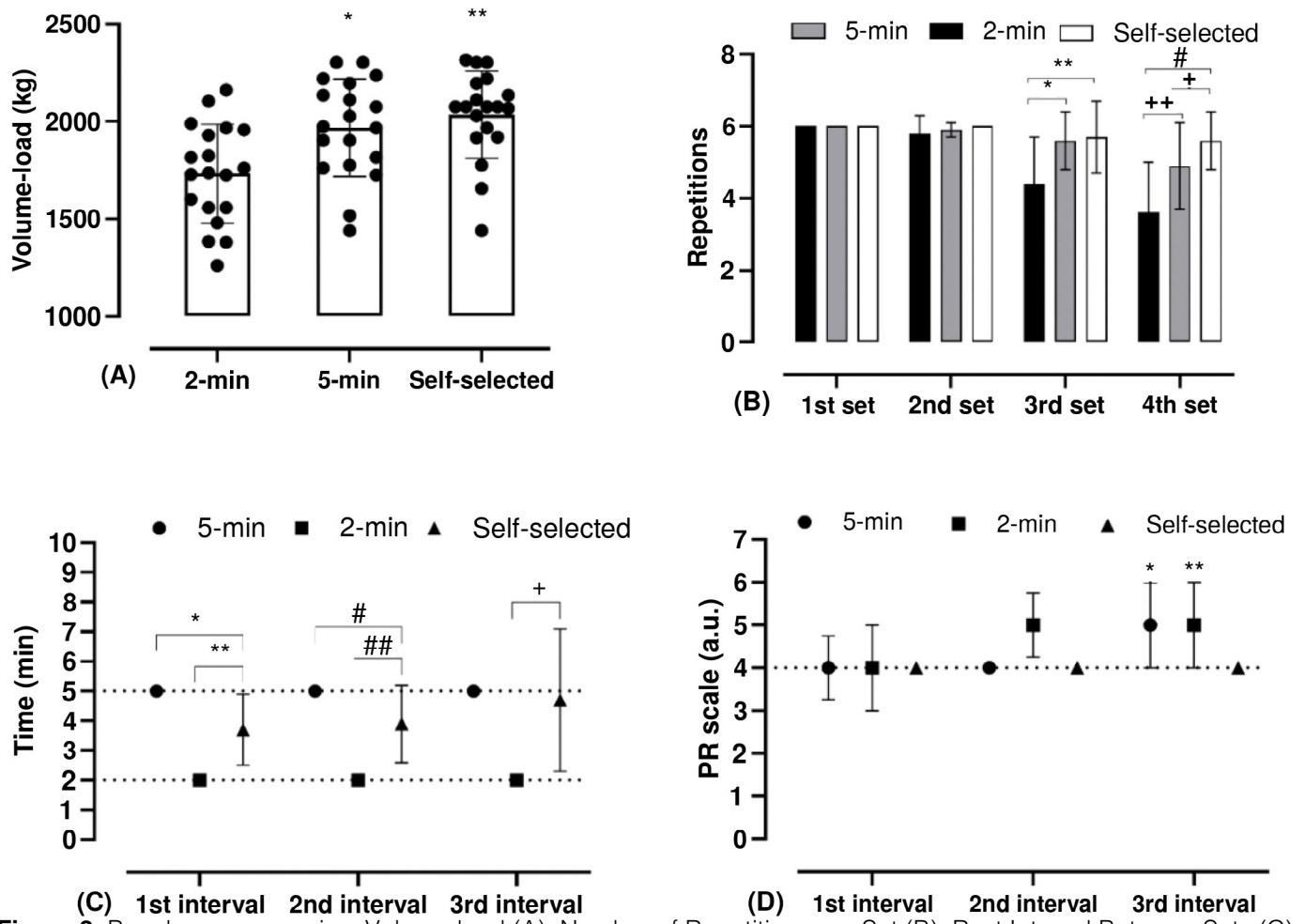


Figure 3. Bench press exercise. Volume-load (A), Number of Repetitions per Set (B), Rest Interval Between Sets (C), and Perceived Readiness (D).

Legend:

*For volume-load: *significant differences compared to 5-min ($p \leq 0.01$); ** significant differences compared to self-selected RI ($p \leq 0.001$).*

*For repetitions: During 3rd set = *5-min > 2-min session (mean difference = 1.2 ± 0.4 reps, p = 0.009); **Self-selected RI session > 2-min session (mean difference = 1.3 ± 0.3 reps, p = 0.001); During = #Self-selected RI session > 2-min session (mean difference = 2.0 ± 0.3 reps, $p \leq 0.001$); + Self-selected RI session > 5-min session (mean difference = 0.7 ± 0.2 reps, p = 0.024); ++ 5-min session > 2-min session (mean difference = 1.4 ± 0.3 reps, $p \leq 0.001$).*

*For rest intervals adopted between sets: *5-min session > self-selected RI session in the 1st interval (mean difference = 1.3 ± 0.3 min, p = 0.001); self-selected RI session > 2-min session in the 1st interval (mean difference = 1.7 ± 0.3 min, $p \leq 0.001$); #5-min session > self-selected RI session in the 2nd interval (mean difference = 1.1 ± 0.3 min, p = 0.006); ##self-selected RI session > 2-min session in the 2nd interval (mean difference = 1.9 ± 0.3 min, $p \leq 0.001$); +self-selected RI session > 2-min session in the 3rd interval (mean difference = 2.7 ± 0.5 min, $p \leq 0.001$).*

*For PR scale: *3rd interval > 1st interval in 5-min (p = 0.045) and **3rd interval > 1st interval in 2-min (p = 0.010).*

The findings of the present study suggest the need for longer rest intervals to avoid decrements in total volume during the bench press exercise. Subjects required approximately 4 minutes (4.1 ± 1.6 min) in the self-selected condition to maintain volume-load levels comparable to the 5-min session. Subjects presented higher total volume-load in both self-selected and 5-min sessions compared to the 2-min RI session. Longer RI (> 3-min) allows performing higher bench press volume-load [8, 10, 20] than shorter RI (< 3-min). In addition to the overall volume-load differences, our set-by-set analysis demonstrated that performance reductions occurred earlier when shorter rest intervals were used. Specifically, in the 2-min session, repetitions decreased significantly from the third set onward, whereas in the 5-min session, reductions were observed mainly in the final set. In contrast, repetitions were maintained across sets during the self-selected session. These findings are consistent with those reported by Ratamess et al. [20] who observed that performance during the bench press declined progressively across sets when shorter rest intervals were adopted, with reductions

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occurring during sets 3–5 with a 2-min interval, during sets 4–5 with a 3-min interval, and only in set 5 when a 5-min interval was used. Together, these results reinforce the importance of adequate recovery duration between sets to delay fatigue and sustain performance during successive sets of upper-body resistance exercise [20].

On the other hand, our findings showed that volume-load in the back squat exercise was not affected by the different rest intervals adopted. Previous studies are contrary to our results [8, 9]. For instance, Rahimi [9] compared the volume performed in the back squat exercise with 4 sets at 85% 1RM and 1, 2, or 5-min RI between sets. The 5-min RI session resulted in the highest volume completed, followed in descending order by the 2- and 1-min RI sessions. The author hypothesized that the smaller volumes obtained under the short RI conditions compared to the 5-min recovery period could be related to the time needed for acidosis clearance, which is between 4 and 10 minutes, and 5-min rest allows enough time to uptake H+ and delays the fatigue in the next sets. Although it seems a tempting hypothesis, our results are dissonant from the author's proposal, given we did not observe volume differences between short, long or self-selected rest intervals. Willardson and Burkett [8] brought new perspectives on the rest interval adopted for lower and upper exercises. In this study, the authors compared total volume in the back squat and bench press exercises performed with four sets of maximum repetitions at 8RM load and three different RI (1, 2, or 5-minute between sets). There were differences in total volume between 1- and 5-min RI sessions and between the 2- and 5-min RI for both exercises. However, the training volume completed were not different between the 1- and 2-min RI sessions in back squat, while a significant difference was observed in the bench press. According to the authors [8, 10], the lack of difference observed between 1- and 2-min RI may have been due to a higher level of endurance exhibited in lower limbs compared to upper limbs.

We can also highlight the importance of the psychological aspects related to greater muscle strength production [21]. In this context, an essential aspect of our study was choosing the RI length based on perceived readiness. We investigated if resistance-trained men would rate their readiness and perform higher total volume when they felt ready to resume work. As mentioned earlier, our results suggest that this PR scale is more appropriate for upper limb than for lower limb exercises. The advantage of PR scale and self-selected RI might be related to the participant's self-judgment about the best moment to perform the exercise, which could increase performance. A previous study about post-activation potentiation showed that when athletes self-selected their rest interval based on PR scale they improved performance in countermovement jump [15]. However, it is difficult to find a plausible mechanism related to self-selected RI and performance or total volume in upper body improvement. The subjects' self-judgment about the time to return to exercise might be related to the teleoanticipatory model, suggesting that the exercise intensity and neuromuscular recruitment are controlled in response to feedback (i.e., exercise-induced peripheral alterations) and feedforward (i.e. ,previous experience and motivation) mechanisms [22-24]. However, it is conceivable that a range of psychophysiological systems influences the perceived readiness of subjects [14], and this hypothesis needs further elucidation.

The present study has some limitations that should be acknowledged. First, a broader analysis including additional psychological variables could provide a better understanding of the use of the PR scale during resistance training sessions. In addition, the assessment of metabolic responses, such as blood lactate, could help elucidate the mechanisms underlying the reduction in performance observed in the bench press exercise [20]. In turn, coaches and practitioners should consider exercise type when prescribing RI. Under the conditions of the present study, a 2-minute rest interval was sufficient to maintain total volume during the back squat exercise. On the other hand, for bench press, higher RI lengths (i.e., 5-min and ≈ 4.1-min, respectively) allowed performance of higher total volumes than shorter RI (i.e., 2-min). Regarding bench press exercise, a minimal RI should be respected to avoid reduced total volume. This RI can be self-selected and anchored on score of 4 - adequately recovered - on the PR scale. The perceived readiness scale can be helpful to determine RI length during the execution of upper limbs exercises.

CONCLUSIONS

Rest interval length influenced performance differently between the bench press and back squat exercises, with longer or self-selected intervals being beneficial for maintaining volume-load during the bench press but not necessary for the back

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squat. The use of perceived readiness to self-select rest intervals appears to be an effective strategy to individualize recovery and maintain performance, particularly during the bench press exercise.

PRACTICAL APPLICATIONS

The findings of this study provide practical guidance for resistance training practitioners and athletes aiming to optimize training outcomes through appropriate rest interval prescription. Coaches and practitioners should consider the specific exercise performed when determining rest interval duration, as the present results demonstrated different responses between the bench press and back squat exercises.

For the bench press exercise, rest intervals longer than 2 minutes, whether fixed (5-min) or self-selected, allowed greater total training volume compared to shorter rest intervals (2-min). Therefore, a minimal rest interval greater than 2 minutes should be adopted to avoid reductions in performance and total volume. In this context, self-selected rest intervals anchored to a Perceived Readiness (PR) score of 4 (“adequately recovered”) may represent an effective and flexible strategy to individualize recovery and maintain performance across sets.

In contrast, for the back squat exercise, rest interval duration (2-min, 5-min, or self-selected) did not significantly influence total training volume. These findings suggest that shorter rest intervals, such as 2 minutes, may be sufficient to maintain performance during lower-body resistance exercises, potentially improving training efficiency without compromising workload.

Overall, these results highlight the importance of tailoring rest intervals according to the specific exercise, muscle groups involved, and individual recovery responses. The incorporation of the PR scale may enhance self-regulation during resistance training, allowing practitioners to better individualize rest duration and maintain consistent training volume across sessions.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

No funding was received for this research to be completed.

ETHICAL APPROVAL

The study followed the guidelines established in the Declaration of Helsinki for human subjects. All subjects signed informed consent and the experiment gained approval from the Research Ethics Committee of the Escola de Educação Física e Esporte da USP (protocol number: 487509/2011).

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