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Acute Effects of Different Set Configurations on Neuromuscular, Metabolic, and Perceptual Responses in Young Women

FRANCISCO DALTON-ALVES†1, LÍGIA MARTINS*2, WITALO KASSIANO†3, MÁRIO SIMIM‡4, ALEXANDRE I. A. MEDEIROS‡4, and CLÁUDIO DE O. ASSUMPÇÃO‡5

[1]Biotechnology and Exercise Biology Research Laboratory, Institute of Physical Education and Sports, Federal University of Ceará, Fortaleza, CE, BRAZIL; [2]Department of Physiology and Biophysics, Institute of Biomedical Sciences, University of São Paulo, São Paulo, SP, BRAZIL; [3]GEPEMENE—Metabolism, Nutrition, and Exercise Laboratory, Londrina State University, Londrina, PR, BRAZIL; [4]Biodynamics Research Group of Human Movement, Institute of Physical Education and Sports, Federal University of Ceará, Fortaleza, CE, BRAZIL; [5]Applied Physiology, Nutrition, and Exercise Research Group, Exercise Biology Research Lab, Department of Sport Sciences, Health Science Institute, Federal University of Triangulo Mineiro, Uberaba, BRAZIL

*Denotes undergraduate student author, †Denotes graduate student author, ‡Denotes professional author

ABSTRACT

***International Journal of Exercise Science* 16(4): 974-986, 2023.** We compared neuromuscular, metabolic, and perceptual responses between different resistance training configurations in young women. In a counterbalanced randomized order, 13 young women performed the following protocols in separate sessions (sets x repetitions): traditional (TRAD): 5x10, 90-s of rest interval between sets; more frequent and shorter total rest (FSR): 10x5, 30-s of rest interval between sets. The sessions were composed of leg press exercise with the same intensity. Force (maximum voluntary isometric contraction [MVIC]) and metabolic (lactate concentration) responses were measured pre- and post-resistance training sessions. The rating of perceived exertion (RPE) was measured after each set. The internal training load was calculated using the session-RPE method. There was a significant reduction in the MVIC only after TRAD configuration (Effect size [ES] = 0.36). The lactate concentration increased in both conditions but was higher after TRAD (ES = 2.81) than FSR (ES = 1.23). The RPE has progressively increased in both configurations. On the other hand, the internal training load was lower in the FSR configuration. From our findings, we suggest that more frequent and shorter total rest is an effective strategy for maintaining the ability to produce force, generating less metabolic stress and lower perceived internal load in young women.

KEY WORDS: Strength training, cluster set, intra-set rest, force, fatigability, neuromuscular function

INTRODUCTION

Resistance training (RT) promotes gains in muscle mass and strength (1). These adaptations allow—among other benefits—to improve neuromuscular performance (1). In this sense, researchers and strength and conditioning professionals manipulate different variables, such as intensity, volume, and rest interval, in order to promote positive adaptations with the minimum of fatigue and in the most efficient way possible (11, 15). In this regard, some set configurations that have become popular are the use of cluster sets and rest redistribution (11, 15). Among the different ways to apply such techniques, the use of inter-repetition and intra-set rest intervals has been effective in allowing the practitioner to train at the same relative intensity (or higher) and volume as the traditional configuration, with the benefit of mitigating residual neuromuscular fatigue and hemodynamic stress during and after the RT session (11, 12, 15).

In fact, in two recent systematic reviews with meta-analysis, the authors demonstrated that different cluster configurations characterized by the inclusion of intra-set rest intervals are effective strategies to reduce fatigue, metabolic stress, and perceptual effort during and after training sessions (11, 15). Importantly, such configurations commonly have similar or greater total rest compared to the traditional protocol (11, 13, 15). Therefore, less is known about whether allowing more frequent recovery in parallel with a shorter total rest time would still confer such advantages in comparison to traditional configuration. This aspect is important, because if such advantages are observed even with a lower total rest time when compared to traditional configuration, this can reduce the total time of the session, making it more efficient and potentially more attractive to practitioners who have less time to train.

Another important aspect frequently sought by researchers and coaches concerns the interplay between internal and external load parameters (19). In this sense, Marston, et al. (18) observed that the session density was able to discriminate sessions with characteristics for the development of strength versus hypertrophy. Namely, the greater the density of the session, the greater the metabolic stress (18). From this, the authors proposed that this external load metric would provide an accurate representation of the interplay between the work performed and the acute internal responses (18). Notwithstanding, the implementation of more frequent rest intervals can modify the acute changes, even in response to two protocols with similar intensity and volume (11, 19). Therefore, it remains to be determined how the inclusion of more frequent intervals and shorter total rest might affect the interplay between internal and external load parameters.

Moreover, a current limitation on this matter is the underrepresentation of women in studies of exercise science. Indeed, when looking more closely at the state of the art regarding set configurations and acute responses, we noticed that a small proportion of the investigations included young women; for example, in the most recent review (11), of the 27 included studies, four were composed of a mixed sample and only one was carried out exclusively with women. Since there is relevant sexual dimorphism in physiological (eg., sex differences in fatigability) responses to exercise (9, 10), this underrepresentation may result in inadequate extrapolation of these results in response to manipulation of the set configuration in women (9, 10, 21). These data highlight the importance of greater inclusion of female participants to guide the prescription of RT for this population, taking into account evidence obtained in young women.

Therefore, given the scenario described above, the present study had as main objectives: (a) to test whether there are differences in neuromuscular, metabolic, and perceptual alterations in response to traditional and more frequent and shorter total rest configurations with similar intensity and volume in young women; in addition, (b) verify whether the metabolic changes are related to external and internal load metrics.

METHODS

Participants

We estimated the sample size using G*Power (version 3.1.9.6). Previous data on the effects of resistance exercise on neuromuscular performance were used to estimate the sample size (13). Thus, we estimated the required sample based on an effect size of 0.63, a significance level of 0.05, and a power of 0.80. The analysis indicated that at least 10 participants were needed to achieve adequate statistical power. Thirteen young women participated in this study (23.3 ± 3.7 years old, 1.61 ± 0.5 m, 58.8 ± 7.6 kg, body fat = 21.5 ± 4.5%). Potential participants were contacted through digital media (e.g., Facebook, Instagram) and personal invitations. As inclusion criteria, a) the participants should have at least six months of practice in the RT; b) who had the 45° leg press exercise in their RT routines; c) not answering "yes" to any of the questions present in the physical fitness readiness questionnaire (Physical Activity Readiness Questionnaire—PAR-Q); d) not have any myoarticular limitations that would limit the participants to carry out the experimental procedures, and; e) not using any ergogenic substances that improves performance or delay neuromuscular fatigue. A detailed description was made for each participant about all the procedures of our study and then they signed the free and informed consent form. The participants were instructed to avoid resistance exercise 48 h before the visits for tests and experimental sessions and to maintain their eating habits. This investigation was performed according to the Declaration of Helsinki and was approved by the local University Ethics Committee (2.266.738). The investigation meets the guidelines set forth by the International Journal of Exercise Science (22). All procedures described below were performed between 6 AM and 10 AM, to avoid possible effects of the circadian cycle.

Protocol

We conducted a crossover, counterbalanced, and randomized study to investigate the acute effects of two different set configurations on neuromuscular, metabolic, and perceptual responses in young women. The total duration of the study was 4 weeks. Weeks 1 and 2 were used for anthropometry measurements and repetitions maximum (RM) testing. Weeks 3 and 4 were used for the application of the experimental training sessions. During that period, each participant visited the laboratory on five occasions to perform the procedures and experimental sessions. Visit one consisted of anthropometric assessment, body composition, and familiarization of the participants with the procedures and equipment. Visits two and three, which took place 48 hours after the first visit, participants performed test and retest of 10 repetitions maximum (10RM) in 45° leg press to determine the load to be used in the experimental sessions. In visits four and five, which took place 72 hours after the third visit, participants performed the experimental sessions composed of 45° leg press exercise, namely: traditional configuration (TRAD) and more frequent and shorter total rest (FSR) (Figure 1). Participants were asked to avoid exercise or sporting activity 72 hours before each laboratory visit.

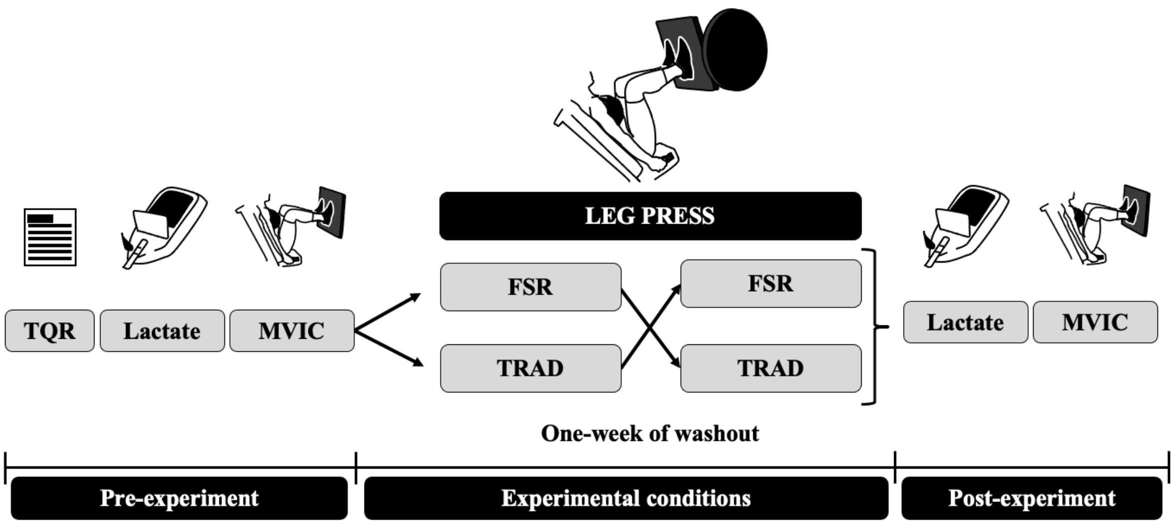

Figure 1. Experimental design. TQR = total quality recovery; MVIC = maximum voluntary isometric contraction; TRAD = traditional configuration; FSR = frequent and shorter total rest.

Total quality recovery: The total quality recovery (TQR) scale (16) was used before both experimental conditions to assess the level of perceived recovery. Upon arriving at the laboratory, the participants were asked how well they were recovered. TQR is a scale that ranges from zero (very poorly recovered/extremely tired), 1, 2, and 3 (not well recovered/somewhat tired), 4 (somewhat recovered), 5 (adequately recovered), 6 (moderately recovered), 7, 8, 9 (well recovered/somewhat energetic), and 10 (very well recovered/highly energetic) (16). A higher level of perceived recovery is associated with higher values. Participants were familiarized with this scale on visits two and three. The data collected in visits four, and five (days of the experimental conditions) were used for the analyses.

Dynamic muscular strength: The determination of the load that was used in the experimental sessions was made from the 10RM test. We adopted this number of repetitions because it is a commonly prescribed intensity (5, 6). The 10RM test was performed in the 45° leg press exercise and was repeated in two non-consecutive days — 48 h interval between sessions. The 45° leg press was performed in a conventional free-weight machine. Initially, the participants were taken to the laboratory at the beginning of the procedures, namely: a general warm-up was performed on a cycle ergometer (Biotec 2100, Cefise, São Paulo, Brazil) lasting five minutes at an intensity corresponding to 50% of the estimated maximum heart rate. After the general warm-up, the participants performed a specific warm-up consisting of two sets of 10 repetitions spaced by one minute of rest; the first set was performed at approximately 50% of the estimated 10-repetition maximum (10RM), and the second set, at 70% of 10RM. Two minutes after the end of the specific warm-up, attempts were made to find the 10RM. Each participant made five attempts, with a five-minute rest interval. The weight adjustment between attempts in which the participant performed more or less than 10 repetitions was ~3–5%. The range of motion necessary to consider a repetition valid was when the knees and hip angles reached 90° and 110°, respectively, with proper technique (14). The adjustments made in the equipment to accommodate the anthropometric characteristics of each participant were recorded and repeated in both the 10RM testing sessions and in the experimental sessions. The tests were monitored by the same evaluators. The mean and standard deviation of 10RM was 124.7 ± 48.3 kg. The reliability measures were obtained from the 10RM scores of the test and retest, and we obtained the intraclass correlation coefficient of 0.99 (0.98–0.99).

Blood lactate concentration: We obtained the lactacidemia at pre — before the warm-up procedures — and immediately after the end of both experimental RT sessions. The lactate concentration was quantified from a blood sample of ~15 µl extracted from the participant's fingers. These samples were immediately inserted into lactate tape containing sodium fluoride solution and inserted in the portable lactimeter (Accutrend® Plus, Roche, São Paulo, Brazil). The lactate concentration result was indicated after one minute. The reliability parameters for this device present a satisfactory coefficient of variation ranging between 1.8–3.3% for low, medium, and high concentrations of lactate; and ICC = 0.99 (3).

Maximum voluntary isometric contraction (MVIC): The force was measured before and after both experimental sessions by the maximum voluntary isometric contraction (MVIC). The tests were performed in a leg press (isometric dynamometer, Cefise, São Paulo, Brazil) with an attached load cell. The signal was captured with an analogic-to-digital converter using a sampling frequency of 100 Hz and analyzed in a specific software (N2000 Pro, Cefise, São Paulo, Brazil). The participants performed the MVIC with the knees and hip angles at 90° and 110°. After completing the blood sample collection, the participants performed the same warm-up as described in the 10RM test. After this stage, the pre-experiment MVIC measurement procedures were started. Participants were placed in a seated position, adjusted based on the manufacturers' recommendations in ~ 110º of hip flexion, according to the anatomical position. The feet were placed on the leg press platform with shoulder-width spacing and the feet were slightly rotated externally. The dynamometer was calibrated before all measurements according to the manufacturer's recommendations. The participants' hands were kept at their sides, holding the equipment handle. The measurement after the experimental conditions had a delay of ~120 s, due to the time of displacement from the 45° leg press machine to the isometric dynamometer, and to adjust the participants' position on the dynamometer. Each participant performed three MVIC lasting 5 s and the rest of 30 s between each repetition. Participants were encouraged by claps and words of incentive to apply as much effort as possible during the test. The highest peak torque among the three trials was considered as MVIC and was expressed in Nm. The assessments were performed by the same evaluators. The reliability of the MVIC was calculated from the values obtained before the experimental conditions and obtained an ICC = 0.97 (0.90–0.99).

Experimental protocols: The present investigation consisted of two experimental sessions in the 45° leg press exercise in a conventional free-weight machine with different configurations, namely traditional (TRAD) and the more frequent and shorter rest (FSR) configurations. Initially, the participant was taken to the laboratory for blood collection to measure lactate before the exercise. Then the participant performed a general warm-up on the cycle ergometer and a specific warm-up on 45° leg press exercise, identical to the procedures described in the 10RM test section. Two minutes after performing the specific warm-up, one of the two experimental sessions. The TRAD configuration was characterized by five sets with the load corresponding to 10RM and 90 s of rest interval between each set; totalizing 360 s. The FSR configuration consisted of 10 sets of 5 repetitions with a 30 s rest interval between sets; totalizing 270 s. Muscle actions — concentric and eccentric — were performed for two seconds and were monitored by a metronome. The sessions were accompanied by the same professionals, who verbally encouraged the participants throughout the sets, as well as, when necessary, provided assistance in the final repetitions so that the participants completed the predetermined number of repetitions (ie., 50 repetitions) — mainly in the TRAD. The time under tension of each set was quantified using a stopwatch and was used to calculate the time under tension of the session. The volume-load was calculated from the multiplication of the number of repetitions x load and is presented in kg. The session density was obtained from the volume-load (kg) divided by the total rest interval in seconds (14, 18). A washout period of seven days was given between experimental sessions to avoid possible effects of residual fatigue.

Rating of perceived exertion (RPE) and internal training load: The OMNI-RES scale (23) was used to obtain the RPE from the experimental sessions. All participants were submitted to two sessions (visits two and three) for the RPE anchoring procedures. Participants were asked to indicate a score corresponding to perceived exertion experienced during the resistance exercise sessions in visits four, and five. The RPE was obtained after the end of each set in both experimental conditions, through the following question: "How hard was this set of repetitions?". The RPE of the session was obtained by the average of the RPE of each set. The internal training load was obtained from the session-RPE method using the following equation: RPE x duration of the session in seconds (20).

Statistical analysis

The normality of the data was tested using the Shapiro-Wilk. The variables TQR, density, time under tension, duration of the session, RPE, and internal training load were compared using the paired t-test. For the primary study aim, we conducted a repeated-measures analysis of variance (ANOVA) with the condition (TRAD vs. FSR) and time (pre vs. post) as fixed factors. When the F was significant, a Bonferroni (Bonf) posthoc test was used to identify possible statistical differences. The Cohen's effect size (ES) was calculated as post- mean minus pre-values mean, divided by pooled pre-values standard deviation (4). The ES values were interpreted as follows: ≤ 0.20 was considered small, > 0.20 to < 0.80 was considered medium, and ≥ 0.80 was considered large (24). For the second aim, we used coefficient Pearson's correlation coefficient (*r*) for testing the potential relationship between the changes (Δ%) of lactate from pre- to post-session and density and internal training load. The *r* values were interpreted as follows: 0.00-0.19 was interpreted as no correlation, 0.20-0.39 was interpreted as low correlation, 0.40-0.59 was interpreted as moderate correlation, 0.60-0.79 was interpreted as moderately high correlation, and ≥ 0.80 was interpreted as high correlation (24). The data were presented in mean, standard deviation, and 95% confidence interval. The accepted level of significance was < 0.05. The data were analyzed using the JASP software (version 0.11.1, Amsterdam, NL).

RESULTS

Table 1 shows the mean and standard deviation values for perceptual and performance measures. There was no difference in the state of recovery before the start of the two experimental conditions. The number of total repetitions and volume-load were the same: repetitions = 50.0 ± 0.0, and volume-load = 6515.3 ± 2430.3. The session density was higher in the FSR condition, with no significant differences for time under tension. The total duration of the session was shorter in the FSR condition. There was no difference in RPE, on the other hand, the internal training load was significantly lower in the FSR condition.

Table 1. Performance and perceptual outcomes in both experimental conditions.

Variables	Conditions		*P*	ES
	TRAD	FSR		
TQR (AU)	7.2 ± 2.1	6.9 ± 2.1	0.447	0.22
Density (kg . s $^{-1}$)	18.1 ± 6.7	24.1 ± 8.9	< 0.001	2.67
Time under tension (s)	196.6 ± 14.7	205.5 ± 12.9	0.159	0.43
Duration of session (s)	556.3 ± 14.7	475.5 ± 12.9	< 0.001	4.59
mean-RPE (AU)	7.4 ± 1.1	7.0 ± 1.7	0.314	0.30
Internal training load (AU)	4133.1 ± 647.0	3362.2 ± 878.1	0.005	1.00

Notes. TRAD = traditional configuration; FSR = frequent and shorter rest configuration; ES = effect size; TQR = total quality recovery; AU = arbitrary units.

With regard to RPE during the experimental sessions, there was a significant effect of time ($F_{4,1}$ = 61.801, P < 0.001), with no effect of interaction time ($F_{4,1}$ = 0.238, P = 0.916) and condition time ($F_{4,1}$ = 1.114, P = 0.314). More precisely, the RPE increased from the 10th repetition, stabilized until the 30th repetition, and increased again at the 40th repetition in both experimental conditions (Figure 2).

The values of mean, standard deviation, confidence interval, and ES for MVIC and lactate are described in Table 2; individual behavior is shown in Figure 3.

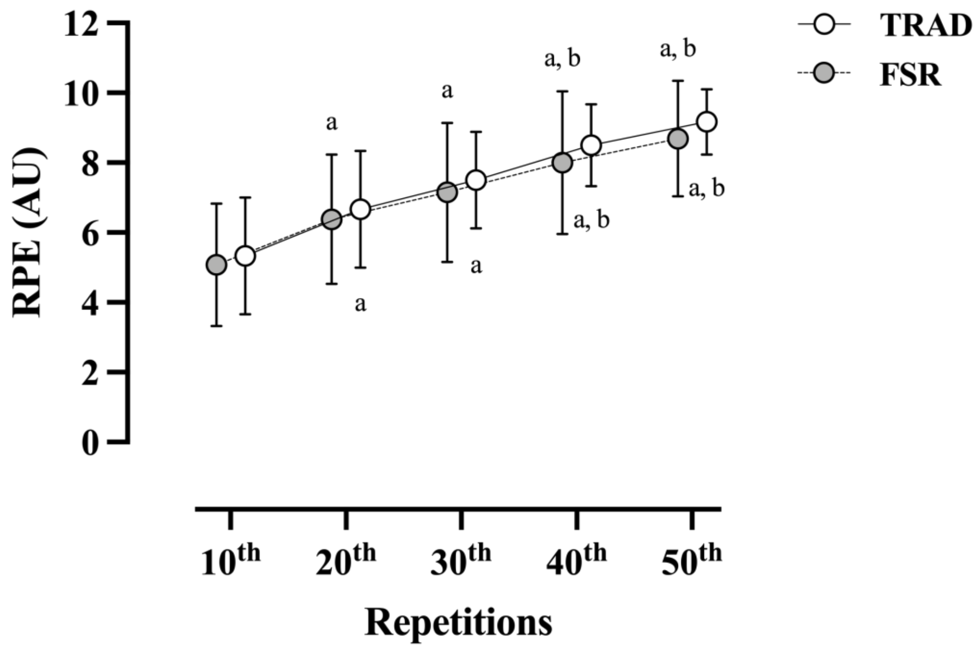

Figure 2. Perceptual behavior in response to TRAD and FSR configurations. TRAD = traditional configuration; FSR = frequent and shorter total rest; RPE = rating of perceived exertion; AU = arbitrary units. a = $P < 0.05$ vs. at 10th repetition; b = $P < 0.05$ vs. at 20th repetition.

Table 2. Neuromuscular and metabolic responses in TRAD and FSR configurations.

	TRAD	FSR
MVIC (Nm)		
Pre	155.9 ± 49.2	152.4 ± 51.0
Post	139.6 ± 38.7*	143.8 ± 48.8
Δ (95% CI)	-16.3 (-31.4; -1.2)	-8.6 (-6.4; 23.6)
ES	0.36	0.17
Lactate (mmol/L)		
Pre	3.84 ± 1.01	4.37 ± 1.42
Post	9.09 ± 2.44*	5.93 ± 1.13*†
Δ (95% CI)	5.25 (3.36; 7.13)	1.55 (0.06; 3.05)
ES	2.81	1.23

Notes. TRAD = traditional configuration; FSR = frequent and shorter rest; MVIC = maximum voluntary isometric; ES = effect size. * = $P < 0.05$ pre versus post; † = significant difference between configurations. Pre and post data are presented as mean and standard deviation, whereas the mean difference (Δ) as mean and confidence interval.

Regarding force output, there was an effect of time ($F_{1, 12} = 9.32$, $P = 0.012$), with no effect of interaction ($F_{1, 12} = 1.56$, $P = 0.240$) and condition ($F_{1, 12} = 0.00$, $P = 0.948$) for the MVIC. From the post-hoc it was possible to observe that the MVIC reduced only in the TRAD condition ($P_{Bonf} = 0.030$), but no after the FSR ($P_{Bonf} = 0.378$) (Table 2 and Figure 3A).

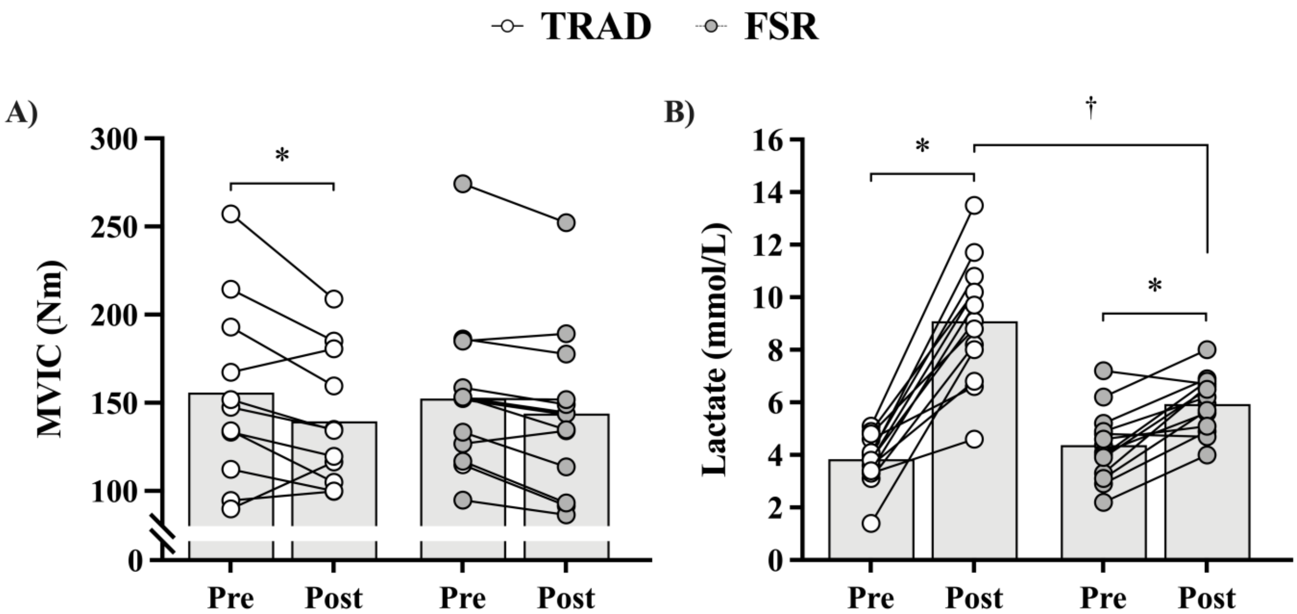

Figure 3. Neuromuscular and metabolic changes in response to the two set configurations. TRAD = traditional configuration; FSR = frequent and shorter total rest; MVIC = maximum voluntary isometric contraction; * = $P < 0.05$ pre versus post; † = significant difference between configurations.

Regarding metabolic changes, there was an effect of interaction ($F_{1, 12} = 7.847$, $P = 0.001$) and time ($F_{1, 12} = 134.804$, $P < 0.001$), and condition ($F_{1, 12} = 4.935$, $P = 0.048$). More precisely, there was an increase in lactate concentration after both experimental conditions (Table 2 and Figure 3B), but this increase was greater after TRAD ($P_{Bonf} = 0.002$).

There was no correlation between changes in the lactate concentration and density and low correlation between changes in the lactate concentration and ITL (Figure 4).

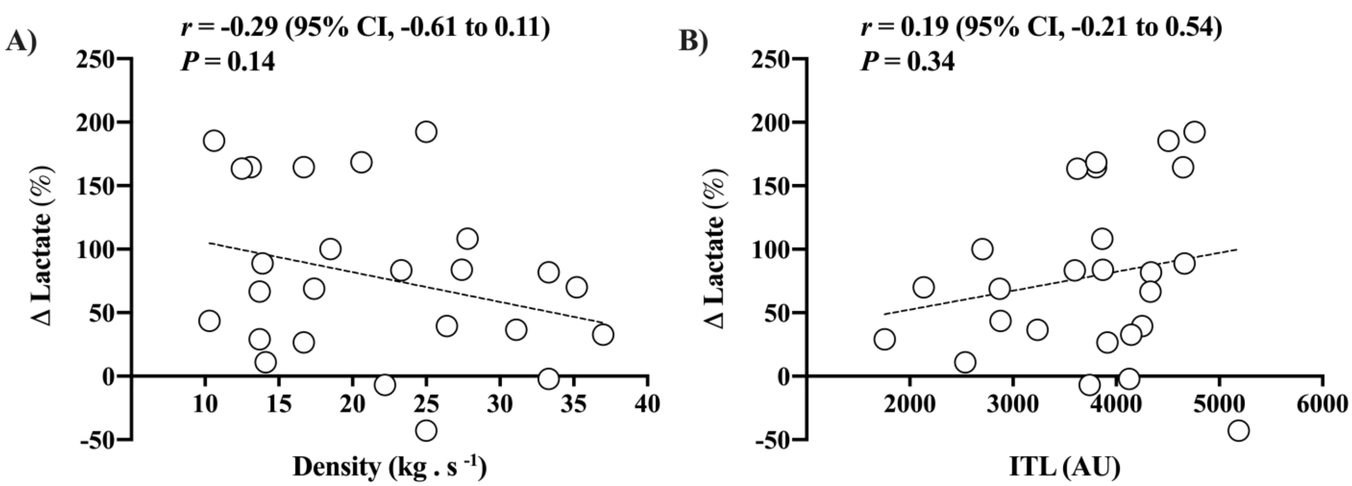

Figure 4. Relationship between metabolic changes and external and internal metrics. ITL = internal training load.

DISCUSSION

In the present study, we sought to test whether there are differences between two sets configurations (TRAD vs. FSR) on neuromuscular, metabolic, and perceptual responses in young women. In addition, we verify if the metabolic changes can be explained by external (ie., session density) and/or internal (ie., internal training load) load variables. Our main findings were: (a) the FSR configuration was effective for maintaining the ability to produce force, and induced lower metabolic stress and internal training load in young women; (b) the FSR configuration allowed performing the exercise with the same relative intensity (10RM) and volume-load in less time (ie., shorter session duration); (c) the RPE increased throughout the sets and in a similar way between both experimental conditions; (d) we found no relationship between metabolic changes, density and internal training load in young women.

The development of strength and power are among the main adaptations induced by RT (1). In this sense, different strategies are being applied in order to optimize these adaptations with the least fatigue (11, 15). Among them, the redistribution of rest within and between sets has become increasingly popular for its effectiveness in maintaining neuromuscular performance during and after a session (11). However, to the best of our knowledge, only one study (21) compared the effects of different sets configurations on the neuromuscular performance of women. In this study, Merrigan, et al. (21) observed that inserting 30 s of rest in the middle of the sets reduced the velocity loss within sets when compared to the traditional protocol. In the present study, we also observed that the FSR configuration did not reduce the force output after an RT session with a high-volume protocol; on the other hand, after the TRAD condition, there was a reduction in MVIC, even with both configurations being performed with the same intensity and volume.

Parallel to these findings on force output, we observed that the inclusion of 30 s in the middle of each set, although it significantly increased the lactate concentration, this change occurred to a lesser extent than after TRAD (see Table 2 and Figure 2). During high-volume training (eg., multiple high-repetition sets) anaerobic glycolysis is probably more prevalent, a fact that can contribute to the accumulation of lactate, as well as other metabolites such as ammonia (7, 8). Interestingly, the FSR configuration favored lower metabolic stress, even in response to a high-volume protocol. These findings can be explained, in part, because of the inclusion of rest intra-set that may have allowed the reestablishment of energy systems, more precisely the glycolytic pathway, attenuating the depletion of ATP and PCr (2, 8). Although debatable, the lower metabolic stress may have contributed to the maintenance of force output in the FSR configuration (2, 8).

RPE increased progressively and similarly in both configurations until repetition 40, as well as without significant differences. These findings are in accordance with a previous study carried out with young women who were also submitted to sessions with five sets in the leg press but with manipulation of the interval between sets (ie., 1 vs. 2. vs 3 min rest interval), in which there was no difference in the RPE (14). These findings can be explained by indications that RPE appears to be largely determined by central commands, and less by what occurs on the periphery (17). On the other hand, in the present study, we observed a greater internal training load in response to TRAD configuration. Together, these findings indicate that the perceived effort alone does not seem to be sensitive to discriminate between the two protocols, on the other hand, when calculating the perceived internal load taking into account the work performed, the FSR condition induces less perceived stress.

Regarding the possible interplay between internal and external load parameters, we seek to verify whether the metric session density (volume-load divided by the total rest interval) and internal training load (RPE x duration) would be related to the induced metabolic changes in RT sessions; and we did not observe a significant relationship between these parameters. In contrast to our findings, Marston, et al. (18) observed a significant correlation between changes in lactate concentration and density (r = 0.66). Therefore, suggesting that this external load metric would represent what happened to metabolic changes (18). A possible explanation for such divergence between our study and Marston, et al. (18) may be in the configuration of the RT sessions. In the present study, we compared protocols with the same intensity (10RM) and volume-load, while (18) compared a protocol that prioritized strength (5RM) versus hypertrophy (10RM). Taken together, such divergences in the findings shed light on the fact that perhaps a single metric — be it internal or external load — is unlikely to accurately represent the effects of all possible set configurations in an RT session.

To our knowledge, this is the first study that compared the effects of the TRAD versus FSR protocol on neuromuscular, metabolic, and perceptual responses in young women. Our study has strengths and weaknesses that deserve to be mentioned. We provide a representative picture of the effects induced by the two sets configurations when presenting the behavior of neuromuscular, metabolic, and perceptual parameters. However, we did not measure mechanical parameters (eg., velocity during and after RT sessions). Another important limitation is the fact that we did not time-course our dependent variables. Therefore, future investigations may consider adding the measurement of mechanical parameters, as well as monitoring the time course of the variables of interest. Furthermore, although we observed that the TRAD configuration induced a reduction in force output, the effect size of the reduction was medium, so further investigations should be conducted to identify whether this change is replicated and what is the practical relevance of this magnitude of reduction in force output. Finally, the RT sessions were composed of a single exercise. Since the RT sessions are composed of more exercises, future studies that take this feature into account are necessary.

Conclusion: From a practical standpoint, our findings indicate that the insertion of more frequent and shorter total rest is an effective strategy to maintain force output, as well as seems to induce lower metabolic and perceived stress in young women. This seems to be possible even when the participant is underwent a protocol with multiple high-repetition sets in a multi-joint lower body exercise. Therefore, strength and conditioning professionals can consider the use of a more frequent and shorter total rest in young women when the objective of the session is to training with high-repetition volume without accumulation of fatigue and lower metabolic stress after the RT session. In addition to these advantages, the adoption of this set configuration may allow shortening the total session duration. Besides, our findings highlight the need to monitor different internal and external load parameters, to obtain an accurate picture of what happened during and after the session; because a single variable (eg., density and internal training load) does not seem to be enough to represent the complex interplay between internal and external loads.

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