Artículo original

Blood lactate concentration and strength performance between agonist-antagonist paired set, superset and traditional set training

João A. A. A. de Souza, Gabriel A. Paz, Humberto Miranda

School of Physical Education and Sports. Federal University of Rio de Janeiro. Rio de Janeiro. RJ. Brazil.

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Summary

Objective: To investigate acute effect of agonist-antagonist paired set (PS), superset (SS) and traditional set (TS) training on maximal repetition performance, ratings of perceived exertion (RPE) and blood lactate (BL).
Material and method: Ten recreationally trained men (27.5 ± 3.8 years; 75.0 ± 5.6 kg; 176.4 ± 4.8 cm) participated in the current study. Firstly, the 8 repetition maximum (RM) loads were determined for the seated row (SR) and bench-press (BP) exercises. Then, three experimental protocols were applied: TS - 3 SR sets were performed followed by 3 BP sets; PS - 3 paired sets were performed between SR and BP exercises in alternate manner; SS - 3 paired sets were performed between SR and BP exercises without rest interval between each set paired set. Blood lactate sampling was measured prior to session (PRE); immediately post-exercise (POST); 3 min (P3), and 5 min (P5) post-exercise.
Results: Greater repetition performance was noted under PS compared to SS and TS protocols for SR and BP exercises, respectively. No differences were noted between SS and TS protocols. Higher blood lactate concentrations were also noted under SS protocol compared to PS and TS, respectively, for POST, P3 e P5 measures. RPE was significantly higher under SS than PS and TS, respectively.
Conclusion: Therefore, the PS may be an interesting method to be adopted in order to increase the repetition performance in acute manner for multi-joint exercises for upper body muscles, as well as, the SS method might be an alternative to increase the metabolic stress and muscle fatigue.

Key words:
Paired set. Strength. Lactate. Coactivation. Performance.

La concentración de lactato en sangre y rendimiento de fuerza entre series emparejadas agonista-antagonista, super series y entrenamiento tradicional

Resumen

Objetivo: Investigar el efecto del entrenamiento con series emparejadas agonista-antagonista (SE), súper series (SS) y series tradicionales (ST), en el rendimiento de repeticiones máximas, la percepción subjetiva del esfuerzo (RPE) y lactato sanguíneo (L).
Material y método: Diez deportistas de recreación (27.5 ± 3.8 años; 75.0 ± 5.6 kg; 176.4 ± 4.8 cm), hombres, fueron voluntariamente sometidos a este estudio. En primer lugar han sido determinadas las cargas de 8 repeticiones máximas para los ejercicios de remo sentado (RS) y press de banca (PB). Posteriormente, se aplicaron 3 protocolos: ST - 3 series de RS seguidas por 3 series de PB; SE – 3 series emparejadas entre los ejercicios RS y PB alternadamente; SS – 3 series emparejadas entre los ejercicios RS y PB sin intervalo de recuperación entre cada serie emparejadas. Muestras de L han sido medidas antes de la sesión (PRE); y inmediatamente después de la sesión (POS); 3 min (P3), y 5 min (P5) después.
Resultado: Se encontró un mayor rendimiento de repeticiones en SE en comparación con SS y ST para los ejercicios RS y PB. No se observaron diferencias entre los protocolos SS y ST. Se observó una mayor concentración de lactato en el protocolo SS en comparación con SE y ST respectivamente, para las mediciones POS, P3 y P5. La RPE fue significativamente mayor en SS, en comparación con PS y TS respectivamente.
Conclusión: Por consiguiente, el SE puede ser un método interesante para ser adoptado con el fin de aumentar el rendimiento de repeticiones en forma aguda para los ejercicios multi-articulares para los músculos superiores del cuerpo, como también, el método SS podría ser una alternativa para aumentar la tensión metabólica y la fatiga muscular.

Palabras clave:
Series emparejadas. Fuerza. Lactato. Coactivación. Rendimiento.

Correspondencia: Gabriel Paz
E-mail: gabriel.andrade.paz@gmail.com

Introduction

Resistance training promotes several adaptations in musculoskeletal such as the increases in maximal strength, hypertrophy, power output, and muscular endurance for fitness and sports practitioners[1]. In order to optimize these adaptations, a few methodological prescription variables are often manipulated: exercise order, rest interval between sets and exercises, number of sets and exercises, muscle actions, training load and frequency[2].

Several training methods are used adopted by coaches and practitioners of resistance training to manipulate the methodological prescription variables with the goal to increase the outcomes[3]. In this sense, agonist-antagonist paired set (PS) training proposes to trigger the muscles with agonist-antagonist role (*i.e.* biceps and triceps brachii) in alternate manner, with or without rest interval between sets and exercises with the goal to increasing the strength performance in a time-efficient manner[4]. Similarly, the superset (SS) method aims to trigger the same or different muscle group or limbs, without rest interval between sets and exercises, with the goal to induce an augmentation in muscle fatigue and metabolic responses, and consequently providing an augmentation in muscle hypertrophy potential[5]. The PS and SS are often associated to greater training efficiency (training volume/time) when compared to traditional set (TS) training, due to the shorter rest between sets and exercises and the short recovery period between like sets[4,6-8].

Recently, a few studies have been observed the acute effects of PS and SS compared to TS on training volume, power output, electromyographic (EMG) activity and training efficiency (loads/min)[4,6,9-15]. Robbins *et al.*[12] found similar training volume and EMG activity of pectoralis major, triceps brachial and anterior deltoid muscles between TS training and PS performing 3 sets in bench pull and bench press exercises, with 4 repetition maximum (RM) loads. The authors adopted 4-minute rest interval between sets and exercises in TS, and 2-minute between sets and exercises in PS. Recently, Maia *et al.*[4] noted higher repetition performance and muscle activation of rectus femoris and vastus lateralis performing PS and SS (*i.e.* lying leg curl and leg extension), adopting shorter rest intervals (without recovery, 30 s and 1-minute) compared to longer intervals (3 and 5 minutes), as well as, compared to the leg extension performed without antagonist preloading (*i.e.* TS condition).

However, there is still a lack of evidence about the effects of PS and SS on metabolic markers, such as, blood lactate concentration pre and post exercise , and also strength performance among training methods. Carregaro *et al.*[13] compared the effect of three methods of antagonist prealoading: multiple sets (MS), SS and reciprocal actions (RA) investigating the effects on EMG activity (*i.e.* vastus lateralis, vastus medialis and rectus femoris), fatigue index, total work and blood lactate concentration performing isokinect knee flexion and knee extension. The authors observed which SS generated higher fatigue index when compared to RA and MS protocols, respectively, as well as, SS promotes significant greater blood lactate concentration after SS when comparing to RA and MS, respectively.

Furthermore, there are still limited evidences about the metabolic, effort, and repetition outcomes performing PS and SS compared to TS method. These evidences may help coaches, athletes and resistance training practitioners during the prescription of training programs, with the goal to increase the outcomes without compromising strength performance. Therefore, the purpose of the current study was to investigate acute effect of PS, SS and TS on maximal repetition performance, ratings of perceived exertion (RPE) and blood lactate concentration.

Material and method

Participants

Ten recreationally trained men (27.5 ± 3.8 years; 75.0 ± 5.6 kg; 176.4 ± 4.8 cm) participated as voluntary in the current study selected by convenience, adopting a non-probabilistic procedure. The inclusion criteria were: with a) to have at least 1 year of resistance training (RT) experience; b) to perform RT ≥ 3 times a week with an average of 1 hour per session); c) to have experience in the execution of selected exercises. The exclusion criteria were: a) to show any medical conditions which could affect the outcomes this study; b) to use nutritional supplements or other ergogenic which could induce alterations in strength and metabolic responses.

The participants were instructed to do not performer any type of exercise 48h before the test or training sessions. All participants answered the *Physical Activity Readiness Questionnaire* and signed an informed consent form in accordance with the Declaration of Helsinki. The study was approved by the ethics committee of the institution with the protocol: 28037114.2.0000.5257.

Procedures

Eight repetition maximum loads determination.

In the week before the experiment, the 8 repetition maximum (RM) loads was determined for each participant for the wide-grip seated row (and bench-press exercises (Life Fitness, Rosemont, IL, USA). The 8RM load was defined as the maximum weight that could be lifted for 8 consecutive repetitions until concentric failure. The executions of both exercises were standardized, and pauses were not permitted between the concentric and eccentric phases. This procedure was controlled by a experienced researcher. If an 8RM was not accomplished on the first attempt, the weight was adjusted by 4–10 kg and a minimum 5-minute rest was given before the next attempt. Only 3 trials were allowed per testing session. The test and retest trials were conducted on different days with a minimum of 48 hours between trials[4]. To reduce the margin of error in testing, the following strategies were adopted[16]: (a) standardized instructions were provided before the test, so the subject was aware of the entire routine involved with the data collection; (b) the subject was instructed on the technical execution of the exercises; (c) the researcher carefully monitored the position adopted during the exercises; (d) consistent verbal encouragement was given to motivate subjects for maximal repetition performance; (e) the additional loads used in the study were previously measured with a precision scale.

Experimental Sessions

After determining the 8RM loads, three experimental protocols were applied in a randomized design, adopting 72h of recovery interval between the test sessions. Before testing, each participant performed a specific warm-up of 12 repetitions with 40% of 8RM loads for both exercises, adopting 2-minute rest interval among exercises, and the beginning of the testing session[14]:

- *Traditional set training.* Three sets were performed in seated row exercise followed by three sets of bench-press exercise, adopting 2-minute rest interval between sets and exercises. The session duration was approximately 10 minutes.
- *Agonit-antagonist paired set.* Three paired sets were performed between seated row and bench-press exercises in alternate manner, adopting 2-minute rest intervals between sets and exercises. The session duration was approximately 10 minutes.
- *Supersets.* Three paired sets were performed between seated row and bench-press exercises without rest interval between each set paired set (*i.e.* SR-BP). Then, a 150 seconds – rest interval was adopted before the next paired set. The session duration was approximately 5 minutes. The OMNI-Res[17] scale was adopted to record the RPE after each set and exercise for all protocols. All sets and exercises was performed until concentric failure with 8RM loads. The fatigue index, commonly defined as the drop in strength and power during a training session, was estimated for each exercise in both orders using the formula proposed by Dipla *et al*[18]: FI = (third set/first set) × 100; where a higher percentage value (%) indicates a superior fatigue resistance.

Blood lactate

After cleansing the site with 70% alcohol, the ear lobe was punctured using a disposable lancet (Accu-check Safe-T-Pro Uno®). The first drop of blood was discarded to avoid contamination with sweat and then a small blood sample was collected (25 ll) before exercise (rest for at least 15 min). Blood sampling was performed after each protocol, at the following times: (a) immediately upon completion (PRE), (b) 3 min (P3), and (c) 5 min (P5) after completion. The samples were placed in labeled microtubules (Eppendorf) containing 50 ll of sodium fluoride solution [1%], and stored at approximately 4°C for 30 min and subsequently placed in a refrigerator. All samples were analyzed using the Accutrend® (Roche)[19].

Statistical analysis

Statistical analysis was performed using SPSS software version 20.0 (Chicago, IL, USA). The statistical analysis was initially performed using the normal Shapiro-Wilk test and homocedasticity test (Bartlett criterion). All variables were normally distributed and homocedasticity. The intraclass correlation coefficient (ICC = $(MS_b - MS_w)/[MS_b + (k\text{-}1) MS_w)$ was calculated to verify the test and retest reproducibility of 8 RM loads determination. Two-way ANOVA for repeated measures followed by post hoc Bonferroni test was applied to determine whether there was a significant difference or interaction between the type of training (TS, PS and SS) and sets[1-3] for repetition performance during seated row and bench press exercises. One-way ANOVA for repeated measures followed by post hoc Bonferroni was applied to verify if there was significant difference between lactate levels and fatigue index between protocols over the time points recorded. Friedman non-parametric test was applied to compare the rating of perceived exertion between protocols and sets for each exercise. The value of p <0.05 was adopted for all inferential analyzes.

Results

The ICC for 8 RM loads was bench press: 0.91 and seated row: 0.92, respectively. The 8 RM loads were bench press: 76 ± 13,2 kg and seated row: 66,8 ± 8,8 kg. Significant differences were noted in repetition performance between the protocols (F = 183.558; p = 0.0001) and sets (F = 48.957; p = 0.0001) for seated row exercise, as well as, there was also a significant interaction between sets and protocols (F = 19.333 p = 0.0001) (Table 1). Greater repetition performance was noted under PS condition for sets 2 (p = 0.001; p = 0.002) and 3 (p = 0.0001; p = 0.0001) when compared to SS and TS protocols, respectively. No differences were noted between SS and TS protocols for all sets performed in SR exercise. Considering bench-press exercise, significant differences were noted between the protocols (F = 85.398; p = 0.0001) and sets (F = 24.868; p = 0.0001), as well as, significant interaction between sets and protocols (F = 12.641; p = 0.0001). Higher repetition performance was observed under PS protocols for sets 2 (p = 0.01; p = 0.0001) e 3

Table 1. Maximum repetition performance (Mean and SD) for seated row and bench press exercises under each set and protocol.

	Set 1	Set 2	Set 3	*p* value	Fatigue Index (%)	*p* value
Seated Row						
Traditional	8 ± 0	6.8 ± 0.4*	5.9 ± 0.7*	-	73.7 §	-
Superset	8 ± 0	6.2 ± 0.4*	5.3 ± 0.4*	0.0001	66.2	0.001
Paired set	8 ± 0	7.6 ± 0.5§¥	6.9 ± 0.3*§¥	0.001	86.2§¥	0.03
Bench Press						
Traditional	8 ± 0	6.8 ± 0.4*	5.9 ± 0.7* Ť	-	73.7 §	-
Superset	7.9 ± 0.3	6.5 ± 0.7*	5.2 ± 1*Ť	0.001	65.8	0.001
Paired set	8 ± 0	7.8 ± 0.4§¥	7 ± 0*Ť§¥	0.001	87.5 §¥	0.001

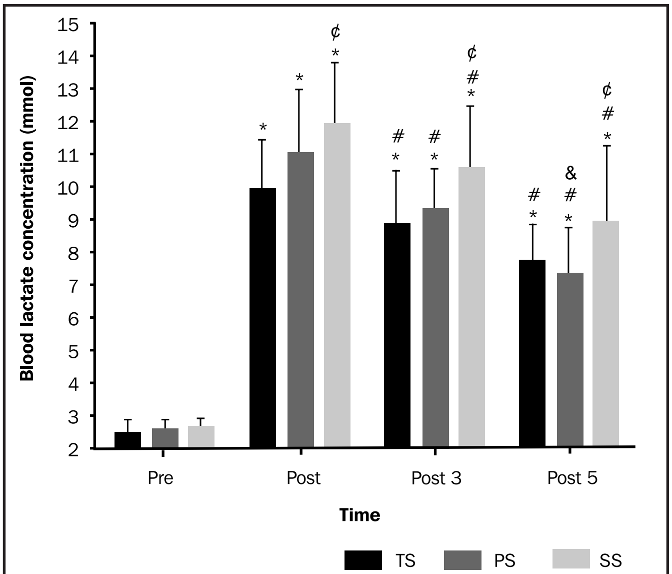
* Significant difference for set 1 ($p \leq 0.05$); Ť significant difference for set 2 ($p \leq 0.05$); § significant difference for superset protocol ($p \leq 0.05$). ¥ Significant difference for traditional protocol ($p \leq 0.05$); *p values refer to traditional set protocol.

($p = 0.001$; $p = 0.001$) when compared to SS and TS protocols, respectively. Moreover, there was no significant difference in repetition performance between TS and SS protocols for bench-press exercise.

Significant decreases in repetition performance was noted between set 2 to 1 and set 3 to 1, for seated row exercise in SS and TS. This reduction was only observed in set 3 compared to 1 for SR under PS condition. However, significant decreases in repetition performance was observed between set 2 to 1, set 3 to 2, and set 3 to 1 for all exercises and protocols for bench-press exercise. Higher fatigue index was noted under PS compared to SS ($p = 0.0001$); ($p = 0.001$) and TS ($p = 0.0001$); ($p = 0.002$) for seated row and bench-press exercises, respectively. Significant differences were also noted between TS compared to SS for seated row ($p = 0.0001$) and bench-press ($p = 0.002$) exercises.

Significant difference in blood lactate concentration was found between the measurements (F = 10.704; $p = 0.001$) and protocols (F = 240 977; $p = 0.0001$), as well as, significant interaction between the measurements and protocols (F = 2.793; $p = 0.019$). There was a significant increase in blood lactate concentrations in POST measure for all protocols compared to PRE condition, respectively (Figure 1). Higher blood lactate concentrations were also noted between P3 and P5 measures, when compared to POST measure under TS ($p = 0.0001$; $p = 0.001$), PS ($p = 0.002$; $p = 0.001$), and SS ($p = 0.0001$; $p = 0.0001$). The PS protocol showed significant difference between the P3 ($p = 0.0001$) and P5 ($p = 0.0001$) measures. In addition, SS protocol showed blood lactate concentrations significantly higher than PS and TS protocols for POST ($p = 0.001$; p 0.0001), P3 ($p = 0.001$; p 0.0001) and P5 ($p = 0.0001$; p 0.002) measures, respectively.

Figure 1. Blood lactate concentration prior to exercise (PRE), post-exercise (POST), 3-minutes post-exercise (P3) and 5-minute post-exercise (P5).



*Significant difference for PRE measure ($p \leq 0.05$); #: Significant difference for POST measure ($p \leq 0.05$); &: Significant difference for P3 measure ($p \leq 0.05$); ¢: Significant difference for TS and PS protocols ($p \leq 0.05$); SS: superset protocol; PS: agonist-antagonist paired set; TS: traditional set protocol.

Table 2. Ratings of perception exertion (OMNI-Res) of each set, exercise and protocol (Values are presented as median).

		Seated Row	
Traditional	3	4.5*§	6* Ť§
Supersets	3	6*	7.5* Ť
Paired sets	2	5.5*	6.5*
		Bench Press	
Traditional	5,5	7*	8*
Supersets	5.5	8*	9*
Paired sets	4	6*§	7*§

* Significant difference for set 1 ($p \leq 0.05$); Ť: significant difference for set 2 ($p \leq 0.05$); §: significant difference for supersets protocol ($p \leq 0.05$).

The RPE was significantly higher for sets 2 and 3 compared to set 1, for all protocols and exercises (Table 2). However, during exercise seated row exercise, the SS protocol showed higher RPE values for sets 2 and 3, compared to TS and PS conditions, respectively. Similar results were observed for the bench press exercise (Table 2).

Discussion

The main findings of the current study were the greater repetition performance found under PS method when compared to TS and SS protocols for both exercises. In addition, similar repetition performance was noted between SS and TS methods, however, SS showed higher levels of blood lactate concentration post-exercise, when compared to TS and PS, respectively. These results corroborate previous studies that found significant differences in strength performance and fatigue index comparing SS, TS and PS training methods[4,8,13,20].

Resistance training is the axis of several sports which requires muscle strength, power, and endurance performance[2]. The repetition performance for a given load intensity is important parameter to monitoring the efficiency of the training programs[3]. In the current study, higher repetition performance was observed under PS compared SS and TS for both exercises. These augmentations in strength performance due to the implementation of PS method have been also reported in the scientific literature. Baker e Newton[9] found significant increase power output performing bench press throws (with 40% of 1-RM) 3-minute after conducting a set of 8 repetitions in bench pull exercise compared to control condition without antagonistic preloading. Paz *et al.*[14] also observed significant increases in repetition performance under a PS protocol performing bench-press and seated row exercises without rest interval in alternate manner with 10RM loads, when compared to a TS of seated row exercise. However, Robbins *et al.*[10] observed similar training volume between PS and TS methods performing three sets of bench pull and bench-press exercises, with 4RM loads. Moreover, the PS protocol was performed in approximately half the time (adopting 2-minute rest interval) compared to TS (*i.e.* 4-minute rest interval). These evidences are in agreement with the current study which showed greater efficiency and fatigue resistance under PS compared to TS and SS methods, respectively.

These potential effects of PS method in strength performance are often associated with some factors such as changes in triphasic neural pathway of activation, increased elastic energy storage, and peripheral fatigue due to the longer rest provide among like sets for each exercise, respectively[4,8,13]. However, the hypothesis associated with changes in the triphasic neural pathway suggests that after antagonist preloading, a braking phase of antagonistic burst may occur and, consequently, increasing the agonist recruitment[9]. Moreover, the results of the current study may not be associated with the above condition, considering that this breaking phase has been reported only during high-speed movements[5]. Additionally, the hypothesis associated with the elastic energy storage is limited, due to the lack of appropriate instruments for evaluating such condition, as observed in previous studies[6,21,22]. Despite the above hypotheses, Maia *et al.*[4] observed significant increases in repetition performance adopting SS and PS methods, with shorter rest intervals (30 s and 1-minute) performing lying leg curl and knee extension exercises with 10-RM loads, as well as, higher muscles activity of rectus femoris and vastus medialis when compared to TS protocol. However, the increases in repetition performance found in the current study are in agreement with the mechanisms proposed by Roy *et al.*[23]. They suggested that the preloading characteristic of APS training has a positive effect on agonist muscles because of the facilitatory stimulation of Golgi tendon organs of knee flexor muscles and muscle spindles of extensor muscles, in this study, the activation of shoulder abductor muscles. On the other hand, in the current study the resistance training session was composed by multi-joint exercises, for this reason the higher recovery period between like sets during PS method may have decreased the peripheral fatigue over the sets due to the muscle mass involved in both exercises.

However, similar repetition performance was noted between SS and TS methods for both seated row and bench-press exercises. These results may be associated to the limited rest between sets and exercises adopted under SS, when compared to TS method. The fatigue index was significantly lower under SS than TS, which corroborate the RPE and blood lactate concentrations data found in SS method when compared to TS and PS, respectively. On the other hand, session duration of SS method was approximately the half in relation to TS condition, which suggested that SS may be more time-efficient than TS method. Carregaro *et al.*[24] also observed higher levels of blood lactate concentrations after a SS protocol, performing three sets of 10 repetitions of knee isokinetic flexion and extension, when compared to a MS and RA protocols, respectively. The authors suggested that these higher fatigue index and blood lactate concentrations in the SS were due to the protocol format where subjects had a lower degree of muscle recovery. However, they observed that considering the total work, fatigue index, and load range the SS method was less efficient when compared to RA and MS.

In the current study, significant augmentation in blood lactate concentration was found between POST and PRE measures for all experimental protocols. Additionally, SS method showed higher lactate values under POST, P3 and P5 measures when compared to TS and PS methods, respectively. These data are in agreement with the study of Carregaro *et al.*[13], who noted higher blood lactate concentration under SS protocol compared to RA and MS. Additionally, only the PS method showed significant decreases in blood lactate concentration comparing P5 to P3 measures. It has been postulated that lactate concentrations can be considered an important indirect marker of metabolic stress during resistance training. According to Gentil *et al.*[25], disturbances in K^+ concentration are associated with increased blood lactate concentration and, consequently, a decrease in excitability caused by muscle fatigue. Under conditions of metabolic stress, the gradual increase of K^+ could lead to inactivation of Na^+ channels which, probably, would reduce the release of Ca^+ by the sarcoplasmic reticulum via decreased amplitude of the action potential[26]. This event leads to failure of action potentials to affect the excitation–contraction coupling of the fiber and reduced strength performance[27].

In the current study, the RPE was significantly higher for sets 2 and 3 compared to set 1 for all exercises and protocols. These results are in agreement with the study of Spreuwenberg *et al.*[28] which shows higher RPE for sets and exercises performed at the end of the resistance training sequence. However, the SS protocol showed higher RPE values for sets 2 and 3, when compared to PS and TS methods for both exercises. However, there was no difference between TS and PS methods. The results of this study demonstrated a positive correlation between blood lactate concentration and RPE. Additionally, there was significant reduction in repetition performance of repetitions over the three sets performed in SR and BP exercises for all experimental protocols. These results may be associated to the shorter rest interval (120 s and 150 s) adopted between sets and exercises, which was not sufficient to maintain the repetition performance over the sets. De Salles *et al.*[29] claim that prolonged rest intervals are needed between sets and exercises to allow a complete resynthesis of adenosine triphosphate (ATP), allowing better muscle recovery and strength performance maintenance.

This study has a few limitations such as, the assessment of only two resistance exercises for upper body muscle, considering that a traditional set training session are often composed by multiple exercises and sets. The small size of the sample is also limitation, which compromising the data reproducibility. On the other hand, the methodology adopted in the current study may be easily applied by coaches and practitioners in RT fields.

Conclusions

In conclusion, the PS promoted greater repetition performance, when compared to TS and SS methods, respectively. However, the SS method showed similar repetition performance than TS protocols, but higher levels of blood lactate and RPE than TS and PS methods, respectively. Therefore, the PS may be an interesting method to be adopted in order to increase the repetition performance (e.g., strength gains) in acute manner for multi-joint exercises for upper body muscles reducing the RPE and metabolic stress, as well as, the SS method might be an alternative to increase the metabolic stress without compromising the strength performance (e.g., hypertrophy stimulus).

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