Artigo Original

REVISTA BRASILEIRA DE CIÊNCIA & MOVIMENTO
ISSN 0103-1716

Acute effects of the intensity in the agonist-antagonist paired-set on the neuromuscular performance

Efeito agudo da intensidade no sistema agonista-antagonista pareado por série sobre o desempenho neuromuscular

COSTA BDV, CUNHA TM, FORTES LS, FREIRE DS, FARAH BQ, MACHADO-OLIVEIRA L, DE LIMA-JÚNIOR D, PIRAUÁ ALT. Acute effects of the intensity in the agonist-antagonist paired-set on the neuromuscular performance. **R. bras. Ci. e Mov** 2020;28(2):149-156.

ABSTRACT: The intensity employed in the agonist-antagonist paired-set (AAPS) system may influence neuromuscular performance due to increased fatigue and decreased antagonist coactivation. However, it is not yet known whether performing submaximal repetitions at different intensities (i.e., without muscle failure) negatively affects agonist muscle performance. The aim of this study was to verify the acute effect of the AAPS system performed at different intensities with submaximal repetitions. 20 trained males in resistance training (RT) (21.8 [3.1] years; 76.9 [9.7] kg; 1.7 [0.0] m; 24.3 [2.6] kg/m^2) participated of this investigation. All the participants were allocated in a randomized order in one of the two AAPS configurations: high-load (HL) or low-load (LL). In the HL condition, the individuals were submitted to one set of eight repetitions at 75% of one-repetition maximum (1RM) in the knee flexion (i.e., antagonist), followed by 75% 1RM knee extension (i.e., agonist) exercise until momentary concentric failure. In the LL condition, they performed one set of 12 repetitions at 50% 1RM in the knee flexion, followed by knee extension at 75% 1RM also until momentary concentric failure. Both experimental conditions presented similar values for the number of repetitions, without significant difference (p = 0.66, ES = 0.15). Thus, our data suggest that the adoption of AAPS system without an increase of the antagonist fatigue and consequently no reduction of coactivation, acutely, may not lead to increased performance of target musculature during a resistance exercise session.

Keywords: Resistance training, number of repetitions, coactivation

RESUMO: A intensidade empregada no sistema agonista-antagonista pareado por série (AAPS) pode influenciar o desempenho neuromuscular devido ao aumento da fadiga e diminuição da coativação do antagonista. No entanto, ainda não se sabe se realizar repetições submáximas em diferentes intensidades (i.e., sem falha muscular) afeta negativamente o desempenho muscular. O objetivo deste estudo foi verificar o efeito agudo do sistema AAPS realizado em diferentes intensidades com repetições submáximas. 20 homens treinados em treinamento resistido (TR) (21.8 ± 3.1 anos; 76.9 ± 9.7 kg; 1.7 ± 0.0 m; 24.3 ± 2.6 kg/m^2) participaram desta investigação. Todos os participantes foram alocados, de forma aleatória, em uma das duas configurações do sistema AAPS: alta-carga (AC) ou baixa-carga (BC). Na condição AC, os indivíduos foram submetidos a uma série de oito repetições a 75% 1RM no exercício de flexão do joelho (i.e., antagonista), seguido por uma série a 75% 1RM de extensão do joelho até a falha concêntrica momentânea. Ambas as condições experimentais apresentaram valores similares para o número de repetições, sem diferença significante (p = 0.66, TE = 0.15). Assim, nossos dados sugerem que a adoção do sistema AAPS sem aumento da fadiga do antagonista e consequentemente sem redução da coativação, agudamente, pode não levar ao aumento do desempenho da musculatura alvo durante uma sessão de exercício resistido.

Palavras-chave: Treinamento resistido, número de repetições, coativação

Contato: Bruna Daniella de Vasconcelos Costa - daniellavasccosta@hotmail.com

Bruna D. de V. Costa[1]
Thiago M. da Cunha[2]
Leonardo de S. Fortes[3]
Diego S. Freire[2]
Breno Q. Farah[4]
Luciano Machado-Oliveira[5]
Dalton de Lima-Júnior[3]
André L.T. Pirauá[4]

[1] Universidade Estadual de londrina
[2] Centro Universitário Tabosa de Almeida (ASCES/UNITA)
[3] Universidade Federal da Paraíba
[4] Universidade Federal Rural de Pernambuco
[5] Universidade Federal de Pernambuco-CAV

Recebido: 19/09/2019
Aceito: 08/05/2020

Introduction

Resistance training (RT) is the most effective strategy for strength development[1-4]. One of the main strategies for designing an RT program in order to minimize the stagnation of gains in neuromuscular adaptations is the use of training systems[5-7] and the agonist-antagonist paired-set (AAPS) is one of them[8]. Also known as superset system[9,10], AAPS consists of performing agonist and antagonist exercises alternately, without or with the minimum rest interval between them[8]. This reduction in the rest interval results in a decrease in training time without a decrease in total volume[11,12]. That is, the increase of the time-efficiency occurs without reducing outcomes.

Previous acute studies have demonstrated the efficacy of the AAPS system on agonist performance[11,13]. Nevertheless, other investigations present contrary findings, with no increase in performance[14] or reduction[15]. Although the mechanisms are still unclear, it has been proposed that previous stimulation of the antagonist muscle in the long term decreases the coactivation process, reducing the resistance against the intended movement[8]. That is, the performance of the agonist is increased due to increased stimulation of the antagonist motor units[8].

In this sense, Robbins et al.[14] investigated the acute effects of performing traditional sets (TS) vs. Complex sets (CS) agonist-antagonist training, on bench press throw (BPT) performance, throw height (TH), peak velocity (PV), peak power (PP), bench pull volume-load (VL), and electromyographic (EMG) activity. The TS condition comprised of three sets of bench pull followed by three sets of bench press throw and CS condition comprised of three sets of the same exercises as the TS condition, but in an alternating manner. The results showed that TH, PV, PP e EMG were not different within and between conditions. In addition, bench pull VL decreased significantly over the sets under both conditions. Although there was no increase in power performance, the CS condition was twice as efficient (output/time) when compared to the TS condition (10-min vs. 20-min). Thus, the CS system seems to be an effective method to improve efficiency without decreasing performance.

Among the strategies employed in the AAPS system, protocols that present higher levels of fatigue (e.g., high-load, a longer time under tension, momentary concentric failure) seem to respond better to the performance of the agonist[13]. Fatigue might act as a stimulus, in other words, the protocols that adopt this strategy seem to produce greater activation of the motor units of the synergistic muscles and subsequent agonist[16]. However, due to conflicting results in the literature, a brief review by Robbins et al.[8] suggested perhaps performing submaximal repetitions could lead to increased reciprocal innervation of agonists, resulting in the prevalence of this mechanism over prolonged fatigue. This phenomenon would explain the absence of increased agonist muscle performance in those studies.

Regarding intensity-load, Psek and Cafarelli[17] analyzed the effect of two protocols with different intensities and duration on the behavior of muscle coactivation during progressive fatigue. Participants were submitted to two conditions, low-intensity and long-duration vs. high-intensity and short-duration, in knee extension exercise. The results showed that both conditions were able to increase the coactivation of the antagonists (i.e., knee flexors), during the knee extension and consequently decrease the force-producing capacity of the agonists. However, in this study, participants were submitted to fatigue protocols. That is, individuals performed repeated isometric contractions until they were unable to produce the required force (time limit of endurance). Therefore, it is not yet clear whether adopting the AAPS system without taking the antagonist muscle to fatigue can also result in increased agonist performance.

To date, no study has analyzed the acute effects of different intensities and submaximal repetitions, adopting the AAPS system in conventional machines on the performance of the subsequent agonist. From a practical point of view, this research helps RT practitioners, who use or who will use the AAPS system within the training program in deciding which strategy to use to optimize performance during RT session. Therefore, the aim of the present study was to examine the acute effect of the AAPS system performed at different intensities with submaximal repetitions. The initial hypothesis was that the protocols configuration of the greater intensity to the antagonist should present greater performance of the agonist.

Materials and methods

Participants

The participants were recruited using the non-probabilistic sampling method, yielding a total of 20 male volunteers aged from 18 to 31 years old (21.8 ± 3.1 years; 76.9 ± 9.7 kg; 1.7 ± 0.0 m; 24.3 ± 2.6 kg/m^2; 4.3 ± 2.2 training age). All participants answered the health history and physical activity questionnaires and met the following inclusion criteria: have at least six months uninterrupted experience in RT, free from any history of muscular or joint injury and did not intake any ergogenic substance for strength and/or muscle mass in the last 6 months. The participants were oriented to maintain their routines, eating habits, and to abstain from any exercise program during the study. After receiving information about the procedures, participants signed in the informed consent form. The study was approved by the institutional ethics and research committee (protocol number: 1.912.701) and followed the ethical principles contained in the declaration of Helsinki (2008).

Study design

This is a randomized and cross-over investigation with two experimental conditions. The investigation consisted of two visits. On day 1, all individuals were submitted to one repetition maximum test (1RM), in the knee extension and flexion exercises, both unilateral, in the dominant leg. After 48-h, the participants returned to the laboratory for experimental sessions. They were allocated, in a randomized manner in one of two protocols AAPS: high-load (HL) or low-load (LL). Then, they were submitted to the reverse protocol. The interval was 20-min between conditions. HL experimental condition was performed adopting 75% of 1RM in the knee flexion (i.e., antagonist) without muscular concentric failure, followed by 75% of 1RM knee extension (i.e., agonist) exercise until momentary concentric failure. LL experimental condition was performed adopting 50% of 1RM in the knee flexion without muscular concentric failure, followed by knee extension at 75% of 1RM also until momentary concentric failure.

Procedures

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Welmy, W300, Caxias do Sul, brazil). Height was measured with a stadiometer to the nearest 0.1 cm, with the participants wearing no shoes. Body mass index was calculated as body mass in kilograms divided by height in meters squared.

One maximum repetition (1RM)

The 1RM test was performed in the knee flexion and extension exercises (Righetto, São Paulo, SP, Brazil), consistent with recognized guidelines as established by the National Strength and Conditioning Association[18]. Briefly, each exercise was preceded by two sets of warm-ups. The first set was performed with eight repetitions at 50% of the estimated load for the first attempt of the 1RM test and the second set with 3 repetitions at 70% 1RM predicted, adopting a 3-min rest interval between them. The tests were performed three minutes after warm-up. Participants were asked to try to complete two repetitions, if at least one repetition was completed on the first attempt, or even if one repetition was not completed, a second attempt was performed after an interval of 3-5 min, with a higher (first possibility) or lower load (second possibility) compared to that used in the previous attempt[19]. This procedure was repeated in all sets. Participants had up to five attempts to find the 1RM load. The 1RM load was defined as the one that it was possible to perform only one repetition maximum.

Resistance training sessions

In the HL condition, they underwent one set of eight repetitions at 75%1RM in the knee flexion, in the lying leg curl exercise (i.e., antagonist), followed by 75%1RM knee extension (i.e., agonist) exercise until momentary concentric failure. In the LL condition, it was performed one set of 12 repetitions at 50%1RM in knee flexion, followed by knee extension at 75%1RM also until momentary concentric failure. Both training protocols were performed on the dominant leg. The number of repetitions in the knee flexion exercise was adjusted in order to equalize the volume-load (number of repetitions x load lifted). The participants were instructed to exhale during the concentric phase and inhale in the eccentric phase during each repetition in both exercises. The aim was to maintain a ratio of 1:2 for the concentric and eccentric actions, respectively, as recommended in a previous study[4].

Statistical analysis

The Shapiro Wilk´s test was used to analyze data distribution. The Student's t-test for paired samples was used to compare HL and LL conditions, with regard to the variables maximum number of repetitions and volume-load. Results are shown as mean and standard deviation. Moreover, effect size (ES) revealed differences in a practical point of view. According to Rhea[20] the following criteria were adopted: $d < 0.35$ = trivial, $0.35 \leq d < 0.8$ = small effect size, $0.8 \leq d < 1.5$ = moderate effect size, and $d \geq 1.5$ = large effect size. Data were analyzed on the SPSS 20.0 statistical package, considering a significance level of 5%.

Results

The general characteristics of the participants are presented in Table 1.

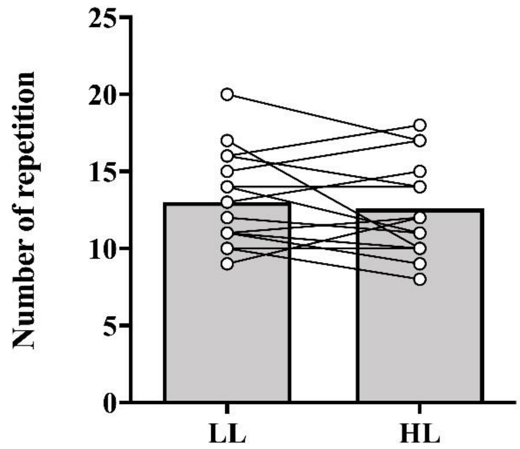
Table 1. General characteristics of participants (n = 20)

Variables	Mean	Standard deviation
Age (years)	21.8	3.1
Body mass (kg)	73.9	9.7
Height (cm)	174	0.05
BMI (kg/m^2)	24.3	2.6
1RM knee flexion (kg)	73.7	9.7

Note: BMI = body mass index; 1RM = one maximum repetition

Figure 1 shows the number of repetitions performed in each experimental session. The results demonstrated that both experimental conditions showed similar values (mean difference = 0.4 repetitions CI95% 1.4 to 2.2), without significant difference (LL = 13.0 ± 2.9 CI95% 11.6 to 14.3 vs. HL = 12.6 ± 2.8 CI95% 11.2 to 13.9; p = 0.66, ES = 0.15).

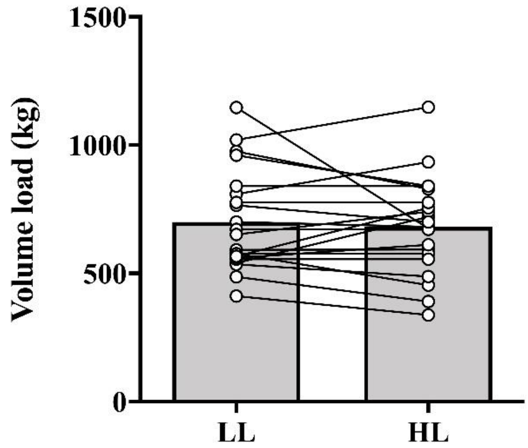
Figure 1. Number of total repetitions of knee extension in each experimental session (n = 20)



Note. Values are expressed as mean and standard deviation. LL = low-load; HL = high-load.

Figure 2 shows the volume-load performed in the two experimental conditions (LL = 701.0 ± 201.4 kg CI95% 606.7 to 795.3 vs. HL = 681.8 ± 192.6 kg CI95% 591.6 to 771.9). No statistically significant difference was revealed (mean difference = 19.2 kg CI95% 106.9 to 145.3; $p = 0.75$, ES = 0.10).

Figure 2. Volume load of knee extension in both conditions (n = 20).



Note. Values are expressed as mean and standard deviation. LL = low-load; HL = high-load

Discussion

This study aimed was to examine the acute effect of the AAPS system performed at different intensities with submaximal repetitions. The main finding of the present study was that when the first exercise of the AAPS system is performed at different intensities (low or high load), without momentary concentric failure, the performance of the subsequent exercise is not increased. Considering these results, the initial hypothesis was refuted, since the performance of the knee extension exercise was not increased in the condition HL.

It is proposed that previous stimulation of the antagonist muscle in RT results in higher performance of the agonist muscle[13, 15]. Although the mechanisms are still unclear, it has suggested that training protocols that produce greater fatigue of the antagonist are capable of generating greater activation of motor units than non-fatiguing protocols, determining the size of the training response[16]. This phenomenon is called the coactivation of the antagonist, which refers to the concurrent activation of the agonist and antagonist muscles[8, 21]. In other words, the pre-fatigue of the antagonist may lead to decreased resistance to subsequent movement, increasing the performance of the agonist force output[8]. Therefore, the more fatigued the antagonist is, the less resistance to agonist movement[21]. Based on these statements, we can explain, in part, our results, since the protocol performed in the present study did not lead individuals to momentary concentric failure. Moreover, previous studies have shown that AAPS protocols that present higher levels of fatigue result in higher performance of the number of repetitions, and volume-load and efficiency (volume-load/time) performed by the agonist muscle compared to protocols with lower levels of fatigue[11-13].

For instance, Maia et al.[13] examined the acute effects of different rest intervals between sets for exercises using the AAPS system (i.e., knee flexion and subsequent knee extension) as a strategy on the number of repetitions performed by the agonist muscle in trained men. The results showed that the protocols with lower rest intervals and consequently higher levels of fatigue (i.e., minimum interval, 30-s and, 1-min) showed higher values in the number of repetitions in knee extension. It is important to note that in all experimental conditions, individuals were brought to momentary concentric failure. Instead, the present study used submaximal effort protocols and consequently lower levels of fatigue. Considering that to increase the performance of the agonist, the antagonist muscle must be submitted to protocols that result in high levels of fatigue, we speculate that the performance of the knee extensors was not increased under any conditions due to the coactivation of the antagonist not having been reduced.

Additionally, Paz et al.[11], analyzed the effect of performing an RT session using AAPS vs. Traditional system, in the bench press (antagonist) and wide-grip seated row (SR) exercises on volume-load and muscle fatigue parameters. The results showed that in the AAPS, the volume-load for the SR exercise was higher when compared to the traditional condition. Moreover, the fatigue index of the pectoralis major muscle was higher in the AAPS condition. These findings confirm that to increase the performance of the target muscle during an RT session, the antagonist needs to be taken close to failure. Given the above, we can infer that the performance of the agonist muscle may not have been increased since, in the knee flexion exercise, individuals were not exposed to exhaustion.

To the best of our knowledge, this is the first study that analyzed the acute effect of different intensities, adopting the AAPS system on agonist muscle performance, using conventional RT machines. This strategy is an interesting feature of this study due to the increased ecological validity and consequently good feasibility. The manipulation of this variable (i.e., intensity) had already been performed in another investigation[21]; however, the resistance exercise protocol was performed in an isokinetic dynamometer. In addition, the type of contraction was different from the present study (i.e., isometric contraction). In other words, the use of this type of instrument makes it difficult for the reproduction of this study in the practical scope.

Even though our study has shown strong points, our data should be analyzed with caution. We are only considering the immediate responses. Thus, future studies are required to analyze these responses over longer periods. Another important factor was the lack of mechanism assessments that could better explain our results (i.e., electromyography), as well as the data, may only be extrapolated to trained young men and cannot be generalized to other populations. In addition, the absence of a 1RM retest is also considered a limitation of our study. Finally, future studies are required to investigate the acute responses of the AAPS system in different intensities with fatiguing protocols to antagonist muscle (e.g., a longer time under tension, momentary concentric failure).

Conclusions

Our data suggest that the adoption of AAPS system performed at different intensities with submaximal repetitions, acutely, does not lead to increased performance of target musculature (i.e., agonist) during resistance exercise, in trained men.

Acknowledgments

The authors thank all the subjects for their engagement in this study.

References

1. Padilha CS, Ribeiro AS, Silva DRP, Nascimento MA, Okino AM, Venturini D, et al. Effect of resistance training and detraining on the oxidative stress in obese older women. Rev Bras Cineantropom Hum. 2015;17(5):517-26.

2. Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of low-vs. high-load resistance training on muscle strength and hypertrophy in well-trained men. J Strength Cond Res. 2015;29(10):2954-63.

3. Schoenfeld BJ, Pope ZK, Benik FM, Hester GM, Sellers J, Nooner JL, et al. Longer Interset Rest Periods Enhance Muscle Strength and Hypertrophy in Resistance-Trained Men. J Strength Cond Res 2016;30(7):1805-12.

4. Silva RG, Silva DRP, Pina FLC, Nascimento MA, Ribeiro AS, Cyrino ES. Effect of two different weekly resistance training frequencies on muscle strength and blood pressure in normotensive older women. Rev Bras Cineantropom Hum. 2017;19(1):118-27.

5. Angleri V, Ugrinowitsch C, Libardi CA. Crescent pyramid and drop-set systems do not promote greater strength gains, muscle hypertrophy, and changes on muscle architecture compared with traditional resistance training in well-trained men. Eur J Appl Physiol. 2017;117(2):359-69.

6. Fink J, Schoenfeld BJ, Kikuchi N, Nakazato K. Effects of drop set resistance training on acute stress indicators and long-term muscle hypertrophy and strength. J Sports Med Phys Fitness. 2018;58(5):597-605.

7. Ribeiro AS, Schoenfeld BJ, Souza MF, Tomeleri CM, Venturini D, Barbosa DS, et al. Traditional and pyramidal resistance training systems improve muscle quality and metabolic biomarkers in older women: A randomized crossover study. Exp Gerontol. 2016;15(79):8-15.

8. Robbins DW, Young WB, Behm DG, Payne WR. Agonist-antagonist paired set resistance training: a brief review. J Strength Cond Res. 2010;24(10):2873–82.

9. Antunes L, Bezerra ES, Sakugawa RL, Dal Pupo J. Effect of cadence on volume and myoelectric activity during agonist-antagonist paired sets (supersets) in the lower body. Sports Biomech. 2018;17(4):502.

10. Weakley JJS, Till K, Read DB, Roe GAB, Darrall-Jones J, Phibbs PJ, et al. The effects of traditional, superset, and tri-set resistance training structures on perceived intensity and physiological responses. Eur J Appl Physiol. 2017;117(9):1877-89.

11. Paz GA, Robbins DW, Oliveira GC, Bottaro M, Miranda H. Volume load and neuromuscular fatigue during an acute bout of agonist-antagonist paired-set vs. traditional-set training. J Strength Cond Res. 2017;31(10):2777–84.

12. Robbins DW, Young WB, Behm DG. The effect of an upper-body agonist-antagonist resistance training protocol on volume load and efficiency. J Strength Cond Res. 2010;24(10):2632–40.

13. Maia MF, Willardson JM, Paz GA, Miranda H. Effects of different rest intervals between antagonist paired sets on repetition performance and muscle activation. J Strength Cond Res. 2014;28(9):2529–35.

14. Robbins DW, Young WB, Behm DG, Payne WR. The effect of a complex agonist and antagonist resistance training protocolon volume load power output, electromyographic responses, and efficiency. J Strength Cond Res. 2010;24(7):1782–9.

15. Carregaro RL, Gentil P, Brown LE, Pinto RS, Bottaro M. Effects of antagonist pre-load on knee extensor isokinetic muscle performance. J Sports Sci. 2011;29(3):271-8.

16. Rooney KJ, Herbert RD, Balnave RJ. Fatigue contributes to the strength training stimulus. Med Sci Sports Exerc. 1994;26(9):1160-4.

17. Psek JA, Cafarelli E. Behavior of coative muscles during fatigue. J Appl Physiol. 1993;74(1):170-5.

18. Haff GG, Triplett NT. Essentials of strength training and conditioning. 4 ed: Human kinetics; 2015.

19. Ritti-Dias RM, Cyrino ES, Salvador EP, Caldeira LFS, Nakamura FY, Papst RR, et al. Influência do processo de familiarização para avaliação da força muscular em testes de 1-RM. Rev Bras Med Esporte. 2005;11(1):34-8.

20. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res. 2004;18(4):918-20.

21. Psek JA, Cafarelli E. Behavior of coactive muscles during fatigue. J Appl Physiol. 1993;74(1):170-5.