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Maximal Exercise Performance and Electromyography Responses after Antagonist Neuromuscular Proprioceptive Facilitation: A Pilot Study

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ABSTRACT

Paz GA, Maia MF, Lima VP, Oliveira CG, Bezerra E, Simão R, Miranda H. Maximal Exercise Performance and Electromyography Responses after Antagonist Neuromuscular Proprioceptive Facilitation: A Pilot Study. **JEPonline** 2012;15(6):60-67. Antagonist stretching may promote agonist performance-enhancement. Thus, the purpose of this study was to investigate the acute effects of antagonist proprioceptive neuromuscular facilitation (PNF) on agonist activation and strength performance. Ten men (22.4 ± 0.9 yrs, 74.7 ± 7.7 kg, 172 ± 0.05 cm) participated as subjects in this study. All subjects had previous resistance training experience. Initially, the 10 RM test and retest were applied for wide grip seated row exercise (SR). In the traditional protocol (TP), the subjects performed a set on SR exercise with 10 RM loads. For antagonist PNF stretching (PNFA) the subjects performed 40 sec of PNF on shoulders adductors followed by a set of SR. EMG data of the latissimus dorsi, pectoralis major (clavicular fibers), biceps brachii and triceps brachii (lateral head) were registered. The paired t-test was used to statistically analyze the data, using an alpha level of $P<0.05$. Significant increase in repetitions was found with PNFA (10.8 ± 0.8) compared to the TP (9.9 ± 0.3) protocol. However, no significant differences were observed on EMG activity for the 4 muscles that were monitored. Therefore, it appears that antagonist PNF stretching may induce acute increase in muscle performance.

Key Words: Electromyography, Stretching, Strength Performance.

INTRODUCTION

Stretching exercises have been used as part of the warm-up before engaging in resistance training in order to increase the range of motion, to reduce the risk of injury, and to improve performance (3,16). Today, it is common to use different stretching techniques and, in particular, the use of proprioceptive neuromuscular facilitation (PNF) is commonly used to lengthen the musculotendinous unit and as a result increasing the range of motion of a specific joint (22).

However, there are questions about the application of stretching before engaging in exercise (7,10). Some authors have reported negative effects on strength performance after PNF (8,12). Thus, several studies examined the effects of PNF applied on agonists musculature, on the other hand, there is no evidences about the potentials effects of antagonist PNF stretching on agonists performance (21). In an effort to evaluate the role of antagonist coactivation, researchers have attempted to stretching the antagonist muscle before a contraction, or activating the prime movers isometrically or eccentrically before performing a concentric action (8,10).

This is based on antagonists neural inhibition after the pre-activation, promoting a reduction in coactivation (5) and, therefore, an increase in performance and the activation of agonists (2). However, the evidence is lacking in the literature to support this hypothesis. Therefore, the purpose of this study was to investigate the acute effects of antagonist contract-relax PNF stretching on agonist muscle activation and strength performance.

METHODS
Subjects
Ten men with mean ± SD of 22.4 ± 0.9 yrs, 74.7 ± 7.7 kg, and 172 ± 0.05 cm participated in this study. All subjects had previous resistance training experience of 2.8 ± 0.9 yrs with a mean frequency of 4, 60-min sessions per week, using 1- to 2-min rest interval between sets and exercises. All subjects were assessed via the Physical Activity Readiness Questionnaire (PAR-Q) (1), and signed an informed consent in accordance with the Declaration of Helsinki. The subjects that showed any functional limitation for the experimental protocols, unable to perform 10 RM test, or presented any medical condition that could influence the tests were excluded. Subjects were encouraged to report for workout sessions fully hydrated and to be consistent in their food intake throughout the duration of the study. They were asked to refrain from any upper-body training in the 48 hrs before each training session. The study protocol was approved by the ethics committee of the Castelo Branco University, number: 015/2011(Rio de Janeiro, Brazil).

Procedures
10 Repetition Maximum Testing (10 RM)
A week before testing, the loads of 10 RM were determined for each subject in the wide grip seated row (SR) exercise. The test and retest were conducted on two different days with a minimum interval of 48 hrs. The 10 RM test aimed at performing 10 consecutive repetitions with maximum load at a constant ratio of 2 sec per phase (concentric/eccentric) until concentric failure (9) The initial load was estimated according to the weight commonly used in resistance training sessions of each subject. The test was stopped when individual was unable to perform the correct technique for the movement or when voluntary concentric failure occurred. In order to reduce the margin of error in testing, previous strategies reported (23) were: (a) standardized instructions were provided before the test, so the individual was aware of the whole routine that involves collecting data; (b) the individual was instructed on the technical execution of the exercises; (c) the tester was alert to the position adopted by the time of testing, because small variations in positioning of the joints involved in the movement could activated other muscles, leading to interpretations of erroneous scores; (d) verbal stimuli were

performed in order to maintain the high level of motivation; and (e) the additional loads used in the study were previously measured with a precision scale. Only 3 trials were allowed per testing session. The interval between each trial during the 10 RM test was fixed at a minimum of 5 min, and after obtaining the load a 10 min interval was given, before performing the following trial. The technique of the exercises executed was standardized. No pauses were allowed between concentric and eccentric phases during the SR exercise. To determine a successful repetition, range of motion was pre-determined for each exercise.

Electromyography

The EMG signal of latissimus dorsi (LD), clavicular portion of pectoralis major (PM), biceps brachii (BC) and lateral head of the triceps brachii (TL) were recorded during the SR exercise. The electrode placement was applied according to Cram and Kasman (6). The acquisition of EMG signals was performed according to the International Society of Electrophysiology and Kinesiology (15). Bipolar active surface electrodes (silver; recording diameter = 1 mm; distance between electrode center = 1cm) were used. Raw EMG signals were recorded with a common mode rejection ratio of 100 dB. The EMG signal was pre-ampli?ed with a gain of 1,000 and band-pass ?ltered (10-450Hz). The signal was sampled at a rate of 1,000 Hz and further recti?ed for analysis. The average of the amplitude was calculated using the root mean square (RMS) value. All processing procedures of EMG signal were performed through Matlab 5.02c (MathworksTM, Natick, USA) routines. The analyses were made taking the mean of the RMS-EMG signal calculated from the repetitions performed. The ?rst and the last repetitions were excluded from the analysis. All EMG signals were interpreted after a normalization of EMG procedure, expressed as the ratio of the true value and that obtained from a maximal voluntary isometric activation (MVIA) test. Three MVIA was performed against a fixed resistance taking into consideration the muscles' function according to its position in the movement (11). The largest RMS value of the 3 MVIAs was used for normalization. The pace adopted in this study (4 sec per repetition) was controlled by a metronome. It was based on practical concerns, like avoiding velocities close to those used in isoinertial or free-weight conditions, and their influence on muscle activation according to previous evidences (4,13,21).

Traditional Protocol (TP).

Initially, the subjects performed a warm-up of 15 repetitions at 50% of 10 RM loads on SR exercise. After 3-min of rest interval, subjects performed a set of SR until concentric failure with 10 RM loads. The number of repetitions completed without error in the technique and EMG signal of LD, BC, PM and TL were recorded.

Proprioceptive Neuromuscular Facilitation on Antagonists (PNFA)

During the PNFA protocol a contract-relax PNF technique (22) was applied on shoulder adductors (antagonist muscles). For contract-relax PNF procedure, the tester performed the passive horizontal abduction of the shoulder with the subject in a stand position, preserving the physiological curvature of the spine, the elbow fully flexed. The abduction was set to the reach highest possible range of motion, when a sense of discomfort or pain was achieved. Then, 1 set of 6 sec of isometric contraction was performed by the subject and after that a lengthened position was held for 4 sec. This procedure was repeated 3 times for a total of 40 sec of PNF and followed the same as previous report (8). After FNP protocol, the subjects immediately performed a set of SR exercise until concentric failure with 10 RM loads. The number of repetitions performed and EMG activity of muscles (LD, BC, PM, and TL) were also registered during SR exercise.

Statistical Analyses

The statistical analysis was done by the Shapiro-Wilk normality test and by the homoscedasticity test (Barlett criterion). The protocol reliability was assessed by means of infraclass correlation calculated

as ICC = $(MS_b - MS_w)/[MS_b + (k-1)MS_w)]$. The paired t-test was conducted to compare the normalized EMG data, number of repetitions, and total work performed in both protocols. The alpha level of 0.05 was used to determine the statistical significance. Effect sizes were used to track the magnitude of change, and for all conditions were calculated and classi?ed as proposed by Rhea (17), as the difference between pretest and post test scores divided by the pretest SD.

RESULTS

The ICC for test and retest of 10 RM for the SR test was 0.91. The load for SR exercise was 60.5 ± 4.3 kg. In the PNFA, significant differences were found on repetitions performance and total work compared to TP (Table 1). The magnitude of effect size was classified as large for repetitions performance and total work (Table 1). In regards to EMG data, no significant differences were found among the 4 muscles monitored and protocols (Table 2).

Table 1. Exercise Performance during the Wide Grip Seated Row (Mean ± SD).

Variables	TP	PNFA	Effect size	Magnitude	P value
Repetitions	9.9 ± 0.3	10.8 ± 0.8*	2.8	Large	0.01
Total Work (repetitions x kg)	598.5 ± 41.1	653 ± 62*	1.3	Large	0.01

TP: traditional protocol; PNFA: neuromuscular proprioceptive facilitation on antagonist muscles. *Significant differences for TP (P<0.05).

Table 2. EMG Amplitude Express as Mean ± SD through Percentage of MVIA.

Variables	BC	LD	PM	TL
TP	35.1 ± 11.3%	73.5 ± 17.7%	21.1 ± 16.2%	15.1 ± 5.8%
PNFA	38.1 ± 12.3%	78.1 ± 18.9%	22.5 ± 10.2%	12.6 ± 5.8%
P value	0.07	0.10	0.21	0.08

BC: biceps braquii; LD: latissimus dorsi; PM: clavicular portion of pectoralis major; TL: triceps lateral head; TP: traditional protocol; PNFA: neuromuscular proprioceptive facilitation on antagonist muscles.

DISCUSSION

The key finding from the current study was the significant increase in agonist muscle performance during the SR exercise after contract-relax PNF stretching on antagonist muscles (shoulder adductors) compared to the TP. Additionally, the current study appears to be the first that investigated the acute effects of PNF stretching on antagonist muscles and agonists through EMG analysis. Although the results showed no significant differences between TP and PNFA for the four muscles investigated, one should consider that the P-values were less than 0.1 for BC, LD, and TL muscles. This means that a higher number of subjects could lead the statistical significance to reach values less than the critical value of 0.05. In this case both agonists almost reach the statistical significance, which would indicate a higher muscle activity after PNF procedure.

Proposed Mechanisms to Explain the Performance-Enhancement
The execution of antagonist work before the performance of agonist muscles has been suggested to enhance power output and strength (4,18). The mechanisms that have been suggested to influence antagonist pre-activation include alteration in the triphasic pattern and phenomena associated with fatigue, such as increased motor unit activation and increased activation of synergist and antagonist muscle (13). In addition, a triphasic pattern of EMG activity, whereby a large burst of agonist activity is followed by a shorter "braking" burst from the antagonistic musculature and finally a second agonist burst, has been suggested during rapid or ballistic contractions (4,18,19). According to Baker and Newton (2), heavy resistance training could modify the timing of the braking burst of the antagonist muscles during the agonist muscles action and the agonist muscle action burst could be continued longer into the total contraction time. The PNFA protocol demonstrated a significant improvement in strength performance of the exercise investigated. Also, it is possible that the contract-relax PNF stretching applied on antagonist muscles results in a facilitator influence from both the Golgi tendon organ of the antagonists (PM and TL) and the muscles spindles of the agonists (LD and BC), a mechanism earlier proposed (20).

Antagonist Coactivation Analyses through Electromyography
No significant differences were found between tests in the antagonist muscle activation (PM and TL), although PM showed a P value to be closed to statistical significance threshold. Assuming an effect of PNF a lower value was observed after stretching, which would indicate lower motor units recruited and/or their firing rate was inhibited by its own Golgi tendon organs and by the muscle spindles of its stretched antagonist (20). Simultaneously, facilitation from both types of receptors acts on the resting antagonist muscle and the consequences of such proprioceptive influences are that the agonist muscle becomes less excitable while its antagonist increases in excitability. Since the effects can last for a few seconds, a motor command arriving from higher motor control centers on the antagonist muscle motor neuron pool during that time interval results in the recruitment of a greater number of motor units and the generation of a correspondingly higher muscle torque output. According to Robbins et al. (18), the studies that investigated the effect of antagonist pre-activation had several limitations as heterogeneous sample, variations in velocity, loads and comparisons between muscles actions. One of the limitations of several studies was not to use instrumentation, such as electromyography to evaluate the electrical muscle response following the protocols (1,2). This may be due to the fact that previous studies focused on different goals, such as understanding the agonist performance during different velocities (4,12,21,) or the effect of reciprocal agonist/antagonist contractions on paretic quadriceps femoris muscles (13).

Limitation, Practical Implications, and Future Investigations
The results of the present study are limited to pre-activation protocols performed over 1 set during a multi-joint exercise (SR). This is not indicative of a resistance training session targeting multiple

muscle groups. Furthermore, the increased in muscle performance observed in the current study does not necessarily yield equivalent, or efficient, chronic development of strength and power. Thus, in the EMG activity for BC, LD, and TL muscles, the P values ranged between 0.05 and 0.10. These results indicated that a larger sample might produce significant differences for muscle activation. Also, the current study is different from several studies that investigated the effects of pre-activation of antagonistic muscle assessed by isokinetic equipment (that differ from the real conditions found in gyms and training centers) in the conventional resistance training machines was used. This is an important point regarding the results of the current study, because it can be applied to most athletes and general population. However, short-term and chronic studies are necessary to elucidate if individuals performing pre-activation protocols can achieve greater gains in strength and total work output compared with a traditional training model.

CONCLUSIONS

The PNF stretching applied on antagonist muscles resulted in a significant greater repetition and total work performance during multi-joint exercise for upper body muscles. The results from reciprocal agonist/antagonist actions observed in the current study my promote advantages in muscle performance, which should be confirmed in chronic studies. Exercise models performed using a reciprocal action protocol, as in the present study, may also be less time-consuming and could be of interest in clinical practice of physical therapy as well as sports training. Despite that no significant differences were found for antagonist muscles, which would lead to doubting the mechanism of improvement, one could not be incisive in such a consideration due to the small sample related to statistical significance found. Clearly, it is important that more subjects are investigated. Nonetheless, future studies should address the effects of different models of antagonist pre-activation with consideration for such factors such as load, velocity, range of motion, different muscle groups, and rest intervals between protocols. Thus, there is justification for practitioners to experiment antagonist pre-activation protocols to improve muscles strength performance. For the researcher, there is ample opportunity for further investigation on this topic. Future research should investigate other muscle groups, movement patterns, as well as possible differences between genders and training levels.

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