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Effect of Different Numbers of Interset Antagonist Proprioceptive Neuromuscular Facilitation Stretching on the Total Number of Repetitions for the Agonists

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ABSTRACT

International Journal of Exercise Science 15(4): 498-506, 2022. Recent studies have observed that stretching applied to antagonist muscles can promote improvement in agonist muscle performance. The purpose of this study was to investigate the effect of different numbers of interset proprioceptive neuromuscular facilitation (PNF) stretching for the antagonists on the total number of repetitions completed for the agonists (quadriceps) in the leg extension exercise. Fourteen physically active individuals (age: 29.35 ± 10.5 years; body mass: 79.1 ± 11.34 kg; height: 170.4 ± 8.7 cm) participated in this study. The following experimental protocols were performed: 1) Traditional protocol (Traditional) – without previous stretching; 2) PNF with lesser duration (PNF1—3 sets of 20 secs.); 3) PNF with greater duration (PNF2—3 sets of 30 secs.). Within the experimental protocols (PNF1 and PNF2), stretching exercises for the antagonists were performed before and between the four sets of the unilateral leg extension exercise. All tests were performed on the dominant limb only. The results showed that there was a significant difference in the total number of repetitions for the PNF2 protocol versus the Traditional protocol ($p = 0.026$). However, there was no significant difference between the PNF1 protocol versus the Traditional protocol ($p = 0.577$). In conclusion, in the leg extension exercise, an extended duration of interset PNF stretching for the hamstrings, promoted greater contractile performance for the quadriceps as demonstrated by significantly greater total repetitions over four sets.

KEY WORDS: Muscle stretching exercises, resistance training, flexibility

INTRODUCTION

Strength training is characterized as an exercise modality in which practitioners load one or more muscles with an external resistance to improve muscle performance (16). Muscle strength plays a key role in maintaining functional capacity and increasing movement efficiency (13). Thus, stretching exercises, between sets, have been commonly used with the aim of promoting improvements in muscle strength performance (20, 29).

Workout methods that improve acute strength training performance are beneficial to maximize the stimulus delivered to the agonist muscles. One such workout method that has received recent attention in scientific studies is the practice of stretching the antagonist muscles between sets (23, 27). The most widely used stretching methods are static, dynamic, and proprioceptive neuromuscular facilitation (PNF). Static and PNF stretching for the agonist muscles has been shown to reduce acute expression of strength and power (2, 4). However, stretching applied to the antagonist muscles may positively benefit agonist muscle performance (9, 15).

Hence, Gomes et al. (9) observed that a PNF stretching protocol for antagonist muscles, composed of sets of 65 seconds, promoted a significant improvement in the repetitions performed in the leg curl exercise. However, in a study conducted by Paz et al. (24), it was observed that the use of four sets with ten seconds of PNF stretching of antagonist muscles did not interfere, either positively or negatively, in maximum isometric strength in the seated row exercise. Additionally, Paz et al. (21) elucidated that one set of 40 seconds of PNF stretching of antagonist muscles, performed between sets, did not promote improvements in the total volume of repetitions in the seated row exercise.

Thus, it seems that the use of different exercises, muscle actions and stretching numbers may have a distinct influence on the total number of repetitions, which is a variable of great importance and not yet clarified. Therefore, the purpose of this study was to investigate the effect of different numbers of interset PNF stretching for the antagonists (i.e. hamstrings) on the total number of repetitions completed for the agonists (quadriceps) in the leg extension exercise. We hypothesized that experimental protocols with stretching exercises would promote a significant improvement in the total number of repetitions. Moreover, we hypothesized that the greater the stretching number, the greater the performance effect in physically active individuals.

METHODS

Participants

The sample consisted of fourteen physically active individuals of both genders (Table 1). The inclusion criteria were: a) practice of strength training for at least one year; b) did not present musculoskeletal lesions. The exclusion criteria were: a) positive response on the physical activity readiness questionnaire (PAR-Q); b) use of controlled medications and/or ergogenic resources.

All subjects signed an informed consent form before participating in the study, which was carried out following the ethical standards provided in Resolution 466/12 (Brazil, 2012). This study was approved by the Human Research Ethics Committee of the University Hospital Clementino Fraga Filho, of the Federal University of Rio de Janeiro, CAEE nº 27779119.2.0000.5257 with the approved registration number 3.904.690.

Table 1. Values of mean and standard deviation of the descriptive characteristics of the sample group.

Age (years)	Body mass (kg)	Height (m)	IMC (kg/m^2)
29.35 ± 10.50	79.10 ± 11.34	1.70 ± 8.70	27.20 ± 3.37

Note: IMC = body mass index.

Protocol

Subjects made five visits with an interval of 48 hours between them (Figure 1). In the first two visits, the following procedures were performed: 1) completing the informed consent form and the PAR-Q; 2) anthropometric measurements; 3) 10-repetition maximum (10RM) test and retest in the unilateral leg extension exercise. In the other visits, the experimental protocols were performed.

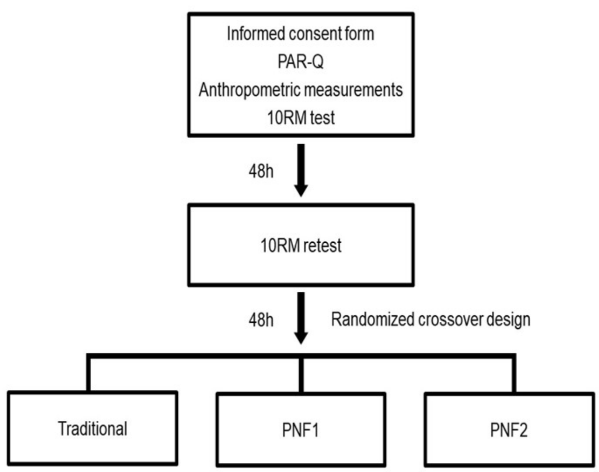

Figure 1. Experimental design.

Initially, a warm-up protocol consisting of one set of 20 repetitions was performed with 50% of an estimated 10RM load for each subject. A maximum of five attempts were made, with an interval of five minutes between them. If the load was not found by the fifth attempt, a new test session was carried out 48 hours later. The test was interrupted under two conditions: when the individual reached concentric failure in the tenth repetition or when more than 10 repetitions were performed. After a 48h interval, a new 10RM test was performed to ensure the test's reproducibility, being considered the highest load found in the two days (14, 18). All tests were performed on the dominant limb only. Additionally, to minimize the margin of error in the 10RM test and retest, the following strategies were adopted: a) all subjects received standardized instructions regarding the test protocol; b) each individual received instructions about the movement execution and, during the tests, an evaluator was attentive to the exercise execution; c) verbal stimuli were used to motivate each individual to make the maximum effort (7, 25).

The experimental protocols were performed in randomized order on three different days: 1) Traditional – without previous stretching and subsequent execution of the unilateral leg extension exercise; 2) PNF with reduced (3 sets of 20 seconds) time under tension for the stretch (PNF1) and subsequent execution of the unilateral leg extension exercise; 3) PNF with expanded (3 sets of 30 seconds) time under tension for the stretch (PNF2) and subsequent execution of the unilateral leg extension exercise. Initially, a warm-up was performed consisting of 1 set of 20 repetitions with 50% of the 10RM load. In the protocols PNF1 and PNF2, the antagonist stretching preceded the execution of each of the four sets of the unilateral leg extension exercise and were always performed at the beginning of the interval period between the sets. Two-minute intervals between sets were used, including the stretching time used in each experimental protocol. Moreover, 100% loads of 10 RM were used; all sets were performed until concentric failure and only the dominant limb was tested; the maximum number of repetitions performed in each set was recorded.

Firstly, in the PNF stretching protocol, subjects were positioned as follows: supine position; with knees, elbows, shoulders, and hips fully extended. Subsequently, the evaluator, with one hand positioned on the heel of the dominant limb and the other hand on the thigh of the contralateral limb of the subject, initiated passive hip flexion until to the subject's discomfort threshold. Upon reaching such an amplitude, it was maintained for the time equivalent to the duration used in each experimental protocol. Then, through manual resistance imposed by the evaluator, the subject was instructed to perform a maximum isometric contraction of the hamstring muscles for 10 seconds. After that time, the subject completely relaxed the muscles, without offering any resistance to the evaluator, who flexed the hip again until the new threshold of discomfort. Upon reaching this point, the limb was held in position for the time equivalent to the duration used in each protocol listed below (1).

The PNF1 protocol consisted of 3 sets of 20 seconds, in which each set had ten seconds of static stretching, 10 seconds of maximum voluntary isometric contraction, and 20 seconds of passive stretching at the new discomfort threshold. The PNF2 protocol involved 3 sets of 30 seconds, in which each set had 20 seconds of static stretching, 10 seconds of maximum voluntary isometric contraction, and 30 seconds of passive stretching at the new discomfort threshold. There were no intervals between sets and only the dominant limb was stretched.

Statistical Analysis
Statistical analysis was performed using SPSS software (version 22.0; SPSS, Inc., Chicago, IL, USA). Initially, in order to test the normality of the data, the Shapiro-Wilk test was performed. Data were presented as mean and standard deviation of the total number of repetitions performed in each experimental protocol. With the normality of the data not rejected, it was performed with one-way ANOVA followed by a Bonferroni post-hoc test to determine if there were significant differences between the experimental groups in relation to the total volume of

repetitions. A two-way repeated measures ANOVA followed by a Bonferroni post-hoc test was performed to compare the total number of repetitions performed in each of the experimental protocols along each of the four sets. The sphericity was verified and the Greenhouse-Geisser correction when necessary. The intraclass correlation coefficient (ICC) was adopted to verify the reproducibility of the 10 RM test. Additionally, effect size calculations were performed to determine the magnitude of the differences, using the scale proposed by Rhea to classify the magnitude of the effect sizes: 0 – 0.35 = trivial; 0.35 – 0.85 = small; 0.85 – 1.5 = moderate; > 1.5 = large (26). In the present study, $p < 0.05$ was adopted for statistical significance.

RESULTS

Table 2 describes the values of mean and standard deviation of the total number of repetitions performed in each set of the unilateral leg extension exercise. As a result, significant differences were observed in the total number of repetitions performed in the first set when comparing the Traditional and PNF2 protocols ($p = 0.036$; effect size = 0.74); and in the third set when comparing the Traditional and PNF2 protocols ($p = 0.019$; effect size = 1.39).

Table 3 describes the values of mean and standard deviation of the total volume of repetitions in the unilateral leg extension exercise. As a result, there was a significant difference in the total number of repetitions when comparing the PNF2 and the Traditional ($p = 0.026$; $F = 3.820$; df = 2; effect size = 1.48) protocol. However, there were no significant differences between the PNF2 versus the PNF1 ($p = 0.476$; effect size = 0.43) protocol and between the PNF1 versus the Traditional protocol ($p = 0.577$; effect size = 0.72).

Table 2. Values of mean and standard deviation of the total number of repetitions performed in each set.

Protocols	Set 1	Set 2	Set 3	Set 4
Traditional	12.1 ± 1.83	12.2 ± 1.71	10.7 ± 2.04	10.0 ± 1.66
PNF1	11.7 ± 1.93	12.0 ± 2.81	12.0 ± 2.73	12.7 ± 3.66
PNF2	13.5 ± 2.90#	13.2 ± 2.55	13.6 ± 2.79£	11.8 ± 3.00
p values	Traditional vs. PNF1 ($p = 1.000$)	Traditional vs. PNF1 ($p = 1.000$)	Traditional vs. PNF1 ($p = 0.352$)	Traditional vs. PNF1 ($p = 0.100$)
	Traditional vs. PNF2 ($p = 0.036$)	Traditional vs. PNF2 ($p = 0.473$)	Traditional vs. PNF2 ($p = 0.019$)	Traditional vs. PNF2 ($p = 0.267$)
	PNF1 vs. PNF2 ($p = 0.169$)	PNF1 vs. PNF2 ($p = 0.543$)	PNF1 vs. PNF2 ($p = 0.178$)	PNF1 vs. PNF2 ($p = 1.000$)

Note: Traditional = traditional protocol; PNF1 = PNF stretching protocol with reduced number; PNF2 = PNF stretching protocol with expanded number; # Significant difference from the traditional protocol ($p < 0.05$); £ Significant difference from the traditional protocol ($p < 0.05$).

Table 3. Values of mean and standard deviation of the total volume of repetitions.

Protocols	Total volume of repetitions
Traditional	45.14 ± 4.81
PNF1	48.57 ± 8.45
PNF2	52.28 ± 6.75*
p values	Traditional vs. PNF1 (p = 0.577)
	Traditional vs. PNF2 (p = 0.026)
	PNF1 vs. PNF2 (p = 0.476)

Note: Traditional = traditional protocol; PNF1 = PNF stretching protocol with reduced number; PNF2 = PNF stretching protocol with expanded number; * Significant difference from the traditional protocol ($p < 0.05$).

DISCUSSION

The key finding of the present study was that extended time under tension for the stretch of interset PNF stretching of the antagonist muscles (PNF2—3 sets of 30 secs.), promoted a significant improvement in the total number of repetitions of the agonist muscles; while the PNF1 protocol with less time under tension for the stretch (i.e. 3 sets of 20 secs.) did not show significant differences versus the traditional protocol. Thus, these findings partially corroborate some previous evidence that observed a significant improvement in strength performance of the agonist muscles after stretching exercises for the antagonist muscles (15, 27).

In a similar study, Paz et al. (23) investigated the acute effects of PNF stretching of antagonists on the strength performance of agonist muscles. Four sets were used, with no interval between them, consisting of six seconds of maximum voluntary isometric contraction and four seconds of static stretching. The stretching protocol preceded the performance of one set, until concentric failure, of the seated row exercise. The authors observed that the PNF stretching exercises promoted a significant improvement in repetition performance of the agonist muscles.

Additionally, in a later study, Paz et al. (22) analyzed the influence of different antagonist stretching methods on the repetition performance of agonists. The PNF stretching protocol consisted of a 40-second set (20 seconds of static stretching and 20 seconds of maximum voluntary isometric contraction) that preceded the performance of a set, until concentric failure, of the seated row exercise. As a result, it was observed that the PNF stretching exercises promoted a significant improvement in repetition performance of the agonists. However, it is important to highlight the different moments of stretching application, training sessions, and exercises used in the studies by Paz et al. (23), Paz et al. (22), and in the present study. In these two studies, even using time under tension for the stretch lower than the time under tension for the stretch used in the PNF1 protocol of the present study, the authors observed that the PNF stretching exercises of antagonists, when performed immediately before the training session, promoted significant improvements in the performance of repetitions in a single set of the seated row exercise, partially contradicting the results of the present study.

In another study, Paz et al. (24) investigated the effects of PNF stretching of antagonist muscles on the performance of the maximum isometric strength of agonists. The stretching protocol consisted of 4 sets, with no interval between them, of six seconds of maximum voluntary isometric contraction and 4 seconds of static stretching, and preceded the performance of the seated row exercise. It was observed that the stretching exercises did not interfere, either positively or negatively with maximum isometric strength of agonists. However, it is important to point out the different stretch application moments, exercises, manifestation of strength and time under tension for the stretch used in the present study and the study of Paz et al. (24).

Another study (21) analyzed the effects of different antagonist stretching methods on repetition performance and total repetitions of the agonists. The PNF stretching protocol consisted of one set of 40 seconds (4 cycles of 6 seconds of maximum voluntary isometric contraction and 4 seconds of static stretching), performed at the end of the interval between the sets, and which preceded the execution of each one of the 3 sets of the seated row exercise. As a result, there was no significant improvement in repetition performance and total repetitions when comparing the PNF and traditional groups. Nevertheless, it is important to highlight that in the study by Paz et al. (21) a single set of 40 seconds of PNF stretching was used; and all stretching exercises were always performed at the end of the interval between sets, which can probably justify the results of the present study.

Furthermore, in a recent study, Nascimento et al. (17) investigated the effects of PNF stretching of antagonists on repetition performance of agonist muscles. A set of 65 seconds (60 seconds of static stretching and 5 seconds of maximum voluntary isometric contraction) was used, which preceded the performance of 3 sets, until concentric failure, of the unilateral leg extension exercise. As a result, PNF stretching exercises did not significantly improve the repetition performance of agonists. However, it is pertinent to highlight the different stretch application moments, number of sets, and time under tension for the stretch used in the study by Nascimento et al. (17) may explain the differences in the results found in the present study.

The scientific literature elucidates some neuromuscular mechanisms as likely responsible for the acute changes in strength performance after performing stretching exercises (30). Among them, the mechanisms that can be considered most relevant is the change in the sensitivity of muscle spindles associated with a change in the ability of a given muscle to produce tension, and the increase in the reflex activity of the Golgi tendon organ (28, 30). Thus, in a given joint, antagonistic and agonist muscles are activated simultaneously, in a synchronized and coordinated manner to improve the precision and efficiency of a given movement (5, 10). This way, it has been suggested that stretching antagonistic muscles may induce an increase in the strength performance of agonists due to greater inhibition of antagonist muscles (22, 23). Conversely, the stretching number may be associated with deleterious effects on strength performance (3). Hence, it is speculated that the reduced number of stretching used in the PNF1 protocol was not sufficient to promote acute neuromuscular changes in antagonist muscles and, consequently, positively interfere in the total number of agonist repetitions.

It should be noted that the present study had some limitations, such as the sample size and the use of a single strength and stretching exercise. Therefore, it is suggested that future studies use a greater number of strength and stretching exercises and that have a larger sample size.

In conclusion, in the leg extension exercise, an extended time under tension for the stretch of interset PNF stretching for the hamstrings (i.e., 3 sets of 30 seconds), promoted greater contractile performance for the quadriceps as demonstrated by significantly greater total repetitions over four sets. Therefore, this can be a good strategy to be used in gyms and training centers when the intention is to train strength and flexibility in the same training session to improve the practitioner's performance, without the additional expense of the session time.

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