Acute Effects of Different Stretching Exercises on Muscular Endurance

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Abstract

Franco, BL, Signorelli, GR, Trajano, GS, and de Oliveira, CG. Acute effects of different stretching exercises on muscular endurance. *J Strength Cond Res* 22(6): 1832–1837, 2008—This study aims to evaluate the acute effects of different stretching exercises on muscular endurance in men, in terms of the number of sets, set duration, and type of stretching. Two experiments were conducted; in the first one (E1), the subjects ($n = 19$) were evaluated to test the effect on the number of sets, and, in the second one (E2), the subjects ($n = 15$) were tested for the effect of set duration and type of stretching. After a warm-up of 10–15 repetitions of a bench press (BP) with submaximal effort, a one-repetition maximum (1RM) test was applied. For E1, BP endurance was evaluated after static stretching comprising one set of 20 seconds (1×20), two sets of 20 seconds (2×20), and three sets of 20 seconds (3×20). For E2, BP endurance was evaluated after static stretching comprising one set of 20 seconds (1×20), one set of 40 seconds (1×40), and proprioceptive neuromuscular facilitation (PNF) stretching. All tests were performed 48–72 hours apart, at which time the muscular endurance was assessed through the maximal number of repetitions (NR) of BP at 85% of 1RM until fatigue. The NR and the overload volume (OV) were compared among tests through repeated-measures analysis of variance. No significant effect of the number of sets on muscular endurance was observed because no statistically significant difference was found when comparing all stretching exercises of E1 in terms of NS ($p = 0.5377$) and OV ($p = 0.5723$). However, significant reductions were obtained in the set duration and PNF on NR ($p < 0.0001$) and OV ($p < 0.0001$), as observed in E2. The results suggest that a stretching protocol can influence BP endurance, whereas a decrease in endurance is suggested to be attributable to set duration and PNF. On the other hand, a low volume of static stretching does not seem to have a significant effect on muscular endurance.

Key Words static, proprioceptive neuromuscular facilitation, flexibility, bench press

Introduction

Enhancing flexibility has been recommended as an important component of exercise programs aimed at physical fitness (23), whereas stretching exercises during warm-up activities have been widely employed by fitness participants and athletes. Stretching is generally employed to avoid muscle injury and to improve performance (1,27); however, this concept has been refuted by some studies (14,29,30). Among the stretching techniques applied, the static method is more often practiced in recreational exercises, likely because of its ease and safety (1,33). Other techniques are often used, such as dynamic (13) and ballistic stretching (21). Another technique that has been recently proposed (26) is known as proprioceptive neuromuscular facilitation (PNF), which is more often applied to those athletes whose performance requires flexibility.

The effect of stretching on physical fitness and strength production has not been established. Some authors have proposed that stretching increases, whereas others suggest that it decreases, strength capacity. Acute static stretching has been shown to decrease the strength of stretched muscles (4,15,21,22). Static stretching has also been observed to significantly reduce the sprinting performance of 20-m runners (20), and it was associated with reduced performance of depth jumpers (7,32) and in reducing vertical jump height (6,34). A decrease in muscle performance in the quadriceps during isokinetic exercise was also observed after PNF and static stretching (17). Evetovich et al. (10) found a decrease in biceps brachii peak torque for two different speeds, 30 and $270° \cdot s^{-1}$, after stretching. On the other hand, a significant decrease in strength performance was not observed after the application of a static stretching protocol (3,8,9,19), and static stretching, employed as part of the warm-up section in professional soccer players, did not reduce speed motor

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TABLE 1. Mean and standard deviation (*SD*) of the main anthropometric characteristics of the sample who performed the experiment 1 (E1) and experiment 2 (E2).

Experiments		Height (cm)	Weight (kg)	BMI (kg·m^{-2})	FM (%)	FM (kg)	FFM (kg)
E1 ($n = 19$)	Mean	176.8	76.9	24.5	10.3	7.9	69
	SD	7.5	6.8	2.7	2.9	2.2	6.9
E2 ($n = 15$)	Mean	175.9	76.8	24.4	10.2	7.8	69
	SD	7.2	7.0	2.6	3.2	2.4	7.2

BMI = body mass index; FFM = fat-free mass; FM = fat mass.

capacity (16). According to Fowles et al. (11), the reason for the decrease in voluntary force production is the depressed motor unit activation, which remains reduced for 1 hour after static stretching. Furthermore, structural alterations are suggested to contribute to neural alterations and to reduce reflex sensitivity (2).

The effect of the stretching period and/or number of sets on muscular performance seems to have been only minimally investigated. Yamaguchi and Ishii (31) found that performing five exercises, each comprising one set of a short period of static stretching, such as 30 seconds, did not affect power production in leg extensions, but, as highlighted by the authors, the stretching time was very short. Fowles et al. (11) found a reduction in force after 13 sets of stretching, each lasting 135 seconds. These data suggest that the number of sets and/or time duration may have an effect on muscle performance after a period of stretching. Despite the important relationship between stretching and muscular capacity in athletic performance, Nelson et al. (22) made a unique investigation of the effect of stretching on muscular endurance and found a deleterious effect on endurance when applying loads of 40, 50, and 60% of body weight.

The purpose of the present study was to assess the influence of single and multiple sets of static stretching on the endurance of upper-limb muscles. Further, the study compares different stimulus durations and static vs. PNF stretching exercises in terms of subsequent muscular endurance.

METHODS

Experimental Approach to the Problem

In the present study, two different and independent objectives were achieved with the aim of investigating the effect of stretching on muscular endurance. The first one was related to the number of static exercise sets, and the second one was related to the set duration of a static exercise and the effect of a PNF exercise. To that end, two different, independent experiments were employed. The first experiment (E1) tested whether the number of sets of a static stretching exercise influences the muscular endurance test. The second experiment (E2) tested whether the set duration of a static stretching exercise has any effect on the response of muscular endurance. In addition, E2 investigated whether a PNF exercise influences muscular endurance.

Subjects

The subjects in E1 were 19 males with a mean (SD) age of 25 (5.1) years, and those in E2 were 15 males with a mean age of 25.6 (4.6) years. All of the subjects were volunteers and regularly practiced resistance training (see Table 1 for the main anthropometrics characteristics); they had been training for activities for at least 6 months before and during the study period. None of them were engaged in any regular or organized stretching program. Written and oral consent from each individual was obtained before the experiment commenced. The experimental protocol was approved by ethics committee of Salgado de Oliveira University. The participants were not informed of the results until the study was completed.

Procedures

The order in which the exercises (Figure 1) were performed in both experiments was warm-up, one-repetition maximum (1RM) test, stretching (when applicable), and the muscular endurance test, accomplished

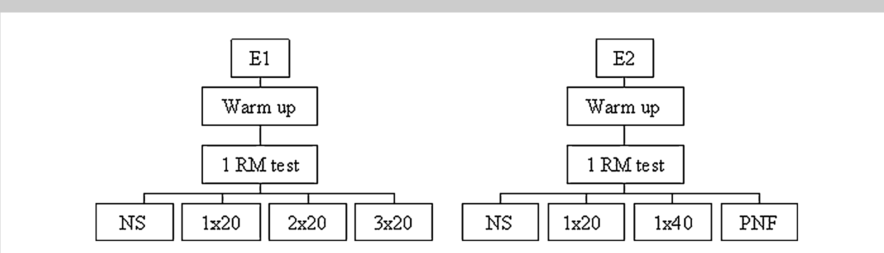

Figure 1. Flow chart illustrating the order of the exercises performed during experiment 1 (E1) and experiment 2 (E2). NS = nonstretching condition.

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on four different days for each experiment. Before any exercise, including stretching, the subjects were submitted to a warm-up that consisted of one set of bench press (BP) exercise. The set included 10–15 repetitions with a submaximal load that was freely selected by the subject. After the warm-up, a test was applied to assess the 1RM of the BP exercise. The protocol to assess the 1RM was similar to that previously reported (28), which showed very high day-to-day reliability. In summary, each subject had a maximum of three 1RM attempts of exercise with 3-minute rest intervals between attempts. Standard exercise techniques were followed for each exercise, and no pause was allowed between eccentric and concentric phases. For a repetition to be successful, a complete range of motion had to be completed, which comprised the range between a fully extended elbow and 90° flexion. The highest value obtained from the three trials was computed as 1RM for further use during the endurance exercise. To guarantee the accuracy of the 1RM test, the subjects received standard instruction on how to perform the exercise, their technique was monitored, and they were encouraged during the attempts.

The two experiments consisted of evaluations of muscle endurance after stretching protocols, assessed on four different days in both experiments. The protocol for the assessment of endurance was the same as that used in a previous study (28), including the 48- to 72-hour interval between each test of each experiment. Muscle endurance was defined as the maximum repetition of BP (MRBP) until fatigue, obtained at 85% of 1RM with the subject in the supine position, lying on a bench, with the subject's feet able to touch the ground. The range of movement during exercise was the same as that employed during the 1RM test. The same procedures that were adopted to avoid measurement errors during 1RM were employed during this test. Moreover, no interval was permitted between the concentric and eccentric phases. The subjects were encouraged to perform as many repetitions as possible at maximal speed, although the speed was not measured. The stretching exercises employed in all exercises were designed to stretch the major muscles involved in BP, and they were performed by subjects in the upright position. The tester held each subject's hands and extended the subject's elbows (Figure 2) until the subject reported discomfort.

The order of tests in both experiments was randomly selected. For E1, each subject performed the MRBP on one of three days, when the nonstretching (NS) condition was assessed. On the remaining days, the subject performed the MRBP immediately after each of the stretching protocols consisting of one set of 20 seconds (1 × 20), two sets of 20 seconds (2 × 20), or three sets of 20 seconds (3 × 20). In E2, as in E1, an NS condition was assessed on one of the days, and the MRBP was performed during the remaining days, following three stretching protocols consisting of one set of 20 seconds (1 × 40), one set of 40 seconds (1 × 40), and the PNF protocol. In all of the protocols, the MRBP evaluation was performed three times, allowing for a recovery period of 3 minutes between each trial. The number of repetitions (NR) was determined by computing the highest score from the three. Further, the overload volume (OV), defined as the product of the NR and the load lifted (85% of 1RM) by each subject, was also computed.

Figure 2. Illustration of the procedure for stretching of target muscles. (A) Starting position; (B) final position.

Statistical Analyses

The NR and OV obtained in each experiment were compared by repeated-measures analysis of variance, and the

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same test was also applied in comparisons of endurance performance between stretching and NS conditions. When applicable, a Tukey honestly significant difference post hoc test was employed, and a significance level of 0.05 was adopted.

Results

The results show that the number of sets did not have any influence on muscle endurance. The data also show that the same values were obtained with and without stretching in E1. No significant differences were found among tests ($F = 0.7314$, $p = 0.5377$) when comparing the NS condition or single and multiple sets of static stretching (Figure 3). The mean (*SD*) repetitions were 11.2 (1.8) for NS, 10.8 (1.9) for 1 × 20, 10.7 (1.4) for 2 × 20, and 11.3 (2.5) for 3 × 20. On the other hand, the duration of the set influenced muscle endurance as shown in E2, because NS, static, and PNF stretching showed the values to be significantly different ($p < 0.05$), with mean (*SD*) repetition values of 11.2 (1.6) for NS, 10.3 (1.6) for 1 × 20, 9.1 (1.8), for 1 × 40, and 8.5 (1.7) for PNF. The lowest performance was obtained after PNF stretching, as the post hoc test revealed a lower value when comparing NS and 1 × 40, NS and PNF, and 1 × 20 and PNF (Figure 3).

The same tendency observed with NR was seen with OV, as no significant difference was observed among all tests ($F = 0.673$, $p = 0.5723$) in E1. The OV values were 995.5 kg (227.2) for NS, 963.5 kg (214.4) for 1 × 20, 946.1 kg (234.2) for 2 × 20, and 986.5 kg (221.1) for 3 × 20. Again, the set duration and PNF were associated with decreased muscle endurance because the tests performed in E2 presented significant differences ($p < 0.05$). The mean (*SD*) of 1 × 20 was 941.9 (184.8) kg, 825.7 (147.1) kg for 1 × 40, and 771.1 (173.0) kg for PNF, and these values were significantly lower than that of NS–1022.3 kg (204.8)–as revealed by a post hoc comparison (Figure 4). As presented with the NR, OV showed the PNF to be lower than 1 × 40, and 1 × 40 differed from 1 × 20 (Figure 4).

Discussion

Flexibility has been recommended as an important component of exercise programs aimed at physical fitness (23). However, the influence of stretching exercises on muscle strength is not well established, because some investigators have proposed that stretching is responsible for decreasing strength (4,15,21,22), some suggest that it does not have an influence (3,9,19), and others suggest that it increases strength (31). Furthermore, few studies have addressed the effect of stretching on muscular endurance, and this is a very important factor in the performance of many athletic activities. The results of E1 in the present study show that muscular endurance in BP performed after static stretching, in single or multiple sets of 20 seconds, was not different from that after NS. However, the results of E2 revealed a significant reduction in muscle endurance based on the type of stretching and the stimulus duration.

The effect of static stretching on muscle strength has been widely investigated by means of isometric (2,4,11), isokinetic (10,12,19), and isotonic (15,21,22) evaluation. All of the studies using isotonic exercises found decreases in the force, whereas those using isometric and isokinetic methods found no difference or decreases. In the present study, in which the isotonic approach was employed, no difference was observed regarding the number of sets. Importantly, the force was not

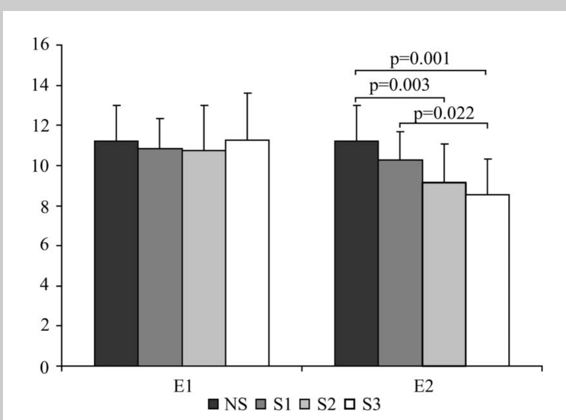

Figure 3. Mean (bar) and standard deviation values of the numbers of repetitions obtained during the nonstretching condition (NS); from experiment 1 (E1), after 1 × 20 (S1), 2 × 20 (S2), and 3 × 20 (S3) stretching; and from experiment 2 (E2), after 1 × 20, 1 × 40, and proprioceptive neuromuscular facilitation stretching, together with the significant values obtained after the post hoc test. No statistical significance was reached in E1 ($p > 0.05$).

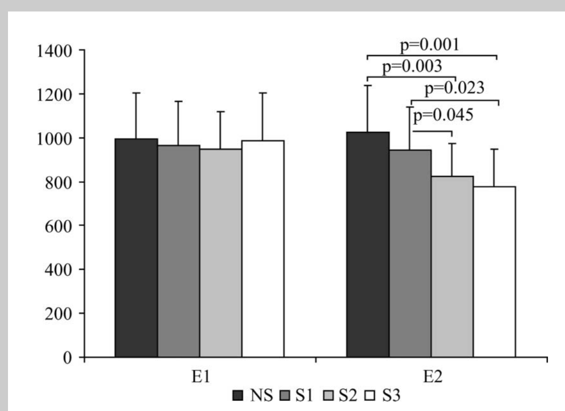

Figure 4. Mean (bar) and standard deviation values for the overload volumes obtained during the nonstretching condition (NS); experiment 1 (E1), after 1 × 20 (S1), 2 × 20 (S2), and 3 × 20 (S3) stretching; and experiment 2 (E2), after 1 × 20, 1 × 40, and proprioceptive neuromuscular facilitation stretching, together with the significant values obtained after the post hoc test. No statistical significance was reached in E1 ($p > 0.05$).

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assessed; rather, the endurance was, which does not depend only on the force. Nelson et al. (22) applied five exercises in a stretching protocol with three sets lasting 15 seconds, followed by an isotonic endurance test in which a reduction of muscular performance after stretching was observed. Fowles et al. (11) found a significant decrease in isometric force after a stretching protocol composed of one exercise with 13 sets of 135 seconds of stimuli. Similarly, Evetovich et al. (10) used exercise of the upper-limb muscles, through isokinetic torque evaluation after a stretching protocol composed of three exercises with four sets lasting 30 seconds each. On the basis of their findings, the authors hypothesized that a reduction in strength performance after successive stretching is attributable to alterations in the viscoelastic properties of the muscle, which, in turn, may alter the length-tension relationship. However, it should be pointed out that most of the studies that found decreases in the force after static stretching exercise employed more than one kind of exercise for the same muscle, with larger ranges and/or numbers of sets than those reported to be used in sport activities, with stimuli lasting from 120 to 3600 seconds (24). In the present study, the absence of a decrease in endurance was observed for subjects who stretched with one, two, or three sets of 20 seconds, providing a total stimuli duration ranging between 20 and 60 seconds, which is lower than the lowest value of 120 seconds presented in the literature. This might lead one to interpret that the high volume of stretching exercises is one of the reasons for the observed reduction in muscle strength after static stretching. On the other hand, in the present work, in the group that was stretched by only one set of 20 and 40 seconds, a statistical reduction was observed relative to the 40-second set only. Thus, the stimuli duration seems to be an important factor in determining whether the static stretch decreases muscle capacity. In summary, the reduction of muscular performance seems to be dependent on the stretching protocol.

Proprioceptive neuromuscular facilitation stretching generally leads to a force decrease (17,18,25). Further, Marek et al. (17) have reported decreases in peak torque, mean power output, and EMG amplitude when comparing prestretching with poststretching procedures. In a similar manner, the present study has shown a reduction of muscle endurance after PNF stretching, even with a small duration and with only one stretching exercise. It should be highlighted that the same exercise duration did not result in a significant reduction of muscle performance with a static method. The theory of autogenic and reciprocal inhibition has been used to explain the larger range of motion gained by PNF when compared with others' methods (5). The autogenic inhibition mechanism refers to a decrease in the excitability of a contracted or stretched muscle, which reduces the efferent drive to the muscle and decreases motor unit activation. This suggests that a larger range of movement is associated with further decreased motor unit activation, which may justify the more significant effect of loss in BP performance caused by a PNF method. Thus, one might hypothesize that the same mechanism that involves PNF, which leads the muscle to gain a large range of movement, can negatively influence the endurance of this muscle. This hypothesis is in accordance with the idea that a PNF method is more likely responsible for the decrease on muscle strength than a static stretch. On the other hand, when a person intends to increase his or her range of movement, a PNF stretch is more beneficial than a static stretch (5).

Practical Applications

The results of this study suggest that some stretching protocols influence subsequent muscular endurance. Moreover, low-intensity static stretching does not significantly affect endurance. This variation may be the result of distinct stretching durations and intensities, which were lower than those usually employed in this type of stretching. However, when a longer duration and a PNF protocol were used, the endurance during a BP decreased. Therefore, in male recreational weight lifters, the type of stretching, static or PNF, and the duration applied before a BP exercise may determine the exercise endurance. This is because only a 40-second static stretching protocol and PNF seem to influence the performance. For those interested in short-term endurance gains, the use of PNF stretching before strength training should be avoided.

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