

ACUTE EFFECT OF A BALLISTIC AND A STATIC STRETCHING EXERCISE BOUT ON FLEXIBILITY AND MAXIMAL STRENGTH

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ABSTRACT

Bacurau, RFP, Monteiro, GA, Ugrinowitsch C, Tricoli, V, Cabral, LF, Aoki, MS. Acute effect of a ballistic and a static stretching exercise bout on flexibility and maximal strength. *J Strength Cond Res* 23(1): 304–308, 2009—Different stretching techniques have been used during warm-up routines. However, these routines may decrease force production. The purpose of this study was to compare the acute effect of a ballistic and a static stretching protocol on lower-limb maximal strength. Fourteen physically active women (169.3 ± 8.2 cm; 64.9 ± 5.9 kg; 23.1 ± 3.6 years) performed three experimental sessions: a control session (estimation of 45° leg press one-repetition maximum [1RM]), a ballistic session (20 minutes of ballistic stretch and 45° leg press 1RM), and a static session (20 minutes of static stretch and 45° leg press 1RM). Maximal strength decreased after static stretching (213.2 ± 36.1 to 184.6 ± 28.9 kg), but it was unaffected by ballistic stretching (208.4 ± 34.8 kg). In addition, static stretching exercises produce a greater acute improvement in flexibility compared with ballistic stretching exercises. Consequently, static stretching may not be recommended before athletic events or physical activities that require high levels of force. On the other hand, ballistic stretching could be more appropriate because it seems less likely to decrease maximal strength.

KEY WORDS warm-up, resistance exercise, flexibility, performance

INTRODUCTION

Stretching exercises are usually part of warm-up routines before involvement in competitive sports and physical activities. It is believed that their use will enhance subsequent performance, reduce the risk of injury, and alleviate muscle soreness symptoms.

There are several stretching techniques, including static, ballistic, dynamic, and proprioceptive neuromuscular facilitation (4,12,26). The most used technique in warm-up routines is static stretching. It has been used because it seems to be easier and safer to apply than the other ones. However, some recent studies have shown that acute static stretching may reduce strength and power production with a detrimental effect on muscle performance during jumping, sprinting, and strength endurance (6,10,21,23,25,28). Therefore, some researchers have recommended that static stretching should not be used right before activities that require high levels of strength and power.

On the other hand, a few studies have reported that ballistic stretching does not seem to affect force production. Unick et al. (24) found no reduction in jumping capacity after hamstrings and quadriceps bobbing exercises. In the same way, Bradley et al. (3) did not find reductions in vertical jumping capacity. However, Nelson and Kokkonen (22) have reported a drop in knee extension and flexion peak torque values (-5.2 and -7.2% , respectively) after hamstrings and quadriceps ballistic stretching. Therefore, there seems to be no agreement on the acute effects of this type of stretching exercise on force production.

To the best of our knowledge, no study has attempted to make a direct comparison between the effects of an exercise bout of static and ballistic stretching on maximal strength. Thus, the purpose of this study was to compare the acute effects of a ballistic and a static stretching protocol on lower-limb maximal strength.

METHODS

Experimental Approach to the Problem

We used a crossover design in which subjects executed all experimental conditions. They had to perform either ballistic

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or static stretching exercises and then were tested for alterations in 45° leg press one-repetition maximum (1RM). Because this was a within-subjects design, stretching sessions were presented in a balanced, random order to avoid any carryover effect. The acute effect of a previous stretching protocol on force production was tested, comparing 45° leg press 1RM values between control and experimental conditions. In addition, the acute effects of the stretching protocols on flexibility were evaluated. Flexibility was measured before and right after the stretching protocols through a sit-and-reach test and hip joint range of motion (ROM) with a fleximeter.

Subjects

Fourteen physically active women, physical education students with at least 1 year of resistance training experience and who were training at least three times per week, volunteered to participate in this study (169.3 ± 8.2 cm; 64.9 ± 5.9 kg; 23.1 ± 3.6 years). The study was approved by the university's ethic committee, and all subjects were informed of the inherent risks and benefits before signing an informed consent form.

Flexibility Tests

- Sit-and-reach: Subjects sat with their heels pressed against the testing board. Knees were extended, and the right hand was placed over the left. Then, they were asked to reach and hold as far as possible along the measuring board, on the fourth bobbing movement. Three trials were performed, and the best was used for statistical analysis.
- Hip joint ROM: Only the right leg was tested because all subjects were right-handed. Individuals laid supine with the opposite lower extremity extended. The fleximeter (Sanny, American Medical, Brazil) was fixed halfway between the greater trochanter and the lateral epicondyle of the right thigh. Then, the same researcher raised the extended right leg up to the point at which the subject reported discomfort, and an assistant kept the left leg extended on the lying surface. The ROM was measured to the closest degree, and the best of three trials was used for statistical purposes.

Maximum Strength Test

Subjects performed a 1RM 45° leg press test right after the specific warm-up. The initial load used for this test was that obtained in the familiarization session. Then, increments of 4, 3, and 3% were used per trial to achieve 1RM load. A 3-minute rest interval was allowed between trials. A maximum of four trials was allowed to achieve the 1RM load. All subjects performed a specific warm-up composed of a five-

repetition leg press set with 50% of the 1RM load obtained during the familiarization session

Experimental Procedures

Subjects had to report to the lab on four different occasions. In the first occasion, they had a familiarization session that reproduced all experimental procedures. In the following three occasions, individuals performed the experimental sessions. These sessions were at least 5 days apart and were presented in a balanced order. Subjects were asked to refrain from any strenuous physical activity 48 hours before testing.

At the beginning of each experimental session, participants performed a general warm-up protocol that consisted of a 5-minute treadmill run at $8 \text{ km} \cdot \text{h}^{-1}$. Immediately after the warm-up, the subjects were submitted to the first flexibility evaluation. Then, they had to perform one of the following conditions:

1. Control: Subjects were submitted to the second flexibility evaluation, followed by the 1RM 45° leg press test.
2. Static stretch: Individuals performed three sets of six static stretching exercises for the quadriceps and the hamstrings, for 20 minutes. Stretching positions were maintained for 30 seconds, and a 30-second rest interval was allowed between them. Then, the subjects were submitted to the second flexibility evaluation, followed by the 1RM 45° leg press test.
3. Ballistic stretch: The same procedures were followed, but instead of holding the stretching positions for 30 seconds, subjects had to bob in 1:1-second cycles for 1 minute. Then, the subjects were submitted to the second flexibility evaluation, followed by the 1RM 45° leg press test. A specific warm-up was always performed before the 1RM test. Figure 1 gives a pictorial view of the experimental design.

Statistical Analyses

A mixed model was performed, with condition (control, static, and ballistic) as a fixed factor and subjects as a random factor, for the 1RM 45° leg press test. A second mixed model was performed, with condition (control, static, and ballistic) and time (pre- and poststretch) as fixed factors and subjects as a random factor, for both flexibility measurements. Whenever a significant *F* value was obtained, a post hoc test with

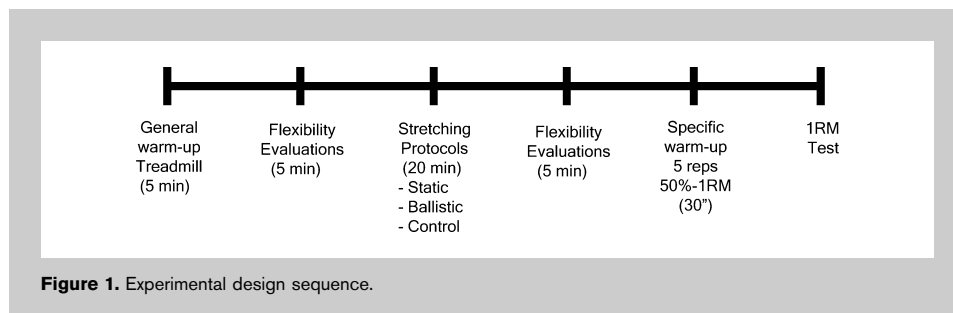


Figure 1. Experimental design sequence.

a Tukey adjustment was performed for multiple comparison purposes. The significance level was set at $p \leq 0.05$

RESULTS

Flexibility significantly improved after both ballistic and static stretching conditions ($p < 0.001$). However, the static condition produced a significantly greater improvement in ROM than the ballistic condition. In addition, fleximeter measurement detected a greater change in ROM after both flexibility protocols than the sit-and-reach test (effect sizes = 0.97 and 0.62, and 1.93 and 0.74, for the ballistic and static conditions, respectively) (Table 1). Figures 2 and 3 describe individual responses after the ballistic and the static stretching protocols, respectively.

Leg press 1 RM decreased significantly after the static condition compared with both the control and the ballistic conditions (Figure 2) ($p < 0.05$). The percentage drop in leg press 1RM after the ballistic and the static stretching protocols was 2.2% and 13.4%, respectively (Figure 4).

DISCUSSION

The purpose of this study was to compare the acute effects of a ballistic and a static stretching protocol on lower-limb maximal strength. Static stretching produced a significant acute drop in force production compared with both ballistic stretching and control (e.g., no stretch), but ballistic stretching did not affect force production. In addition, both stretching protocols produced acute increments in flexibility (sit-and-reach and hip joint ROM test). However, the static condition produced greater increments in flexibility.

Sit-and-reach and hip joint ROM measurements indicate that both the ballistic and the static stretching exercises were effective in improving flexibility acutely. Our results show

TABLE 1. Acute changes in flexibility after the ballistic stretching, the static stretching, and the control condition.

	Sit-and-reach (cm)	Hip joint range of motion ($^{\circ}$)
Control Pretest	36.6 $\pm$ 5.8	112.2 $\pm$ 12.1
Control Posttest	37.0 $\pm$ 5.8	113.6 $\pm$ 11.6
Ballistic Pretest	36.8 $\pm$ 6.1	114.7 $\pm$ 12.4
Ballistic Posttest	40.4 $\pm$ 5.6*†	126.6 $\pm$ 12.2*†
Static Pretest	36.8 $\pm$ 5.7	114.4 $\pm$ 10.6
Static Posttest	41.1 $\pm$ 6.0*†‡	136.3 $\pm$ 12.1*†‡

Values expressed as mean $\pm$ SD.

*Significantly greater than pretest value ($p < 0.001$).

†Significantly greater than control posttest value ($p < 0.001$).

‡Significantly greater than ballistic posttest value ($p < 0.05$).

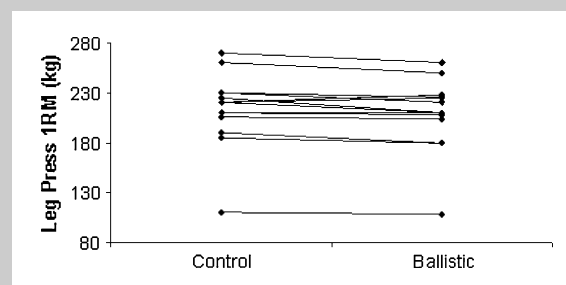


Figure 2. Individual values of leg press one-repetition maximum (1RM) (kg) in the control condition and in the ballistic stretching condition.

a greater improvement in flexibility after the static than after the ballistic protocol. Other studies have also reported results in the same direction. Nelson and Kokkonen (22) have reported 9% improvement in the sit-and-reach test after passive ballistic stretching, whereas Fowles et al. (11) found 21% improvement in plantar flexion ROM after static stretching. A possible explanation for the greater increase in flexibility after the static exercise may be the viscoelastic stress relaxation that occurs when the muscle tissue is kept stretched in a fixed position (17,18). The stress relaxation seems to be attributable to a increased tendon elasticity and a decreased muscle viscosity, which produces a decreased passive joint torque (15).

It is interesting to note that hip joint ROM improvement was greater than sit-and-reach improvement for static and ballistic stretching exercises (effect sizes 1.93–0.97 and 0.74–0.62, respectively). It is difficult to explain why hip joint ROM improved more than sit-and-reach flexibility acutely. A possible explanation would be that hip joint ROM isolates the joint, whereas the sit-and-reach movement involves hip and lower-back flexibility. Shoulder extension and hand positioning can also influence the test results. Furthermore, sit-and-reach is performed actively, whereas hip joint ROM was measured passively, which seems to give a greater degree of control to the movement.

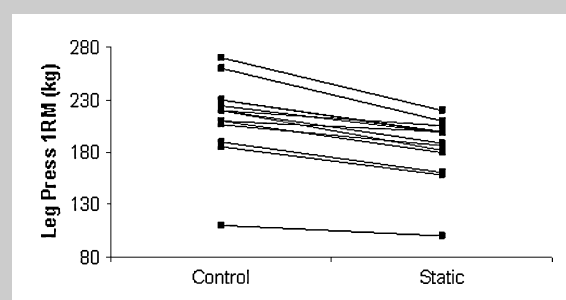
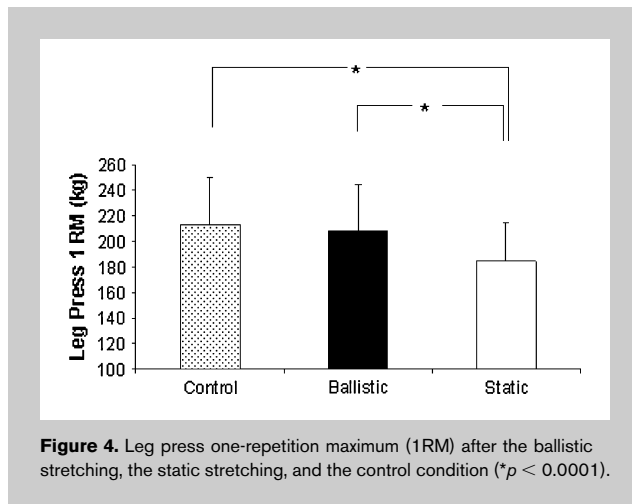


Figure 3. Individual values of leg press one-repetition maximum (1RM) (kg) in the control condition and in the static stretching condition.



The effects of stretching exercises on muscle force capacity are contradictory. Yamaguchi and Ishii (27) have reported increased leg power after dynamic stretching. McMillian et al. (19) found increased T-drill, medicine ball throw, and five-step-jump performance after dynamic stretching but not after static stretching. Similar results were obtained by Little and Williams (16), who found that dynamic stretching was most effective to prepare for high-speed activities (10-m sprint, flying 20-m sprint, and agility) and that static stretching was not detrimental to performance. Church et al. (4) also did not observe negative effects of static stretching on vertical jump performance. On the other hand, Fletcher and Jones (10) found a significant decrease in 20-m sprint performance after acute passive and active static stretching. Bradley et al. (3) have reported a decreased jumping height after ballistic and proprioceptive neuro-facilitation stretching routines, when data from squat jumps and countermovement jumps were collapsed. Wallmann et al. (25) also found a decrement in vertical jump height after a bout of static stretching of the gastrocnemius muscle.

Egan et al. (8) do not report any significant impact of static stretching on peak torque production during concentric knee extension at 60 and 300°·s⁻¹. However, Cramer et al. (7) found decreased knee extensor concentric peak torque at both low (60°·s⁻¹) and high (240°·s⁻¹) angular velocities after active and passive static stretches, whereas Nelson et al. (21) observed deleterious effects only on knee extension concentric torque performed at slow velocities (60 and 90°·s⁻¹). Curiously, Cramer et al. (5) found that a static stretching bout did not affect knee extensor eccentric peak torque production at 60 and 80°·s⁻¹. It seems that static stretching produces impairments in muscle force production. This impairment may be associated with the stress relaxation reported above. The increased stress relaxation could impair muscle force production as a result of changes in the force-velocity and length-tension relationships. On the other hand, ballistic stretching may enhance stretch reflex activity and increase force production. Bradley et al. (3)

found a decrease in jumping height only when squat and countermovement jump data were collapsed. Squat jumps do not use the stretch reflex, whereas the countermovement jump has an important stretch reflex component (1,2); this is an important confounding factor.

As a conclusion, static stretching seems to produce an acute impairment on maximal lower-limb force production. In addition, static stretching exercises produce a greater acute improvement in flexibility compared with ballistic stretching exercises.

PRACTICAL APPLICATIONS

Our findings, in conjunction with previous studies (7,9,13,14,20,29), indicate that a static stretching protocol produced a significant reduction in maximal strength performance. Consequently, this stretching technique may not be recommended before athletic events or physical activities that require high levels of force. Ballistic stretching could be more appropriate because it seems less likely to decrease maximal strength. On the other hand, static stretching may be used in warm-up routines of sports that rely more on ROM than on maximal strength.

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