A 10-Week Stretching Program Increases Strength in the Contralateral Muscle

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1Department of Kinesiology, Louisiana State University, Baton Rouge, Louisiana; 2Exercise and Sport Science Department, Brigham Young University—Hawaii, Laie, Hawaii; 3Department of Kinesiology, Leisure and Sports Science, East Tennessee State University, Johnson City, Tennessee; and 4Physical Therapy Department, East Tennessee State University, Johnson City, Tennessee

Abstract

Nelson, AG, Kokkonen, J, Winchester, JB, Kalani, W, Peterson, K, Kenly, MS, and Arnall, DA. A 10-week stretching program increases strength in the contralateral muscle. J Strength Cond Res 26(3): 832–836, 2012—It was questioned whether a unilateral stretching program would induce a crosstraining effect in the contralateral muscle. To test this, 13 untrained individuals participated in a 10-week stretching program while 12 other untrained individuals served as a control group. For the experimental group, the right calf muscle was stretched 4 times for 30 seconds, with a 30-second rest between stretches, 3 d wk−1 for 10 weeks. Strength, determined via 1 repetition maximum (1RM) unilateral standing toe raise, and range of motion (ROM) were measured pre-post. In the treatment group, the stretched calf muscle had a significant (p < 0.05) 8% increase in ROM, whereas the nonstretched calf muscle had a significant 1% decrease in ROM. The 1 RM of the stretched calf muscle significantly increased 29%, whereas the 1RM of the nonstretched calf muscle significantly increased 11%. In the control group, neither 1RM nor ROM changed for either leg. The results indicate that 10 weeks of stretching only the right calf will significantly increase the strength of both calves. Hence, chronic stretching can also induce a crosstraining effect for strength but not for the ROM. This study also validates earlier findings suggesting that stretching can elicit strength gains in untrained individuals.

Key Words crosstraining, plantar flexor strength, ankle range of motion

Introduction

Many researchers have reported that unilateral strength training causes a significant increase in voluntary strength not only in the trained limb but also in the contralateral untrained limb (see [3,16] for review). The training effect seen in the contralateral limb is known as crosstraining, crosseducation, or the crosstension effect. The physiological mechanisms underlying the strength increases in the contralateral untrained limb have not been completely identified. Nevertheless, Farthing (3) provides evidence to suggest that possible mechanisms for improvement include adaptations in motor learning and control rather than changes in peripheral physiology. In his review, Zhou (16) concludes that the mechanisms which best explain the crosstraining phenomenon are changes in the spinal cord. Zhou (16) bases his conclusions upon the results of research using electrical muscle stimulation (EMS). The EMS is as effective as isometric contraction is ([16] and sources cited therein) and much better than eccentric contractions in evoking the crosstraining effect (7). Zhou (16) suggests that EMS is able to generate a large crosstraining effect because it involves afferent modulation.

If Zhou’s (16) conjecture that afferent input is a key to crosstraining is correct, then long-term regimens of static passive stretching should also induce strength gains in a contralateral nonstretched limb. Not only does the passive stretching of a muscle activate muscle afferents without activating the motor neurons (9,13) but passive stretching can also cause increases in the strength of the stretched muscle (10,11,15). Moreover, Smith (14) has shown that when sudden stretches are applied to the contraction during a static training session, crosstraining effect is greater than that seen with static training alone. Finally, when compared with concentric and isometric training, eccentric training elicits the greatest crosstraining effect ([16] and sources cited therein), and one of the ways eccentric work differs from concentric and isometric work is that it places a greater stretch upon the musculotendinous unit. On the other hand, Handel et al. (6) reported no increase in the strength of the...
control contralateral leg after an 8-week unilateral contract-relax stretching program (passive stretch after isometric contraction). A lack of an increase in strength in the contralateral muscle after unilateral isometric training, however, is not an uncommon occurrence (2,4,8). Therefore, the lack of crosstraining may have occurred because the isometric actions negate or lower the neural mechanisms involved with crosstraining. Nevertheless, more information concerning this phenomenon would be helpful. Hence, the purpose of this investigation was to determine whether a unilateral stretching program would induce a crosstraining effect in the contralateral muscle. It was hypothesized that stretching the calf of 1 limb would increase both strength and range of motion (ROM) of the contralateral unstretched limb.

**METHODS**

**Experimental Approach to the Problem**

To determine whether a unilateral stretching program could induce a crosstraining effect in the contralateral muscle, a pretest, training program, posttest research paradigm was used. Initially, 25 volunteers’ ankle ROM and calf strength were obtained for both the right and left legs with the ROM test always preceding the calf strength test by 30 minutes. Each person was tested 2–3 hours postprandial and was asked to refrain from physical exercise and caffeine consumption for 24 hours the pretests. After these pretests, 13 (6 men, 7 women) participants were randomly assigned to a treatment (TR) group, whereas the other 12 (6 men, 6 women) were assigned to a control group. The TR group performed supervised right calf stretching 3 d wk⁻¹ for 10 weeks, whereas the C group did not engage in any supervised activity. All persons were instructed to maintain their current physical activity. In addition, they were asked to refrain from performing any stretching or strength training activities for the duration of the investigation. Each individual’s diligence in maintaining their prescribed activity program was monitored by weekly reports. Moreover, all local (Oahu’s Koolauloa district, population ≈20,000) recreational facilities were monitored by the research staff, and the presence of any subjects was noted and collaborated with their exercise logs.

At the end of the 10 weeks, posttests were administered to each person at the same time of the day as the pretest and the posttests, and they followed the exact pretest protocol using the same testers and the methods.

**Subjects**

Twenty-five undergraduate students, enrolled in professional physical education classes, volunteered to participate in the study. Pretest descriptive values for the participants are presented in Table 1. Before the onset of initial testing, the students were either physically inactive or minimally recreationally active. Minimum recreational activity was defined as sporadic participation in sporting activities not >4 times a month and for <60 minutes per session. Anyone who was currently doing regular physical training or who initiated a regular program during the study was excluded from the study. The study was approved by the appropriate institutional review board, and each participant gave both written and oral consent before engaging in the experiment.

**Testing Procedures**

All testing of a single individual was performed over 2 days, with the flexibility testing always done on day 1 and calf strength testing on day 2. Active ROM at the ankle joint was measured with a simple, plastic hand-held device called an angle finder (Dasco Pro Inc., Rockford, IL, USA), by following the procedures of Cornwell et al. (1). The subject stood on the floor with 1 foot roughly 2 ft behind the other foot. The subject then flexed the knee of the leading leg and dorsiflexed the ankle of the trailing leg while keeping the foot flat on the floor. After the subject was in this initial position, the experimenter placed the straight edge of the angle finder at an ink mark on the Achilles tendon just proximal to the calcaneus. The subject then leaned forward toward the leading leg and maximally dorsiflexed the trailing leg ankle joint keeping the foot flat on the ground and the knee fully extended. When a subject could not further dorsiflex the ankle without raising the heel from the floor or flexing the knee, a reading of the angle the Achilles tendon formed with the vertical was taken. Three readings were taken for each ankle joint, and the average of these readings was taken as the ROM measurement. In our laboratory, the ROM reliability, as assessed by an intraclass correlation, equals 0.99.

Strength was measured before and after the 10-week program using a 1 repetition maximum (1RM) unilateral standing toe raise. Each lift was performed in a Smith machine, which prevented bar travel in all but the frontal plane. To ensure that the unused leg did not bear any weight, the unused leg was flexed at the knee and ankle, and the dorsal portion of foot at

<table>
<thead>
<tr>
<th>TABLE 1. Subject description.*†</th>
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<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>TR (male)</td>
</tr>
<tr>
<td>TR (female)</td>
</tr>
<tr>
<td>C (male)</td>
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<tr>
<td>C (female)</td>
</tr>
</tbody>
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*TR = treatment; C = control.  †Values are mean ± SD.
the ankle joint was rested against the Achilles tendon. Before beginning the 1RM measurement, the person rested a barbell on the shoulders and then the plantar flexed as high as possible. The height of this lift was marked on the Smith machine, and each succeeding lift was judged successful only if the barbell again reached this height mark. The initial weight was 137 N, and after a 1-minute rest, the weight was incremented by an additional 22 N. This weight increment and rest period were repeated until the subject failed to reach the height mark. Once the subjects failed to reach the mark, they rested for 1 minute and tried the lift again. If failure occurred a second time, the previous lifted weight was recorded as the 1RM. If the lift was successful the second time, the protocol was continued until 2 successive failures occurred. In our laboratory, the strength test reliability, as assessed by an intraclass correlation, equals 0.98.

**Stretching Procedure**

For 10 weeks, each TR group participant did supervised active static stretching of the right calf muscle. The calf muscle was stretched 3 d wk−1 with at least 1 day between sessions. Each day’s stretching regimen consisted of stretching the right calf muscle for 30 seconds, followed by 30 seconds of rest, repeated 4 times. The calf muscle was stretched by having each person stand erect on a beam approximately 30 cm above the floor. The left foot was placed flat on the beam surface with the left knee slightly bent to reduce weight bearing by the left leg. The ball of the right foot rested near the edge of the beam with the heel hanging unsupported over the edge of the beam. The right knee was kept straight with the ankle dorsiflexed. Finally, the person leaned forward and rested both hands against a wall for support. For the stretch, the subjects were instructed to place the majority of their weight upon the right leg and to lower the right heel toward maximal dorsiflexion, until the stretch produced in the calf muscle was at the maximally tolerable level. Although no attempt was made to quantify the amount of stretch applied each time, this procedure has been shown previously to increase not only ROM but also muscular strength, power and endurance (12).

**Table 2.** The influence of the stretching program upon ankle ROM.†‡

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-ROM (°)</th>
<th>Post-ROM (°)</th>
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<tr>
<td>TR left ankle</td>
<td>62.3 ± 7.3</td>
<td>61.8 ± 8.1‡</td>
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<tr>
<td>TR right ankle</td>
<td>61.6 ± 7.5</td>
<td>57 ± 8.4‡</td>
</tr>
<tr>
<td>C left ankle</td>
<td>61.2 ± 6.4</td>
<td>61.0 ± 6.7</td>
</tr>
<tr>
<td>C right ankle</td>
<td>60.7 ± 6.8</td>
<td>60.3 ± 7.3</td>
</tr>
</tbody>
</table>

*ROM = range of motion; TR = treatment; C = control.
†Values are mean ± SD.
‡Significant improvement over the prescore.

**Statistical Analyses**

The dependent variables analyzed were ankle joint ROM and calf raise 1RM. A 3 × 2 (treatment vs. control × right leg vs. left leg × pre vs. post) analysis of variance (ANOVA) with repeated measures (pre vs. post) was used for data analysis of both ROM and 1RM. Post hoc ANOVA involved, where appropriate, the use of Bonferroni t-tests. Significance was set at p ≤ 0.05.

**Results**

**Range of Motion**

The influence of the stretching program upon ankle joint ROM is presented in Table 2. The interaction between treatment, leg, and time (F[1,48] = 12.92, p = 0.008) was significant. Post hoc analysis showed that all the significance was because of the stretched TR calf muscle having a significant 8% increase in ROM, and the nonstretched TR calf muscle having a significant 1% increase in ROM. On the other hand, both C group calf muscles remained unchanged.

**Strength (1 Repetition Maximum)**

Table 3 reports the influence of the stretching program upon calf raise 1RM. The interaction between treatment, leg, and time (F[1,48] = 10.64, p = 0.002) was significant. Post hoc analysis showed that the significance was because of the stretched TR calf muscle having a significant 29% increase in calf raise 1RM, and the nonstretched TR calf had a significant 11% increase in calf raise 1RM. Both calf muscles of the C group, however, remained unchanged.

**Discussion**

As stated above, the purpose of this investigation was to determine whether a unilateral stretching program would induce a crosstraining effect in the contralateral muscle. As mentioned above, Zhou (16) suggested that the most likely mechanism behind crosstraining is one that resides in the spinal cord. Zhou (16) makes this suggestion based upon studies that showed EMS inducing greater crosstraining.
strength gains via the ability of EMS to modulate afferent nerve activity. Because passive stretching of a muscle can increase strength (10,11,15) without activating the motor neurons, and can activate afferent activity (9,13), it appeared that a long-term passive stretching program would induce the crosstraining effect.

The results indicate that 10 weeks of stretching the right calf muscle alone will not only significantly increase the strength and ROM of the right calf muscle but also the strength and ROM of the left calf muscle (albeit to a lesser extent). Interestingly, the strength gain of the nonstretched leg was 56% of the strength gained by the stretched leg. This 56% difference is close to the average strength difference of approximately 60% between the contralateral and ipsilateral limbs, reported by Zhou (16). Thus, passive static stretching alone may be as successful in developing a crosstraining effect as traditional strength programs though obviously more work needs to be done in this area to validate such a strength of relationship.

The above findings when coupled with the other research, however, suggest that the crosstraining of strength may be specific to the training program. First, Guissard and Duchateau (5) found no strength gains in either the stretched or nonstretched contralateral muscle after stretching the plantar flexors 10 minutes, 5 d wk⁻¹ for 6 weeks. Interestingly, Peviani et al. (12) have shown that after 1 week of repeated 10-minute daily sessions of stretching, the mRNA expression of 2 muscle growth inhibitors, myostatin and atrogin-1, was increased. This suggests that just like weight training, an overtraining response can be induced by stretching. A lack of strength crosstraining is not very surprising when the trained muscle is primed for degradation; thus, the findings of Guissard and Duchateau (5) make sense in that regard. Second, Handel et al. (6) found no crosstraining effect on contralateral strength gains when passive stretching was preceded by a 70% isometric contraction. Because muscle lengthening actions such as stretching and eccentric contractions are more likely to increase the neural output of the muscle spindles, the work of Handel et al. (6) suggests that muscle spindle activity is necessary for crosstraining and this input can be overridden by subsequent differing neural inputs.

Conversely, the improvement seen in this study may not be related to the stretching exercises. It is possible that the strength gains in the nonstretched leg were the result of muscle contractions used to stabilize the body during the stretches. Although in some cases standing on 1 leg can lead to a stabilization stimulus, it is unlikely that this phenomenon is a major factor in this current study. The design of this study tried to eliminate any weight bearing or strength stimulus on the left (nonstretched) calf. Each individual was asked to place no weight upon the unstretched leg and to use both arms and the stretched leg as stabilization points. In addition, the left leg was to be relaxed as much as possible such that no tension could be felt in the calf. A nonstressed left leg was strongly encouraged at each training session and random periodic checks of muscle tension (manual palpitation) were made during the training. Although these actions did not necessarily eliminate any training effect, the researchers feel that any possible noncompliance was infrequent and not sufficient to induce the gains seen. In addition, because body mass is part of the resistance in the calf raise 1RM, it is possible that changes in body mass could confound the changes in strength. As shown in Table 1, however, the average body mass fluctuated ±1 kg pre to post. It is highly unlikely that this small change had any influence upon the 1RM.

Future research in this area should investigate the relationship between static stretching and crosstraining strength adaptation in populations that are highly trained. Additional investigations should explore the efficacy of this training modality for the development of athletic performance, in clinical populations, and for the prevention of detraining.

**Practical Applications**

The results of this study would apply the best to rehabilitation settings. Our results suggest that practitioners wishing to minimize strength loss in immobilized limbs should consider static stretching the mobile limb. It is possible that the addition of static stretching to any traditional resistance exercise with the contralateral mobile limb will lead to reduced loss of the neural components of strength in the immobilized limb. In addition, individuals attempting to maintain strength, when traditional forms of resistance training are not available (i.e., when traveling), could use static stretching as a method to minimize the strength losses because of detraining.

**References**

Chronic Stretching Induces Strength Crosstransfer


