Unilateral PNF Hamstring Stretching on Contralateral Hamstring Flexibility

A project completed in partial fulfillment of the requirements for the Honors Program

by

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Unilateral PNF Hamstring Stretching on Contralateral Hamstring Flexibility

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Abstract:

Unilateral strength exercises have become a useful tool in the rehabilitation setting due to noticeable contralateral effects. **PURPOSE:** The goal of this study was to examine if similar cross-over effects are noticeable when completing a unilateral stretching program. **METHODS:** Hamstring range of motion for both legs was measured with use of a goniometer prior to and post proprioceptive neuromuscular facilitation (PNF) stretching regimen. Nine male subjects (age 18-40) completed a 25 day PNF self-stretching program on the non-dominant leg (SL) to examine if there was a cross over in flexibility to the dominant, non-stretched leg (NSL) upon completion of the program. **RESULTS:** Flexibility in the NSL showed a significant increase (p = 0.05). No significant difference in flexibility was found between SL and NSL upon completion of 25 days of PNF-stretching regimen. **CONCLUSION:** A cross-over effect in flexibility can be observed after completion of a unilateral PNF stretching program.
Introduction

First observed over a century ago, cross-education is a documented phenomenon in which unilateral strength training has been shown to increase strength of the contralateral homologous muscle group (21,25). Analysis of multiple studies has shown overall a modest increase in strength in the typically untrained, contralateral limb (3,5,13,21,25). In recent years, rehabilitation settings have begun to use unilateral training because research indicates that adaptations can be crossed to the contralateral, usually injured and/or immobile, homologous limb. Rehabilitation after injury mainly focuses on regaining full strength and range of motion of the injured area. Recent research indicates that by implementing unilateral training for the healthy limb, the possibility exists that the injured limb may maintain strength and range of motion despite being immobilized. Numerous studies have been conducted to examine the effects of unilateral strength training on contralateral performance (3–5,13–17,21,22,24,28,29,33,35)

There are several possible mechanisms for the cross-education effect. Recent work has implicated neural adaptations in response to resistance training in contralateral limbs. Evidence indicates that high-force, voluntary contractions on one side of the body results in an increase of the efficiency of the neurons controlling the opposite limb (4). With an increase in neural stimulation, the contralateral limb increases in strength (4,16,21). Another possible hypothesis states that resistance training of the unilateral side causes motor learning adaptations that the contralateral limb can access during voluntary contraction (4). This suggests that neural stimulation at the spinal cord due to unilateral exercises positively affects the ability of the contralateral limb to efficiently activate the muscles innervated by the same spinal nerve during voluntary contraction.

The phenomenon of contralateral training has begun to branch out from resistance and strength training to stretching. Recently, two studies have been conducted to examine unilateral effects of stretching. One study compared proprioceptive neuromuscular facilitation (PNF) versus passive stretch effects on neuromuscular performance. They found a reduced change in electromechanical delay on the untrained leg of a subject who performed a PNF stretching regimen (20). The reduction in change of electromechanical delay proposes rapid muscle activation in the contralateral limb is maintained; meaning maintained joint stability and flexibility (20). Another study, examining a 10-week stretching program of the right calf muscle, found no evidence for an increased range of motion for the contralateral side (23). The only significant increase was in strength of the contralateral muscle (23).

Given the lack of experimental data and evidence, this study aimed to determine the effect of unilateral PNF stretching on the range of motion of the contralateral limb. Based on studies examining the effect of PNF stretching on range of motion, PNF stretching has a greater influence on increasing flexibility in comparison to active and passive stretching, thus, the use of PNF stretching rather than active or passive (12,32). The mechanism driving this increased
flexibility could be due to autogenic inhibition, and reciprocal inhibition (12). Studies have shown that during PNF stretching, inhibitory signals of the Golgi tendon organ, responsible for inhibiting over-stretching of a muscle, are low or nonexistent; this being a potential mechanism for increased flexibility (12). PNF stretching appears to be effective because it utilizes the antagonistic relationship between opposing muscles of the stretched limb. During PNF, the antagonist muscle shortens during contraction, allowing the desired stretched muscle to elongate further, resulting in a greater range of flexibility (12). Some of the proposed mechanisms originate in the stretched leg and send neural impulses to the spine, suggesting the possibility of neural adaptations crossing over to the contralateral leg (12). Based on previous work, we hypothesized that completion of a unilateral PNF stretching protocol will result in a cross-over effect of increased flexibility in the contralateral limb.

Methods

Participants:

Subjects for the study were male college students and staff members at Ohio Dominican University. Nine healthy men gave their written informed consent to participate in this study after being informed of experimental protocol and any potential risks or discomforts of the study prior to their participation. To be selected for the study, participants had to be males, age 18-40 years, not a collegiate or club athlete, and have no injuries to the hamstring muscle group. All participants were moderately active (participated in cardio exercises, on average, three times per week), but had not participated in systematic flexibility training. Participants were asymptomatic of injury at the time of initial assessment and they were instructed to refrain from stretching of both hamstrings for 24-hours prior to baseline flexibility testing. Before recruitment, the study was approved by the Ohio Dominican University Institutional Review Board.

Experiment design and procedures:

Flexibility (range of motion) was measured using a goniometer placed on the hip. Participants lied flat on their back with both legs straightened flat on the ground. The participants wrapped the center of a towel around the foot of the leg being measured with the foot flexed. The ends of the towel were used by the participant to pull the leg towards the chest until resistance from the hamstring muscle was felt, ensuring the knee was locked straight. The opposite limb remained flat on the ground. Range of motion measurement via a goniometer was taken with the axis on the greater trochanter, one arm along the longitudinal axis of the femur and the other arm through a point midway between the anterior and posterior trunk (32). If the knee flexed, participant lowered leg to relaxed position before the procedure was repeated. Protocol was repeated for opposite leg. A baseline range of motion measurement for the non-dominant leg and the contralateral dominant leg was recorded before experimental protocol began. A final range of motion measurement was taken upon completion of experimental protocol. All goniometer measurements were taken in the morning for all participants.
For the stretching intervention session, participants completed a 25 day stretching regimen. Participants underwent self-administered PNF stretching on the non-dominant leg (Stretched leg/SL). PNF consisted of placing the flexed foot of the SL in the middle of a towel. Either end of the towel was held in each of the participants’ hands. Participants lay in supine position. The PNF stretch consisted of a 10 second static stretch and a 10 second hamstring isometric contraction (32). Participants repeated the PNF stretch protocol five times. PNF stretching was performed each day for twenty-five days.

**Results**

The influence of the unilateral PNF-stretching regimen upon both the stretched leg (SL) and the non-stretched leg (NSL) is presented in the Figures 2, 3, and 4 below, with pre-stretch regimen degrees of motion is presented in Figure 1. Analysis showed that there was a significant increase in flexibility in the SL (p = 0.00231) as presented in Figure 3, as well as the NSL (p = 0.02758), presented in Figure 4. No significant difference was noticed between the SL and NSL pre-stretch regimen (p = 0.56620) as presented in Figure 1, or between the SL and NSL post-stretch regimen (p = 0.07385), presented in Figure 2. Results found an approximate 15% increase in SL flexibility between pre- and post-PNF stretching regimen, as well as an approximate 12% increase in NSL flexibility between pre- and post-PNF stretching regimen.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>29.2 ±7.14</th>
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<tbody>
<tr>
<td>Height (cm)</td>
<td>183 ± 5.08</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>94.4 ± 18.7</td>
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</tbody>
</table>

Table 1- Participants’ physical characteristics. All values reported as mean ± SD.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-PNF Stretch Regimen Flexibility</th>
<th>Post-PNF Stretch Regimen Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSL (degrees)</td>
<td>SL (degrees)</td>
</tr>
<tr>
<td></td>
<td>87.1 ± 10.9</td>
<td>89.9 ± 9.13</td>
</tr>
<tr>
<td></td>
<td>97.4 ± 6.88</td>
<td>103.4 ± 6.42</td>
</tr>
</tbody>
</table>

Table 2- Flexibility measurements for NSL and SL, pre and post PNF stretching regimen. Values represent mean ± SD.
Figure 1- Degrees of motion of the knee joint for pre-PNF stretching regimen for non-stretched leg (NSL) and stretched leg (SL). No significant differences were found ($p = 0.56620$). Values represent means ± SD.
Figure 2- Degrees of motion of the knee joint for post-PNF stretching regimen for non-stretched leg (NSL) and stretched leg (SL). No significant differences were found (p = 0.07385). Values represent means ± SD.
Figure 3- Degrees of motion of the knee joint for stretched leg (SL) pre and post stretching regimen. *Significant differences were found (p = 0.00231). Values represent means ± SD.
Figure 4- Degrees of motion of the knee joint for non-stretched leg (NSL) pre and post stretching regimen. *Significant differences were found (p = 0.02758). Values represent means ± SD.
Discussion

As stated above, the purpose of this study was to determine the effect of unilateral PNF hamstring stretching on the contralateral limb’s range of motion. It was hypothesized that a cross-over effect to the contralateral limb would be observed as an increase in flexibility. Similar to previous findings, our results indicate that 25 days of PNF stretching the SL hamstring alone significantly increases the flexibility for the SL hamstring. However, our principle finding is that stretching the SL hamstring also elicited an increase in range of motion in the hamstring of the NSL hamstring. A brief discussion of the results follows.

As mentioned above, numerous studies have demonstrated a cross-over effect with resistance strength training (3–5,13–17,21,22,24,28,29,33,35); however, relatively few studies have been conducted to investigate unilateral stretching on contralateral flexibility (20,23). Carroll proposed two mechanisms for the cross-over effect of unilateral strength training. First, unilateral strength training could cause neural drive to the contralateral limb, inducing control system adaptations. Second, neuromuscular adaptations in the trained limb could be accessed by the opposite limb (4,7,10,11). These adaptations can take place at a number of sites; however, a few in particular seem to apply to unilateral stretching.

Figure 2 displays no significant difference between the post-PNF stretch regimen SL flexibility and NSL flexibility. Increases in flexibility were similar with the SL increasing in flexibility by approximately 15% and the NSL flexibility increasing by approximately 12%. The lack of a significant difference between the post-flexibility measurements for SL and NSL indicates that a cross-over effect in flexibility is noticeable after 25 days of unilateral PNF hamstring stretching.

Figure 4 indicates a significant increase in flexibility in the NSL from pre-PNF stretching regimen to post-PNF stretching regimen. This significant increase may be explained by Carroll’s proposed mechanisms for unilateral strength training within neural mechanisms and/or spinal cord mechanisms; especially since PNF stretching requires a muscle contraction similar to strength training (4,12,32). Cross-over effects due to neural mechanism adaptations change the way muscles are activated by the central nervous system. One important piece of evidence is that muscular training can increase neural firing rates and may alter motor unit synchronization on the trained side (4,6,19,26,34). These alterations trigger modifications associated with motor drive, motor planning and execution (4). If, in fact, these adaptations cross to the contralateral limb as expected, the involved limb can also have an increased ability to synchronize and execute muscular movements. These movements can include strength training activities, as well as the similar movements of the muscle during PNF stretching.

Spinal cord mechanisms have a complex system of circuits that influence motor function of the motor neurons as well as the descending command of these neurons (4). It is particularly important to examine the interneurons roll in cross-education. A study performed using cats
found interneurons that receive afferent inputs cross the midline to excite or inhibit contralateral motor neurons (8). Delwaide and Pepin demonstrated that a contralateral afferent stimulus in humans causes a similar reflex to that of the cat (8). Therefore, similar interneurons to those of cats contribute to the cross-over effect observed in humans, as there are widespread contralateral spinal activations during unilateral exercise (4,8). This known spinal activation could be reasoning for the changes in flexibility shown in Figure 4. Since the participant is activating the hamstring and quadriceps of the stretched leg during the PNF stretch series, it is possible that the spinal cord stimulation used for the SL can be accessed during activity using the NSL.

Lee, Gandevia and Carroll examined another mechanism in which voluntary activation of the contralateral limb increased after completion of four weeks of unilateral strength training(16). The significant increase in voluntary activation found was due to a smaller superimposed twitch after contralateral training(1,2,9,16,18,27). The initial presence of a superimposed twitch suggests a failure of the motor cortex to reach maximal output(16). This submaximal output is due to a failure of drive at or upstream the level of the motor cortical output(9,16,30,31). A smaller superimposed twitch indicated that the subjects were able to more effectively recruit motor neurons, thus an increase in the motor cortex ability to produce a voluntary contraction(16). An increase in voluntary motor recruitment could drive the contralateral limb during flexibility or completion of PNF stretching; however, measurement of each limb’s voluntary motor recruitment when stretching or performing a flexibility test would have to be measured first.

Conclusion and Clinical Applications

Our results showed a significant increase in the flexibility of the NSL hamstring upon completion of a twenty-five day unilateral PNF-hamstring stretching program. Despite the significant change in flexibility of the NSL hamstring upon completion of this study, there still lie questions about its therapeutic utility. It is unrealistic to propose that unilateral stretching on its own should be more effective than completion of an actual stretching regimen for the target limb. However, the significant increase in hamstring flexibility of the target limb suggests that the cross-over effect might be beneficial in certain circumstances. That is, unilateral stretching may be beneficial in circumstances in which the contralateral limb is unable to exercise (e.g., limb immobilization after injury). There has been evidence supporting the use of cross-education strength training that may apply to cross-education flexibility as well (4,14,16,17,21,22,24,29). Additionally, a combination of unilateral strength training and/or “real” strength training with unilateral flexibility training may prove added benefits for the affected limb. These possible benefits should be evaluated and are an area for future research.


