Ipsilateral Proprioceptive Neuromuscular Facilitation Hamstring Stretching Results in Bilateral Improvements in Flexibility: Study Results and Clinical Application

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Proprioceptive neuromuscular facilitation (PNF) stretching of the hamstrings improves flexibility but requires assistance from a clinician or partner. The original intent of our work was to assess the efficacy of self-assisted PNF hamstring stretching using a commercially available device. The authors observed improved flexibility in the stretched leg and, to a lesser extent, in the contralateral leg. While this was at first simply interesting, the finding became clinically relevant in the subsequent application in the care of a patient with low-back pain with radiating pain. This report provides study data and describes the translation of study findings into the care of a patient in a clinical setting.

Keywords: central mediation, radiating pain, stretch tolerance

KEY POINTS

- ▶ Self-assisted proprioceptive neuromuscular facilitation (PNF) stretching results in improvements in hamstring flexibility.
- ▶ Unilateral stretching results in bilateral improvements suggesting a central contribution to stretch tolerance.
- ▶ Contralateral hamstring stretching may be of clinical importance in the management of radiculopathy and other clinical conditions.

Stretching of muscle-tendon units, especially the hamstring muscles, is a common practice of active individuals and is also included in the plan of care of patients with low back, leg, and knee conditions. Although stretching acutely reduces force production and may impair performance,^{1,2} muscular tightness has been identified as a risk factor for muscle injury³ and been associated with patellar tendinopathy, patellofemoral pain,⁴ and low-back pain.⁵ Thus, hamstring stretching remains a common component of injury management and prevention programs.

Hamstring flexibility can be improved with self-directed passive or active stretching or static or proprioceptive neuromuscular facilitation (PNF) stretching. The PNF stretching is effective in improving hamstring flexibility⁶⁻⁸ because a window of inhibition of muscle activity occurs after the contraction of the hamstring muscles (contract-relax) or contraction of antagonist quadriceps muscles (agonist contract) or a combination. The PNF stretching, however, requires assistance of a partner or clinician. In addition to needing assistance, some individuals may

not sufficiently relax to allow the partner to apply optimal force to stretch the muscle-tendon unit.

The Arthro-Motion Inc (Phoenix, AZ) Knee in Motion (KIM) device has a unique handbrake system that allows an individual to set positions of isometric resistance and also apply overpressure to the hamstring muscles, permitting self-assisted PNF hamstring stretching. This project began as an effort to assess the efficacy of the KIM device for self-administered PNF stretching. Healthy young adults with limited hamstring flexibility performed stretches on their most limited side with the contralateral limb serving as a control. Flexibility of the stretched hamstring muscle improved, and by the conclusion of the third session, improvements in the contralateral hamstring flexibility exceeding minimal detectable change (MDC) were observed. Subsequent to data collection, we had the opportunity to apply these findings in the care of an athlete-patient suffering from low-back pain with radiating pain.

In this report, we provide the results of the initial study intended to assess the feasibility of using the KIM device to improve hamstring flexibility, discuss the limited literature available regarding contralateral effects of unilateral stretching, and describe a clinical application of what first seemed to be just an interesting observation.

Description of the Study Protocol

Study Participants

Potential participants were recruited from a university community via flyers and word of mouth. Recruitment materials specified inclusion criteria including age of 18–40 years, self-perception of tight hamstrings, absence of hamstring injury in the previous year, not currently recovering from a musculoskeletal injury, and absence of limitations in hip or knee motion due to an existing condition or previous injury. In other words, we were

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looking for relatively young, healthy adults with self-reported hamstring tightness that was not connected to injury.

Based on Nagarwal et al.⁹ we anticipated a mean improvement in hamstring flexibility of 15° with a SD of 5°. Thus, 12 participants were needed for $B = .80$ with $\alpha = .05$. To guard against greater variance and potential drop out, 20 participants were enrolled in the study.

Study Procedures

All participants signed an informed consent form detailing the purpose, benefits, and risks of the hamstring protocol (University of Connecticut Institutional Review Board Approval # H19-036) prior to starting the study. We assessed hamstring flexibility with the participant laying supine, the hip flexed to 90°, and the knee passively extended to tolerance. Using methods similar to those described by Youdas et al.¹⁰ who reported very good reliability (intraclass correlation values [ICC] >.92, SEM = 3°, MDC = 7°), 1 examiner positioned the hip in 90° flexion and extended the knee to the point of passive motion limit. A second examiner recorded the hamstring flexibility using a standard goniometer. Data were recorded as degrees from full knee extension with the hip flexed to 90°, thus larger values indicated greater knee flexion and thus less hamstring flexibility. Twenty-one of 22 prospective participants demonstrated a 30° or greater limitation in hamstring flexibility and continued in the study. These baseline measures were recorded and served as the prestretch measure on the first day of the study.

Participants were instructed in the use of the KIM device through a brief demonstration (Figure 1). All participants then completed a 3- to 5-minute warm-up on a stationary bicycle at a self-selected intensity. The stretching protocol consisted of four cycles of a 20-second hamstring stretch and 10-second isometric contraction plus a final 20-second hamstring stretch. Hamstring flexibility was reassessed as described above with the order of assessment (stretched vs. nonstretched limb) randomly selected. Participants returned to the clinic two more times within 10 days and all of the procedures were repeated. Participants were asked to continue their daily activities including exercise and sport participation as normal.

Figure 1 — Positioning for stretching of the left hamstring. Left hand is operating the handbrake (foreground).

Data Analysis

Data were analyzed through analysis of variance and confidence intervals (CIs) between key timepoints (baseline—final measure) and overall change in flexibility between sides were calculated.

Results

Twenty participants (five women [age = 22.0 ± 0.7 y, height = 1.58 ± .05 m, mass = 60.5 ± 7.3 kg] and 15 men [age = 24.2 ± 4.0 y, height = 1.78 ± .10 m, mass = 82.9 ± 12.8 kg]) completed the study. One participant only completed the initial session and discontinued participation due to schedule conflict.

The mean and SD for motion limitations are found in Table 1. A greater improvement in flexibility of approximately 12° (95% CI [7.7, 15.7]) was observed across time (within and between days) in the stretched versus nonstretched leg. While the greatest gains were observed in the stretched leg (mean difference = 26.4°, 95% CI [21.4, 31.6]), improvements were also observed pre–post stretching (mean difference = 14.2°, 95% CI [8.1, 20.3]) in the nonstretched leg with the greatest improvement observed on the third day of training. While the improvements were not as great, and did not occur as quickly as on the stretched side, the changes exceeded the established MDC from Youdas et al.¹⁰ (7°).

Initial Impressions From the Study

The improvement in hamstring flexibility in the stretched leg was anticipated based on the results from previous investigations. The participants quickly learned how to use the device to place a load on the hamstring muscles and maintain a comfortable stretch by setting the hand break. They became equally proficient at performing a 10-second isometric contraction, releasing the break, and moving to a new position indicative of greater hamstring extensibility. The results suggest that the KIM or a similar device can be used in clinical and training facilities to help patients and clients improve hamstring flexibility without the assistance of others.

The extent of improvement in the nonstretched leg was not anticipated. It is possible that the observed improvement in the nonstretched leg could have been the result of warm-up and the related assessment of flexibility. However, neither the warm-up nor the assessments were vigorous. The magnitude of improvement (twice the estimated MDC at final measurement) suggests that other influences explain most or all of the improvement in nonstretch limbs. We are not the first to report bilateral improvement in flexibility with unilateral stretching. Chaouachi et al.¹¹ and Killen et al.¹² observed bilateral improvement in hamstring flexibility following stretching of unilateral hamstrings muscles. Killen et al.¹² found improvements in the unstretched limb following a single session of static stretching as

Table 1 Hamstring Flexibility—Mean ± SD

Day	Stretched leg	Nonstretched leg
Day 1 PRE	50.3 (9.2)	45.8 (8.4)
Day 1 POST	36.5 (10.4)	43.8 (9.9)
Day 2 PRE	42.5 (12.1)	42.0 (10.2)
Day 2 POST	31.1 (10.1)	38.6 (10.8)
Day 3 PRE	36.6 (9.3)	41.9 (10.0)
Day 3 POST	23.9 (12.6)	31.6 (12.1)

Note: Values are degrees from full knee extension in 90° of hip flexion.

well as a single session of foam rolling. Chaouachi et al¹¹ reported bilateral improvements in hamstring flexibility following a single session of static and dynamic unilateral stretching with greater improvements following dynamic stretching consisting of eight sets of 30 seconds of a kicking motion (hip flexion and knee extension). In light of the evidence suggesting potential improvements in the unstretched limb, we did not anticipate such a dramatic improvement. Perhaps the improvements were not associated with structural changes in muscle length, but rather systemic neurological changes.

Improvements in hamstring flexibility have been attributed, at least in part, to reduced neural tension.¹³ Pietrzak and Vollaard¹⁴ reported contralateral improvements in hamstring flexibility following a single session of a novel neurodynamic tension technique performed in a modified long-sit slump position. They reported the improvements were retained at 3-week follow-up. The positioning of our participants in the KIM device is similar to the positioning for a slump-test assessment without the cervical flexion component. The similarities in participant positioning and results from these two studies provide further evidence that improvements in hamstring flexibility are mediated by neural tension.

Translation Opportunity to Patient Care

Subsequent to data collection, we had the opportunity to assess straight leg performance on a patient with low-back pain with radiating pain receiving care in our clinic. The 28-year-old female patient (ht = 1.63 m, mass = 59.0 kg) reported right lower-extremity paresthesia, mild L-5 sensory change, and had 4/5 (manual muscle test) great toe extension. The magnetic resonance imaging confirmed that she had a L5 – S1 posterior lateral disc herniation with intervertebral foraminal encroachment. At the time of introducing left PNF hamstring stretching, she was responding well to an extension-based therapeutic exercise regime, but continued to experience radicular symptoms with lumbar flexion and sitting as well as a feeling of an uncomfortable hamstring tightness. She was a habitual runner and noted some tightness in her hamstring muscles in general but not any associated discomfort.

She agreed to perform a hamstring stretching regimen as described in the study protocol above in an effort to alleviate the discomfort. We initially introduced stretching of her left leg only as her right straight leg raise was positive for pain and increased foot paresthesia at approximately 20°. Following one bout of stretching as described previously, and without any other intervention, straight leg raise on her right side to 50°, as assessed by a naïve provider, caused no radiating symptoms. This finding in a single patient encounter added an important perspective to the findings from our original study. Perhaps, the neurophysiological mechanism (especially the decrease in neural tension) was a factor in her immediate improvements.

The patient then received one planned, guided, epidural corticosteroid injection. Her extension-based exercise regimen was progressed and included continuation of contralateral PNF hamstring self-stretching. The patient was also encouraged to stretch her right hamstring as tolerated. The patient experienced a full resolution of symptoms, including her complaint of persistent hamstring tightness associated with distance running, and has resumed all activities.

While the addition of PNF stretching to the plan of care cannot be confirmed as contributing to the outcome, the report from the patient and desire to use the KIM regularly suggest PNF stretching enhanced recovery. Her response to the hamstring stretching is consistent with the findings of Lee and Kim¹⁵ who reported

improvements in pain, disability, and motion following a program of hamstring stretching in a cohort of adults being treated for low-back pain with radiating symptoms. The patients in their study performed an active knee extension while supporting their hip at 90°.

We chose to initiate stretching of her unaffected (left) leg based on the findings of our study and the high level of irritability of the patient's right leg. Our results, experience in the care of the patient, and the limited data available from previous studies suggest the potential for an immediate cross-over benefit from stretching exercises. This observation is also consistent with the results of studies investigating a contralateral response to resistance training.

Improved muscle force generation through neuromuscular adaptations induced by training the contralateral limb, particularly through high-load eccentric contractions, has been established.¹⁶ Meta-analysis on data from 10 separate studies revealed a moderate effect (ES = 0.56) on force production. Such knowledge has led to early training of the uninvolved leg in patients recovering from significant knee and other lower-extremity injuries. Although much more investigation is needed to ascertain the extent to which contralateral PNF hamstring stretching will benefit patients, our results suggest that PNF hamstring stretching in a seated position improves stretch tolerance bilaterally, suggesting a central neurophysiological mechanism similar to that regulating improvement in force production. In a manner similar to training an uninvolved leg to promote early gains in force generation in an injured leg, contralateral stretching may be effective in the care of patients suffering from low-back pain with radiating pain.

Clinical Takeaway

The interpretation of the results of the original study and application of the findings warrants caution. The study was delimited to healthy young adults without symptoms completing three stretching sessions over 10 days. While participants were asked not to change their normal activity and exercise regimen, we relied on self-report of compliance. The patient assessed in the clinic was receiving care and agreed to add the stretching to her exercise regimen. These results, however, indicate that self-assisted PNF stretching with the KIM device is a very efficient means of addressing hamstring flexibility in a clinical setting. Moreover, PNF stretching of the contralateral limb may facilitate central changes regulating neural tension and sensitization for those with unilateral low-back pain with radiating pain. The protocol we describe may offer clinically meaningful benefits in the management of these patients as part of a comprehensive plan of care. This practice-based evidence warrants further research investigation and clinical exploration.

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