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Human Kinetics
CRITICALLY APPRAISED TOPIC

The Effectiveness of PNF Versus Static Stretching on Increasing Hip-Flexion Range of Motion

Landon Lempke, Rebecca Wilkinson, Caitlin Murray, and Justin Stanek

Clinical Scenario: Stretching is applied for the purposes of injury prevention, increasing joint range of motion (ROM), and increasing muscle extensibility. Many researchers have investigated various methods and techniques to determine the most effective way to increase joint ROM and muscle extensibility. Despite the numerous studies conducted, controversy still remains within clinical practice and the literature regarding the best methods and techniques for stretching. ***Focused Clinical Question:*** Is proprioceptive neuromuscular facilitation (PNF) stretching more effective than static stretching for increasing hamstring muscle extensibility through increased hip ROM or increased knee extension angle (KEA) in a physically active population? ***Summary of Key Findings:*** Five studies met the inclusion criteria and were included. All 5 studies were randomized control trials examining mobility of the hamstring group. The studies measured hamstring ROM in a variety of ways. Three studies measured active KEA, 1 study measured passive KEA, and 1 study measured hip ROM via the single-leg raise test. Of the 5 studies, 1 study found greater improvements using PNF over static stretching for increasing hip flexion, and the remaining 4 studies found no significant difference between PNF stretching and static stretching in increasing muscle extensibility, active KEA, or hip ROM. ***Clinical Bottom Line:*** PNF stretching was not demonstrated to be more effective at increasing hamstring extensibility compared to static stretching. The literature reviewed suggests both are effective methods for increasing hip-flexion ROM. ***Strength of Recommendation:*** Using level 2 evidence and higher, the results show both static and PNF stretching effectively increase ROM; however, one does not appear to be more effective than the other.

Keywords: muscle flexibility, proprioceptive neuromuscular facilitation, hypomobility, tightness

Clinical Scenario

Stretching exercises are commonly prescribed during warm-up and cool-down protocols, strength and conditioning training programs, and rehabilitation programs. Stretching is applied for the purposes of injury prevention, increasing joint range of motion (ROM), and increasing muscle extensibility.[1] Two common methods of stretching in clinical practice are static stretching and proprioceptive neuromuscular facilitation (PNF) stretching. It is generally believed that PNF stretching will result in increased ROM compared with static stretching due to increased inhibition of the targeted muscle. Researchers have investigated both static and PNF stretching techniques to determine the most effective way to increase joint ROM by altering the extensibility properties of muscle, but despite the numerous studies conducted, controversy still remains within clinical practice and the literature regarding the best methods and techniques for stretching. To add to the controversy, synonymous terms describing ROM measurement are being implemented but differ in their measurement techniques. In the articles examined, the terms hip ROM, knee extension angle (KEA), and hamstring extensibility were used synonymously to describe the hip-flexion motion that was opposed by the hamstring group. For the purpose of this article, the term hip-flexion ROM will be used instead of the previously mentioned terms to merge the multiple synonymous terms into one.

Lempke is with the University of Georgia, Athens, GA. Wilkinson is with the Dept of Sports Medicine, Union Medical Group Bone & Joint Center, Terre Haute, ID. Murray is with the Dept of Sports Medicine, University of Houston, Houston, TX. Stanek is with Illinois State University, Normal, IL. Lempke (lblempke@uga.edu) is corresponding author.

Focused Clinical Question

Is PNF stretching more effective than static stretching for increasing hamstring muscle extensibility in a physically active population?

Summary of Search (Best Evidence Appraised and Key Findings)

- The literature was searched for level 2 evidence or higher and a PEDro score of 5/10 or higher for articles that compared PNF stretching with static stretching and their effects on hamstring extensibility or hip-flexion ROM in a physically active population.
- The initial literature search returned 11 possible studies related to static versus PNF hamstring stretching; 5 studies met the inclusion criteria and were included.
- One study measured hip ROM via the single-leg raise (SLR) test.[2]
- Three studies measured active KEA.[3–5] Two of those studies used goniometry to measure ROM.[3,5] The remaining study used an inclinometer to measure ROM.[4]
- One study measured passive KEA with goniometry.[6]
- One study found greater improvements using PNF over static stretching for increasing hip flexion.[2]
- Four studies found no significant difference between PNF stretching and static stretching at increasing hip-flexion ROM.[3–6]

Clinical Bottom Line

The reviewed evidence suggests that PNF stretching is equivalent to static stretching in regard to improving hip-flexion ROM. The length of treatment varied greatly with only one study utilizing a stretching protocol for a 4-week period.[2] Of the 5 studies, 4 measured KEA, either actively or passively. Only one study found self-PNF stretching to be more effective than static stretching for hamstrings; however, different assessment protocols for hip ROM were measured. More research must be conducted to make a definitive and evidence-based decision about the best stretching technique for increasing hamstring extensibility.

Strength of Recommendation

Using level 2 evidence and higher, the results show that static stretching and PNF stretching both effectively increase hip-flexion ROM; however, one does not appear to be more effective than the other.

Search Strategy

Terms Used to Guide Search Strategy

- **P**atient/Client group: healthy and active individuals
- **I**ntervention/Assessment: manual or assisted PNF hamstring stretching
- **C**omparison: static hamstring stretching
- **O**utcome(s): increased hamstring extensibility

Sources of Evidence Searched (Databases)

- PubMed
- Ovid
- EBSCO
- Google Scholar
- ScienceDirect

Search Terms

- PNF versus static stretch
- PNF versus static hamstring
- PNF stretch hamstring
- PNF versus static hip

Limits Used

- Level 2 evidence or higher
- PEDro score of 5/10 or higher
- Research published in the past 15 years

Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies were limited to humans
- Limited to English language
- Compared static hamstring stretching with any form of PNF hamstring stretching
- Subjects were healthy and participated in some form of regular physical activity
- Studies utilized a randomized control trial design

Exclusion Criteria

- Injured or previously injured population
- Comparison of PNF with static stretching of any other muscle(s)
- Studies that did not specifically compare PNF stretching with static stretching

Results of Search

A total of 5 relevant studies were located and categorized as shown in Table 1 (based on levels of evidence[7]). All 4 examiners searched the available literature.

Best Evidence

The studies listed in Table 2 were identified as best evidence and selected for inclusion in this review. These articles were selected because they were graded with a level of evidence of 2 or higher and compared the effectiveness of PNF hamstring stretching with static hamstring stretching by analyzing hamstring extensibility through either hip ROM or increased KEA.

Summary of Best Evidence

Implications for Practice, Education, and Future Research

All articles reviewed address the use of PNF stretching versus static stretching for the purpose of increasing hip-flexion ROM. Overall, the results from this critically appraised topic are inconclusive in regard to indicating whether PNF stretching is more effective than static stretching in increasing hip-flexion ROM. The reviewed literature demonstrates that hip-flexion ROM will increase regardless if PNF or static stretching is utilized.

Stretching techniques are commonly used for the purpose of increasing muscular extensibility and ROM. Additionally, stretching techniques can help prevent musculoskeletal injuries, reduce muscular pain, improve muscular force capabilities, and subsequently improve activities of daily living or athletic performance.[5,8] There are many types of stretching techniques, including dynamic, static, ballistic, and PNF. Of those techniques, 2 commonly used techniques are static stretching and PNF stretching.[5]

Table 1 Summary of Study Designs of Articles Retrieved

Study design/ methodology of articles retrieved	Level	Number located	Author (year)
Randomized control trial	2	5	Yıldırım et al[2] (2016) Lim et al[5] (2014) Feland et al[6] (2001) Funk et al[4] (2003) Puentedura et al[3] (2001)

Table 2 Characteristics of Included Studies

	Study 1 (Yıldırım et al,[2] 2016)	Study 2 (Lim et al,[5] 2014)	Study 3 (Feland et al,[6] 2001)	Study 4 (Funk et al,[4] 2003)	Study 5 (Puentedura et al,[3] 2011)
Study design	Randomized control trial	Randomized control trial	Randomized control trial	Randomized control trial	Randomized control trial
Participants	Of the 40 students (17 males and 9 females; mean age = 21.5 (1.3) y; mean body height = 172.8 (8.2) cm; and mean body mass index = 21.9 (3.0) $kg \cdot m^{-2}$) with bilateral hamstring tightness, only 26 completed the study (52 lower extremities). Exclusion criteria: >70° of hip flexion, history of hamstring injury, and/or current musculoskeletal pain.	A total of 48 males (mean age = 22.38 (2.31) y; mean height = 173.63 (3.59) cm; and mean weight = 68.50 (9.15) kg) participated in this study. Inclusion criteria: reduced hamstring extensibility of 20° found during the active knee extension test. Exclusion criteria: history of injury that could alter hamstring muscle extensibility (eg, herniated disk, ligament damage, muscle damage), history of neuromuscular surgery within the last 5 y, or engage in flexibility training.	A total of 97 subjects (66 males and 31 females; mean age = 65 y) volunteered at the Huntsman World Senior Games. Subjects were excluded if they had recently completed an active warm-up, participated in sporting activities earlier, were experiencing signs or symptoms of delayed onset muscle soreness (DOMS), or had soreness from previous injury.	A total of 40 division I college athletes (20 males and 20 females; mean age = 19.7 (1.4) y and mean weight = 72.5 (13.4) kg) participated in this study. Subjects participated in 3 sports: 20 subjects in baseball, 13 subjects in field hockey, and 7 subjects in rowing. No inclusion or exclusion criteria were annotated.	A total of 30 subjects (17 males and 13 females; mean age = 25.7 (3.0) y) who were also students and faculty from a university participated in this study. Exclusion criteria: possible pregnancy, hamstring injury within the past year, exceeding 80° in initial active knee extension test, and/or participation in sports that required regular hamstring stretching. No subjects were excluded.
Intervention investigated	Subjects were randomly allocated to one of 4 groups: (1) SS (10 repetitions for 30 s), (2) self-PNF stretching (contact for 10 s and relaxed for 10 s), (3) Mulligan traction straight leg raise technique (3 repetitions), or (4) no intervention. SLR tests were used to assess hip-flexion ROM. Hamstrings were concluded to be hypomobile if their SLR was ≤70°. All interventions and tests were performed bilaterally. The intervention groups were supervised during interventions. All stretching interventions were performed once a day, 3 d a week for 4 wk. Subjects were supine when the researcher passively flexed the hip joint while the knee was fully extended to the end point where firm resistance was felt in the hamstring muscle group. Another researcher measured the hip-flexion angle with a digital goniometer, and it was measured and repeated 3 times for each limb with average value recorded.	Subjects were randomly allocated to one of 3 groups: (1) static stretch group (1 repetition for 30 s), (2) PNF hold-relax group (3 repetitions of hamstring isometric contractions for 6 s followed by relaxation for 5 s), or (3) control group. All interventions were applied to the hamstrings once. Subjects were positioned supine on a treatment table with the nontested thigh and pelvis attached to the table with velcro. Active knee extension test was applied from this position and uses to assess hamstring extensibility. Hamstring maximal voluntary contractions were assessed in a prone position in 30° of knee flexion with the ankle fixed in place before and after stretching interventions. Postural balance was assessed via double-limb balance on a force plate with the subjects determining their comfortable stance width and arms placed by their sides before and after stretching interventions. A 360° stainless steel goniometer, surface EMG, and a force measuring plate were used to collect measurements.	Subjects were randomly assigned to one of 3 groups: (1) contract-relax PNF stretching (2 repetitions of 10 s of stretching and 6 s of hip extension contraction; total time of 32 s), (2) SS (1 repetition of 32 s), or (3) control group. Subjects performed 4 toe touch stretches to decrease the viscoelastic behavior. All groups were measured pretest and posttest using a goniometer (stayed in place from pretest to posttest measurements). Knee extension ROM was measured with the patient supine on a treatment table, nontest leg parallel and in contact with a bar on the table. Hip was flexed to 90°–100° to ensure hamstring tightness, and then, the knee extended until mild discomfort was felt for both interventions.	Subjects had baseline hamstring mobility assessed. Participants were randomly assigned following baseline assessment to either 5 min of PNF or SS. Two additional variables were assessed by either 5 min following stretching without exercise or 5 min following stretching performed after a 60-min conditioning program. The program consisted of 10 min of cycling exercise performed before and after an upper-body exercise program consisting of weightlifting. Within 7 d, the procedure was repeated with PNF and SS crossed over. Hamstring mobility was assessed via the active knee extension test. Subjects were supine on a table, and the knee and hip were both placed into 90° of flexion with. Subjects were asked to actively extend the knee as far as possible	Subjects were randomly assigned into one of 2 groups: (1) SS (2 repetitions of 30 s) or (2) HR-PNF stretching (4 repetitions of 10 s maximal isometric contraction followed by 10 s passive stretch). Left leg of subjects served as a control for interventions. Both interventions resulted in 80 s of intervention times. Subjected warmed up for 5 min maintaining a set resistance similar for all subjects to ensure consistency between subjects. Subjects were supine on a treatment table secured underneath a pulley system that pulled a nylon rope attached to the subject's ankle via a laced ankle brace that also kept the ankle and foot in a neutral position. Stretching force was perpendicular to the lower leg, and stretching force was applied via free weights attached to another pulley. Torque was standardized to 5% of each subject's body mass, which resulted in varying free weight to be applied for each subject's intervention. Stretching instructions were given to the subject through specified verbal communication, and durations were monitored using a stopwatch. Active knee extension test was measured using a digital inclinometer (over anterior leg on tibial tuberosity) 3 times on the control leg first and then repeated on the subject's test leg.

(continued)

Table 2 (continued)

	Study 1 (Yıldırım et al,[2] 2016)	**Study 2 (Lim et al,[5] 2014)**	**Study 3 (Feland et al,[6] 2001)**	**Study 4 (Funk et al,[4] 2003)**	**Study 5 (Puentedura et al,[3] 2011)**
Outcome measure(s)	Outcome measure was hip-flexion ROM and was assessed via passive SLR test.	Outcome measures included active knee extension angle, muscle activation during maximum voluntary isometric contraction, and static balance.	Outcome measure was passive knee extension angle.	Outcome measure was hamstring flexibility via the active knee extension test.	Outcome measures included the active knee extension test angles at premeasurement and postmeasurement.
Main findings	No differences between groups were found for age, body mass index, and initial hip-flexion ROM. A significant increase in hip-flexion ROM was found in all intervention groups after a 4-wk period ($P < .05$). Results demonstrated a significant increase in hip-flexion ROM in both the Mulligan TSLR technique and PNF stretching groups compared with SS ($P = .02$ and $P = .02$). No significant difference was found between Mulligan TSLR technique and PNF stretching groups ($P = .92$).	A significant difference was found in active knee extension ROM after the application of both stretching interventions ($P < .05$). Both intervention groups showed significant increases in knee extension ROM compared with the control group ($P < .05$). No significant difference was found between SS and PNF hold-relax stretching. The control group showed no significant difference in knee extension ROM. Maximal voluntary isometric contraction significantly increased only in the SS group after the stretching ($P < .05$). Static balance showed no significant difference between stretching techniques in any of the groups.	Wilcoxon signed-rank tests showed median difference in scores between pretest and posttest were significantly different in all 3 groups. A statistical difference from pretest to posttest was found between the control group and the CR-PNF group ($P < .001$), and the control group and the static group ($P < .001$). No differences were found between the CR-PNF and static treatment groups ($P = .15$). Results did not change after accounting for age. Median differences between both intervention groups were significant for men, but not for women, and for those aged <65 y, but not for those aged >65 y.	A significant group by time interaction ($P = .05$) was found due to increased hamstring flexibility achieved with PNF from the baseline measure to the 60-min post exercise measure. Post hoc analysis resulted in no significant differences between static and PNF at any time points. Hamstring flexibility showed significant increases after exercise for the PNF intervention ($P = .05$) compared with no exercise or baseline. No differences were found within the SS group across time. No order effect among conditions were found, and no differences between PNF and SS conditions were observed.	No significant difference was found among the groups before treatment ($P = .12$); however, a significant difference after the treatment was present ($P < .001$). Pairwise comparisons resulted in a significant difference between HR-PNF and control groups ($P < .001$) and between SS and control groups ($P = .01$). No difference was found between the 2 stretching conditions ($P = .78$). Both stretching conditions increased active knee extension angle significantly over time ($P < .001$).
Level of evidence	2	2	2	2	2
Validity score	PEDro score: 5/10	PEDro score: 5/10	PEDro score: 6/10	PEDro score: 6/10	PEDro score: 7/10
Conclusion	A 4-wk stretching intervention is beneficial for increasing hip-flexion ROM in bilateral hamstring tightness; however, PNF stretching and Mulligan TSLR technique show no differences.	Application of either SS or PNF stretching is effective at increasing muscle extensibility without reducing muscle activity or postural stability. SS and PNF stretching demonstrated no significant differences.	No differences in hamstring flexibility were found between interventions as a total cohort. Men may respond differently to stretching techniques compared with women, and those individuals older than 65 y may find differences between techniques as well.	Findings suggest that PNF stretching and exercise may be more effective in increasing hamstring flexibility compared with just PNF without exercise or SS overall.	Results demonstrate no benefit of SS over HR-PNF at increasing hamstring flexibility. Both interventions demonstrated similar increased changes in hamstring flexibility.

Abbreviations: CR-PNF, contract-relax PNF; EMG, electromyography; HR-PNF, hold-relax PNF; TSLR, traction straight leg raise; PEDro, Physiotherapy Evidence Database; PNF, proprioceptive neuromuscular facilitation; ROM, range of motion; SLR, single leg raise; SS, static stretching.

The static stretching technique is a widely used method that extends the muscle length by autogenic inhibition exciting the Golgi tendon organ.[5] This technique involves passively stretching a given antagonist muscle by placing it in a maximal position of stretch and holding it there for an extended time period.[5,8] Recommendations for the optimal time for holding this stretched position typically indicate that a 30-second hold time repeated 3 to 4 times will provide the most beneficial results.[8] This type of stretching technique is considered much safer for sedentary or untrained individuals.[8]

However, the resistance to musculotendinous stretching involves not only the viscoelastic properties of muscle and connective tissue but also the neurological reflex and voluntary components of muscular contraction.[5] Therefore, PNF stretching techniques are used to increase joint ROM by performing voluntary muscle contraction and promoting muscle relaxation to reduce the reflexive components that cause muscle contraction.[9] PNF techniques were first used for treating patients who had various neuromuscular paralyses but are now widely used as a stretching technique for increasing flexibility.[9] There are a number of different PNF techniques that are used for stretching, including slow-reversal-hold-relax, contract-relax, and hold-relax techniques.[5,8,9] All involve some combination of alternating contraction and relaxation of both agonist and antagonist muscles. It is recommended that a 10-second active push phase followed by a 10-second passive relax phase repeated 3 times be used for optimal results.[9,10]

Theoretically, PNF stretching techniques should be superior to static stretching techniques because they activate not only the muscle fibers but also the sensory receptors within the agonist and antagonist muscle as well.[5] However, our review of the literature within the last 15 years contests the ideology that PNF is superior regarding stretching; specifically, of the hamstring group to increase hip-flexion ROM. Out of the 5 studies used in our critically appraised topic, 4 suggest there are no differences in using static stretching or PNF stretching to increase muscular flexibility of the hamstring muscle group.[2–4,6]

When comparing the studies used in this critically appraised topic, 3 studies used hold-relax PNF stretching techniques,[3–5] 1 study used contract-relax PNF stretching techniques,[6] and the last study used a self-PNF hold-relax stretching technique monitored by an investigator.[2] The studies examined participants from 19 to 79 years old,[2–6] and 3 studies used an exercise warm-up.[2–4] Four studies measured extensibility by knee extension[3–6] compared with 1 study that used hip ROM as its measure.[2] Three studies included a control group compared with a static stretching group and a PNF stretching group.[3,5,6]

The hamstring muscle group is a multijoint muscle, which is most frequently damaged in the human body.[3] Stretching techniques are a treatment that is commonly applied to this muscle group to prevent injury and promote function postinjury. While this critically appraised topic came to an inconclusive conclusion in regard to which stretching technique is the most effective in improving hamstring muscle ROM, it appears that more research needs to be conducted to come to a definitive answer.

Most studies did not include participants with hamstring pathologies; however, to determine the effectiveness of this treatment technique, perhaps more studies examining individuals with hamstring hypomobility should be conducted. An additional factor to consider is the structural properties that cause a greater resistance to change in hamstring length in males than females.[11] The studies examined used a mixture of male and females, but none of the studies examined differences between males and females in the control or experimental groups. It is also important to note age can be a factor as well. In a study conducted by Feland et al,[6] PNF stretching was superior in regard to ROM in males and those under the age of 65 years after an initial stretch. Another study also demonstrated that stretch duration in an older population can allow for more ROM compared with that of a younger population.[12] Finally, the use of various measurement techniques for hamstrings (sit and reach, single-leg raise test, KEA, and stand and reach), the variances in active and passive ROM, the different types of PNF techniques, the duration of stretches, and the subjective nature of clinicians' feelings of tight muscular end feel when putting a subject into a stretch likely introduces measuring error and variability even in studies using similar stretching techniques.

Even without consistent evidence to support the use of PNF stretching over static stretching, there appears to be little to no risks for clinicians to make their own personal decision in the type of stretching application. In regard to hamstring stretching, emphasis should be placed on an initial stretching protocol of 5 days a week for 6 weeks, then stretching 3 times a week to maintain initial ROM improvements.[13,14] More research is needed in this area to support or refute the common belief that PNF stretching is superior compared to static stretching in regard to ROM benefits. Therefore, clinicians should base their approach on factors such as patient preference, stretching frequency, ease of instruction, clinician expertise and familiarity, and requirements for clinician assistance rather than on assumptions of relative effectiveness.

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