Journal of Athletic Training 2001;36(1):16–19

www.journalofathletictraining.org

Effects of Hot or Cold Water Immersion and Modified Proprioceptive Neuromuscular Facilitation Flexibility Exercise on Hamstring Length

Darren G. Burke*; Laurence E. Holt†; Roy Rasmussen*; Natalie C. MacKinnon†; Jeffery F. Vossen*; Thomas W. Pelham†

*St Francis Xavier University, Antigonish, Nova Scotia, Canada; †Dalhousie University, Halifax, Nova Scotia, Canada

Darren G. Burke, MSc, and Laurence E. Holt, PhD, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Roy Rasmussen, PhD, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Natalie C. MacKinnon, BSc, and Jeffery F. Vossen, MSc, contributed to conception and design, analysis and interpretation of the data, and drafting and final approval of the article. Thomas W. Pelham, MSc, PT, CSCS, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Laurence E. Holt, PhD, School of Health and Human Performance, Faculty of Health Professions, Dalhousie University, Halifax, Nova Scotia, Canada B3H 3J5. Address e-mail to holt@152.dal.ca.

Objective: To compare the changes in hamstring length resulting from modified proprioceptive neuromuscular facilitation flexibility training in combination with cold-water immersion, hot-water immersion, and stretching alone.

Design and Setting: Training-only subjects stood motionless for 10 minutes, while subjects in the cold group stood in a cold-water bath (8° ± 1°C) immersed up to the gluteal fold for 10 minutes, and subjects in the hot group stood in a hot-water bath (44° ± 1°C) immersed up to the gluteal fold for 10 minutes. All subjects exercised only the right lower limb using a modified proprioceptive neuromuscular facilitation flexibility protocol, consisting of 1 set of 4 repetitions. This procedure was followed for 5 consecutive days.

Subjects: Forty-five uninjured subjects (21 women, 24 men; age range, 18–25 years) were randomly assigned to the cold, hot, or stretching-alone group.

Measurements: Subjects were measured for maximum active hip flexion on the first and fifth days.

Results: Group results were assessed using a 2 × 3 analysis of variance, comparing changes in hamstring length from pretest to posttest. All 3 groups had significant improvements in hamstring length (pretest to posttest) ($P < .05$). However, no significant differences occurred among groups.

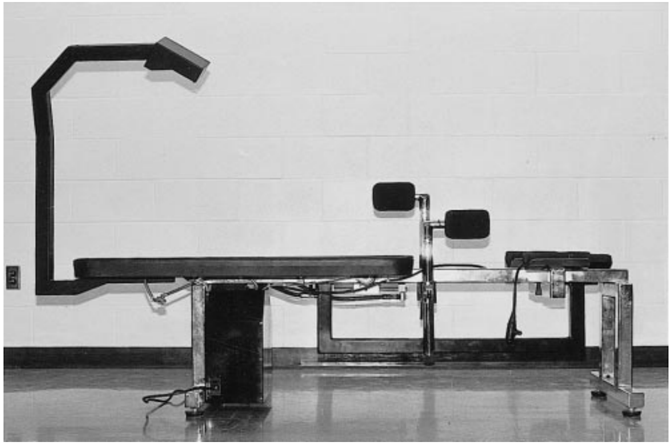
Conclusions: No advantage was apparent in using complete hot or cold immersion to increase hamstring length in healthy subjects.

Key Words: thermal agents, stretching

Flexibility training is generally accepted as an important aspect of conditioning for athletic and occupational performance and is widely used as an effective method in the treatment and prevention of injuries.[1,2] Flexibility exercises are designed to increase tissue elasticity, thereby increasing range of motion (ROM) of specific joints. Increased ROM is believed to both enhance athletic performance[2–4] and decrease the severity and frequency of injuries.[1,2]

Stretching techniques can be categorized as static, ballistic, slow active, and proprioceptive neuromuscular facilitation (PNF). *Scientific Stretching for Sport—(3S)* describes a modification of PNF.[2] Benefits realized through modified PNF flexibility training are superior to benefits realized through static and ballistic techniques.[3,5,6] The modified PNF technique is said to create short-term neural adaptations and short-term and long-term modifications within the viscoelastic components of the muscle-tendon-fascia unit.[4]

In therapeutic settings, in which the goal is to restore functional range and strength as near to preinjury status as possible and in the shortest amount of time, muscle injuries are frequently treated with some form of PNF exercises. Stretching exercises are often combined with the application of thermal agents. Lentell et al[7] studied the effect of thermal agents and prolonged static stretching on shoulder flexibility. Subjects in the stretching-alone, heat, ice, and combined heat and ice groups all demonstrated improved shoulder flexibility compared with subjects in the control (no-intervention) group. No significant differences were found among the treatment groups. However, Taylor et al[8] found that subjects in the heat group demonstrated significantly greater flexibility scores than subjects in the cold group (both groups performed static stretching after the application of heat or ice) or subjects in the stretching-alone group. Conversely, researchers investigating combined PNF flexibility training and cryotherapy found



The flexibility training apparatus.

that cold application over the muscle, before and during stretching, was significantly more productive in increasing flexibility than stretching alone.[5]

A review of the literature reveals no consensus regarding a specific protocol for the use of hot or cold application during rehabilitation. Heat is thought to improve the vascular circulation to and around the injured site, thereby speeding up the repair process by decreasing connective tissue adhesions and removing metabolic wastes,[9] whereas cryotherapy is used to decrease inflammation and diminish the stretch reflex response to elongation. The direct effect of either hot or cold application and increased ROM is poorly understood. Therefore, our purpose was to compare the changes in hamstring length resulting from modified PNF flexibility training in combination with hot, cold, or no thermal treatment before exercise.

METHODS

Subjects

Forty-five uninjured subjects (21 women, 24 men; age range, 18–25 years) were recruited from an undergraduate college population. They reported no history of endocrine or thermoregulatory disorders, arthritic conditions, or musculoskeletal injuries. None of the subjects were exercising strenuously at the time of the study, and they were instructed to carry out normal daily activities. The exercise protocol was approved by the departmental ethics committee for studies involving human experimentation, and all subjects signed an informed consent. Thirty-nine subjects completed all requirements of the study.

Experimental Design

On day 1 of the study, subjects were familiarized with the flexibility training apparatus (Scientific Stretching Ltd, Halifax, Nova Scotia, Canada). This machine has a moveable arm, a hydraulic motor, and an integrated computer that displays angle, force output, and duration of contraction (Figure). The validity and reliability of the instrument has been previously described by Holt et al[10] and Schmitt et al.[3,4] Subjects were randomly assigned to 1 of 3 groups: a cold-treatment group, a hot-treatment group, or a stretching-alone group. Each subject in the cold-treatment group stood in a cold-water bath (8° ± 1°C) immersed up to the gluteal fold for 10 minutes. Each subject in the hot-treatment group stood in a hot-water bath (44° ± 1°C) immersed up to the gluteal fold for 10 minutes. The stretching-alone group subjects stood motionless for 10 minutes. The duration of this study was 5 consecutive days, and the study involved daily treatment and training. All measures were performed on the right lower limb.

Flexibility Training Protocol

Before testing and treatment on the first day, subjects were positioned on the flexibility training machine (Figure), with the resistance pad adjusted to the midcalf level. Each subject produced a maximal active hip flexion (MAHF) with the leg fully extended at the knee while maintaining the lower back against the support platform. The angular measure was visible to both the subject and investigator, and it represented pretest hamstring length. Once the MAHF position was attained, subjects produced a maximal voluntary isometric contraction (MVIC) of the hip extensor musculature.

More precisely, in the supine position with the pelvis firmly held to the machine's top padded platform, the subject actively moved the right leg (extended at the knee joint) to MAHF to the horizontal plane. At this point, the machine's readout gave the acquired angle. Once the angular displacement was recorded, the subject gradually built to maximum force (ie, perceived MVIC). Subjects were instructed to stop if they experienced any pain or discomfort. At MVIC, the readout provided the acquired angular torque. The MVIC values were recorded for all subjects. From this score, percentage of MVIC scores were calculated.

Upon completion of these initial measurements, subjects engaged in their respective treatment protocols. Immediately after treatment, subjects positioned themselves on the exercise machine and began the training protocol, which consisted of 1 set of 4 repetitions. The intensity of muscular effort for each repetition was based on the initial MVIC. Repetitions were progressive and consisted of the following: (1) 60% of MVIC, (2) 70% of MVIC, (3) 80% of MVIC, and (4) 100% MVIC. On each repetition, subjects were instructed to perform a 4-second build-up to the appropriate isometric contraction of the hamstring musculature, followed by a 6-second hold of the contraction. Subjects performed the same duration of isometric contraction (4 seconds + 6 seconds = 10 seconds), followed by a 5-second relaxation and repositioning via a concentric contraction of the antagonist. This procedure has been previously described by Holt et al[10] and Schmitt et al.[3,4] The force output generated during each repetition was visible to both the subject and the investigator, with the force of the fourth repetition (100% MVIC) used to determine the effort of progressions on the following day. Two independent laboratories[3,11] have used this machine successfully in the area of PNF flexibility research.

On the last day and after the training protocol, each subject produced an MAHF, with the leg fully extended at the knee. The angular measure was visible to both the subject and investigator, and it represented posttest hamstring length. A methodologic limitation of the study was the lack of a control group. Future research endeavors in this area must account for this shortcoming.

Statistical Analysis

We assessed group results using a 2 × 3 (pretest and posttest × 3 groups: hot treatment, cold treatment, and stretching alone) analysis of variance, comparing changes in hip joint flexion from pretest to posttest. Significant differences were accepted at the α level $P < .05$, where $P < .05$ was the probability that no difference existed.

RESULTS

The data were assessed for group differences in hamstring length between and within each group. All 3 groups had a significant ($F_{df} = 1$, $P < .05$) increase in ROM after the 5 consecutive days of modified PNF flexibility training (pretest to posttest). Stretching-alone group subjects had a mean increase of 25.9° ± 4° (pretest, 74.1° ± 10°; posttest, 100.1° ± 10°), while cold-group subjects had a mean increase of 23.5° ± 7° (pretest, 78.3° ± 11°; posttest, 101.8° ± 8°), and the hot-group subjects had a mean increase of 25.6° ± 9° (pretest, 75.0° ± 12°; posttest, 100.6° ± 13°). Group comparisons of the change in hamstring length showed no significant difference ($F_{df} = 2$, $P > .05$) among the 3 groups.

DISCUSSION

Two main findings resulted from this study: (1) Modified PNF flexibility training alone or in conjunction with heat or cold thermal agents resulted in significant increases in hamstring length, and (2) The particular experimental temperature applications used in this study did not differ in their ability to influence the changes in hamstring length expected during modified PNF training.

It is not surprising that each group experienced significant increases in hip joint flexion from pretest to posttest. Joint ROM has been shown to increase somewhat regardless of the stretching method used,[6] with modified PNF exercise found to yield superior results.[1,2] Of the 3 basic kinds of stretching (ballistic, slow stretch, and PNF), research has shown that PNF and its derivatives are the most effective techniques for increasing flexibility.[12–18]

Theorists[2] have focused on the neurophysiologic bases of PNF, stating that the excitatory afferents of the neuromuscular spindle or the inhibitory afferent of the Golgi tendon organ (GTO), or both are responsible for the effects. During a PNF stretch, an isometric contraction of a stretched agonist for an extended period of time may cause activation of its neuromuscular spindle.[2] Impulses from the afferent fibers of the spindle pass directly to the spinal motor neurons of the motor units supplying the same muscle, resulting in an even stronger isometric contraction. During this process, inhibition of the antagonist occurs, which is followed by a facilitation effect once the antagonist concentrically contracts.

During the full ‘‘reversal of antagonists,’’ as seen in the method we employed in our study, the increase in tension created during the isometric contraction of the prelengthened agonist is thought to facilitate a release of its fascia, which results in an increased capacity to lengthen when the antagonist contracts concentrically.[2] Should the antagonist be in a position where it cannot, through its concentric effort, move the limb through a greater displacement, then very light pressure from the partner or a machine can achieve the increase in ROM. Both the fascia and the spindle of the agonist adjust to the newly lengthened position. These impulses travel via branches to inhibitory interneurons, causing postsynaptic inhibition of the motor neurons to the agonist. Increasing the tension increases the impulses from the GTO. These impulses can override the impulses coming from the neuromuscular spindles, allowing the muscle to reflexively relax after the initial reflexive resistance to the change in length (autogenic inhibition), thus lengthening the muscle.

At the MVIC of the agonist during PNF, it has been suggested that performance differentiation (increases in joint extensibility) can be accomplished through the neurologic apparatus by recruitment of receptor organs (spatial summation) and by temporal summation, the transmitting of the number of impulses per unit of time over the same fiber.[12] How long the facilitatory effects (inhibitory effect on the neuromuscular spindle) of the GTO last is unknown. However, 1 serious limitation to this hypothesis is that no study has directly evaluated the proposed neurologic components in PNF (GTO, muscle spindle, and other components).

Although previous studies have reported greater ROM gains when cryotherapy is used before PNF exercises,[5] there were no differences among group changes in hamstring length in this study. Most of the cryotherapy and PNF studies have used 10 minutes of superficial ice massage or an ice pack to cool the specific musculature. The superficial application of cold may cause specific physiologic reactions, such as a decrease in local metabolic function, local edema, nerve conduction velocity, and muscle spasm and an increase in local anesthetic effects.[19] Some of these factors are thought to enhance the gains realized with modified PNF flexibility exercises. One possible difference between superficial ice application and cold-water immersion is the vascular response. When a small surface area is exposed to cold temperature, compensatory vasodilation by the deeper vascular system attempts to compensate for the cold surface area, resulting in increased blood flow to the tissues underlying the site of exposure. This vascular reaction occurs to maintain a relatively constant deep tissue temperature.[19] Perhaps the superior gains reported using ice and modified PNF are due to increased vascular flow, and thus, increased temperature to the deep myofascial tissues, whereas the physiologic changes resulting from the complete immersion of the lower limb into cold water create survival vascular responses, restricting blood flow to all peripheral sites to regulate core temperature. Although the superficial application of cold does not completely penetrate into the deeper underlying tissues, perhaps it is this vascular change that influences the gains in ROM experienced during cryotherapy.

Further research is necessary to determine the deep-tissue physiologic changes associated with superficial hot or cold application. Different techniques of thermal therapy or cryotherapy may lead to conflicting results.

REFERENCES

1. Holt LE, Holt JB, Pelham TW. What research tells us about flexibility, I. *Biomechanics in Sports.* 1996;XIII:175–179.
2. Holt LE. *Scientific Stretching for Sport—(3S).* Halifax, Nova Scotia: Sport Research Ltd; 1974.
3. Schmitt GD, Pelham TW, Holt LE. Changes in flexibility of elite female soccer players resulting from a flexibility program or combined flexibility and strength program: a pilot study. *Clin Kinesiol.* 1998;52:64–67.
4. Schmitt GD, Pelham TW, Holt LE. A comparison of selected protocols during proprioceptive neuromuscular facilitation stretching. *Clin Kinesiol.* 1999;53:16–21.
5. Cornelius W, Jackson A. The effects of cryotherapy and PNF on hip extensor flexibility. *Athl Train J Natl Athl Train Assoc.* 1984;19:183–199.
6. Etnyre B, Abraham L. Gains in range of dorsiflexion using three popular stretching techniques. *Am J Phys Med.* 1986;65:189–196.

7. Lentell G, Hetherington T, Eagan J, Morgan M. The use of thermal agents to influence the effectiveness of a low-load prolonged stretch. *J Orthop Sports Phys Ther.* 1992;16:200–207.
8. Taylor BF, Waring CA, Brashear TA. The effects of therapeutic application of heat or cold followed by static stretch on hamstring muscle length. *J Orthop Sports Phys Ther.* 1995;21:283–286.
9. Prentice W. *Therapeutic Modalities in Sports Medicine.* 3rd ed. St Louis, MO: Mosby; 1994:197–200.
10. Holt LE, Pelham TW, Campagna PD. Hemodynamics during a series of machine-aided and intensity-controlled proprioceptive neuromuscular facilitations. *Can J Appl Physiol.* 1995;20:407–416.
11. Gribble PA, Guskiewicz KM, Prentice WE, Shields EW. Effects of static and hold-relax stretching on hamstring range of motion using the FlexAbility LE 1000. *J Sport Rehabil.* 1999;8:195–209.
12. Alter MJ. *Science of Stretching.* Champaign, IL: Human Kinetics; 1988.
13. Anderson B, Burke ER. Scientific, medical, and practical aspects of stretching. *Clin Sports Med.* 1991;10:63–86.
14. Greipp JF. Swimmer's shoulder: the influence of flexibility and weight training. *Physician Sportsmed.* 1985;13(8):92–105.
15. Holt LE, Travis TM, Okita T. A comparative study of three stretching techniques. *Percept Mot Skills.* 1970;21:611–616.
16. Prentice WE. A comparison of static stretching and PNF stretching for improving hip joint flexibility. *Athl Train J Natl Athl Train Assoc.* 1983; 18:56–69.
17. Sady SPM, Wortman M, Blanke D. Flexibility training: ballistic, static or proprioceptive neuromuscular facilitation? *Arch Phys Med Rehabil.* 1982; 63:261–263.
18. Wallin D, Ekblom B, Grahn R, Nordenborg T. Improvement of muscle flexibility: a comparison between two techniques. *Am J Sports Med.* 1985; 13:263–268.
19. Weston M, Taber C, Casagranda L, Cornwall M. Changes in local blood volume during cold gel pack application to traumatized ankles. *J Orthop Sports Phys Ther.* 1994;19:197–199.