2007-01-01

Acute Stretch Perception Alteration Contributes to the Success of the PNF "Contract-Relax" Stretch

J. Brent Feland
brent_feland@byu.edu

Sterling C. Hilton

See next page for additional authors

Original Publication Citation
Mitchell UH, Myrer JW, Hopkins JT, Hunter I, Feland JB, & Hilton SC. (27). "Acute Stretch Perception Alteration Contributes to the Success of the PNF "Contract Relax" Stretch". The Journal of Sport Rehabilitation, 16(2), 85-92.

Authors
J. Brent Feland, Sterling C. Hilton, J. Ty Hopkins, Iain Hunter, Ulrike H. Mitchell, and J. William Myrer

Journal of Sport Rehabilitation, 2007, **16**, 85-92

Acute Stretch Perception Alteration Contributes to the Success of the PNF "Contract-Relax" Stretch

Ulrike H. Mitchell, J. William Myrer, J. Ty Hopkins, Iain Hunter, J. Brent Feland, and Sterling C. Hilton

Context: Some researchers have suggested that an alteration of stretch perception could be responsible for the success of the contract-relax (CR) stretch, a stretch technique derived from proprioceptive neuromuscular facilitation (PNF). ***Objective:*** This study was conducted to determine if the alteration of the stretch perception is a possible explanation for the range of motion (ROM) gains of the CR stretch. ***Participants:*** Eighteen subjects performed two stretches in randomized order: the slow stretch and the CR stretch. ***Main Outcome Measure:*** The stretch intensity was controlled. The stretch force was measured and compared between the slow stretch and CR stretch. ***Results:*** There was a significant difference between the stretch force that could be applied in the PNF stretch (126.0 N) and the slow stretch (108.4 N); $P = 0.00086$. The average stretch tolerance progressively increased with successive trials from 120.6 N in the first trial to 132.4 N in the fourth trial. ***Conclusion:*** The alteration of stretch perception plays a role in the success of the CR form of PNF stretching. At least four repetitions of the CR stretch are recommended to get the greatest ROM gain. ***Key Words:*** proprioceptive neuromuscular facilitation, range of motion gain, flexibility

Decreases in joint range of motion (ROM) can be produced by diverse mechanisms. According to Hutton,[1] there are four different kinds of constraints: (1) neurogenic (voluntary and reflex control), (2) myogenic (involving the passive and active properties of the muscle), (3) joint (involving the physical structures of the articulation), and (4) connective tissue. Stretching exercises try to influence the first two, the neurogenically or myogenically caused restrictions.[1] Accordingly, acute stretch responses have been attributed to either neurophysiological factors (reflex activity) or biomechanical factors.[1-3] For the purpose of this study, the muscles that limit the range and that we want to stretch are termed target muscles (ie, hamstrings). The muscles that function as their antagonists are called opposing muscles (ie, quadriceps).[4]

In addition to biomechanical and neurophysiological factors, it has been suggested that proprioceptive neuromuscular facilitation (PNF) stretches alter stretch

Ulrike H. Mitchell, J. William Myrer, J. Ty Hopkins, Iain Hunter, and J. Brent Feland are with the Department of Exercise Sciences and Sterling C. Hilton is with the Department of Educational Leadership and Foundations, all at Brigham Young University, Provo, UT.

perception[3,5-8] and therefore yield greater range of motion (ROM) gains compared to traditional stretching techniques. Halbertsma and Goeken[5] concluded that neither a 10-minute stretch[8] nor a 4-week daily home stretching program made short hamstrings any longer or less stiff, but only altered the stretch tolerance. Magnusson et al[3] expanded those findings by demonstrating that contract-relax (CR) PNF stretches acutely modified stretch perception. The authors of these studies concluded that stretch perception is a major factor in explaining why some stretching techniques yield greater gains in ROM than others.

The primary purpose of this study was to compare acute stretch perception alteration from successive repetitions of CR PNF stretches with a static stretch of equal duration. Our secondary purpose was to assess if stretch perception changed over successive trials during CR PNF stretching.

Methods

Subjects

Eighteen subjects, 16 males and two females (age 26.3 ± 5.9 yr, height 1.77 ± 0.10 m, body mass 79 ± 19 kg), with tight hamstrings volunteered for this study. Hamstring tightness was defined as 20° or greater loss of full right knee extension (0°) with the right hip at 90° of flexion and the left leg extended on the treatment table while in the supine position.[9] The mean hamstring tightness in our study was 36°(± 8.7°).

Exclusion criteria were assessed by questioning each subject during the initial screening. They were history of lower extremity infirmity or pathology within the year prior to testing, neurological impairments in the lower extremities, osteomyelitis, acute inflammatory joint disease, rheumatoid arthritis and osteoarthritis, advanced osteoporosis, pregnancy, current intake of medication specifically designed to effect musculoskeletal tissue such as anti-inflammatory, pain relief, or arthritic medication. Subjects who started a new activity that addressed flexibility within the month before this study were also excluded. Subjects were asked to keep their activity level constant for the one-week duration of their participation in the study. The study was approved by the university institutional review board. All subjects signed a university institutional review board approved consent form. All subjects were familiarized with the starting position of the stretches and were able to practice maximal voluntary isometric contractions (MVICs) of the hamstrings in that position until they felt comfortable with the procedure. Subjects were scheduled for data collection sessions the following week.

Instrumentation

A hand-held dynamometer (microFET2, Hoggan Health Industries, Draper, Utah) was used to measure the amount of stretch force used by the primary investigator during the passive phase of the stretch. Hip and knee ROM was measured with a standard plastic goniometer.

Testing Protocol

Overview. After warm up, the subjects performed two different stretches on two different days, randomly assigned, blocked on the subject. The amount of pressure that was exerted during the passive phase of the stretch was compared between the slow stretch and the CR stretch and between the different trials of one CR stretch.

Dynamometer Placement. The placement of the dynamometer was kept consistent over the days of data collection by positioning it 5 inches proximal to the heel, at 90° to the lower leg.

Stretching Techniques. The subjects warmed up for both stretches on the two testing days by riding the stationary ergometer (Monarch 818E, Stockholm, Sweden) at 75 Watts at a comfortable cadence (60-70 RPM) for 5 minutes before data collection. The slow stretch was performed once for 40 s and the CR stretch technique was performed four times[2] at 10 s each. Time between trials was 20 s, necessitated by the time needed to read and reset the dynamometer. Two days were given between the two different stretches to reduce carry-over effect between stretches. This is considered an appropriate time frame between stretches.[7,10,11]

The subjects started in the following position (Figure 1): supine on a padded examining table with the right hip flexed to 110° as measured by a standard goniometer. This position was controlled by a 5 cm wide strap, which securely fastened the thigh to a post. To stabilize the position, the left thigh and the pelvis were strapped to the table. The investigator knelt in front of the subject with the subject's right lower leg resting on her shoulder. The investigator held the subject's thigh with both hands while extending the subject's right leg to a point of restriction, where

Figure 1 — Starting position for the slow stretch and the CR stretch .

the hamstrings became tightened. This point was determined through a combination of verbal feed-back from the subject indicating tightness, but not pain, and a clinical soft tissue end feel sensed by the investigator. High intra-tester reliability has been reported for this method.[12]

Subjects were asked to rate their stretch discomfort intensity on a verbal numeric rating scale (NRS) of 0 to 10, with 0 indicating "no pain" and 10 indicating the "worst pain imaginable."[13] Subjects were asked to identify the point at which the stretching discomfort level reached a "4 out of 10." The number 4 was chosen to represent moderate discomfort, simulating a clinical stretch.

For the *slow stretch*, the investigator exerted a push extending the subject's knee for 40 s. This duration has been established as an effective time of stretching for enhancing the flexibility of the hamstring muscles.[14] The intent was to maintain a 4 on the verbal NRS throughout the stretch. The subject informed the investigator when the force being applied to the leg reached the desired level of 4 and when it decreased or increased so the investigator could adjust the level of exerted force. The peak amount of pressure exerted onto the leg was monitored by a dynamometer (microFET2, Hoggan Health Industries, Draper, Utah) positioned between the investigator's shoulder and the subject's lower leg, 5 inches proximal to the heel.

For the *contract-relax stretch (CR)*, the investigator again brought the subject's right leg to the same point of hamstring restriction. The subject then actively maximally contracted the hamstrings for six seconds[15] into the investigator's shoulder (phase one). Immediately following the isometric contraction, the therapist passively stretched the hamstrings for ten seconds (phase 2). Again, the subject reported when the stretching discomfort was perceived to be a 4 out of 10 on the verbal NRS. This perceived level of discomfort was maintained for the 10-s stretch. This stretch was performed 4 times with 20 s between each repetition. Range of motion gains were measured throughout the four repetitions. All manual stretch assistance was provided by the same therapist.

Dependent Variable Force

Force was the amount of push exerted by the investigator in order to elicit a 4 out of 10 on the verbal NRS by the subject during both the CR PNF stretch and the slow stretch. This information was used to determine whether there was a significant difference in stretched perception between the CR PNF stretch and the slow stretch, as well as whether the stretch perception changed over successive trials during the CR stretching.

Data Analysis

This was a cross-over experimental research study. To determine whether there was a significant difference in stretch perception alteration between the slow stretch and CR stretch, average peak force readings of the four trials for CR stretch and the one trial of the slow stretch were used in a paired *t*-test. We employed a one-way ANOVA to determine if stretch perception changed over successive trials during the CR stretch. The α-level for both statistics was set at 0.05. Range of motion was a control variable only.

Table 1 Data for Stretch Tolerance

CR stretch tolerance	Mean in N
Trial 1	120.6 (± 25.2)*
Trial 2	124.5 (± 28.24)
Trial 3	126.9 (± 29.71)
Trial 4	132.4 (± 60.11)*

*Trial 1 and Trial 4 are statistically significantly different.

Results

The PNF stretch had a significantly higher average stretch tolerance (126.0 + 26.5 N) than the slow stretch (108.4 + 28 N); $P = 0.00086$. The CR stretch exhibited a progressive increase in stretch tolerance over the four trials (Table 1). There was a significant increase in force application between the first and fourth trials ($P = 0.035$). We found that the mean ROM increase for the four repetitions in the CR stretching method was 17.36° + 10.79°.

Discussion

Our study's primary purpose was to determine whether acute stretch perception alteration was a possible contributing factor for the success of CR stretches.

We compared the subject's perception of a certain stretch intensity, using two different stretches: the slow stretch and CR stretch. We hypothesized that if we maintained the same level of perceived discomfort, but were able to exert greater stretch force through successive trials, the subject's stretch tolerance had increased. The results indicate that a muscle contraction prior to its stretch seems to alter stretch perception acutely by possibly raising the pain threshold. Since the two stretches used identical positioning, total stretch time, and the same verbal numeric rating scale, and were only different in that one stretch used a pre-stretch contraction, it may be concluded that this factor (the hamstring contraction) contributes to the change in stretch perception. We were able to exert, on average, a 17.7 N greater stretch force in the CR stretch than in the slow stretch for a discomfort perception of 4 on the verbal NRS. This is in accordance with conclusions by several authors.[3,5,6,8,16] Magnusson et al's study[3] also examined stretch perception during a static CR stretch. They collected data on passive knee flexion torque, obtained with a KinCom dynamometer and surface hamstring EMG. They found that the maximal tolerated joint angle and passive torque were greater in the PNF stretch than the static stretch, while the EMG activity remained unchanged. Based on those findings and the finding that the passive properties of the muscle-tendon unit was not altered to a greater degree with the PNF stretches than with the static stretches, it was concluded that the greater muscle length was possible not because of a decrease in muscle activation (inhibition), but because of an alteration of the stretch perception that allowed for greater viscoelastic stress relaxation.[2,6,14,17] Magnusson et al's study[3] used the subject's indication of pain in the posterior thigh rather than a pain scale as we did. Pain scales have been found to be more sensitive than verbal descriptors.[13] Another difference of our study is that we repeated the PNF stretches four times, while Magnusson et al[3] performed only one stretch. Our approach is more clinical, since repeating a PNF procedure several times is commonly done during therapeutic and athletic muscle stretching exercises.[4]

Halbertsma and Göeken[5] measured alterations in pain threshold after a four-week home exercise stretching program, and Halbertsma et al[8] repeated the study with a one-time 10-min static stretch. An elasticity curve of the hamstring muscle was obtained at the beginning and end of the home program and compared with a control group. For the pre- and post test both groups underwent passive straight leg raising using a straight-leg-raising device. The subjects were asked to push an off push-button at the first sensation of pain while their hamstrings were stretched. These studies[5,8] showed no marked increases in elasticity (measured by maximum exerted passive muscle moment), but they demonstrated a significant increase in muscle extensibility and a significant increase of the stretching moment tolerated by the passive hamstring muscles. They concluded that stretching exercises did not alter the hamstrings' stiffness but did influence extensibility which was credited to an increase in stretch tolerance. Two distinct differences exist between those studies and ours. First, the aim of Halbertsma et al[5,8] studies was to evaluate alterations in stretch tolerance after a long term and a 10-min stretching protocol, while our study assessed the alterations in stretch tolerance immediately after the contraction, during the stretch. Second, our study's secondary purpose was to look at the effects of successive repetitions of CR stretches, not just one. While several of the authors assessed the effects of repeated static stretches,[5,10,14,16,18] none looked at the outcome when using consecutive CR stretches.

Our results indicate that the stretch tolerance is raised progressively during four successive repetitions of the CR procedure. A contraction before the stretch does increase stretch tolerance. When repeated, the force needed to produce a 4 on the verbal NRS was significantly higher in the fourth than the first repetition. The other trials showed a trend toward increasing force from trial 1 to 2, from 2 to 3, and from 3 to 4, but they were not significantly larger. Many researchers[19-24] have investigated the effects of exercise on pain perception. The conclusion seems to be that exercise, including resistance exercise, produces an analgesic effect. These research papers might lay the foundation for a possible explanation how the isometric contraction in the CR stretch can produce an analgesic effect and therefore alter stretch perception.

Limitations

This study was limited to examining the effects of a specific PNF stretch on the hamstring muscles. The subjects were volunteers in a university setting and thus may not represent a random sample of the general population. Also, only 2 out of 18 subjects were female and the results may not be representative for both genders.

Conclusion

This study supports the growing research evidence that increased stretch tolerance is a major contributing factor in the success of ROM gains through PNF techniques, possibly by raising the pain threshold.[3,5,6,8,16] Moreover, our research indicates that stretch tolerance is acutely affected during a clinical protocol of CR stretching. In order to achieve the greatest acute ROM gains, when using the CR stretch, at least four successive repetitions should be performed to take advantage of the progressive increases in stretch tolerance.

References

1. Hutton RS. Neuromuscular Basis of Stretching Exercises. In: Komi PV, ed. *Strength and Power in Sport.* Vol 3 of the Encyclopedia of Sports Medicine. Oxford: Blackwell Scientific Publications; 1992:29-38.
2. Taylor DC, Dalton JD, Seaber AV, Garrett WE. Viscoelastic properties of muscle-tendon units: the biomechanical effects of stretching. *Am J Sports Med.* 1990;18(3):300-309.
3. Magnusson S, Simonsen E, Aagaard P, Dyhre-Poulsen P, McHugh M, Kjaer M. Mechanical and physiological responses to stretching with and without preisometric contraction in human skeletal muscle. *Arch Phys Med Rehabil.* 1996;77:373-378.
4. Chalmers G. Re-examination of the possible role of Golgi tendon organ and muscle spindle reflexes in proprioceptive neuromuscular facilitation muscle stretching. *Sports Biomech.* 2004;3(1):159-183.
5. Halbertsma J, Goeken L. Stretching exercises: effect on passive extensibility and stiffness in short hamstrings of healthy subjects. *Arch Phys Med Rehabil.* 1994;75:976-981.
6. Magnusson S, Simonsen E, Aagaard P, Sorensen H, Kjaer M. A mechanism for altered flexibility in human skeletal muscle. *J Physiol.* 1996;497(1):291-298.
7. Magnusson SP. Passive properties of human skeletal muscle during stretch maneuvers. *Scand J Sci Sports.* 1998;8:65-77.
8. Halbertsma J, van Bolhuis A, Goeken L. Sport stretching: effect on passive muscle stiffness of short hamstrings. *Ach Phy Med Rehabil.* 1996;77:688-692.
9. Feland J, Myrer J, Schulthies S, Fellingham G, Measom G. The effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older. *Phys Ther.* 2001;81(5):1110-1117.
10. Magnusson S, Simonsen E, Aagaard P, Kjaer M. Biomechanical responses to repeated stretches in human hamstring muscle in vivo. *Am J Sports Med.* 1996;24(5):622-628.
11. Spernoga S, Uhl T, Arnold B, Gansneder B. Duration of maintained hamstring flexibility after a one-time, modified hold-relax stretching protocol. *J Athl Train.* 2001;36(1):44-48.
12. Hayes K, Petersen C. Reliability of assessing end-feel and pain and resistance sequence in subjects with painful shoulders and knees. *J Orthop Sports Phys Ther.* 2001;31(8):432-445.
13. Flaherty SA. Pain measurement tools for clinical practice and research. *J Am Assoc Nurse Anesth.* 1996;64(2):133-140.
14. Magnusson S, Simonsen E, Aagaard P, Gleim G, McHugh M, Kjaer M. Viscoelastic response to repeated static stretching in the human hamstring muscle. *Scand J Med Sci Sports.* 1995;5:342-347.
15. Nelson K, Cornelius W. The relationship between isometric contraction durations and improvement in shoulder joint range of motion. *J Sports Med Phys Fitness.* 1991;31(3):385-388.
16. Magnusson S, Aagaard P, Simonsen E, Bojsen-Moller F. A biomechanical evaluation of cyclic and static stretch in human skeletal muscle. *Int J Sports Med.* 1998;19:310-316.
17. McHugh M, Magnusson S, Gleim G, Nicholas J. Viscoelastic stress relaxation in human skeletal muscle. *Med Sci Sport Exer.* 1992;24(12):1375-1382.

18. Halbertsma J, Mulder I, Goeken L, Eisma W. Repeated passive stretching: acute effect on the passive muscle moment and extensibility of short hamstrings. *Ach Phy Med Rehabil.* 1999;80:407-414.
19. Bruehl S, Chung OY. Interactions between the cardiovascular and pain regulatory systems: an updated review of mechanisms and possible alterations in chronic pain. *Neurosci Biobehav Rev.* Jul 2004;28(4):395-414.
20. Koltyn KF, Garvin AW, Gardiner RL, Nelson TF. Perception of pain following aerobic exercise. *Med Sci Sports Exerc.* Nov 1996;28(11):1418-1421.
21. Koltyn KF, Arbogast RW. Perception of pain after resistance exercise. *Br J Sports Med.* Mar 1998;32(1):20-24.
22. Koltyn KF. Analgesia following exercise: a review. *Sports Med.* Feb 2000;29(2):85-98.
23. Koltyn K, Trine M, Stegner A, Tobar D. Effect of isometric exercise on pain perception and blood pressure in men and women. *Med Sci Sport Exer.* 2001;33(2):282-290.
24. Koltyn KF, Umeda M. Exercise, hypoalgesia and blood pressure. *Sports Med.* 2006;36(3):207-214.