CALIFORNIA STATE UNIVERSITY, NORTH RIDGE

THE EFFECT OF NEURAL TENSION STRETCHING ON HAMSTRING MUSCLE FLEXIBILITY

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in Kinesiology

by

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August 1997
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ACKNOWLEDGEMENTS

This thesis has taken a number of years in formulation, research and writing. I would like to thank the thirty-one subjects for their time, cooperation, patience and willingness to participate.

I would like to thank Dr. Steven Loy, Dr. George Holland, Dr. Bill Vincent and Terry Gillette, MA,PT for their guidance, participation and finalization of this project. I am deeply indebted to all of them for helping me achieve a life long goal of obtaining a Master’s degree in Kinesiology.

I would like to thank my research assistant, Kecia Weller, for her invaluable support. Without her help, this project could not of been completed. Kecia helped me set up my massage table, stretch the subjects and drag the table to the various faculty buildings throughout the campus. We approximated that we walked about five miles a day around campus throughout the study.

Most of all, I would like to thank my Husband Fred, for the sacrifices of our time together, his continuous support, encouragement and patience throughout my graduate studies.
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ABSTRACT

THE EFFECT OF NEURAL TENSION STRETCHING ON HAMSTRING MUSCLE FLEXIBILITY

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Christa L. Harris

Master of Arts in Kinesiology

Tight hamstring muscles can lead to a strain injury in athletes especially sprinters. Neural tension stretching is a valuable technique that should be included in an athlete's stretching program in order to prevent a hamstring muscle injury. This study compared the effects of a neural tension stretching technique, i.e. the slump stretch, to a static straight leg raise (SLR) stretch on subjects with clinically short hamstrings. Thirty-one volunteers, 22-65 years old, were randomly assigned to one of three groups; a slump stretch group, a static SLR stretch group or a control group. The Active Knee Extension (AKE) and Passive Straight Leg Raise (PSLR) tests were used to assess hamstring flexibility both pre and post-test. The experimental groups were stretched seven days a week for four weeks. The results indicated a significant increase \( p \leq 0.05 \) in hamstring flexibility in the slump group compared to the static SLR and control groups using the AKE flexibility test. It was concluded that the Slump stretch technique was more effective in increasing hamstring flexibility in subjects with short hamstrings than the static SLR stretch technique.
Introduction

Stretching is an important factor in preventing muscle strain injuries in athletes. Neural tension stretching, via the slump stretch, is a valuable technique that should be included in an athlete's stretching program in order to prevent or minimize lower extremity muscle strain injuries. This technique should also be included in the rehabilitation program of an injured athlete in order for the athlete to regain full performance potential.

According to Butler (1) the neural system is a dynamic organ and when change is imparted in one area of the neural system, it may affect the whole system. Any trauma to tissue surrounding a nerve may predispose the nerve to injury even if the nerve is not directly injured by the trauma. Furthermore, a tissues' response to injury is inflammation and repair by scarring (2). Thus, any time connective tissue is damaged, it will attempt to repair itself and that reparative process may entrap and constrict nerves passing through or around the tissue (2).

Neural tension stretching, via the slump stretch, maximizes the excursion of both the neural and connective tissue components of the nervous system from the brain to the terminal branches of the sciatic nerve in the foot (3). This technique is performed in the sitting position, combining the components of full spinal flexion and the straight leg raise (SLR) (4). A sustained passive stretch, with or without small or large amplitude oscillations, is performed either through the available range or at the limit of...
maximal stretch (1).

One study has compared neural tension stretching to traditional techniques in the rehabilitation of hamstring injured Australian Rules Football players with hamstring injuries (5). The results of this study indicated that traditional treatment plus neural tension stretching, via the slump stretch, was more effective in returning an athlete to full function than using traditional treatment alone. This is the only study to date comparing neural tension stretching to a traditional technique yet no quantification of improved flexibility was provided. The purpose of the present study is to compare the effects of a traditional muscle stretching technique, the static Straight Leg Raise (SLR), to neural tension stretching, (the slump stretch) on hamstring muscle flexibility.

METHODS

Subjects

Thirty-one healthy university staff, faculty and students, ranging in age from 22-65 years, were recruited as subjects. All subjects met the following criteria: 1) no history of a diagnosed lumbar, hip, knee and ankle pathology or surgery within the last six months, 2) no previous hamstring muscle injury within the last six months, 3) no history of a systemic disease or abnormal neurological signs and symptoms, 4) clinically short hamstring muscles, operationally defined as having a Passive Straight Leg Raise (PSLR) of ≤ 70 degrees, and 5) a positive slump neural tension test.
Physical therapists routinely use neural tissue tension tests for the assessment and treatment of neuromusculoskeletal disorders and pain syndromes. The slump test is one example of a neural tension test designed to evaluate movement of the pain-sensitive neuromeningeal structures within the vertebral canal (4). The slump test consists of a subject sitting in the full slump position, (i.e. full cervical, thoracic, and lumbar flexion). The knee is extended and when a painful stretch sensation is felt which limits any further knee extension movement, the knee is held in this position and the subject is allowed to extend their head. If the painful stretch sensation decreases or is alleviated, this is a positive slump test. A positive slump test indicates a restriction of movement of the neural tissue. Neural tissue must be able to move and lengthen fully in order to adapt to the body’s many joint and extremity positions.

Subjects were randomly assigned to a control group (n=10), a static SLR stretching group (n=9) and the slump stretching group (n=12). All subjects completed an institutionally approved informed consent form.

Hamstring flexibility testing

An electronic goniometer, the Orthoranger II, was used to measure knee extension range of motion during the Active Knee Extension (AKE) test and straight leg raise range of motion during the Passive Straight Leg Raise (PSLR) test.

Pre and post-test hamstring flexibility was assessed by both AKE and
PSLR tests for all subjects by the same Registered Physical Therapist (RPT). Both methods have been utilized to measure flexibility and demonstrated to be sensitive to changes in flexibility (6, 7). The order of testing was randomized for all subjects for the pre-test and performed in the same order for the post-test. The leg to be tested was randomly assigned for each subject. Prior to testing, the AKE and PSLR tests were demonstrated for the subject on the non-test leg. No warmup was done on the test leg prior to testing.

For the AKE test, the subject was placed in a supine position on a plinth. The lower extremity not being tested was maintained flat on the table and the thigh and pelvis were strapped down in order to minimize pelvis and lumbar spine movement. The Orthoranger II was placed on the plinth and cleared to zero. The hip was then placed at an 90 degree angle as measured by the Orthoranger. The hip angle was then maintained at 90 degrees with the help of an assistant. In this position, the knee was passively extended to a 90 degree angle, i.e., the tibia was parallel to the plinth, and the Orthoranger was placed one inch below the tibial tuberosity. The knee was passively flexed or extended to the point that the Orthoranger measured zero degrees. At this point, the subject was asked to slowly and actively extend the knee while maintaining the hip at a 90 degree angle. The end range of knee extension was measured by reading the Orthoranger’s angle. The AKE test was repeated two more times and these three
measurements were averaged to reflect hamstring muscle length.

In the PSLR test, the subject was also in a supine position on a plinth with the opposite thigh and pelvis strapped down to minimize pelvis and lumbar spine movement. The Orthoranger II was placed on the thigh just above the patella and cleared to zero for the starting position. A PSLR was performed by the tester to P1 (the point at which the subject first felt a stretch) and continued until P2 (the point of maximum stretch/discomfort) while the tester maintained the knee in full extension. The Orthoranger’s angle was then recorded at P2. The PSLR test was repeated two more times, and these three measurements, at P2, were averaged to reflect hamstring muscle length.

**Stretching Procedure**

**Static Straight leg raise (SLR)**

Subjects in this group were statically stretched three times for 30 second durations with a 30 second rest between stretches. The subject was placed in the same position on a plinth as performed in testing. A passive SLR was performed by the researcher up to P1 and then continued until P2 and held in this position for 30 seconds while maintaining full knee extension. This procedure was then performed on the opposite extremity. The static SLR was done by the same RPT Monday, Wednesday and Friday for four weeks.

After the initial stretching session, the subject was instructed in home
static SLR stretching. The subject was instructed to use a strap around the foot to pull the leg up passively with the knee in full extension up to maximum stretch. The subject was asked to do three repetitions of stretching for 30 seconds with a 30 second rest between stretches, Tuesday, Thursday, Saturday and Sunday at approximately the same time of day.

**Neural tension stretching**

Subjects in this group were given the neural tension stretching technique, the slump stretch (three times a week) for four weeks. The slump stretch technique was performed in the following manner:

1. The subject was asked to sit well back on a plinth with the thighs fully supported.
2. The subject was asked to place their hands behind his or her back (Fig. A).
3. The subject was then asked to 'slump' or 'sag' down through the trunk (spinal flexion) (Fig. B).
4. The tester then applied pressure with one arm across the upper back/shoulder area in order to maintain the spinal flexion position.
5. The subject was then asked to put his or her 'chin to chest' (neck flexion).
6. Pressure was then added to the neck flexion and maintained by the use of the tester's hand (Fig. C).
7. The subject was then asked to extend the knee actively followed by dorsi flexing the foot (Fig. D & E).

If the subject did not exhibit full knee extension, three repetitions of 30
second duration of passive knee extension was performed by the tester on the subject. There was a 30 second rest period between stretches. This procedure was then performed on the opposite extremity. If the subject exhibited full knee extension with ankle dorsiflexion, pressure was then applied by the tester to maintain these two movements at the full end of the range of motion (Fig. H). Three repetitions of 30 seconds of passive hip flexion was then done with a 30 second rest between stretches. This technique was progressed to add in hip adduction and internal rotation in hip flexion, if needed. The slump stretch was done by the same RPT who did the static SLR stretch, and the home slump stretching was performed by the subjects for the same amount of time and on the same days of the week as was done for the static SLR group. Figure I shows a diagram of the two stretching techniques.

The subjects in the stretching groups were asked at each session if they were performing their home stretching and the procedure was reviewed to ensure proper technique. If any of the stretching subjects missed a static SLR or slump stretching session performed by the tester, the subject was asked to perform the home stretching procedure instead, Table 1.

Subjects in the control group participated in the pre and post-treatment AKE and PSLR tests. They did not perform any stretch training during the four weeks.

All subjects were asked not to exercise during the four-week study or if a
subject was already exercising, he or she was asked not to change the intensity, frequency or duration of their exercise program.

Data Analysis

An analysis of variance (ANOVA) was used to evaluate percent change for both the PSLR and AKE flexibility measures. A Tukey’s post hoc test was used to determine significance between groups. The level of significance was established at $p \leq 0.05$. For determination of reliability of both the AKE and PSLR tests the mean of three test trials was used. Daily attendance was kept. The stretching subjects participated in a combination of stretching sessions by the tester and home stretching for seven days a week for four weeks.

Results

An ANOVA was used on the pre-test AKE and PSLR data (range of motion in degrees) to evaluate if the three groups were equal prior to stretching. The pre-test AKE means and the standard deviations for the slump group was $32.5 \pm 11.5$, the static SLR group $45.2 \pm 9.1$ and the control group $42.7 \pm 13.4$. The pre-test ANOVA results indicated a significant difference between the groups prior to stretching ($F = 3.69, p = 0.04$). Tukey’s post hoc test showed a significant difference ($p < 0.05$) between the slump and static SLR group for the AKE pre-test.

The PSLR pre-test means and standard deviations for the slump group were $61.2 \pm 8.3$, the static SLR group $66.1 \pm 9.9$ and the control group $68.4 \pm$
The results of the PSLR pre-test ANOVA indicated that there were no significant differences among the groups prior to stretching, \( F = 1.6, p = 0.22 \).

The post test AKE group means for percent change, standard deviations and ANOVA results are shown in Fig. J. The ANOVA results indicated a significant between group treatment difference relative to percent change, \( F = 4.8, p < 0.015 \). Tukey's post hoc test showed a significant difference \( p < .05 \) between the slump stretching group and both the static SLR and control groups for the AKE flexibility test. The Effect size for the AKE flexibility test was \( R^2 = 0.26 \) indicating 26% of the variance between groups may be attributed to treatment.

The post test PSLR group means for percent change, standard deviations and ANOVA results are listed in Fig. K. The ANOVA results indicated no significant difference between the groups relative to percent change, \( F = 2.76, p = 0.08 \).

Discussion

The pre-test ANOVA on the AKE flexibility test indicated that there was a significant difference \( p < 0.05 \) between the slump and static SLR groups prior to stretching. Even though it appears that the slump group was tighter on hamstring flexibility compared to the static SLR group and had a greater potential for improvement to begin with, the static SLR group still had potential for improvement. However, this mean group difference may have
contributed to the large differences in improvement of the slump group. Furthermore, although statistically significant, the pre-test mean degree difference in range of motion between the slump and static SLR groups was only twelve degrees which in the author's opinion is not clinically significant.

More detailed analysis of the post-test percent change data revealed a large variation for the slump group as indicated by the 63.5% standard deviation compared to the other two groups. One subject in the slump group exhibited a 167.4% improvement from pre to post test and another subject exhibited a 178.9% improvement. This could be another factor contributing to the large subject variation in the slump group and again the dramatic differences between the slump and static SLR groups. However, the data still suggests the slump stretch to be advantageous to the static SLR stretch.

Most studies have investigated the static SLR stretch alone or the static SLR stretch compared to Proprio Neuromuscular Facilitation (PNF) stretching techniques on hamstring muscle flexibility. In agreement with previous studies (8, 9, 10), we did not find a significant increase in hamstring flexibility with the static SLR stretch. In contrast, a number of studies have demonstrated an increase in flexibility following static SLR stretching (7, 11, 12, 13, 14). However, Worrell et al. (10) indicated these studies did not control for pelvic positioning when performing hamstring stretching, which the authors believe is a confounding factor in hamstring stretching.

The PSLR and AKE tests have both been well utilized to test hamstring
flexibility. Interestingly, the results of the present study present differing
findings with the PSLR not reaching statistical significance although the
data suggests that there might be differences with a larger sample size.
Although we cannot speculate why the differences occurred, it suggests that
perhaps the AKE test is a more sensitive measure of flexibility and that
perhaps further investigation comparing the tests is required.

When performing the slump stretch technique, both the neural tissue and
the hamstring muscles are being stretched. According to Massey (5), the
slump test can be used to differentiate limitation due to hamstring length
from limitation due to neural/dural tension. A positive response to the slump
test indicates limitation due to neural tension, and a negative response
indicates limitation due to hamstring muscle tightness. All subjects in the
present study exhibited a positive slump neural tension test. It is suggested
that the increases in hamstring flexibility observed were due to a
combination of stretching of the neural tissue and the hamstring muscles.
The significant difference in hamstring flexibility between slump and static
SLR stretching may be due to the slump stretch involving more of the neural
tissue as compared to the static SLR thus making the slump stretch more
effective.

Neural tissue, like all other soft tissue, responds to the forces applied to it
(1). The anatomical basis for the effectiveness of slump neural tension
stretching is that the nervous system can be adapted to lengthen, i.e., neural
tissue compliance. Fidel et al. investigated the neural tissue compliance after one clinical trial of repeated knee extension mobilizations while in the full slump position. The authors found that the angle of knee extension significantly decreased following the knee extension mobilizations speculating neural tissue compliance. During the slump stretching sessions in the present study, we also found this to be true. Fidel et al. cited two other significant studies in pathological situations which again support the theory of neural tissue compliance over time.

Kornberg and Lew (5) also investigated the concept of neural tissue compliance and they demonstrated that in grade I hamstring injuries, traditional treatment in combination with the slump stretch technique was a more effective treatment than traditional treatment alone. This is the only study to date to compare a neural tension stretching technique to a traditional treatment although it evaluated the effectiveness strictly through a sports application and not a quantification measure of change in flexibility.

Conclusion

We looked at the comparison between a standard stretching technique and a neural tension stretching technique on a muscle's flexibility. The slump stretch proved to be significantly more effective in increasing hamstring muscle flexibility than the static SLR when evaluated by the AKE flexibility test. Further research is required on different populations regarding increasing a muscle's flexibility with a neural tension stretching
The slump stretch can be a very vigorous technique and it is suggested that this stretch be performed by a Licensed Physical Therapist trained in the evaluation and application of the technique especially on subjects with a history of a cervical, thoracic and/or lumbar pathology. It should be noted that the technique can be taught to the lay person but again the slump stretch should be done with appropriate caution and care.
Figures A-E and H. Slump Stretching Technique (Butler, 1991)
Figure I. Slump and Static SLR Stretching Techniques (Butler, 1991)
TABLE 1

Number of subjects that missed stretching sessions

<table>
<thead>
<tr>
<th>Missed Sessions</th>
<th>Slump Number of Subjects</th>
<th>Static SLR Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
AKE

$F = 4.845, p < 0.05 \ (R \text{ Squared} = .26)$

$\star 52.4 \pm 63.5$

Figure J. AKE Mean Percent Improvement
PSLR

$F = 2.76, \ p = 0.08 \ (R \text{ Squared} = .16)$

Figure K. PSLR Mean Percent Improvement
EXTENDED REVIEW OF THE LITERATURE

Introduction

The rehabilitation of an athlete suffering from a muscle strain injury must address all structures injured if the athlete is to regain full performance potential. The hamstring muscle strain is a common injury in runners, especially sprinters. Health professionals use well-known techniques such as ice, electrical stimulation, ultrasound, massage, muscle stretching and strengthening in the treatment program of the muscle strain injury. However, a surrounding structure of the muscle injured, (i.e., nerve tissue) may also be damaged and treatment should be directed to restore the normal function of this structure.

Neural tension stretching (i.e., stretching of the nervous tissue) is an important technique that should be included in the rehabilitation program in order for the athlete to regain full performance potential. This review discusses the many etiological factors related to the hamstring muscle strain, with emphasis on decreased hamstring flexibility. Several studies are discussed regarding muscle stretching techniques in shortened or strained hamstring muscles. Neural tension stretching, via the slump stretch, is described and several studies are presented investigating the efficacy of neural tension stretching techniques in the rehabilitation of the athlete suffering from shortened or strained hamstring muscles.
Predisposing Factors Related to Hamstring Muscle Strains

Several etiological factors have been speculated as being related to injury of the hamstring muscle. Insufficient flexibility of the hamstring muscles, physiological shortening of the hamstring muscles due to fatigue, poor strength and/or endurance of the hamstring muscles, inequality in strength of the right and left hamstring muscles are a few factors. Strength imbalance between quadriceps and hamstring muscles, inadequate warmup and stretching prior to activity, dys-synergic contraction of the hamstrings during running, and poor running style placing greater strain on the hamstring muscles have also been implicated as predisposing factors. An important predisposing factor is inadequate treatment of the original injury with the athlete returning to training and competition before full recovery, leading to recurrent injury (Agre, 1985). The most frequently cited possible causes are muscle strength imbalances and decreased flexibility of the hamstring muscle group.

In 1970, Burkett performed a study of possible causes of hamstring strains in football players and track athletes. Burkett chose to study these athletes because of the high incidence of hamstring injuries among competitors in these sports. Twelve track subjects and five football subjects in the experimental groups sustained first or second degree hamstring strains. The control groups consisted of eighteen track subjects and thirty-two football subjects who had not suffered a hamstring injury. The five
variables assessed were bilateral strength imbalance between knee flexors, and between knee extensors, bilateral combined hamstring/quadricep muscle strength, flexion-extension strength ratio, and a sit-and-reach stretch. The results showed a significant difference ($p < 0.05$) in bilateral strength between flexors, and the flexion-extension strength ratio for both samples. From the results of this study, Burkett suggested that the reduction of the strength imbalances between limbs could be useful in the prevention of hamstring strains.

In a similar study, Liemohn (1978) examined factors that might have caused hamstring injuries in Indiana University male track athletes. The purpose of the study was to examine selected measures of strength and flexibility secondary to their correlation with event/athlete idiosyncrasies. Seven of the twenty-seven subjects sustained hamstring injuries prior to the collection of the data. The measurements made by Liemohn included quadriceps and hamstring strength, and unilateral hip flexibility. Liemohn reported that the seven injured subjects tended to be less flexible at the hip, (right hip 85.45 degrees, left hip 88.05 degrees), and less flexible bilaterally (L/R 1.016) than the non-injured. Liemohn also reported that factors such as hamstring/quadriceps strength ratios and strength imbalance between the left and right legs affects injury risk.

Hamstring Muscle Stretching

Gajdosik (1991) reported that shortened hamstring muscles have been
associated with various clinical disorders and sports-related injuries. Gajdosik studied the effects of three weeks of daily static stretching of short hamstrings on passive straight leg raising (SLR), maximal hamstring length (MHL), and the hamstrings maximal resistance to passive stretch (MRPS). Twenty-four men with SLR ≤ 70 degrees were randomly assigned to a stretching group or a control group. Subjects in the stretching group completed daily static stretching of the hamstrings for three weeks. The results of Gajdosik's study showed that daily static stretching of short hamstrings muscles significantly increased (p < 0.001) the MHL and MRPS. The muscles' length increased with a concomitant increase in their ability to withstand a greater passive lengthening force.

Osternig, Robertson, Troxel and Hansen (1990) performed a cross sectional study investigating the effects of sustained stretch (SR) and two modified PNF techniques - contract-relax (CR) and agonist contract-relax (ACR) - on hamstring muscle activation and knee extension range of motion in different athletic populations. Thirty subjects were divided into three groups, including ten endurance athletes, ten high-intensity athletes, and ten control subjects. The three stretching techniques were applied to each subject with the order of application rotated across subjects. The techniques were: one 80 second trial of stretch-relax (SR) and five trials each of contract-relax (CR) and agonist contract-relax (ACR). In the CR condition, a trial consisted of two five second contractions each sequentially followed by a five
second interval of muscle stretch. In the ACR condition, the subject performed two five second, maximal contractions of the quadriceps muscle to extend the knee. Each contraction was interspersed by five seconds of relaxation.

The results revealed that ACR produced 89-110% greater hamstring EMG activity and 9-13% more knee joint range of motion than CR and SR. The endurance athletes generated 58-113% more hamstring EMG activity than the high-intensity and control group across all stretch conditions, whereas the endurance group attained less range of motion than the high-intensity and control group for CR and ACR conditions. Osternig et al. reported that muscle soreness and strain can result from injudicious stretching of muscles under eccentric loading. The authors indicated that the results of this study support the notion that care should be exercised when applying stretching techniques. Osternig et al. concluded that the differential effects of various stretch techniques among dissimilar athletic populations should be considered if stretch-induced injury is to be avoided.

Starring, Gossman, Nicholson and Lemons (1988) compared cyclic stretching with sustained stretching using a mechanical device to increase the resting length of the hamstring muscles. The two stretching methods were compared to determine the ability of the stretching techniques to maintain an increase in resting hamstring muscles length after one week without treatment. Group one subjects (5 men, 17 women) underwent cyclic
stretching of their right hamstring musculature, and Group two subjects (5 men, 16 women) underwent sustained stretching of their right hamstring musculature. The stretching procedures were performed for 15 minutes on 5 consecutive days. An Active Knee Extension Test (AKET) was performed both pre and post stretching to determine hamstring muscle flexibility. A follow-up examination of the subjects relative knee extension range of motion was made one week posttreatment. The Group one subjects had a mean ROM increase of 15.4 + 5.0 degrees after the five stretching treatments and maintained a mean ROM increase of 10.4 + 5.5 degrees on the follow-up examination (p<.001). In Group two, the five stretching treatments resulted in a mean ROM increase of 13.4 + 4.4 degrees, and a mean increase of 7.9 + 4.0 degrees was maintained on the follow-up examination (p<.001). Starring et al. concluded that fifteen minutes of cyclic or sustained stretching of the hamstring muscle group for five consecutive days resulted in significant ROM increases. After one week without treatment, the subjects retained a significant percentage of their increase in ROM.

Halbertsma & Ludwig (1994) studied the extensibility, stiffness, and electromyographic activity of the hamstring muscles with an instrumental straight-leg raising set-up. Fourteen healthy subjects, aged 20 to 38 years, were selected for the study and were found to have clinically short hamstrings. One group of seven subjects was treated during four weeks with a daily home exercise program aimed at stretching the hamstrings, whereas
the untreated group was used as a control. Instrumental straight-leg raising was performed in the subjects of both groups both pre and post-test. Results indicated a slight but significant increase in the extensibility of the hamstrings accompanied with a significant increase (p<.05) of the stretching moment tolerated by the passive hamstring muscles, however the elasticity remained the same. Halbertsma and Ludwig concluded that stretching exercises do not make short hamstrings any longer or less stiff, but only influence the stretch tolerance.

Magnusson, Simonsen, Aagaard, Dyhre-Poulsen, McHugh and Kjaer (1996) examined whether differences exist in EMG activity, passive torque, and stretch perception in a static stretch compared to a PNF technique, the contract-relax stretch. Ten male subjects participated in the study. Stretch-induced mechanical response in the hamstring muscles during passive knee extension (PKE) was measured as knee flexion torque while hamstring surface EMG was measured. Final position was determined by extending the knee to an angle that provoked a sensation similar to a stretch maneuver. At a constant angle stretch, the knee was extended to 10 degrees below final position, held 10 seconds, then extended to the final position and held for 80 seconds. During the variable angle stretch, the knee was extended from the starting position to 10 degrees below the final position, held 10 seconds, then extended to the onset of pain. Subjects produced a 6 second isometric contraction with the hamstring muscles 10 degrees below the final position in
the contract-relax stretch, but not in the static stretch. Statistical analysis indicated that the constant angle contract-relax and static stretch did not differ in passive torque or EMG response. In the final position, passive torque declined 18% to 21% in both contract-relax and static stretch (p<.001), while EMG activity was unchanged. In the variable angle protocol, maximal joint angle and corresponding passive torque were significantly greater in contract-relax compared with static stretch (p<.01), while EMG did not differ. Magnusson et al. concluded that at a constant angle the viscoelastic and EMG response was unaffected by the isometric contraction. However, the variable angle protocol demonstrated that the PNF stretching altered stretch perception.

In contrast, Sullivan, Dejulia and Worrell (1992) also compared static stretching and a PNF hamstring stretching technique while maintaining the pelvis in two testing positions: anterior pelvic tilt (APT) or posterior pelvic tilt (PPT). Two groups of ten subjects were randomly assigned to either an APT or PPT position. Each subject performed eight sessions using PNF on one leg and static stretch on the other leg while maintaining the pelvis in the assigned position. The Active Knee Extension Test (AKET) was used to assess hamstring flexibility. Statistical analysis indicated that the APT group significantly increased hamstring flexibility (p=0.0375). There was not a significant difference between static stretch or PNF stretching technique in the APT position. There was not a significant increase in hamstring
flexibility in the PPT group with either stretching technique (p>0.05). The authors concluded that the results suggest that APT position was more important than stretching method for increasing hamstring muscle flexibility.

McClure and Pratt (1996) examined whether stretching the hamstring muscles affects extensibility, as indicated by straight leg raising (SLR), lumbopelvic posture and the relative amounts of lumbar and hip motion during forward bending. Thirty-nine healthy subjects with tight hamstrings (i.e. SLR of ≤ 70 degrees) were randomly assigned to either a stretching group or a control group. A three-dimensional digitizer was used to measure lumbar, pelvic, and hip positions while subjects were in a standing position and during partial and full forward bending. Hamstring muscle length was characterized using two methods, the SLR and the AKET. The stretching group stretched daily for three weeks. The regimen consisted of slow, static stretching (via the SLR) for 15 seconds, followed by a 15 second rest, ten times daily on both lower extremities. Statistical analysis indicated that straight leg raising and hip motion during late and total forward bending were increased after stretching (p<0.05).

Duration of hamstring muscle stretching

Several studies have examined the amount of time of hamstring muscle stretching on increasing hamstring flexibility. Halbertsma, Bolhuis and Goeken (1996) evaluated the effects of one ten minute stretch on muscle
stiffness in subjects with short hamstrings. Sixteen healthy subjects participated in the study. To select subjects with short hamstrings, the finger-ground distance had to be greater than 0cm (unable to touch the floor when bending forward) and the Passive Straight Leg Raise (PSLR) was not to exceed 80 degrees. One group of ten subjects performed static stretching exercises during ten minutes interspersed with relaxing, whereas the untreated group of six subjects was used as a control. An instrumental straight-leg-raising set-up was used to measure the force needed to lift the leg, range of motion, pelvic-femoral angle, and the EMG of the hamstrings. These variables were used to provide information about the stiffness, elongation and the state of activity of the hamstring muscles. Statistical analysis indicated that one ten-minute stretch resulted in a significant increase \( p<0.05 \) in passive muscle moment, range of motion, and elongation of the hamstrings. There was no significant change in the course of the passive muscle stiffness curve with respect to the prestretch stiffness curve. Halbertsma et al. concluded that one ten-minute session of static hamstring stretching does not influence the course of the passive muscle stiffness curve. Thus, the increased range of motion, i.e. the extensibility of the hamstrings, resulted from an increase in the stretch tolerance.

Borms, Van Roy, Santens and Haentjens (1987) examined the effect of different durations of static hamstring stretching exercises on hip flexibility. The experimental group, consisted of 20 sedentary women, 20-30 years of
The stretching program lasted for ten weeks and consisted of two 50 minute sessions per week. The control group of 15 sedentary women did not participate in the stretching program. Hip flexibility was determined before, during and at the end of the program by means of a goniometric measuring technique. Three sub-groups were formed, each following the same program except that the duration of the static stretch differed (group one, ten seconds; group two, twenty seconds; group three, thirty seconds). Statistical analysis indicated that for all three stretching groups, hip flexibility improved significantly after ten weeks of stretching ($p < 0.05$). No significant differences in hip flexibility were noted between the three sub-groups at the end of the stretching program. The authors concluded that ten seconds of static hamstring stretching was sufficient for improving hip flexibility.

Bandy and Irion (1994) examined the length of time the hamstring muscles should be placed in a sustained stretched position to maximally increase range of motion. Fifty-seven subjects (40 men, 17 women), ranging in age from 21 to 37 years participated in the study. These subjects exhibited limited hamstring muscle flexibility via the Active Knee Extension Test (AKET), i.e. 30 degree loss of knee extension. The subjects were randomly assigned to one of four groups. Three groups stretched five days per week for 15, 30 and 60 seconds. The fourth group served as the control group and did not stretch. Before and after six weeks of stretching, flexibility of the hamstring muscles was determined via the AKET. Data analysis revealed a
significant group x test interaction (p<0.05), indicating that the change in flexibility was dependent on the duration of stretching. Further post hoc analysis revealed that 30 and 60 seconds of stretching were more effective at increasing flexibility of the hamstring muscles than stretching for 15 seconds or no stretching. No significant difference existed between stretching for 30 seconds and for one minute, indicating that 30 seconds of stretching the hamstring muscles was as effective as the longer duration of one minute. The authors concluded that a duration of 30 seconds was an effective time of stretching for enhancing the flexibility of the hamstring muscles.

Hamstring Muscle Strength and Flexibility

Jonhagen, Nemeth & Eriksson (1994) studied eleven sprinters who had sustained a hamstring strain injury during one of the two seasons before the investigation. Nine sprinters who had never injured their hamstring muscles were included as the control group. The flexibility of the hamstrings and the eccentric and concentric muscle torque were measured in the hamstrings and quadriceps muscles at different angular velocities. A Kin-CoM Isokinetic Dynamometer was used for testing muscle strength. Concentric torques were tested at three different velocities: 30, 180, and 270 deg/sec, while the eccentric torques were tested at 30, 180, and 230 deg/sec. The aim of the study was to determine whether there were any differences in eccentric and concentric hamstring and quadriceps torques between sprinters who had suffered from previous hamstring strain injuries and uninjured
sprinters. The authors reported that the sprinters with the previous hamstring strain injuries had significantly tighter hamstrings than the uninjured sprinters ($p<0.05$). Also, the uninjured sprinters had significantly higher eccentric hamstring torques at all angular velocities, 30, 180, and 230 degrees/sec, ($p<0.01$, $p<0.01$, and $p<0.001$). They also had significantly higher concentric quadriceps and hamstring torques at 30 degrees/second but not at higher velocities ($p<0.05$). The authors concluded that the sprinters with a history of a hamstring strain injury differed from the uninjured runners, being weaker in eccentric contractions and in concentric contractions at low velocities.

Worrell, Perrin, Gansneder & Gieck (1991) also compared isokinetic strength and flexibility measures between hamstring injured and noninjured athletes. Sixteen university athletes with a hamstring strain injury within the last eighteen months were matched by motor dominance, sport, and position to sixteen university athletes without a history of a hamstring injury. Each subject was tested for concentric and eccentric quadriceps and hamstring peak torque and reciprocal muscle group ratios on the Kin-Com Isokinetic Dynamometer at 60 deg/sec and 180 deg/sec. Analysis of variance indicated that the injured extremity was significantly less flexible than the noninjured extremity within the hamstring injured group and the hamstring injured group was less flexible than the noninjured group ($p<0.05$). The strength results of this study showed no significant differences between the
hamstring strain injured and noninjured group on any isokinetic measure evaluated.

Both of the above studies showed a significant decrease in hamstring flexibility of the injured athletes however the two studies differ in regards to hamstring strength. Jonhagen et al. (1994) explains that one of the reasons no significant strength differences were found in the Worrell et al. study could be due to the fact that the athletes came from different types of sports, i.e. football, track, soccer and lacrosse, and only one was a sprinter whereas all of the subjects in Jonhagen et al.'s study were sprinters. There was also a marked difference in the severity of the hamstring injuries of the athletes in the two studies. In the Worrell et al. study, the average absence from a sport was about two weeks which indicated a mild strain injury while in Jonhagen et al.'s study, the average absence from the sport was almost two months indicating a moderate to severe hamstring strain injury, (Jonhagen et al., 1994).

Worrell, Smith and Winegardner (1994) examined the relationship between hamstring flexibility and hamstring muscle performance. The purpose of the study was to determine the most effective stretching method for increasing hamstring flexibility and to determine the effects of increasing hamstring flexibility on isokinetic strength. Nineteen healthy university students participated in the study. Hamstring muscle flexibility was assessed with the Active Knee Extension Test (AKET). A Biodex Isokinetic
dynamometer was used to measure eccentric and concentric hamstring peak torque values at 60 and 120 degrees/second. A two-way analysis of variance was used to compare the two stretching techniques: PNF contract-relax and static stretch. Statistical analysis indicated no significant increase (p>0.05) in hamstring flexibility even though increases occurred with each technique: static stretch (+21.3%) and contract-relax (+25.7%). Significant increases occurred in peak torque eccentrically at 60 degrees/second (p<0.05, +8.5%) and 120 degrees/second (p<0.05, +13.5%) and concentrically at 120 degrees/second (p<0.05, +11.2%). No significant increase occurred concentrically at 60 degrees/second. The authors concluded that increasing hamstring flexibility was an effective method for increasing hamstring muscle performance at selective isokinetic conditions.

Neural Tension Stretching

A strain injury to a muscle can affect the surrounding nervous tissue by direct inflammation and eventually scarring. The nervous system contains a great amount of connective tissue in various forms and structure. The structural component of the nervous system exhibit a specialized anatomy which allows for adaptation of body positions. For example, in peripheral nerves, axons have a wavy appearance in a longitudinal view. The nerve can be lengthened somewhat before the slack is taken up in the individual axons. This ability is an important structural safety feature of peripheral nerves, since they must be mobile to accommodate relative limb
length changes during limb movement. Nerve roots, on the other hand, are relatively immobile in the intervertebral foramen. Therefore, elongation of a peripheral nerve can be transmitted proximally to the nerve root. This is the anatomic basis for nerve tension tests such as the straight leg raise test for the sciatic nerve (Jewell, 1988).

The Slump Test is a neural tension stretching technique that applies a full stretch to the dura, cord, and nerve roots by adding neck flexion, straight leg raise, and ankle dorsiflexion to trunk flexion in a sitting position. This test provides a means of assessing adverse neural tension to a greater degree than the standard tests of tension (i.e., straight leg raise, passive neck flexion and prone knee bend).

The Slump Test is being used by many physical therapists as a valuable tool in the rehabilitation process of an injured athlete and the clinical results seen in the athlete's overall performance have been very positive. However, few studies exist in the objective testing of the efficacy, anatomical, and physiological changes that occur in the body during the Slump Test. A study was performed by Kornberg and McCarthy (1992) to evaluate the effect of the Slump Test on sympathetic outflow as measured by lower limb temperature change. Ten elite track and field athletes were selected as subjects. The subjects were randomly divided into two groups, right lower limb slump stretching and left lower limb stretching while the opposite lower limb not stretched served as the control. Four points were
chosen along the posterior lower limbs. A telethermographic imaging camera was used to detect the thermal gradient along the lower limb at these points. Kornberg et al. stated that since skin temperature is proportional to skin blood flow, skin temperature can be used to quantify autonomic function. Repeated measures analysis of variance indicated significant (p < 0.001) small temperature increases at all four locations for the stretched limb. Consistent small declines in skin temperature for the control limb from pre to post-mobilization were also observed. Kornberg et al.’s finding in this study showed that neural tension stretching, via the slump stretch, increases the facilitation of the autonomic nervous system in the stretched limb of normal elite athletes.

Slater, Vincenzino and Wright in 1994 examined the indirect effects of the ‘sympathetic slump’ technique on peripheral sympathetic nervous system function. Twenty-two normal, asymptomatic adults participated in the study. A randomized, repeated measures, double-blind, placebo controlled protocol was used to evaluate the effect of ‘sympathetic slump’, placebo and control conditions on skin conductance and skin temperature in the upper limbs. The placebo and experimental conditions were applied three times for twenty seconds with a minute rest between each application. Multivariate analysis of variance (MANOVA) was used to analyze the two-way, within-subjects design. ‘Sympathetic slump’ produced a significantly (p<0.01) greater increase in skin conductance than either placebo or control. A
greater increase in skin conductance was observed in the right upper limb compared to the left upper limb, in keeping with the fact that the technique used in the study was intended to bias the right sympathetic trunk. Significant ($p<0.05$) changes in skin temperature occurred for both 'sympathetic slump' and placebo compared to control, however there was no significant difference between 'sympathetic slump' and placebo.

'Sympathetic slump' did however appear to exert a greater differential effect between sides (R<L) than did the placebo technique. Slater et al.'s finding in this study demonstrated that the 'sympathetic slump' technique influences peripheral sympathetic nervous system function. This technique has the potential to differentially increase sympathetic activity in the ipsilateral upper limb.

In another recent study, Vincenzino, Collins and Wright (1994) investigated the effect of two neural stretching techniques on skin conductance and temperature in the distal C6 dermatome. A randomized, repeated measures, double blind, placebo controlled study design was used to investigate the physiological effect of a C5-6 left lateral glide technique with the right upper limb in either the upper limb median tension or the upper limb radial tension positions. Thirty-four normal, asymptomatic adults participated in the study. The placebo and experimental conditions were applied three times for thirty seconds with a minute rest between applications. The two-way within-subjects design was assessed using the
MANOVA procedure. Radial and median nerve tension positions produced significantly ($p<0.01$) greater increases in skin conductance than did placebo or control. The radial nerve tension position produced a greater increase than did the median nerve position but this was not significant. There were no significant changes in skin temperature. Vincenzino et. al. concluded that the results provide objective evidence of a physiological effect in the peripheral sympathetic nervous system that is produced by the neural tension stretching techniques.

Fidel, Martin, Dankaerts, Allison and Hall (1996) examined the effects of cervical spine sensitizing maneuvers, (Cervical flexion and extension), in the slump position in a normal population. A second objective of the study was to determine if there was a change in the knee extension angle after ten repetitions of passive knee extension mobilizations during the slump stretching technique. The final objective of the study was to determine whether protective muscular activity, as evidenced by EMG, existed in a normal population in the medial hamstrings during the slump test. Twenty-seven healthy subjects, ages 22 to 55, were randomly assigned to two groups based on initial cervical spine position. One group was placed in a maximal slump position with full cervical flexion and another group was placed in a maximal slump position with the cervical spine in extension. A Kin Com computer controlled dynamometer was used in the study to monitor simultaneously the angle of the right knee joint, passively flex and extend
the knee at a constant velocity of 10 degrees/second, and to integrate hamstring muscle activity via the internal EMG apparatus. Using a cross-over design, the angle of right knee extension at the onset/limit of pain (P1/P2) was determined before and after ten passive knee extensions at 10 degrees/second to P2 in both groups. Hamstring muscle activity was recorded during the ten repetitions. Statistical analysis, (MANOVA), indicated that cervical spine flexion during the slump test had a significant effect on the measured angle of knee extension and the angle of knee extension at P1 and P2 significantly decreased following the passive knee extension mobilization, (p<0.05). Thus, in a normal population, there was less right knee extension with cervical spine flexion compared to that with the cervical spine in extension. There also was a significant decrease in the angle of right knee extension at P1 and P2 following ten repetitions of passive right knee extension mobilization in the slump position. The authors stated that these findings support the hypothesis of neural tissue compliance after one clinical trial of passive knee extension mobilizations during the slump stretching maneuver.

Kornberg and Lew (1989) conducted another study on the efficacy of the Slump Stretching technique. The purpose of the study was to compare the recovery period of hamstring injured football players being treated with traditional treatment and slump stretching, to traditional treatment alone. Traditional treatment included ultrasound, electrical stimulation, ice and
g gentle hamstring stretching. Kornberg et al. postulated that if symptoms were caused strictly by hamstring muscle pathology then stretching neural structures would have no benefit on recovery time. A double blind survey was set up in eight professional Australian Rules football clubs. Sixteen players were treated along traditional lines and served as the control group. Twelve players were treated by traditional methods in addition to the slump stretching. The recovery period was defined as the number of matches missed because of a hamstring injury and one complete pain free match. Of the twelve players treated by traditional methods and slump stretching, only one player missed more than one match. All sixteen players treated by traditional methods alone missed one or more matches. The results showed a significant difference ($p < 0.001$) in using traditional treatment plus the slump stretching compared to traditional treatment alone. Traditional treatment plus slump stretching was more effective in returning the player to full function as evidenced by the twelve players ability to complete one painfree match with no further missed matches. Kornberg et al. concluded that the traditional treatment of grade I hamstring injuries with slump stretching is a more effective program for managing this type of injury.

**Summary**

A hamstring muscle strain can be a debilitating injury to an athlete, especially those athlete's participating in sports which require rapid movements and/or sprinting. There are many etiological factors related to
hamstring strains. Strength imbalances between the hamstrings and/or quadriceps and the flexion-extension strength ratios have been found to be related to the occurrence of hamstring strains. Subjects suffering from a hamstring strain tended to be less flexible both at the hip joint and bilaterally in the lower extremities compared to non-injured subjects. Daily static stretching of shortened hamstrings has been found to increase the medial hamstring length, which is the most frequent of the three hamstring muscles damaged in a strain injury. Thus, there is a concomitant increase in the hamstrings' ability to withstand a greater passive lengthening force.

A rehabilitation program must include a variety of techniques addressing all the injured anatomical structures in order for the injured athlete to return to competition at full performance potential. Proprioception neural muscular facilitation (PNF) along with other modalities have long been used in the treatment of athlete's with muscle strain injuries. Very few clinicians understand or incorporate neural tension stretching techniques in the rehabilitation program. Neural tension stretching, via the slump stretch, increases the facilitation of the autonomic nervous system in the stretched lower limbs of normal elite athletes. Neural tissue compliance has been shown to occur, by the decrease in the knee extension angle, after one clinical trial of passive knee extension mobilization in the slump stretching technique. Other neural tension techniques, e.g., sympathetic slump, radial and median tension positions, increase peripheral sympathetic nervous
system function in the upper limbs. It has been shown that traditional
treatment plus slump neural tension stretching is a more effective program
in treating football players with grade I hamstring strains. These players
were able to return to full function sooner with lower reinjury risk. More
research is needed, however, regarding the effect of neural tension stretching
on the recovery process of muscle strain injury and correlation with
recurrent injury.
APPENDIX A

EXTENDED RESEARCH REVIEW OF LITERATURE APPENDICES

References


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APPENDIX B

INFORMED CONSENT FORM FOR NEURAL TENSION/STATIC STRAIGHT LEG RAISE STRETCHING AND FLEXIBILITY STUDY PARTICIPATION

The thesis project conducted by Christa Harris, P.T. is part of the requirements for the M.A. degree in Exercise Physiology at California State University, Northridge.

Description of Research:
The research will add to the limited literature on the effects of neural tension stretching and human performance. I am confident that this information will be of assistance to physical therapists, athletic trainers, physicians, athletes and non-athletes. It is my intention to demonstrate that neural tension stretching is a better form of stretching, than traditional techniques, in minimizing low back pain/stiffness and hamstring muscle tightness.

Subject Information:
Each subject will be in the study for approximately four weeks. There will be two days of testing for each subject both before and after the four week period. The testing consists of a Biodex isokinetic test for hamstring strength, Active Knee Extension and Passive Straight Leg Raise tests for hamstring muscle flexibility. There is a slight possibility that the participant will experience some lower limb muscle soreness following the Biodex isokinetic tests. However, this is normal and will only last for a short period. Subjects randomly chosen to be in the experimental group will receive either the Slump neural stretching technique or the Passive Straight Leg Raise. The normal responses that may be felt during the Slump stretching technique is a slight discomfort in the mid-thoracic spine and in the back of the knee. However, this will cease immediately following the technique. The abnormal responses to Slump stretching, which are rare, are dizziness, blurred vision, numbness/tingling in both hands or both feet at the same time, nausea and/or head pain. If the participant experiences any of these symptoms, the stretching procedure will be immediately stopped and the subject will be excluded from the study and referred to a physician. There is a very rare possibility that the stretching techniques may aggravate an old low back problem however both stretching techniques will be performed by a Licensed Physical Therapist and extreme care will be taken to avoid any re-injury. Subjects will be responsible for their own medical care if needed.
Confidentiality:
Any information that is collected in this study that can be identified specifically with the subject will remain confidential and will be disclosed only with your written permission or if required by law. The cumulative results of this study will be published, but the names or identity of subjects will not be made known.

Benefit of Participation:
Subjects will not receive monetary compensation. However, participation will provide subjects with a greater insight into a treatment technique that may improve hamstring muscle performance. The Slump and Passive Straight Leg Raise techniques may be of value if the subject has ever suffered from a hamstring strain or low back injury that may have hindered your daily activities, occupational or athletic performance.

Concerns:
If you wish to voice a concern about the research, you may direct your question(s) to Research and Sponsored Projects, human subject committee, 18111 Nordhoff Street, California State University Northridge, Northridge, CA 91330, or phone 818-677-2901. If you have specific questions about the study you may contact Dr. Steven Loy, faculty adviser, 18111 Nordhoff Street, Northridge, CA 91330, or phone 818-677-3220 or Christa Harris, P.T at (310) 394-7085.

You should understand that participation in this study is completely voluntary, and you may decline to participate or withdrawal from the study at any time without jeopardy. Likewise, the investigator may cancel this study at any time.

I have read the above and understand the conditions outlined for participation in the described study. My signature indicates that I am both qualified and willing to participate as a subject in the described investigation.

_________________________________________  ________________
Subject’s Signature                                Date

_________________________________________  ________________
Investigator’s Signature                          Date
APPENDIX C

SUBJECTS DESCRIPTIVE AND EXPERIMENTAL RAW DATA

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## APPENDIX D

### PERCENT CHANGE

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