To the Graduate Council:

I am submitting herewith a thesis written by Bradley Johnson entitled "The Efficacy of Active Isolated Stretching in the Improvement of Hamstring Flexibility." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Human Performance and Sports Studies.

Wendell Liemohn, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

THE EFFICACY OF ACTIVE ISOLATED STRETCHING IN THE IMPROVEMENT OF HAMSTRING FLEXIBILITY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Brad Johnson

May 1998

DEDICATION

This thesis is dedicated to my parents

Mr. Ronnie Johnson

and

Mrs. Beverly Johnson

without their love and support I

would never have had the opportunity

to accomplish this.

ACKNOWLEDGMENTS

There are many people that have made this possible, but I particularly want to thank the ones that had an instrumental role in the completion of this thesis. First I would like to thank Kelly Johnson for her help with data collection and statistical analysis, and I would also like to thank Jason Crum for his assistance with data collection. Next I would like to thank Dr. Wendell Liemohn for sticking with me and guiding me through this process. Finally I would like to thank Dr. Ed Howley and Dr. Dixie Thompson for serving on my committee and Dr. Deborah Judd for her statistical expertise.

Without the help of these people I would not have been able to achieve this great accomplishment.

ABSTRACT

The purpose of this study was to investigate the efficacy of active isolated stretching (AI) vs. static stretching (SS) in the improvement of hamstring flexibility. A literature review showed that SS does significantly increase hamstring length, but that PNF techniques are more effective. There were no studies found in the literature on the effectiveness of AI. Nine female and three male subjects were trained for five weeks. The right leg was trained using an AI protocol three times a week and the left leg was trained using a SS protocol three times a week. Subjects were tested prior to training, at mid-training, and at post-training using a passive straight leg raise (SLR) test and an active knee extension test (AKE). Three by two repeated ANOVA showed that both AI and SS increased hamstring length at the .001 significance level. The ANOVA also found no significant difference between AI and SS at pre, mid, or post-training when analyzing the dependent variable AKE data. The same ANOVA found no significance with SLR data at pre and mid-testing. It did however, show a significance at the .003 level when SLR post-test data was analyzed, favoring the AI trained leg.

TABLE OF CONTENTS

CHAPTER		PAGE
1.	INTRODUCTION	1
	Purpose	2
	Hypothesis	2
2.	REVIEW OF LITERATURE	3
	Viscoelastic Properties of the Muscle-tendon Unit	3
	The Stretch Reflex	5
	Inhibition of the Stretch Reflex	6
3.	METHODS AND PROCEDURES	9
	Subjects	9
	Testing	9
	Training	10
	Statistical Analysis	11
4.	RESULTS	12
	Dependent Variable: SLR	12
	Dependent Variable: AKE	13
	Pearson Correlation Coefficients	12
	Table 1.	13
5.	DISCUSSION	14
	Dependent Variable: SLR	14
	Dependent Variable: AKE	15
	Other Considerations	15

TABLE OF CONTENTS

Conclusion 16

REFERENCES 17

APPENDICES 20

VITA 26

LIST OF ABBREVIATIONS

AI_____active isolated stretching

AKE_____active knee extension

EMG_____electromyography

GTO_____golgi - tendon organ

ROM_____range of motion

SD _____standard deviation

SLR_____straight leg raise

SR _____stretch reflex

SS_____static stretching

Chapter 1 Introduction

Flexibility one of the major components of physical fitness, has received much attention from researchers over the years, although many questions related to flexibility remain to be answered. Flexibility has been defined as "the range of movement which is possible about a single joint through a series of articulations" (21), or simply the range of motion (ROM) about a joint. Good flexibility has been shown to be important in the prevention of injury during activity, as well as in the improvement of performance in specific motor skills (12,20, 23). Flexibility is also important in rehabilitation of joint injuries (21,25); moreover, it has been shown that a lack of ROM is a risk factor for low back pain (4,5).

The importance of flexibility can be seen quite clearly with only a limited explanation of each benefit. With an increased ROM a joint, or a muscle and its associated connective tissue articulating with that joint, is less likely to be injured; furthermore, if an injury does occur, a full ROM will be needed for a complete recovery (3). The amount a muscle-tendon unit can be lengthened determines how much potential energy can be stored by that unit during eccentric contraction. Therefore, secondary to the increased potential energy, a muscle-tendon unit is capable of dissipating greater force during concentric contractions (25). This benefit makes it a focal point for coaches, athletic trainers, and physical therapists.

Even though flexibility is deemed important there is limited knowledge on how flexibility can be improved through exercise. Despite this lack of

knowledge, there are several methods that have been shown to be effective in increasing flexibility. Although static stretching (SS) is effective in increasing flexibility, several studies have shown proprioceptive neuromuscular facilitation (PNF) to be a more effective technique (8,9,19,20,21). Most recently there has been a new technique known as active isolated stretching (AI) espoused by Mattes (24). Wharton & Wharton state that AI appears to be effective when used with athletic populations (24), but its effectiveness in relation to SS is unknown.

AI is a combination of an active stretch and a passive stretch. The intial stretch is active and is carried to the end of active ROM. When end active ROM is reached an additional passive stretch is added. This passive stretch is held for a short duration, approximately 2-sec, and the stretch is repeated multiple times (24).

Purpose:

The purpose of this research was to compare the efficacy of the AI vs. SS technique for the improvement of hamstring length. These two techniques were compared over a five week training period to determine which was the most effective at increasing hamstring length.

Hypothesis:

There will be no difference between the effectiveness of AI and SS stretching techniques in the improvement of hamstring flexibility over a five week training period.

Chapter 2 Review of Literature

Viscoelastic Properties of the Muscle-tendon Unit:

An understanding of the properties of the muscle-tendon unit is of vital importance to the physiological explanation of increases in ROM. Muscle and tendon display viscoelastic properties; this means that they have elastic properties allowing for rebound and viscous properties allowing for plastic deformation (16,17,23). Taylor et al. (23) imply that length changes are directly proportional to the applied forces or loads. They also state that viscous properties are time-dependent and rate change-dependent, with rate of deformation of the tissue being directly proportional to the forces applied. It is these characteristics and their responses to training programs that are believed to allow for increases in flexibility.

The elastic properties are often most clearly represented by the use of a spring as a model (Fig. A-1). As a spring is stretched its deformation is solely dependent on the load or force applied to it. When that load is removed the spring returns to resting length, assuming the tension is maintained for a brief period of time (10). Muscle and tendon show the same characteristics, thus the elastic properties represent the reversibility of changes in muscle-tendon length. The reversibility is, however, dependent on the load or force applied to that muscle-tendon unit, as well as its duration (10,16,17).

A hydraulic piston or dash-pot model is often used to represent the viscous properties of the muscle-tendon unit (Fig. A-1). If a high force is applied to a hydraulic piston, at a high rate, the piston is going to resist with a

great amount of force. If this same force were applied gradually over time the piston's resistance would be decreased and the hydraulic system could be manipulated. This model demonstrates that changes in muscle-tendon unit length are not only dependent upon the amount of force applied, but also on the rate and duration of the force application (16,17,23). It is these qualities that most flexibility techniques address, but in reality the viscous and elastic properties must be thought of as being functionally integrated and not independent of one another (23).

Viscoelastic materials have several characteristics that are important to flexibility. The first one that will be discussed is stress relaxation. Stress relaxation is the gradual decrease in tension within the muscle-tendon unit when it is placed under a constant load (12,16,17,23). This decrease in tension is due to a lengthening of the viscoelastic material of the muscle-tendon unit. An analogy would be wrapping a rubber band around a bundle of papers. If the rubber band is removed quickly there is not apt to be a change in its length. However, if it is left over night the rubber band will lengthen and the tension will be reduced considerably. An In vivo example of this occurs in static stretching. When a SS regimen is followed there is typically a decrease in tension and an increase in ROM (12,16,17).

Another important characteristic of viscoelastic materials is strain rate dependence. This means that the tension within a material is dependent on the rate at which the force is applied. The faster the rate of force application the higher the tension will be in the tissue, and consequently, more resistance to lengthening. Changes at the cellular level are very unlikely under

circumstances in which the force is applied quickly. However, slower force application allows for greater stress relaxation to occur because the increase in time permits changes at the cellular level (12,16,17,23).

The Stretch Reflex:

The stretch reflex (SR) is one of the body's many protective mechanisms. This reflex protects muscle-tendon units from being over extended and thus, can prevent many injuries from occurring; the SR is also important in the maintenance of posture (7,18). Before an explanation of the SR is given, there must first be an understanding of the receptor that initiates the SR, the muscle spindle.

Muscle spindles are receptors located in parallel with muscle fibers, and they detect stretch within a muscle. A muscle spindle is made up of intrafusal fibers, that have been described as attenuated extrafusal muscle fibers (18). These intrafusal fibers are much smaller and there are two types; large nuclear bag fibers and the smaller nuclear chain fibers. The middle portion of the intrafusal fibers serve as receptor site for the primary endings (annulospiral) of the Ia sensory afferents; the secondary endings (flowerspray) of the type II sensory afferents are found primarily at the ends of the nuclear chains (18). The primary (annulospiral) endings are stimulated by the rate of change as well as the amount of change in length of the muscle-tendon unit. Secondary (flowerspray) endings are stimulated when a stretch is maintained at a lengthened range (7).

The contraction of a muscle that occurs as a result of the muscle spindle being stretched is the SR. The SR results in the contraction of a muscle that occurs as a reaction to its being stretched. If this reflex contraction occurs, it can resist a lengthening stretch, and theoretically make it more difficult to obtain an increase in the length of the musculotendinous unit. The reflex occurs when a muscle is stretched quickly. In this scenario the muscle spindle's "annulospiral" endings are stimulated; this activates the Ia afferent fibers, which return to the ventral horn of the spinal cord and monosynaptically stimulate the alpha and gamma motor neurons (7, 18). The activation of the alpha motor neurons results in the contraction of the extrafusal muscle fibers of the muscle being stretched (7,18,21).

Inhibition of the Stretch Reflex:

Though the SR is important as a protective measure for the body it could plausibly be a hindrance when trying to increase flexibility. Fortunately there are ways of inhibiting or overriding the SR. The two that will be discussed here, and are relevant to this study, are autogenic inhibition and reciprocal inhibition.

Autogenic inhibition is the overriding of the muscle spindle induced contraction by the golgi-tendon organs (GTO), SS is theorized to work through this type of inhibition. The GTO's are sensitive to tension or stretch on the tendons(14, 18). GTO threshold can be achieved by extensive passive stretch or active muscle contraction. It is believed that contraction of a single muscle fiber is sufficient to reach the GTO's threshold (14). When the GTO's

threshold is reached they cause a relaxation within the muscle. Thus, they can counteract the response of the SR that is initiated by the muscle spindles.

When a muscle is stretched the muscle spindles initiate the SR. There will be an initiation of the SR because the muscle spindles have a much lower threshold than do the GTO's (21). The SR causes a contraction in the muscle being stretched, which resists any further lengthening. Once the threshold of the GTO's is reached the GTO's override the muscle spindles and cause a relaxation in the target muscle. This relaxation will allow for further stretch to occur. Not only is this effective for increasing muscle-tendon length, but it also appears to be a protective measure as well. This relaxation can prevent injuries that might be caused by excessive reflex contraction (14,21).

The second form of inhibition, reciprocal inhibition, is very different from autogenic inhibition. Reciprocal inhibition deals with the relationship between the agonist and antagonist muscle groups. It is theorized that active contraction of the agonist muscle will inhibit the motor neurons that supply its antagonist. This motor neuron inhibition, thus, prevents the contraction that could be caused by the SR (21). AI is theorized to work through this type of inhibition, but it also is believed to prevent the activation of the type II (flowerspray) endings, because of its short duration (2-sec).

Several EMG studies have been done to determine if there actually is an inhibitory effect on the target muscle from these forms of inhibition (8,19,20). Osternig et al (20) and Moore et al (19) both did EMG studies comparing SS and similar PNF techniques. Though both of these studies found the PNF techniques to be the most effective for increasing ROM, they

also found that the highest EMG activity was present in the target musculature during PNF use. The SS did show significant increases in ROM, but not as large as the increases resulting from the PNF techniques. SS did however, have significantly lower EMG readings in both of these studies. From these studies it would appear that reciprocal inhibition may not be as important in the improvement of ROM as originally thought.

Chapter 3 Methods and Procedures

Subjects:

Fifteen subjects from a physical activity class volunteered to participate in this research. All subjects read and signed an informed consent form that had been approved by the University of Tennessee, Knoxville's Institutional Review Board. Age, height, weight, and gender were the demographic variables recorded for each subject.

Testing:

Prior to the initiation of the training protocols, each subject was tested using two different hamstring length testing protocols. This testing consisted of both an active knee extension test (AKE) and a passive straight leg raise test (SLR). The AKE was administered with the subjects lying supine and their hip and knee both flexed to 90°. The hip was set to 90° with a goniometer and with the posterior thigh positioned against a support to ensure that it remained at this angle. An inclinometer was then placed on the tibial tuberosity, with 90° being 0, and the subject slowly extended the knee to the end of active ROM, at which the inclinometer was read. This procedure was repeated three times for each leg; the mean of the three trials constituted the pre-treatment score for each leg.

The passive SLR was administered while the subject was supine with the low back flat, hip in a neutral position, the knee fully extended, and the contralateral knee flexed. Once again the inclinometer was placed on the

tibial tuberosity and zeroed at this position. The leg was then slowly lifted by the researcher to the end of passive ROM where the inclinometer was read. As with the AKE this was repeated three times for each leg and a mean of those three measures was taken as the pre-treatment score. The above tests were also administered at 2.5 weeks into training and post-training. There was no specific sequence followed for test administration, and activity prior to testing was not controlled.

Training:

Subjects participated in the testing and training programs during the meeting time of their physical activity class. Each subject was their own control as they participated in the testing and training programs. Subjects participated in the training three days a week, each day that their class met, for five weeks (15 training sessions). During this time all subjects were asked to refrain from any other exercises that might in some way affect their hamstring length.

Subjects used the AI stretching protocol for their right leg and the SS protocol for their left leg. The AI protocol consisted of 15 2-sec stretches with a 2 sec relaxation period between stretches (24). A rope was wrapped around the arch of the foot and then an active SLR was performed to end active ROM. At this point the rope was tensed to increase the stretch to end passive ROM; this end passive ROM was held for 2-sec and then relaxed. To reiterate, this was repeated 15 times resulting in 30-sec total of stretching.

Hamstring Flexibility

The SS protocol administered to the left leg consisted of three 10-sec stretches with a 10-sec relaxation period between each stretch (4). Once again a rope was wrapped around the arch of the foot to assist in the stretching; however, during the SS the subjects pulled their leg up with the rope passively (i.e. the hip flexors were not used). Although both legs underwent different protocols, the length of stretching for each training session was 30-sec.

Statistical Analysis:

Data from pre-tests, mid-tests, and post-tests were compared bilaterally, using a 2 x 3 repeated measures ANOVA, also called a treatment by treatment by subject design, to determine if there was a statistically significant difference between AI and SS. The same ANOVA also determined if there were increases over time in hamstring flexibility using the SS and AI techniques. These were performed on both SLR and AKE data. Intraclass correlation coefficients were also calculated to determine reliability for both the AKE and SLR tests (2).

Chapter 4 Results

Fifteen subjects, five male and ten female, participated in the initial testing; however, three did not complete the requisite number of training sessions to be included as subjects in this research. The means and standard deviations of the flexibility scores of the 12 subjects (9 female & 3 male) that completed the training are shown in Table 1; this table gives scores at pre-training, mid-training, and post-training. Intraclass Correlation coefficients for SLR were .97 and .99 for the right and left respectively; for AKE they were .98 for both the right and left.

Dependent Variable: SLR:

Treatment by treatment by subject ANOVA performed on SLR data showed that there was no statistically significant differences between AI & SS at pre-training and mid-training. However, on the post-training SLR test a significance of .003 favoring the AI-trained leg was shown. The ANOVA showed a 0.001 significance level for AI and SS when the two techniques were compared over time, showing that both techniques increased hamstring flexibility (Fig. B-1 & Fig. B-2). On pairwise comparison of estimated marginal means on SLR data, neither AI or SS showed statistically significant increases from pre-test to mid-test, but both showed a significant increase from mid-test to post-test (.001 level) .

Dependent Variable: AKE:

Treatment by treatment by subject ANOVA showed no statistical significance between AI and SS when comparing AKE test scores at pre-training, mid-training, and post-training. It did however, show an overall increase in hamstring flexibility at the .001 significance level for both AI and SS when the data was compared over time (Fig. B-3 & Fig. B-4). Pairwise comparisons of estimated marginal means on AKE data showed that SS had statistically significant increases from pre-test to mid-test (.008 level), and mid-test to post-test (.018 level). The same comparisons showed that AI had a statistically significant increase from pre-test to mid-test (.001 level), but not from mid-test to post-test (.975 level).

Table 1. Pre, Mid, Post-Training Scores

Dependent Variable:			
SLR[a]			
SS:	Pre	Mean = 93.47°	SD = 14.96°
	Mid	Mean = 94.58°	SD = 9.43°
	Post	Mean = 107.66°	SD = 15.13°
AI:	Pre	Mean = 94.80°	SD = 15.95°
	Mid	Mean = 96.04°	SD = 22.00°
	Post	Mean = 112.94°	SD = 14.70°
AKE[b]			
SS:	Pre	Mean = 63.38°	SD = 13.40°
	Mid	Mean = 74.02°	SD = 10.66°
	Post	Mean = 77.20°	SD = 10.33°
AI:	Pre	Mean = 65.20°	SD = 12.72°
	Mid	Mean = 75.18°	SD = 11.58°
	Post	Mean = 75.22°	SD = 11.61°

[a]Mean and SD represents degrees of hip flexion

[b]Mean and SD represents degrees of knee extension

Chapter 5 Discussion

Dependent Variable: SLR:

Treatment by treatment by subject ANOVA of SLR data showed AI to be more effective than SS for improving hamstring flexibility over a five week training period.

The scope of this study did not allow for EMG activity to be measured during testing, thus there is no way to determine the amount of inhibition initiated by AI or SS. However, several studies have compared EMG readings of SS and PNF techniques with similar components of AI (10,11,18). These studies showed SS had lower EMG readings, when using surface electrodes than did the PNF techniques that were similar to AI. Contrary to the EMG findings SS showed the least increase in ROM in all the studies. These results tend to diminish the importance of EMG inhibition in increasing muscle-tendon unit length. Cornelius & Hinson (3) also showed that concentric contraction of the hip flexors during passive stretch was as effective as traditional PNF techniques in increasing hamstring flexibility. Cornelius & Hinson (3) did not investigate EMG activity. The concentric contraction method investigated by Cornelius & Hinson (3) is the technique most similar to AI. The absolute results of these studies would lend themselves to the support of the SLR results showing AI to be more effective than SS for increasing hamstring flexibility.

Dependent Variable: AKE:

The AKE results did show significant improvement in hamstring flexibility for AI and SS, but they showed no significant difference between the two techniques. This could have been due to limitations of the AKE test itself rather than the AI technique. The AKE test does not allow for increases in measurement once full knee extension is reached, because the hip must be kept at 90° flexion during the test. Since AI did show significant improvement from pre-test to mid-test, but not from mid-test to post-test it is possible that subjects could have reached the maximal measurement of 90° prior post-training AKE testing; thus, not showing the significance found in the SLR data. AI did show a statistically significant increase form mid-test to post-test when SLR data was compared. This is a hypothesis that requires further investigation.

Other Considerations:

A study by Grady & Saxena (13) suggest that there can be cross training effects between legs resulting in increases in flexibility. Their study showed that when the gastrocnemius muscle on one leg was stretched, and showed increased flexibility, that in approximately 40 percent of the subjects the contralateral gastrocnemius showed similar increases in flexibility. This cross training effect was not taken into consideration and is a factor that needs to be addressed in subsequent studies with similar research design.

Conclusion:

In conclusion, this study has given varying results concerning the efficacy of AI over SS for increasing hamstring flexibility. However, the fact that significance was found does give credence to further, more in-depth investigation of AI. It can be concluded from this study that both AI and SS are clinically useful for increasing hamstring flexibility. however, from the results of this investigation it cannot be definitively shown which technique is more effective.

References

References

1) Bandy WD & Irion JM: The effect of time on static stretch on the flexibility of the hamstring muscle. *Phys Ther;* 74 (9): 845-52 Sept. 1994.
2) Baumgartner TA: Estimating reliability when all test trials are administered on the same day. *Res Quar,* 40 (1): 222-25,
3) Biering - Sorenson F: Physical measurements as risk indicators for low back trouble over a year period. *Spine;* 9: 106-110,1984.
4) Borms J, Van Roy P, Santens JP, & Haentjens A: Optimal duration of static stretching exercises for improvement of coxofemoral flexibility. *J Sport Sci;* 5:39-47, 1987.
5) Cady LD, Bischoff DP, Oconnell ER, Thomas PC, & Allan JH: Strength and fitness and subsequent back injuries in firefighters. *J Occu Med;* 21 (4): 269-72, April 1979.
6) Cornelius W & Hinson M: The relationship between isometric contractions of hip flexors and subsequent flexibility in males. *J Sports Med; 20:* 75-80, 1980.
7) de Groot J: The Spinal Cord. In Correlative Neuroanatomy, San Mateo, CA: Appleton & Lange, 27 - 42. 1991.
8) Etnyre B & Abraham L: Antagonist muscle activity during stretching: a paradox re-assessed. *Med Sci Sport & Exerc;* 20 (3): 285-89, 1987.
9) Etnyre B & Lee E: Chronic and acute flexibility of men and women using three different stretching techniques. *Res Quar Exerc & Sport; 59* (3): 222-28, 1988.
10) Frankel V & Burstein A: *Orthopedic Biomechanics.* Philadelphia. Lea & Febiger, 1970.
11) Gajdosik RL, Rieck MA, Sullivan DK, & Wightman SE: Comparison of four clinical tests for assessing hamstring muscle length. *J Ortho Sport Phys Ther; 18* (5): 614-18, Nov. 1993.
12) Gajdosik RL: Effects of static stretching on the maximal length and resistance to passive stretch of short hamstring muscles. *J Ortho Sport Phys Ther; 14* (6): 250-55, Dec. 1991.
13) Grady JF & Saxena A: Effects of stretching the gastrocnemius muscle. *J. Foot Surgery;* 30: 465-69, 1991.
14) Jami L: Golgi tendon organs in mammalian skeletal muscle: functional properties and central actions. *Physio Rev;* 72 (3), 623-666, 1992.
15) Liemohn W: Flexibility/Range of Motion. In *Resource Manual for Guidelines for Exercise Testing and Prescription,* Durstein et al, Eds. Philadelphia: Lea & Febiger, 327-36, 1993.

16) Magnusson SP, Simonsen EB, Aagaard P, Gleim GW, McHugh MP, & Kjaer M: Viscoelastic response to repeated static stretching in the human hamstring muscle. *Scand J Med Sci Sports* vol 5: 342-47, 1995.
17) Magnusson SP, Simonsen EB, Dyhre-Poulsen P, Aagaare P, Mohr T, & Kjaer M: Viscoelastic stress relaxation during static stretch in human skeletal muscle in the absence of EMG activity. *Scand J Med Sci Sports* vol 6: 323-38, 1996.
18) Marieb E: The peripheral nervous and reflex activity. In *Human Anatomy and Physiology,* New York: Benjamin/Cummings Publishing Co., Inc.,423-54, 1992.
19) Moore M & Hutton R: Electromyographic investigation of muscle stretching techniques. *Med Sci Sport Exerc*; 12 (8), 322-29, 1980.
20) Osternig L, Robertson R, Troxel R, & Hansen P: Differential responses to proprioceptive neuromuscular facilitation stretch techniques. *Med Sci Sport Exerc*; 22: 106-11, 1990.
21) Prentice W: A Comparison of static stretching and PNF stretching for improving hip joint flexibility. *Athletic Training*; Spring: 56-59, 1993.
22) Sullivon M, DeJulia J, & Worrel T: Effect of pelvic position and stretching method on hamstring muscle flexibility. *Med Sci Sport Exerc; 24: 1383-89, 1992.*
23) Taylor D, Dalton J, Seaber A, & Garrett W: Viscoelastic properties of muscle-tendon units. *Am J Sport Med; 18* (3):300-309, 1990.
24) Wharton P & Whaton J: Stretching the next generation. *Runner's World* Feb. 1994: 76-81.
25) Worrel T, Smith T, & Winegardner J: Effect of hamstring stretching on hamstring muscle performance. *J Ortho Sport Phys Ther*; 20 (3): 154-59, 1994.

Appendices

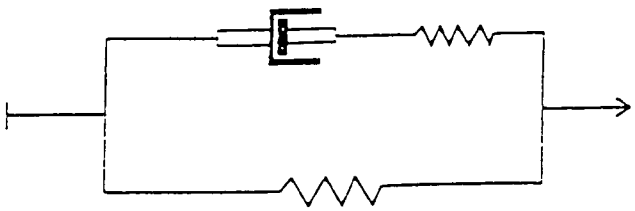


Fig. A-1: **This figure shows a spring and hydraulic piston working both in series and in parallel, representing the elastic and viscous properties of a muscle-tendon unit. Spring and Dash-pot model of viscoelasticity, adapted from. Taylor D, Dalton J, Seaber A, & Garrett W: Viscoelastic properties of muscle-tendon units. *Am J Sport Med; 18 (3): 300-309, 1990.***

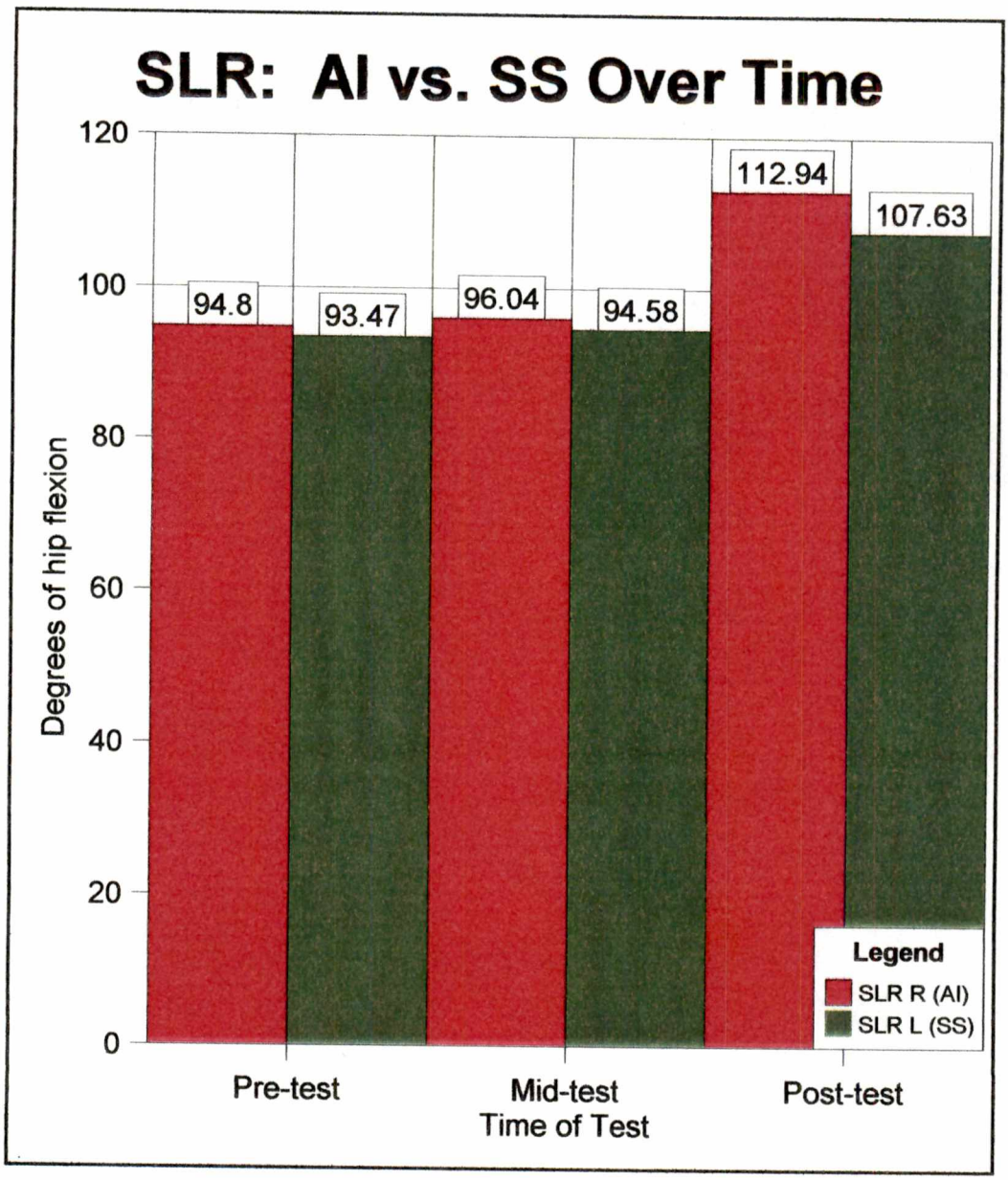


Fig. B-1: Comparison of AI & SS over time using SLR mean test scores. Shows that neither AI or SS produced increases in hamstring length over the first 2.5 weeks of training, but that both showed significant increases form 2.5 weeks to 5 weeks at the .001 level of significance. There were no statistically significant differences between AI & SS at pre or mid-testing, but at post testing AI showed a statitistically significant (.003) greater increase in hamstring flexibility than did SS.

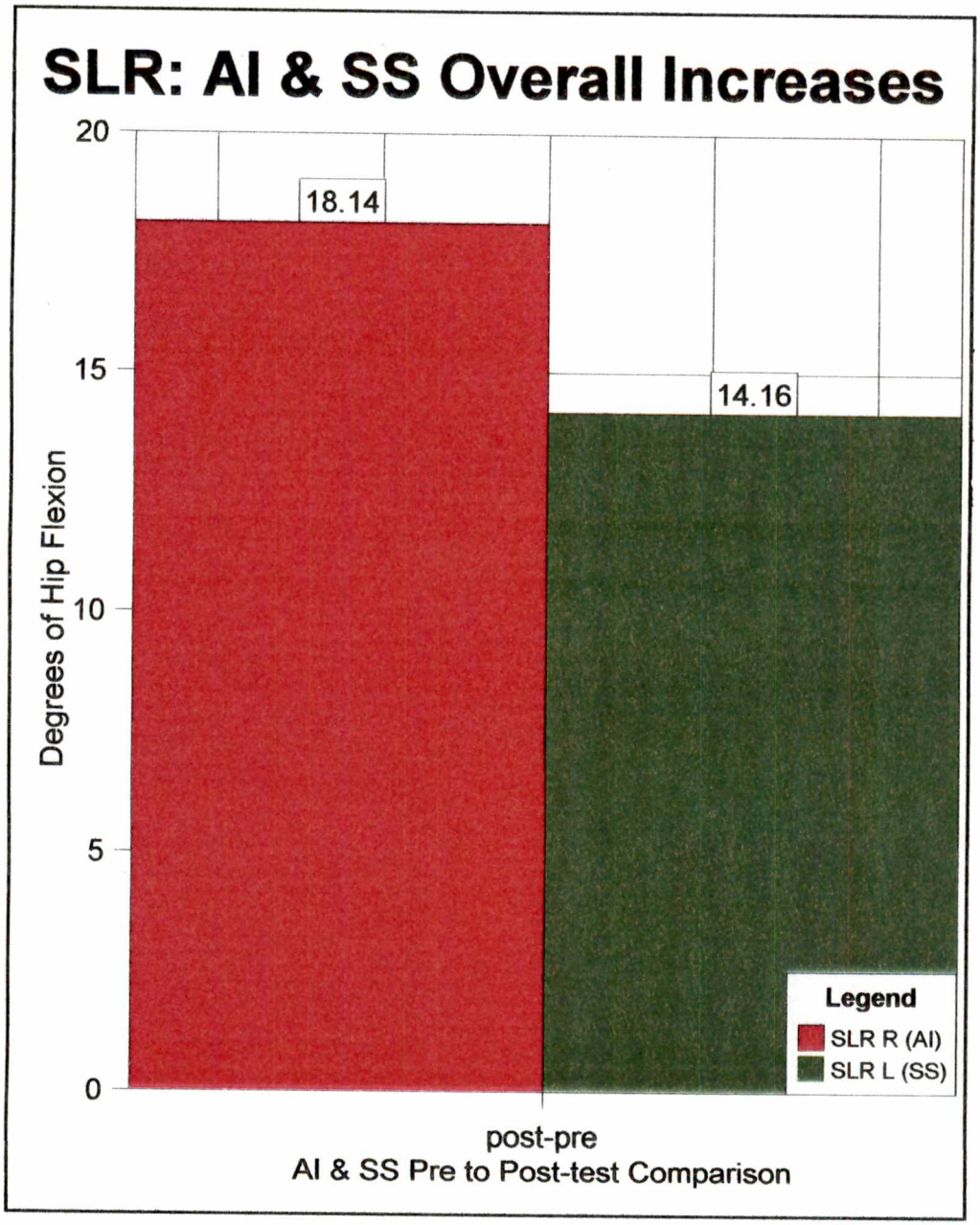


Fig. B-2: Comparison of SS & AI overall increase using SLR mean test scores. This shows that both AI and SS produced significant increases in hamstring length (.001 level for both). This figure also shows that AI produced a greater increase in hamstring length than did SS (.003 level).

Hamstring Flexibility

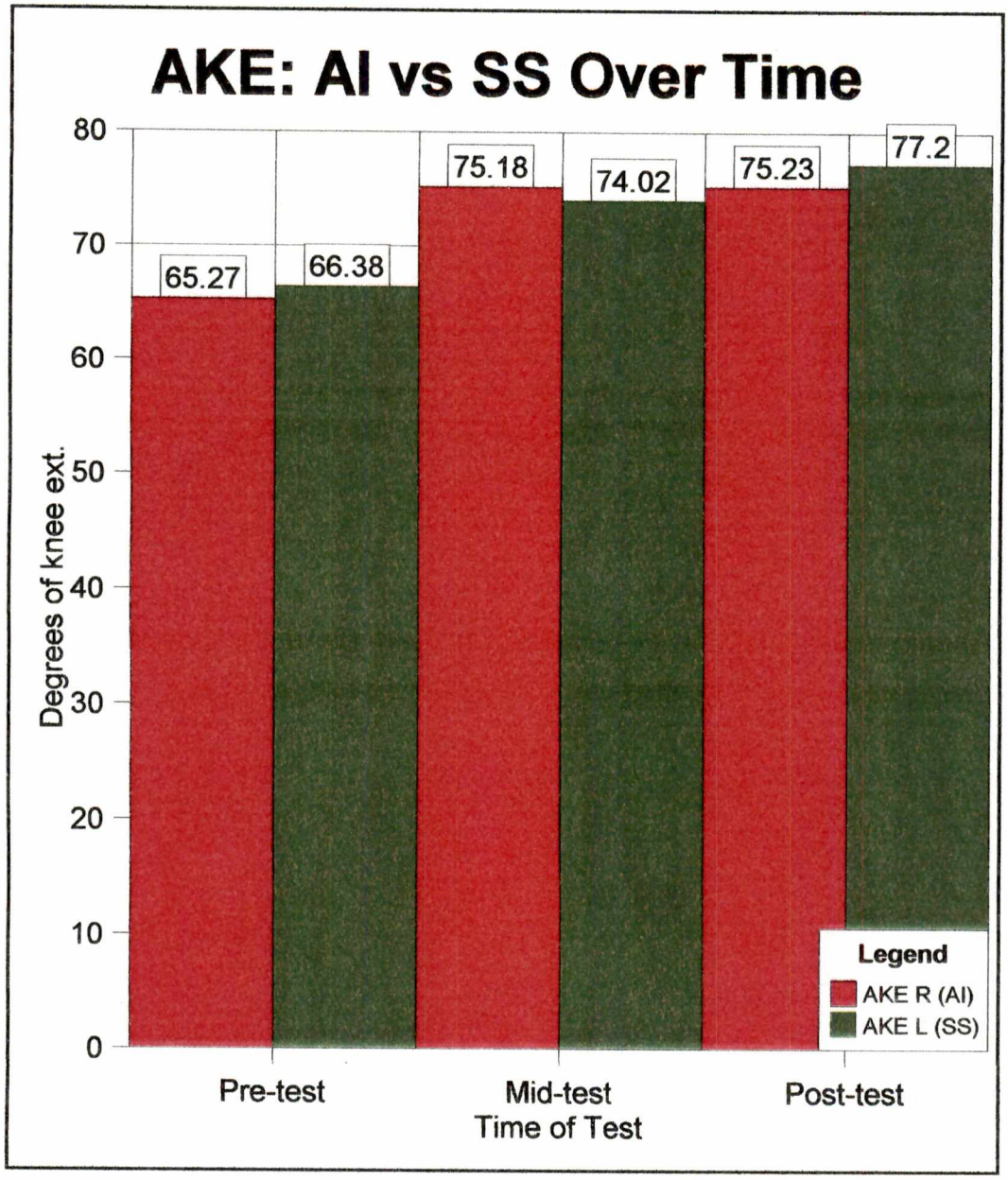


Fig. B-3: Comparison of AI & SS overtime using AKE mean test scores. This figure shows that both AI & SS showed significant increases in the first 2.5 weeks of training (.001 & .008 levels respectively) and that SS also showed a significant increase form 2.5 to 5 weeks (.018 level) while AI did not show an increase during the same time (.975 level). There was however, no statistically significant difference between AI & SS when compared at pre, mid, or post-testing.

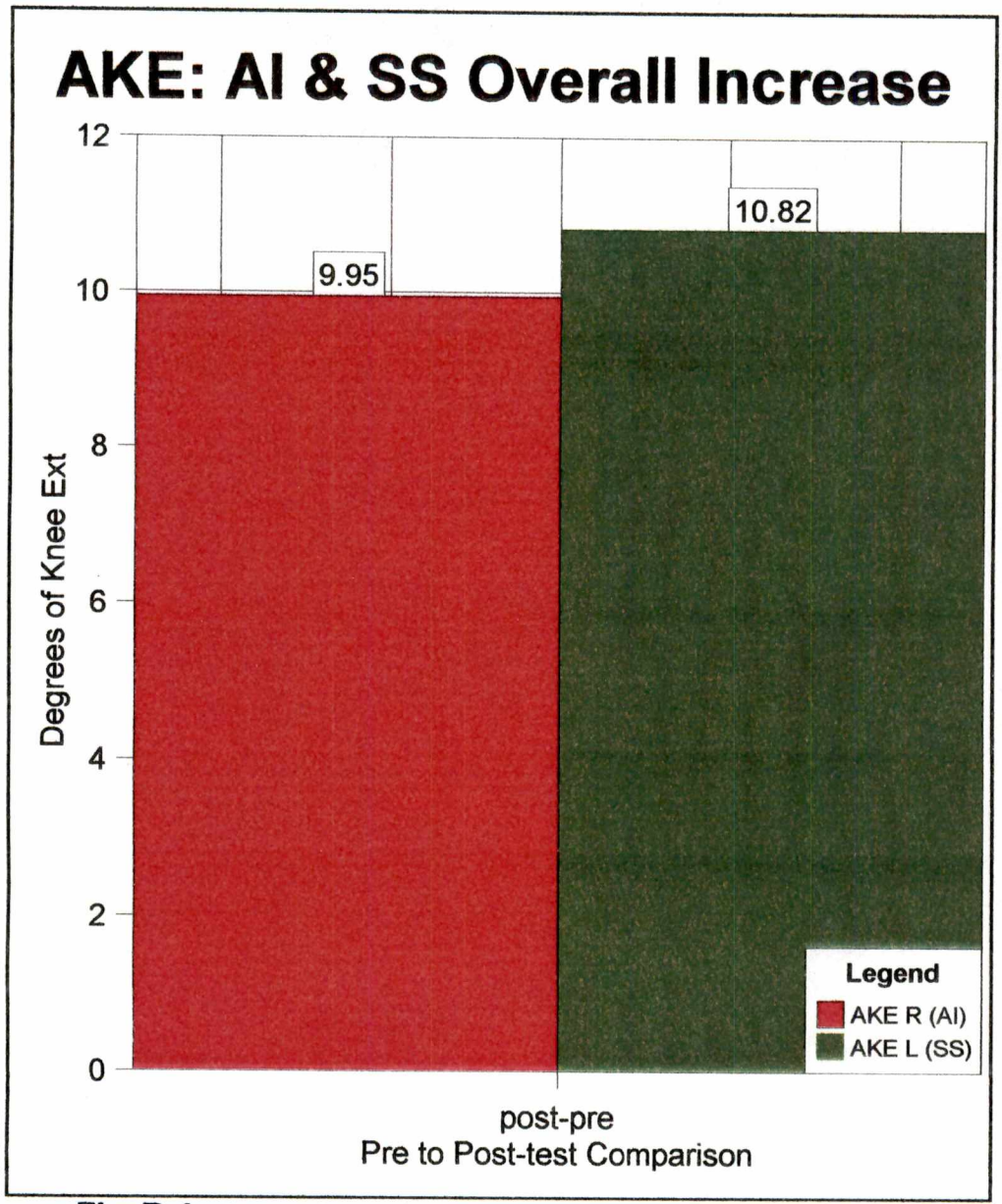


Fig. B-4: Comparison of AI & SS overall increase using mean AKE test scores. This figure show that both AI & SS produced statistically significant increases in hamstring length (.001 level) and that there was no statistically significant difference between AI & SS (.198 level).

VITA

Brad Johnson was born in Shreveport, Louisiana on January 18, 1972. He attended schools in the public system of Ruston, Louisiana, the Lincoln Parish School System, where he graduated from Ruston High School in May of 1990. Brad entered Centenary College, in Shreveport, Louisiana, in the fall of 1990 and graduated in the spring of 1994 with Bachelor of Science degrees in Exercise Science and Applied Science. Following graduation he entered the University of Tennessee, Knoxville's graduate school to pursue a Master of Science in Human Performance and Sports Studies. During his tenure at the University of Tennessee he was a Graduate Teaching Associate in the Physical Activity Unit. In the spring of 1996 Brad was accepted into the Louisiana State University School of Allied Health Physical Therapy Program, in Shreveport, Louisiana. Brad will complete his Master of Science, in Human Performance and Sports Study in the Spring of 1998 and will complete his Master of Physical Therapy in the fall of 1998.