Effect of Thirty Second Static Stretch on Hamstring Muscle Flexibility in Subjects Over Age 65

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EFFECT OF THIRTY SECOND STATIC STRETCH ON HAMSTRING MUSCLE FLEXIBILITY IN SUBJECTS OVER AGE 65

By

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THESIS

Submitted to the Department of Physical Therapy at Grand Valley State University Allendale, Michigan in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1996
EFFECT OF THIRTY SECOND STATIC STRETCH ON HAMSTRING MUSCLE FLEXIBILITY IN SUBJECTS OVER AGE SIXTY-FIVE

ABSTRACT

The purpose of this study was to determine the effect of a thirty second static stretch on hamstring muscle length in a sample of healthy people over age sixty-five. Twelve individuals between the ages of 65 and 89 were randomly assigned to two groups: a treatment group which performed one repetition of a thirty second static stretch of the hamstrings, one time per day for four weeks, and a control group which did not perform a hamstring stretch. ANCOVA results were calculated as p=.046, implying a significant treatment effect. Overall power was calculated as .541. The results suggest that in the healthy elderly, thirty seconds is an adequate duration to apply a static stretch and achieve therapeutic effects.
Dedication

This manuscript is dedicated to my family, who made it possible for me to complete the work, and especially my daughter, who inspired me to persevere.
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CHAPTER 1

INTRODUCTION

It is widely accepted in the clinical setting that range of motion, or flexibility, is decreased in the elderly. Certainly there are proven histologic and physiologic changes that occur in the human musculoskeletal system that support such a loss. The research that has addressed identification of the norms of range of motion in the elderly, however, shows minimal or no decrease from the general population (Roach & Miles, 1991; Walker, Sue, Miles-Elkousy, Ford & Trevelyan, 1984). This research, however, has neglected assessment of the flexibility of the two joint muscles that potentially limit motion at a joint. It is my belief that assessment of this aspect of range of motion would indeed show significant decrement in the elderly population.

Debate exists in the identification of norms of flexibility. In her invited commentary of the research of Bandy and Irion (1994, 59), Joan Walker, Ph.D., PT, questioned the researchers' criterion for decreased range of motion as "having greater than 30 degrees loss of knee extension measured with the femur held at 90 degrees of hip flexion" (the 90/90 test position). She suggested that in the absence of pathology, those subjects with greater than 30 degrees of knee flexion at termination of the 90/90 test (57 out of 75 initial subjects) were merely expressing a slightly lower, but normal, range of motion. She suggested that
muscle flexibility of the hamstrings is a trait with a normal distribution, and that individuals with knee flexion above 30 degrees are simply on the low end of that distribution. A question arises as to the validity of this statement, based on the relatively small number of individuals (14 out of 75 original subjects in the study) who, to carry Walker's analogy further, represent the entire left side of the distribution curve. In addition, a sample can be normally distributed and still be pathologic for the trait measured. Finally, the Bandy and Irion study in no way attempted to conclude that it's sample was representative of the population. A much more comprehensive study would be required to identify the norms of scores of hamstring flexibility using the 90/90 test.

In the absence of normative data regarding flexibility of the hamstrings, researchers must rely on the clinical experience of others. Bandy and Irion (1994) chose -30 to zero degrees of knee extension with 90 degrees of hip flexion, as their range of normal hamstring length, without citing a rationale for this choice of range. Magee's (1992) orthopedic assessment text, as well as Scully and Barnes' (1989) general text, cite Suadek (1990), who proposed the 90/90 test as an assessment of hamstring length, and ranges of greater than 20 degrees of knee flexion as less than normal hamstring length. Kendall and McCreary (1983) assess hamstring length with the supine straight leg raise test. They consider normal hamstring length to allow 70 degrees of hip flexion with full knee extension. Neither Saudek or Kendall remark on the consideration of age in developing their norms.
The impact of flexibility loss in the elderly population may be best understood in light of the International Classification of Impairments, Disabilities and Handicaps (ICIDH), the disablement model proposed by the World Health Organization (Jette, 1994). Disablement, a concern which is prominent in the elderly population, is defined by Jette as "the various impacts of chronic and acute conditions on the functioning of specific body systems, on basic human performance, and on people's functioning in necessary, usual, expected and personally desired roles in society." (Jette, 1994, 11) The ICIDH attempts to "delineate the major pathways from disease...to functional consequences" (Figure 1) (Jette, 1994, 12).

<table>
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<td>the intrinsic pathology or disorder</td>
<td>loss or abnormality of psychological, physiological or anatomic structure or function at organ level</td>
<td>restriction or lack of ability to perform an activity in a normal manner</td>
<td>disadvantage due to impairment or disability that limits or prevents fulfillment of a normal role</td>
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Applying the age-related changes in flexibility to this model, the "intrinsic pathology" would be the aging process occurring in the musculoskeletal tissues.
The impairments that would be noted include the primary impairments of decreased flexibility of the joints and muscles, and the secondary impairments of faulty balance and gait disturbances. The disabilities that could result from the effects of the impairments on normal activities might include a decreased ability to bathe and dress safely, and an increased risk of falls. The associated handicaps could include a decreased quality of life, increased likelihood of requiring attendant care or institutionalization, and increased financial burdens associated with cost of treatment or loss of professional roles.

Falls are a major source of morbidity in the elderly, and thus are the subject of many studies. Researchers are trying to identify and isolate the factors most important in causing or predicting falls, such as vision, vibration sense, strength, balance, aerobic capacity, postural sway, and proprioception. The relationship of these factors is complex, and also influenced by social, psychological, temporal and environmental factors. The faller is not merely the summation of his various risk factors, and an individual's level of impairment may not be a valid predictor of his or her predisposition to falling. Only consideration of all factors, intrinsic and extrinsic, and design of an individualized treatment plan that includes correction, adaptation and practice, can reduce a patient's likelihood of falling. One area of impairment that can readily be addressed by physical therapy is flexibility, which has been correlated with an increased incidence of falls (Gehlsen & Whaley, 1990; Tinetti, 1988).
Physical therapists have the education in anatomic structure, physiology, neural control mechanisms, and pathologic and normal age-related changes, which particularly qualifies them to treat the aspects of function and mobility, of which flexibility is a part. In addition, physical therapists spend a great amount of time with the patient, often seeing them in the environments in which they function, such as their home or a long term care facility. This time allows physical therapists to assess all components of functional activities, to determine impairments and design a specific corrective or adaptive treatment plan.

A sound theoretical basis for evaluation and treatment techniques is required in order to maintain the integrity of the physical therapy profession. Physical therapists' lack of consensus about adequate duration of stretch has been a problem area in exercise prescription for a long time. This study proposes to extend the question of duration of stretch to the elderly. Age-related changes in muscle and connective tissue structure suggest that the elderly may need to hold a stretch longer than a younger person. This study will assess the effects of a thirty second stretch, which has been identified as an optimal duration of stretch in a younger population, on a group of healthy, community-living elderly.
CHAPTER 2

REVIEW OF LITERATURE

BASIC DEFINITIONS

FLEXIBILITY

Anderson and Burke (1991, 63) define flexibility as "range of motion in a joint or series of joints that are influenced by muscles, tendons, ligaments, bones and bony structures." They further identify two kinds of flexibility: static and dynamic. Static flexibility is the available range of motion of the joint, easily measured in degrees. Dynamic flexibility is more difficult to define and measure. It is the ability of the joint to move in it's available range - a quantitative and qualitative measure of the relative "stiffness" of the joint. The soft tissue structures surrounding the joint contribute to it's dynamic flexibility. Kendall and McCreary also consider flexibility as joint range of motion and all the structures which might limit it (1983). Kisner and Colby (1990) define it as a tissue's ability to yield to a stretch force. It appears that flexibility is a general term, not exclusively applied to muscle.
SHORTNESS OR TIGHTNESS

These terms appear interchangeable, and are more specific to description of muscle length. Kendall and McCreary (1983) describe their tests of hamstring length with this terminology, and cite muscle shortness as a cause of faulty postural alignment and decreased mobility. Magee (1992) uses the vocabulary of tightness, as well as contracture, in his assessment of hamstring length. Kisner and Colby define contracture as "shortening or tightening" of muscle or other tissue, and go on to identify several types of contracture; "myostatic contracture" is the adaptive shortening of a musculotendinous unit in the absence of pathology (1990).

STRETCHING

Kisner and Colby (1990) define stretching as any technique designed to lengthen shortened soft tissue structures, and increase range of motion. They identify two types of stretching: passive stretch and active inhibition. Passive stretch utilizes an externally applied force, either manual or mechanical, to elongate the muscle. Active inhibition requires active participation of the subject to move the limb into a lengthened position, thus theoretically decreasing tone, or resistance to stretch, in the muscle being stretched.

Anderson and Burke identify ballistic stretch and static stretch as two methods to stretch muscles and other soft tissues, and proprioceptive neuromuscular facilitation as a method of increasing length of a muscle by actively inhibiting the muscle in conjunction with applying a static stretch (1991).
Static stretch in this case is essentially identical to passive stretch as described by Kisner and Colby. Ballistic stretch is a rapidly applied stretch to a muscle at its end range, which is repeated several times (bouncing).

BIOMECHANICAL RESPONSE TO STRETCH

Passive stretch of a musculotendinous unit stresses both the contractile and noncontractile elements. The noncontractile elements include the parallel elastic component, which comprises the fascial layers surrounding the muscle belly, the fasciculi and the individual muscle fibers, and the series elastic component, of which the tendon is the primary structure (Palastanga, Field, & Soames, 1989; Taylor, Dalton, Seaber, & Garrett, 1990; Kisner & Colby, 1990). The contractile elements are the actin and myosin filaments.

The reaction of the muscle to passive stretch is described as having both an elastic component, described by its passive tension curve, and a viscous component which includes the stress relaxation response, the creep response, hysteresis, and strain rate dependence (Taylor et al., 1990; Herbert, 1988; Lehmkuhl & Smith, 1983). With any type of stretch, however, the goal is the same: permanent change in the length of the tissue. There is research to support that the tension developed in passively stretched muscle results from the properties of the parallel elastic component, and alternatively, research that attributes the tension to the contractile element, the muscle fiber itself (Herbert, 1988). Whether the tension is concentrated in the intramuscular connective tissue or in the myofilaments, the response of the muscle to a low-load
prolonged stretch has been measured. When the stretch is applied, tension rises in the muscle. If that tension is high enough and the stretch is held, the tissues will undergo creep and stress-relaxation, resulting in a decreased tension in the muscle and a new resting length. The cumulative effects of repeated low-load stretch to a muscle will be a permanent change in the muscle length.

Because tendon has a much higher stiffness than muscle, when a relaxed muscle is stretched the increase in length always results from the muscle lengthening, not the tendon. Herbert (1988) cites research that suggests that the gains in flexibility achieved after stretching are due to the viscous properties of the muscle and are temporary, lasting only eight minutes to twenty four hours. The validity of this argument is called into question in light of the research by Bandy and Irion (1994), in which subjects who participated in a flexibility program were given two days rest before the post-test measurement, and yet showed significant improvements in flexibility. The work of Taylor et al. (1990) supports the tenet that increased muscle length after stretching results from the viscoelastic properties of muscle, and correlates this with clinically relevant stretching parameters such as rate of stretch, duration of stretch, number of repetitions, and preconditioning effects.

How long the gains resulting from a stretching program persist has not been specifically studied, but it should vary depending on the individual's activity level and type, and whether a maintenance program for flexibility was initiated. Both Herbert (1988), and Gossman, Sahrmann and Rose (1982) agree that
pathologic length changes in muscle are correctable, and require both restoring normal length and providing active movement and strengthening in the new range to maintain it. No studies, that this investigator is aware of, compare the biomechanical properties of muscle and tendon in young adult and elderly adult subjects. Based on current information on the physiologic changes that occur in muscle and tendon with age, however, it may be that older tissues would have different biomechanical properties and responses to stretch.

**NEUROLOGIC CONTROL OF STRETCH**

There are two primary sources of afferent neural information about muscle position and movement: the Golgi tendon organ and the muscle spindle. The Golgi tendon organ (GTO) is the sensory organ receptive to changes in tension of a muscle. It is most receptive to changes that result from active muscle contraction. It is only sensitive to passive tension, due to stretch of a relaxed muscle, when the stretch is near the end of the physiologic range of the muscle. If the muscle is suddenly stretched or exposed to an excessive tension in this end range, the GTO will be activated. The response in this case would be twofold: increased activity of Group Ib afferents synapsing disynaptically or polysynaptically on Ib inhibitory interneurons, would inhibit the alpha motor neuron of the agonist and synergist muscles. Simultaneously, increased stimulation of Ib excitatory interneurons would facilitate the alpha motor neurons to the antagonists. This would effect a joint movement away from the maximally stretched position. Obviously, this is not a therapeutic use of the GTO to
increase muscle length, however it may result from an inappropriate stretching technique (Moore, 1984).

The muscle spindle is the sensory organ that has traditionally been considered to control a muscle's response to stretch. Information regarding muscle spindle structure and function can be found in Sholz and Campbell's (1980) review of the muscle spindle, as well as Kandel, Schwartz, and Jessell's neurology text (1991). Historically, it has been believed that as a muscle is passively lengthened, the change in length is sensed by the spindle, and through it’s afferent and efferent connections, facilitation of the homonymous and synergist muscles and inhibition of the antagonist muscles would occur. The quantity and rate of stretch effect the magnitude of the response, so that greater changes in length or greater velocities of stretch produce rapid recruitment of larger numbers of alpha motor neurons to resist the stretch. The tension produced during the stretch was supposed to be primarily the result of this neural control loop. Today, it is believed that the primary functions of the muscle spindle and GTO are to provide proprioceptive input to the central nervous system, but response to that information is controlled by higher neurologic centers. This doesn't mean that the connections described earlier don't exist or function. It does mean that their function can be modified by higher centers, which may in fact override their reflex actions depending on the situation. This change in perception of the function of the muscle spindle comes as a result of research on electromyography (EMG) response to lengthening of muscle, and characteristics
of innervated and denervated muscle in response to stretch (Sholz & Campbell, 1980; Taylor et al., 1990).

Additional information about muscle and joint position and movement is received by both joint mechanoreceptors and cutaneous mechanoreceptors. These receptors are stimulated by the mechanical deformation of non-muscular tissues that accompanies movement of a joint or by the mechanical deformation of the skin as a joint moves through a range of motion. Information from these receptors can either facilitate or inhibit the reflex activity of a muscle or tendon, thus influencing tone in the muscle (Isaacs, 1993). Kandel cites a study by Gandeviam, McCloskey et al. which found that for best position sensation, cutaneous, joint and muscle spindle afferents need to be working together (1991).

CORRELATION BETWEEN FLEXIBILITY AND FALLS

According to Hornbrook, Stevens and Wingfield (1983, 309), falls are "a complex equation of the interactive elements of impaired physical and sensory function, reduced health status, risk-taking behaviors, and environmental hazards." They describe a model for understanding the etiology of falls, stressing that interventions need to be both deficit specific and functional (See Fig 2).
FIGURE 2 from Hornbrook, 1993 (310)

BIOBEHAVIORAL-ENVIRONMENTAL MODEL OF FALLS

PHYSICAL STRUCTURE
- Strength
- Joints—range, pain
- Senses—vision, vestibular, somatosensory
- Brain structure

PHYSIOLOGIC FUNCTION
- Balance
- Reaction time
- Coordination/proproprioeption
- Gait
- Cognitive function

BEHAVIOR
- Risk taking
- Preventative/protective behaviors
- Adaptive behavior

ENVIRONMENT
- Gradient of surface
- Texture of surface
- Lighting
- Resilience of surface
- Objects in pathway
- External forces—gravity, moving object

OUTCOME
- Falls
- Injuries
- Medical care use
- Death
- Quality of life
Theorized benefits of exercise include a reduced risk of falling, and a reduced incidence of injury given a fall (Buchner & Coleman, 1994). Tinnetti, Speechley and Ginter (1988) studied risk factors associated with falls, and while they did not address flexibility specifically, they did assess gait and balance disturbances, attributing these to underlying neurologic and musculoskeletal impairments. They found that deficits in balance and gait significantly increased risk of falling. Risk of falling was found to increase linearly as the number of risk factors increased. Multiple risk factors for falls are commonly found in the elderly. Gehlsen and Whaley (1990) compared balance, strength and flexibility between a group of elderly with no history of falls to a group with a history of falls. They found a significant difference between the groups in flexibility measures of hip flexion and knee flexion, with non-fallers having greater range of motion than fallers.

The Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) trials, a series of seven independent studies assessing efficacy of intervention techniques to reduce incidence of falls in the elderly, included flexibility training, in conjunction with other interventions such as strengthening, balance, endurance training, medication changes, education, behavioral changes, functional activity training, and/or nutritional supplementation. Results of all studies were published as a Meta-analysis (Province et al., 1995). Results showed significantly reduced risk of falls in two of the seven groups, and near-significant reduction in falls in another two groups. The other three studies
showed an increase in falls in the treatment group. Overall, assignment to a group that received an exercise intervention led to decreased incidence of falls at $P = .07$, which approaches significance. Attempts to isolate effects of single exercise types showed balance training as the only significant intervention. However, this finding should be viewed cautiously, as fall incidence was the result of the interactive effects of the interventions in the trials.

**BIOLOGIC AND PHYSIOLOGIC EFFECTS OF AGING**

In a review of the literature on age-related muscular changes, Payton and Poland (1983) found that the aging process resulted in muscle atrophy due to both a loss in number and size of muscle fibers, decreased conduction at the myoneural junction, decreased mitochondrial activity evidenced by a decrease in mitochondrial enzymes, and increased fibrofatty deposition in the muscle.

Pickles (1989) suggested that there is also a loss of fluid and inorganic salts, resulting from degeneration of the sarcolemma, which contributes to reduced force-production capacity in muscles, as well as symptoms of lethargy. Donatelli and Owens-Burkhart attributed loss of fluid to decreased space between collagen fibers. They suggested that this results in decreased mobility of collagen fibers at the molecular level and increased collagen fiber crosslink formation (1981). Dehydration is a common occurrence among the elderly and potentially increases these normal age related effects. The theoretical results of these changes in tissue composition and structure is a decreased extensibility of the tissues.
In a study of changes in rat tendon properties with aging, Vailas, Pedrini, Pedrini-Mille, and Holloszy (1985) found the following: there was no significant difference between young and elderly rats, regardless whether they had exercised or were sedentary, in patellar tendon dry weight. However, there was significantly increased collagen content and decreased ground substance in the older rats. If this finding is extended to human subjects, the increased proportion of collagen combined with decreased matrix would seem to support a loss in extensibility and increased stiffness in the tissues.

Weston (1993) found increased collagen stability, which he concluded was not due to increased number of cross-linkages, but to increased strength of cross-link bonds. This stability resulted in decreased collagen compliance with increased age. This effect is increased by immobility and decreased by exercise (Donatelli & Owens-Burkhart, 1981; Woo, Gomez, Amiel, Ritter, Gelberman, Akeson, 1981).

EFFECTS OF EXERCISE IN THE ELDERLY

In spite of the many changes that result with aging, elderly tissues are still able to respond to a training stimulus with improved function (Menard, 1993). In a study by Mills (1994), elderly patients who participated in a low-intensity aerobic exercise program showed significant improvements in flexibility. Frekany and Leslie also found improved flexibility in patients over age 71 following an exercise program to improve flexibility (1975). For a review of many studies on exercise effects on skeletal muscle structure and strength, the reader is referred
to Finch and Schneider's Handbook of the Biology of Aging (1985). To this researcher's knowledge, no study has been done to date to assess a treatment protocol for improving flexibility, designed for and tested on a younger population, in an older population, which is the purpose of this study.

STUDIES ON STATIC STRETCH

Debate exists as to the effectiveness of static stretch to improve flexibility of the hamstrings. Many studies have addressed the effects of static stretch (Starring, Gossman, Nicholson & Lemons, 1984; Wessling, DeVane, & Hylton, 1987; Madding, Wong, Hallum & Madeiros, 1987; Gajdosik, 1991; Bandy & Irion, 1994). Bandy and Irion's 1994 study of effect of duration of static stretch on gains in flexibility is the most recent, and is a well designed study. Randomly assigning fifty-seven mixed-sex subjects aged 20 to 40 years to four groups, one control group which received no stretch, and three treatment groups which received 15, 30 or 60 second stretches, the researchers conducted a six week program of static stretching to the hamstring muscles. Individuals stretched one time per day, five times per week, for six weeks.

Pretest and posttest measures of hamstring flexibility, assessed by the 90/90 test, were compared using an ANOVA to determine any significant differences between the four groups. It was found that there was a significant difference in final range of motion scores between the groups who had stretched for 30 or 60 seconds versus the control or the group who stretched for 15 seconds. Further, it was found that there was no significant difference between
the group who stretched for thirty seconds and the group who stretched for sixty
seconds. From these findings, it appears that a thirty to sixty second static
stretch repeated daily for six weeks is sufficient to produce plastic deformation of
the hamstring muscles.

From this study, the researchers concluded that a period of at least 30
seconds was optimal for improving flexibility. Stretching durations longer than 30
seconds were questionable in their ability to improve flexibility more than 30
second stretches. The findings of Bandy and Irion contradict the earlier study by
Madding, Wong, Hallum and Madeiros (1987). In a study of 72 male subjects
aged 22-40 years, they found that for a single repetition of passive stretch, 15
seconds of stretch produced significant gains in flexibility of the hip adductors.
Stretches of 45 seconds and 2 minutes produced no significant difference in
flexibility compared to 15 second stretches. The disparity between these two
studies may be explained with several considerations. The sample size used by
Madding et al. was only 18, and was perhaps too small to accurately reflect the
differences between the levels of the independent variable. Different muscle
groups were used in the studies, which could have different responses to stretch.
Also, the Madding et al. study applied only a one-time stretch, measuring the
gain in flexibility immediately after the stretch. In this case, the resultant increase
in length of the muscle could be considered completely due to the hysteresis
response of the muscle. This is not a clinically significant application of
stretching, and it would be questionable to apply the findings of the study to a
clinical model in which a stretch is repeated several times a day, for a prescribed number of days or weeks, the summative effects of which would be permanent, or plastic, length changes. The Bandy & Irion study attempted to apply a more clinically relevant stretching protocol, however they did not address the effects of varying the number of stretch repetitions per day on flexibility.

There are many studies which compare different stretching techniques, such as static stretch, PNF stretching techniques, and prolonged stretch (Light, Nuzik, Personius & Barstrom, 1984; Etnyre & Abraham, 1986a, 1986b; Godges, MacRae, Longdon, Tinberg & MacRae, 1989; Sullivan, DeJulia & Worrell, 1992; Halbertsma & Goeken, 1994). These studies all apply the techniques with different protocols, making judgments as to the validity and generalizability of the results difficult. In all of the studies cited, however, static stretch has been found to be effective to increase flexibility. It is a technique associated with minimal risk of injury, it is easy to teach and to learn, and can be reliably reproduced by a variety of patients in a home program. Further, in order to make comparisons between stretching techniques, it would be advantageous to first identify the best protocols for each of the techniques, using these as a basis for comparison.
CHAPTER 3

METHODOLOGY

DESIGN

The purpose of this study was to determine the effect of a thirty second static stretch on hamstring muscle extensibility in healthy, community-living elderly in the West Michigan area. It is a pretest and posttest control group experimental design.

POPULATION AND SAMPLE

This study used a convenience sample of healthy, community-living elderly persons, male and female, residing in a federally-subsidized housing complex. All volunteers were screened on the criteria for inclusion or exclusion in the study. All individuals were: age 65 or older; independent in all activities of daily living; completed the Medical History Questionnaire (Appendix A); signed an informed consent form (Appendix B); underwent a screen of present physical status (Appendix C); had greater than 15 degrees of knee flexion while maintaining 90 degrees of hip flexion (90/90 test); and agreed not to begin or escalate an exercise program during the duration of the experiment. Criteria for exclusion from the study included: requiring some level of assisted living; failure to sign the informed consent form; previous medical history of low back, pelvis,
hip or lower extremity fractures, active low back pain or history of laminectomy, diabetes, peripheral vascular disease or leg cramps, stroke, rheumatoid arthritis, hip or knee replacement, or any chronic medical condition which might effect normal response of the lower extremity to stretch; findings on physical screen of a positive neural tension test, less than 110 degrees of passive hip flexion, less than 0 degrees of passive knee extension, 90/90 test of less than 15 degrees knee flexion, and signs of neurological dysfunction such as unilateral muscle weakness or sensory changes; not agreeing to delay initiating or increasing the intensity of an exercise program for the duration of the experiment; and unavailability of a watch or clock with a second hand to time the duration of stretch.

EQUIPMENT

A fifteen-inch, double-armed, full-circle goniometer was used to assess range of motion at the terminal point of the 90/90 test. The goniometer was measured against three known angles drawn with a protractor, to reduce systematic error. The ICC value calculated from these measures was 1.000. Testing was performed on a portable plinth. One inch wide cotton belting material was provided by the researcher, and used to hold the leg in a position of static stretch to the hamstrings.
PROCEDURES

After completion of the Human Subjects Review process at Grand Valley State University, the director of the apartment complex was approached and presented a summary of the proposed experiment. Upon approval to use the site, volunteers were recruited by use of flyers posted around the building. Twenty-eight volunteers signed up at the front desk. The researcher contacted by phone all persons who signed up to answer any questions they had, and to administer portions of the Medical History Questionnaire, to determine if they had any condition which would make them ineligible to participate. Subjects who were eligible were scheduled a one hour appointment with the researcher. This appointment consisted of signing the informed consent form (Appendix B), completion of the Medical History Questionnaire (Appendix A), the physical examination (Appendix C), a pretest measurement of the individual's hamstring muscle flexibility as measured by the 90/90 test, and instruction in the stretch technique (Appendix D). The 90/90 test was performed using the surface landmarks described by Norkin and White (1985) as follows: Subjects were positioned supine with both the hip and knee of the leg to be measured in 90 degrees of flexion; the center of the goniometer fulcrum was positioned over the lateral epicondyle of the femur, the proximal arm aligned with the greater trochanter, and the distal arm aligned with the lateral malleolus of the tibia. The knee was passively extended to the point where resistance to further motion was felt by the examiner or the subject. The right leg was arbitrarily chosen as the
test leg, unless the individual reported a history of previous injury of the right hip, knee, or ankle, in which case the left leg became the test leg. The opposite, or untested leg, was maintained in hip and knee flexion with the foot flat on the mat, to flatten the low back, and to eliminate any effect tight hip flexors may have had on the measurement.

At this point, any subjects who did not meet the criteria for inclusion in the study were eliminated. All twelve remaining subjects were instructed in the stretch technique, although not all were subsequently assigned to the group which performed the stretch. Static self-stretch of the hamstrings was performed in a supine position, using one-inch wide cotton belting which was held in the subjects hands and looped around the heel of the leg to be stretched, with the knee held in extension, and with the arms supporting the weight of the leg. Subjects used their arms to raise the leg until the point when a mild stretching sensation was felt in the back of the thigh. This intensity represents a clinically accepted low-load stretch. An exercise log (Appendix E), to document daily completion of the stretch, as well as a written sheet of instructions for proper performance of the stretch, was delivered and explained to all subjects. To ensure learning of the proper performance of the stretch, all subjects were required to perform the stretch with no verbal guidance from the researcher.

Once initial data collection was completed, each subject was randomly assigned to one of two groups, and those two groups were randomly designated as control group or treatment group. Subjects were notified by phone of which
group they were in and of the experiment start date. Individuals in the control group (n = 6, 1 male and 5 female, mean age = 76.3, standard deviation = 8.29) did not perform the stretch during the experiment, and individuals in the treatment group (n = 6, 6 female, mean age = 73.5, standard deviation = 4.81) performed a home program of one stretch session per day, holding the stretch for thirty seconds, timed by a watch or clock. They completed one repetition of the stretch per session, seven days per week, for a total of four weeks. Each completed stretching session was documented in the exercise log. After four weeks, all subjects were retested on the 90/90 test using identical methods as described for the pretest.

**DATA ANALYSIS**

Intratester reliability was determined by a test-retest design on 3 subjects from the control group, using the pretest measure and a measure taken one week later to determine the intraclass correlation coefficient. To determine whether significant differences between the two groups existed, an analysis of covariance (ANCOVA) was performed, using the pretest measures of hamstring flexibility as the covariate. Significance for all statistical tests was accepted at the .05 level (Portnoy & Watkins, 1993).
CHAPTER 4

RESULTS

The results of pretest, one-week and posttest measures of hamstring flexibility using the 90/90 test of all subjects is presented in Table 1. The means for pretest and posttest measurements, and the adjusted means from the ANCOVA, for each group are presented in Table 2.

TABLE 1

PRETEST, ONE WEEK AND POSTTEST MEASURES OF HAMSTRING FLEXIBILITY OF ALL SUBJECTS (90/90 test)

<table>
<thead>
<tr>
<th>ID #</th>
<th>GROUP</th>
<th>PRETEST</th>
<th>ONE WEEK</th>
<th>POSTTEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>24</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>50</td>
<td>29</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>T</td>
<td>49</td>
<td>NA</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>17</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>20</td>
<td>NT</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>23</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>T</td>
<td>42</td>
<td>NA</td>
<td>27</td>
</tr>
<tr>
<td>8</td>
<td>T</td>
<td>42</td>
<td>NA</td>
<td>41</td>
</tr>
<tr>
<td>9</td>
<td>C</td>
<td>49</td>
<td>NT</td>
<td>38</td>
</tr>
<tr>
<td>10</td>
<td>T</td>
<td>42</td>
<td>NA</td>
<td>20</td>
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<tr>
<td>11</td>
<td>C</td>
<td>34</td>
<td>43</td>
<td>40</td>
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<tr>
<td>12</td>
<td>T</td>
<td>36</td>
<td>NA</td>
<td>28</td>
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</tbody>
</table>

C = control group  T = treatment group
NA = not applicable, as these were subjects in the treatment group
NT = not tested, subjects in the control group not included in the reliability study
TABLE 2

<table>
<thead>
<tr>
<th></th>
<th>GROUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONTROL (n=6)</td>
<td>TREATMENT (n=6)</td>
</tr>
<tr>
<td>PRETEST</td>
<td>33.3 (13.38)</td>
<td>38.0 (11.08)</td>
</tr>
<tr>
<td>POSTTEST</td>
<td>31.3 (12.03)</td>
<td>26.0 (15.09)</td>
</tr>
<tr>
<td>ADJUSTED POSTTEST</td>
<td>33.6</td>
<td>23.7</td>
</tr>
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</table>

The intraclass correlation coefficient (ICC) value for the intrarater reliability study using pretest and one-week measures of hamstring flexibility (n = 3) of the control group was .88. The ICC value of pretest and posttest measures of hamstring flexibility of the control group (n = 6) was .92.

All subjects in the treatment group showed improvement in 90/90 test scores at posttest, with a mean gain of 12.0 degrees, standard deviation of 7.48 degrees, and range of 1-22 degrees. One individual in the treatment group showed a minimal improvement of only one degree. The reason for this is unclear. It may be that the subject was not compliant with the daily performance of the stretch, or performed the stretch incorrectly.

The ANCOVA results (See Table 3) showed no significant interaction between group and treatment (p = .316), and a significant difference between treatment and control for pretest and posttest measurements of hamstring flexibility (p = .046). The covariate, pretest range of motion of knee flexion, was
found to be significant at \( p = .001 \). Statistical power analysis revealed a power of .541.

TABLE 3

ANALYSIS OF COVARIANCE FOR ADJUSTED MEANS: COMPARISON OF KNEE FLEXION MEASUREMENTS FOR TREATMENT AND CONTROL GROUPS

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>covariate</td>
<td>1</td>
<td>1395.56</td>
<td>1395.56</td>
<td>26.97</td>
<td>.001</td>
</tr>
<tr>
<td>between groups (adjusted)</td>
<td>1</td>
<td>277.33</td>
<td>277.33</td>
<td>5.36</td>
<td>.046</td>
</tr>
<tr>
<td>within groups (error)</td>
<td>9</td>
<td>465.77</td>
<td>51.75</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>11</td>
<td>1946.67</td>
<td>176.97</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION OF RESULTS

This study assessed response of healthy elderly to a thirty-second static stretch of the hamstrings muscles. Results of the ANCOVA demonstrated that for this sample, a thirty-second static stretch of the hamstrings performed once daily for four weeks produced a significant improvement in 90/90 test measurements of hamstring flexibility.

Power was calculated as .541, primarily due to the small sample size. The effect of this low power is on the generalizability of the findings to the target population. Although the findings were significant in spite of the low sample size, the scope of this study must be limited to a pilot study. Reproduction of the study on a larger population is required in order to make predictions to the population of healthy elderly. Discussion of the findings of this study will only be able to compare it's sample's results to previous research.

Intratester reliability for the goniometric measurements was high (ICC = .88), however there was one outlier in the one week measurement data which was excluded. This individual's pretest knee flexion measurement was 50
degrees, one-week measurement was 21 degrees, and posttest measurement was 47 degrees. Reasons for the discrepancy in one-week measurements were not clear. The subject reported no medication changes which may have affected her flexibility. She did, however, report a recent increase in activity level, unrelated to exercise. It is possible that her increased activity level, which required a great deal more walking than usual, may have had an effect on her hamstring length. Another explanation for the lower one week measurement was that she was preoccupied at that time, and not attending as much to the sensation of stretch in her hamstring, allowing an increased range of motion at the knee. Another possible explanation for the discrepancy is tester error, although consistency in technique was practiced throughout the study.

The decision to exclude the measurement was based on several factors. The large difference between the pretest and week-one scores was not supported by the posttest score to be a true value. An ICC value was calculated using the pretest and posttest scores of the entire control group and was found to support exclusion of this subject from the reliability study (.92). The reliability coefficients, with the outlier excluded, fell within the ranges reported by other studies which assessed intratester reliability (ICC ranges of .80 to .99). Finally, clinical experience did not support such a vast change in flexibility which was then reversed, as these measurements implied. Exclusion of this subject however, because of the small sample size, reduced the value of the reliability measure. By excluding one subject from the reliability data, one-fourth of the
sample was excluded. Inclusion of that subject, however, would lower the reliability to .34, which is unacceptable for the application of any statistical tests to the data.

DISCUSSION OF RESULTS WITHIN THEORETICAL FRAMEWORK

Although there appears to be a scientifically based consensus of the effects of aging on musculoskeletal tissue structure and biomechanical properties, the relationship of these changes to function in the elderly has yet to be studied. Age-related changes in muscle and connective tissue would suggest a decreased level of flexibility in the elderly, as well as a decreased response to a stretch stimulus. This study demonstrates an attempt to relate known effects of aging, such as decreased connective tissue extensibility and increased fibrofatty deposition in the muscle, with the functionally significant attribute of flexibility. This study assessed the effect of a thirty-second, low load, static stretch program on hamstring muscle flexibility in subjects over age sixty-five, and found a significant effect in this sample. Therefore, it appears that the parameters of frequency, duration, and intensity which were applied in this study were sufficient to create a permanent change in hamstring muscle length in the subjects of this sample. The impact of this finding on treatment of elderly patients with flexibility loss is suggestive that, for the elderly patient with adaptive muscle shortening, therapists need not increase durations of stretch beyond 30 seconds to show significant improvement. However, the relationship of age and intrinsic muscular
or neurologic pathology with stretch has not been addressed within this study, and might have significantly different results.

**DISCUSSION OF RESULTS COMPARED TO LITERATURE**

The results of this study support previous research findings that static stretch improves flexibility, and suggests that in the healthy elderly it is an effective treatment for improving flexibility. Thirty seconds was chosen as the stretch duration based on the study by Bandy and Irion (1994), which found that in a healthy younger population, stretch durations of thirty seconds were as effective as sixty seconds in improving flexibility. Thirty seconds was also a sufficient duration to result in significant improvements in hamstring flexibility in this sample of elderly subjects. Another finding of this study is that a four week protocol of stretching, one time per day every day, resulted in significant improvement in flexibility. Clinically, this is significant, for as time allotted by insurance companies for therapy based on diagnosis is closely monitored and often cut, therapists can improve efficiency by incorporating flexibility exercises in a home program, and still expect significant results in a four week period.

This study adds to the research differentiating stretch techniques by providing information on response of healthy elderly to a static stretching protocol. The clinical significance of this is that, while the debate about most effective stretching method may continue, therapists should feel confident in the choice to prescribe a static stretching home program to their patients, knowing that it will result in significantly improved range of motion. In regards to the
elderly, this study suggests that in the absence of pathology elderly patients will also benefit from static stretch programs, although additional studies with a larger sample are required to improve the confidence of that statement.

CONCLUSIONS

This is the first study which has assessed response of people over age 65 to stretch. Although the sample size limits generalizability of the results of this study, the finding of significant improvement in hamstring flexibility in the treatment group affirms the need for additional studies on the effect of stretching procedures on the elderly.

LIMITATIONS OF STUDY

The most significant limitation of this study is the low power (.541), which creates limitations regarding the generalizability of the results to the target population of healthy elderly. Other limitations of this study included the use of a home program to apply the treatment variable, which introduced the possibility of communication of information between the groups that might have affected the results. This risk was increased because all subjects were instructed in the stretch technique. Also, compliance may have been decreased in the home program, and individuals may have falsely stated that they performed the treatments as required. Subjects learned the stretch technique in one session with no opportunity for the researcher to retest to assure they had retained it.
Consequently, subjects could have been performing the stretch incorrectly during the experiment.

RECOMMENDATIONS FOR FURTHER RESEARCH

There are several variables which should be considered in a study of the relationship of age and flexibility. To address within the same study the effect of the same stretching program on both a younger population and an elderly population, including a variety of stretching durations as in the Bandy and Irion study, would make it possible to make direct comparisons between older and younger subjects' response to stretch. It would also be valuable to assess response of elderly subjects to a variety of stretching techniques, such as low-load prolonged stretch, PNF stretch techniques and static stretch. Finally, further research to assess the impact of decreased flexibility of various muscle groups on function in both the healthy and patient elderly populations will aid clinicians in justifying stretching programs for these patients.


**APPENDIX A**

MEDICAL HISTORY QUESTIONNAIRE  
Researcher to review with subject  
ID # ____________________________  
Date ________________

<table>
<thead>
<tr>
<th>Medical Condition</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back injury, back pain, x-rays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthritis or gout (which joints)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lupus erythematosus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain injury/head injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal cord injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee pain/injury/surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip pain/injury/surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancer, tumor, cyst</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edema, lymphedema</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg cramps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular disease, claudication, PVD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiopulmonary problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td></td>
<td></td>
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<tr>
<td>Emphysema</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart attack</td>
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<td></td>
</tr>
<tr>
<td>Multiple Sclerosis</td>
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<td></td>
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<tr>
<td>Parkinson's disease</td>
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<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fractures (where)</td>
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<td></td>
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<tr>
<td>Guillane-Barre</td>
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<td></td>
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<tr>
<td>Poliomyelitis</td>
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<td></td>
</tr>
<tr>
<td>Spina bifida</td>
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<td></td>
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<tr>
<td>Vision/eye problems/glasses</td>
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<td></td>
</tr>
<tr>
<td>Hearing loss/hearing aid</td>
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<td></td>
</tr>
</tbody>
</table>

**Comment on any yes answers:**
MEDICAL HISTORY QUESTIONNAIRE

ID #___________________________
Date______________

__Any other past or present health problem not listed?

__Have you ever received physical therapy? If "yes", for what conditions?

__List past surgeries:

__List medications currently taking:

__Do you require any assistance from another individual to perform any of the following (circle if yes)
  - bathing/grooming/toileting
  - dressing
  - preparing food/eating
  - maintenance of your home (light housework)
INFORMED CONSENT TO PARTICIPATE

Grand Valley State University Department of Physical Therapy study on effect of duration of static stretch on gains in hamstring flexibility in the elderly.
Principal Investigator: Erin Bloomquist, Student PT

I, the volunteer subject, understand that I am agreeing to participate in a physical therapy graduate research study designed to study the effect of duration of stretch on flexibility of the hamstring muscle group, the muscles in the back of the thigh, in persons age 65 and older. This study will add to physical therapists knowledge of how best to treat elderly patients with loss of flexibility.

I understand that I will be asked to submit to several screens to determine my eligibility to participate in the study, which include a physical exam, a medical history questionnaire, and a screen for level of independence in daily activities. I understand that I may not be chosen to participate in the study based on the findings in the screen, and that if chosen, I may not be included in the group to receive the stretching treatment. I understand that the researcher will need to schedule one hour for this screen and instruction in the stretching technique. I understand that I will be asked to wear a gown during parts of this experiment, which will be provided by the researcher, in order to allow the researcher to locate and measure my range of motion, and that I will be draped with a sheet for modesty. I understand that this is not required of me for participation in the study.

I understand that during this study I should not experience any pain; the stretching procedure should only feel like a mild stretch. I understand the risks associated with the activities performed in this study, though minimal, include overstretching, which could cause pain in the muscle. In the event of an injury in
the course of this study, I understand it will be my responsibility to seek medical attention through my family physician.

I understand that the information obtained during this study will be kept confidential. If the data are used for publication, no names or other identifiers will be used. I understand that my participation in this study is on a volunteer basis and that I may withdraw from the study at any time. I also understand that the researcher may terminate my participation in this study at any time after she has explained the reason for doing so. I understand that any questions I have regarding this study will be answered at any time. Erin Bloomquist, the primary researcher, will be available at (616)874-8676, to answer my questions. I may also contact the Chair of the Research Committee, Jane Toot, at Grand Valley State University, phone number (616)895-2682, or Paul Huizenga, Head of Human Subjects Review at Grand Valley State University, phone number (616)895-2472.

I have explained to ______________________________ the purpose of the research, the procedures required, and the possible risks and benefits to the best of my ability.

______________________________  Date  __________
Investigator

I confirm that Erin Bloomquist has explained to me the purpose of the research, the study procedures, and the possible risks and discomforts as well as benefits that I may experience. I have read and understand this consent form. Therefore, I agree to give my consent to participate as a subject in this research project.

______________________________  Date  __________
Participant

______________________________  Date  __________
Witness to Signature
APPENDIX C

PHYSICAL EXAMINATION FORM

ID#___________________________
DOB_________________
SEX_____ 

HEIGHT___________
WEIGHT___________

OBSERVATION
Posture:

Gait:

AROM (with overpressure):  
F=full motion; L=limited motion  

<table>
<thead>
<tr>
<th>Peripheral joint scan</th>
<th>L</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>arms behind head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>arms behind back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>arms over opposite shldr.</td>
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<td></td>
</tr>
<tr>
<td>wrist flex/ext</td>
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<tr>
<td>hand open/close</td>
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<td></td>
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<tr>
<td>squat and recover</td>
<td></td>
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</tr>
<tr>
<td>stork</td>
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</table>

Lumbar spine and pelvis

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>R</th>
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<tr>
<td>rotation (sitting)</td>
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</tbody>
</table>

FOR ANY RANGE "L" DESCRIBE ENDFEEL AND PAIN:
STRENGTH

C1/C2—CERVICAL FLEX/EXT/ROT/LATFLEX  
C3/C4—SHOULDER SHRUG  
C5—SHOULDER ABDUCTION  
C6—ELBOW FLEXION  
C7—ELBOW EXTENSION  
C8—THUMB EXTENSION  
T1—FINGER ABDUCTION  
L2—HIP FLEXION  
L3—KNEE EXTENSION  
L4—ANKLE DORSIFLEXION  
L5—EXT. HALLICUS LONGUS  
S1/S2—ANKLE PLANTARFLEXION

DERMATOME SCAN (note any asymmetry)  
C4-T1;L1-S1

REFLEXES/TONE

BRACHIORADIALIS  C5/C6  
BICEPS  C6  
TRICEPS  C7  
QUADRICEPS  L2-L4  
GASTROCO-SOLEUS  S1/S2

FLEXIBILITY

ILIOPSOAS (THOMAS TEST)  
RECTUS FEMORIS (MOD. THOMAS)  
HAMSTRINGS (90/90)  
TFL (OBER)  
ADDUCTORS

DURAL MOBILITY

STRAIGHT LEG RAISE  
PRONE KNEE BENDING TEST
APPENDIX D
APPENDIX D

INSTRUCTIONS FOR HOME STRETCHING

TO BE PERFORMED ONE TIME PER DAY, EVERY DAY, FOR FOUR WEEKS

1. LIE ON YOUR BACK ON THE FLOOR.

2. BEND BOTH HIPS AND KNEES SO THAT YOUR FEET ARE ON THE FLOOR.

3. LOOP THE STRETCH CORD AROUND YOUR RIGHT ANKLE, RAISING YOUR FOOT OFF THE FLOOR TO DO SO.

4. PULLING WITH YOUR ARMS, LIFT YOUR LEG SO THAT YOUR KNEE STRAIGHTENS. AT SOME POINT, YOU WILL FEEL A STRETCH IN THE BACK OF YOUR THIGH.

5. HOLD THE LEG IN THE POSITION AT WHICH YOU FEEL THE STRETCH FOR THIRTY SECONDS (BY THE CLOCK TIMER). IT SHOULD NOT BE PAINFUL, ONLY A STRETCHING SENSATION. USE YOUR ARMS TO HOLD YOUR LEG UP.

6. AFTER THIRTY SECONDS SLOWLY LOWER THE LEG DOWN TO THE FLOOR.

7. MARK OFF ON YOUR EXERCISE LOG AFTER COMPLETING THE STRETCH.
APPENDIX E
EXERCISE LOG

INSTRUCTIONS: EACH DAY THAT YOU PERFORM THE EXERCISE, MARK OFF IN ONE SPACE IN THE EXERCISE LOG. YOU NEED TO DO ONE STRETCH PER DAY FOR FOUR WEEKS. IF YOU MISS A DAY, DO NOT MARK A SPACE.

<table>
<thead>
<tr>
<th>DAY</th>
<th>WEEK</th>
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<th>3</th>
<th>4</th>
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<td>THURSDAY</td>
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<tr>
<td>FRIDAY</td>
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</tr>
<tr>
<td>SATURDAY</td>
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