THE UNIVERSITY OF MANITOBA

FLEXIBILITY PROGRAMS FOR THE HAMSTRINGS: A COMPARISON OF UNSUPERVISED VERSUS SUPERVISED FLEXIBILITY PROGRAMS

By

Constance M. Klassen

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Of

Master of Science

Table of Contents

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Dedication

I dedicate this thesis to Ainsley for showing me that life is too short to take things for granted, to Uncle Paul for being the person that one could only inspire to be, and to Dale and Hayden for all of their support and understanding throughout my graduate program. You never let me give me up – thank you!

List of Tables

List of Figures

Abstract

FLEXIBILITY PROGRAMS FOR THE HAMSTRINGS: A COMPARISON OF SUPERVISED VERSUS UNSUPERVISED FLEXIBILITY PROGRAMS

Presented by: Connie Klassen

Thesis Committee:
Dr. Glen Bergeron (Advisor), Dr. Greg Gannon (Internal), Dr. Wendy Dahlgren (External)

Throughout the course of history, flexibility and stretching programs have long been a part of training and conditioning programs as a means of injury prevention, as well as an integral component of injury rehabilitation. The majority of the literature indicates that significant flexibility benefits are achieved via stretching programs. However, the majority of the research focuses on how long the stretches should be held, or how often the stretches should be performed. Rehabilitation specialists regularly promote the benefits and importance of stretching exercises, and in the clinical setting the short-term effects are readily apparent and validated on a daily basis. Clinical therapists are typically required, by insurance agencies, to progress individual rehabilitation programs from a supervised clinically – based rehabilitation program to an unsupervised, home exercise program. As well, most coaches recognize the importance of stretching exercises, yet due to time-constraints, structured stretching and flexibility sessions are often neglected and it is assumed that athletes will adequately prepare themselves.

The purpose of this study is to compare the effectiveness of a supervised stretching program versus an unsupervised stretching program on hamstring flexibility. A secondary purpose is to examine the effectiveness of a six – week stretching program on the dominant leg versus the non-dominant leg.

Fourty-seven subjects participated in this study, including members of the Canadian National Ringette team (N=25) and the University of Manitoba women's hockey team (N=22). The Canadian National Ringette team was selected because the national team athletes are required to train unsupervised, in their respective cities between training camps, which occurred once every couple of months. The Canadian Ringette team, therefore, represented an ideal unsupervised group. The University of Manitoba women's hockey team was selected because of the elite abilities of the athletes, the sport's similarity to ringette (i.e. incidental contact, skating skills), and the fact that the team trained on a daily basis, with student therapists present for all training sessions, and therefore represented an ideal supervised group.

Single factor analyses of variance (ANOVA) were conducted to determine if significant differences existed between the unsupervised and the supervised groups, and the non-dominant limb and the dominant limb. There was no significant difference between the unsupervised group and the supervised group ($p<0.05$). As well, there was no significant difference between the non-dominant limb and the dominant limb ($p<0.05$). A two way ANOVA was conducted to investigate for any group by limb

dominance interaction. There were no significant interaction between groups when all factors were accounted for ($p<0.05$).

The results of this study confirm that long-term stretching programs do have a significant effect on the flexibility of the hamstring muscles; however, there is no evidence to support the role of supervision for those programs or the need to modify the program according to the individual's dominant limb.

CHAPTER 1

Introduction

Flexibility is considered to be an important component of fitness and physical conditioning programs (Starring, Gossman, Nicholson & Lemons, 1988; Magnusson, Aagaard, Simonsen & Bojsen-Moller, 1998). Stretching exercises to improve one's flexibility are a widespread practice amongst competitive and recreational athletes (Magnusson et al, 1998). Both clinical and scientific investigations have proposed that a muscle that does not undergo periodic lengthening will develop a decreased resting length and extensibility (Starring et al, 1988), of which the hamstrings are an example.

The benefits derived from stretching include increased range of motion, decreased muscle soreness and a decrease in the prevalence of injury (Wilson, Wood & Elliott, 1991; Willy, Kyle, Moore & Chleboun, 2001). The proposed mechanisms for these benefits are a potential increase in the musculotendinous length, an increased stretch tolerance, an alteration in muscle stiffness, and viscoelastic stress relaxation (Willy et al, 2001).

Good muscle flexibility reportedly allows the muscle tissue to accommodate to the imposed stresses more easily, thereby allowing for more efficient and effective movements. The increased efficiency and effectiveness in movements assists in the prevention or minimization of injuries and possibly enhanced performance (Bandy, Irion & Briggler, 1998).

Clinically, therapists are routinely expected to provide clients with a home program, however research has indicated that continued compliance for these programs drops to 35% (Willy et al, 2001). In 1993, Sluijs, Kok and van der Zee reported that prolonged supervision was a “strong factor in compliance”. Subsequently, there is a lack of research that compares the effects of a supervised stretching program versus those of an unsupervised stretching program.

As a part of human nature, humans early on in life select a dominant limb, most often referred to as right-handed or left-handed. Similarly, humans also show preference for lower limb dominance in sport (Alter, 1993). Although there is plenty of research evaluating the effectiveness of stretching on the lower limb, most notably the hamstring muscles, there is a lack of research that distinguishes between the dominant limb and the non-dominant limb.

Purpose of the Study

The purpose of this study was to evaluate the effects of supervision on a six-week stretching program for hamstring flexibility in a female population of ringette and ice hockey players. A secondary purpose was to compare the effectiveness of a six-week stretching program on the dominant leg versus the non-dominant leg.

Null Hypotheses

The null hypotheses for this study were that there would be no significant difference between the effects of a supervised stretching program and an unsupervised stretching program on hamstring flexibility upon completion of a six-week stretching program for hamstrings. There would also be no significant difference found in the effects of the stretching program on the dominant leg versus the non-dominant leg.

Delimitations

1. All subjects were free of lower limb pathology for a period of at least three months prior to and during the study.
2. All subjects were training for their sport or activity at the time of the study.
3. It is presumed that elite athletes are more fit that the general population.
4. Subjects in the unsupervised group were on the honour system in completing their daily stretching log book.
5. Subjects may have had different pain / discomfort thresholds, resulting in variable intensity of their stretch during their stretching program.
6. The unsupervised group was the Canadian National Ringette Team training for a world championship, and the supervised group was the University of Manitoba women's hockey team training for a national championship.

Limitations

1. Subjects were assigned to a group based on the team that they were associated with (Canadian National Ringette team – unsupervised group; University of Manitoba women's hockey team – supervised group).
2. Subjects may not be able to achieve full knee extension in the test position (90 degrees of hip flexion).

Significance of the Study

Throughout the course of history, flexibility and stretching programs have long been a part of training and conditioning programs as a means of injury prevention, as well as an integral component of injury rehabilitation. Rehabilitation specialists consistently promote the benefits and importance of stretching exercises, and in the clinical setting the short-term effects are readily apparent and validated on a daily basis (Magnusson, Simonsen, Aagaard & Kjaer, 1996b).

The intent of this study is to evaluate the effectiveness of a six-week training program and to determine if there are benefits to supervised or unsupervised training. These benefits would be of great interest to clinicians and insurance companies when deciding to develop home programs for clients, or have their clients attend formal stretching programs under supervision. As well, these results would be of interest to coaches and team therapists / trainers regarding the daily supervision of their athletes' stretching programs.

The results of a six-week stretching program on the flexibility of the dominant limb versus the non-dominant limb would be useful information for clinicians and team therapists. It would help them determine if a more concerted focus is needed on the dominant limb or the non-dominant limb. Clinicians and team therapists could then evaluate injuries by limb dominance to see if the inflexibility of the non-dominant limb is placing that limb at a greater risk for injury and therefore requires a more focused flexibility program. On the other hand, is the dominant limb hyperflexible and therefore at risk for greater injury because of a higher rate of utilization?

Definition of Terms

Active Stretching: the stretching of muscles, tendons, and ligaments as the result of contractions produced by the antagonist muscles (Hall, 1995).

Passive stretching: the application of an external force, either manually or mechanically, to move the segment to the end range of motion, lengthening the shortened tissues (Kisner & Colby, 1996).

Ballistic stretching: high-intensity, very short duration "bouncing" action (Kisner & Colby, 1996).

Static stretching: slow, passive elongation of a muscle to tolerance and sustaining that position for a period of time (Bandy et al, 1998).

Dynamic stretching: the ability to use range of joint movement in the performance of a physical activity at either normal or rapid speed (Alter, 1996).

First sensation of pain: unpleasant stretch in the target muscle during the passive stretch (Halbertsma, Mulder, Goeken & Eisma, 1999).

Femoral length: the distance measured from the anterior superior iliac spine to the lateral joint line of the knee.

Tibial Length: the distance measured from the medial joint line of the knee to the distal edge of the medial malleolus.

CHAPTER 2

Review of Literature

Introduction

This section will address issues related to this study. Topics reviewed in this section include (1) the anatomy of the hamstring muscle group, (2) a review of the histology of the musculotendinous unit, (3) factors related to the effectiveness of stretching, and (4) a review of the protocols for relevant hamstring muscle testing.

Hamstring Muscles

Anatomy and Function of the Hamstring Muscles

The hamstring muscle group, as they are collectively referred to, consists of three muscles: semimembranosus and semitendinosus (medially) and biceps femoris (laterally). All three muscles share a common proximal attachment to the ischial tuberosity, with the short head of the biceps femoris muscle also attaching to the linea aspera and the lateral supracondylar line of the femur. Distally, the semitendinosus muscle attaches to the medial surface of the superior portion of the tibia, the semimembranosus attaches to the posterior part of the medial condyle of the tibia and the biceps femoris attaches to the lateral side of the head of the fibula. Since the hamstring muscles cross both the hip and knee joints, they act to extend the hip joint and flex the knee joint. When the knee joint is in a flexed position, the biceps femoris externally rotates the tibia, and the semitendinosus and semimembranosus muscles internally rotate the tibia (Moore, 1992).

Also considered to be a part of the hamstring muscle group is the adductor magnus muscle. The adductor magnus muscle contributes to the hamstring muscle group with a proximal attachment to the ischial tuberosity and its distal attachment to the adductor tubercle of the femur. The hamstring portion of the adductor magnus muscle extends the hip (Moore & Dalley, 1999).

Innervation of the Hamstring Muscles

All of the hamstring muscles receive neural supply from divisions of the sciatic nerve. The semimembranosus muscle, the semitendinosus muscle and the adductor magnus muscle are all innervated by the tibial division of the sciatic nerve (L4, L5, S1, and S2). The long head of the biceps femoris muscle also receives its innervation from the tibial division of the sciatic nerve, while its short head is innervated by the common peroneal division of the sciatic nerve (L5, S1 and S2) (Moore & Dalley, 1999).

Physiology of Stretching

Neurophysiological Response of the Musculotendinous Unit

The muscle spindle is the major sensory organ and lies parallel to the muscle fibers, or extrafusal fibers. Consequently, when the muscle is stretched, the muscle spindle is also stretched. The muscle spindle is covered by a sheath of connective tissue, which contains two specialized types of muscle fibers know as the intrafusal fibers. There are two types of intrafusal fibers: (1) the nuclear bag fiber, which is large and contains numerous nuclei centrally packed throughout its diameter, and (2) the nuclear chain fiber, which contains many nuclei along its length. The muscle spindle is typically composed of two nuclear bag fibers and four to five nuclear chain fibers. The ends of the intrafusal fibers contain actin and myosin filaments and are capable of shortening (Alter, 1996; McArdle, Katch & Katch, 1996). The actin filament serves to regulate the binding of the filaments. The myosin possesses numerous short lateral projections (cross-bridges) that extend toward the actin filaments and are the binding site between the actin and myosin filaments that produces muscle tension (Alter, 1996).

The muscle spindle is comprised of three different nerve fibers; two are sensory afferent fibers and one is a motor efferent fiber. The annulospiral nerve fiber is the primary afferent nerve fiber and is wrapped around the midregion of the nuclear bag fiber and the nuclear chain fiber. The function of the annulospiral nerve fiber is to respond directly to the stretch of the muscle spindle, and its firing frequency is directly proportional to the degree of stretch. The second, smaller afferent nerve fibers are the flower-spray endings. These sensory fibers are mainly attached to the nuclear chain fibers, although they do have some attachments to the nuclear bag fibers. The flower-spray fibers are less sensitive to stretch than the annulospiral fibers. The flower-spray fibers respond to a more sustained stretch, while the annulospiral fibers respond to the initial onset of stretch. Stimulation of the afferent nerve fibers results in a signal transmitted to the spinal cord causing a reflexive activation of the motorneurons innervating the stretched muscle. This in turn causes the muscle to contract, which reduces the stretch stimulus from the spindles (McArdle et al, 1996).

The single motor efferent nerve, known as the gamma efferent fibers, innervates the contractile ends of the intrafusal fibers allowing them to contract when the muscle shortens thereby maintaining an optimal length so that they are always sensitive to undue stretch throughout the range of motion. The gamma efferent fibers are activated within the brain and provide the mechanism for maintaining optimal sensitivity of the muscle spindle, regardless of muscle length. This mechanism protects the muscle spindle from forceful lengthening of the muscle, even though it may currently be contracted (McArdle et al, 1996).

Muscle spindle fibers monitor the velocity and duration of stretch and sense changes in length of the muscle (Kisner & Colby, 1985; Hall, 1995). The muscle spindles respond to both slow and fast stretching, with a faster rate of stretching provoking a stronger response (Hall, 1995; McArdle et al, 1996). The stretched muscle spindles respond in two ways. First they initiate the stretch reflex, which involves the neural transmission across a single synapse. The afferent nerves carry stimuli from the muscle spindles to the posterior horn of the spinal cord where they stimulate the efferent nerves which then carry the excitatory signal from the anterior horn of the spinal cord to the muscle, resulting in the development of tension within the muscle (Ganong, 1991; Hall, 1995, McArdle et al, 1996).

Secondly, the muscle spindles inhibit the development of tension in the antagonist muscle group via reciprocal innervation, in which interneurons within the spinal cord are activated. Excitatory impulses are transmitted to the agonistic muscles, while inhibitory impulses are transmitted to the antagonistic muscles. The resulting stretch reflex acts as a self-regulating, compensating mechanism, which permits the muscle to adjust to varying loads and lengths (Ganong, 1991; Hall, 1995).

A second sensory receptor in the muscle is known as the Golgi tendon organ (GTO) (Kisner & Colby, 1985; Ganong, 1991; Hall, 1995; McArdle et al, 1996). The GTO is located near the musculotendinous junction (Kisner & Colby, 1985; Hall, 1995; McArdle et al, 1996) and wraps around the ends of the extrafusal fibers of the muscle (Kisner & Colby, 1985; McArdle et al, 1996). The GTOs are encased in tendinous tissues that is relatively inelastic as compared to muscle. The GTOs are stimulated by tension within the tendon caused by either active muscle contraction (Kisner & Colby, 1985; Hall, 2995; McArdle et al, 1996) or passive stretch (Kisner & Colby, 1985). The GTO is a protective mechanism that inhibits contraction of the muscle in which it lies, thereby preventing musculotendinous injury due to excessive muscle contraction. It has a very low threshold for firing after an active muscle contraction and has a high threshold for firing with passive stretching (Kisner & Colby, 1985; McArdle et al, 1996).

It has been proposed that the harder a muscle is stretched, the stronger is the reflex contraction due to the effects of the muscle spindle. However, when the tension becomes great enough, the contraction suddenly stops and the muscle relaxes. This relaxation in response to a sustained stretch is known as the inverse myotatic stretch reflex (Kisner & Colby, 1985; Ganong, 1991; McArdle et al, 1996).

<u>Structural and Mechanical Characteristics of the Tendons</u>

Tendons are important structures within the musculoskeletal system, as they transmit the forces generated by muscles to the bony attachments. Although tendons are relatively small, they are very strong. The distal portion of the tendon is typically larger and with its ropelike structure, is better developed. The proximal portion, however, is composed of shorter, smaller fibers with a fleshy attachment to the bone. At most of the attachment sites, the tendinous fibers insert directly into the bone at a 90 degree angle. There are some fibers, however, that will attach to the bone at an acute angle, subsequently blending into the periosteum. There is a gradual transition in material composition over a distance of approximately one millimeter, through the four zones at the attachment site (tendon, fibrocartilage, mineralized fibrocartilage, and bone) (Zachazewski, Magee & Quillen, 1996).

The musculotendinous unit represents the link between the skeletal system and the contractile component of the muscle. As such, its stiffness affects how quickly external forces imposed on the skeletal system are transmitted through the muscle. Therefore, the stiffness of the musculotendinous unit has the potential to modulate the incidence of muscular injury (Starring et al, 1988).

Also affecting the muscle's extensibility is a sheet of fibrous connective tissue surrounding it, known as fascia. There are two types of fascia, superficial fascia which lies immediately below the skin's surface, and deep fascia which is far more extensive. The deep fascia which is comprised of dense connective tissue lines the body wall and extremities. The deep fascia holds muscles together and separates them into functioning groups, allowing for free muscle movement (Tortora, 1992; Alter 1996). The deep fascia has three functions within the body: (1) it provides the framework for the body by binding the muscles together and ensuring the proper alignment of the muscle fibers, (2) it enables the forces, either actively produced by the muscle or passively imposed on the muscle, to be transmitted by the whole tissue safely and effectively, and (3) it provides the necessary lubricated surfaces between the muscle fibers that enables muscles to change shape. The sum of the muscle's fascia accounts for 41% of its total resistance to movement, and therefore may limit range of motion (Alter, 1996).

When the tendons, musculotendinous units and fascia are tight, they affect joint range of motion and therefore require stretching. The key factors to increasing flexibility in connective tissue are to understand how they respond to various intensities and durations of stretch and to recognize that it requires a remodeling of the connective tissue's basic architecture (Kisner & Colby, 1985, Tortora, 1992).

Each musculotendinous junction is comprised of a "layered region of infoldings connecting the terminal actin filaments" to the tendon. (Zachazewski et al,1996). These infoldings increase the contact area so that stress are reduced, and thereby ensuring that the musculotendinous junction is loaded by a shear force instead of a tensile force, which serves to reduce the areas of stress concentration (Zachazewski et al, 1996).

The material strength of connective tissue is related to the ability to resist stress. Mechanical stress is the internal resistance to an external force. There are three forms of stress (shear, compression and tension), with tension being a factor in stretching. Tension is defined as a tensile force that is applied perpendicular to the cross-sectional areas of the tissue in a direction away from the tissue. Strain is the amount of deformation that occurs when stress is applied (Alter, 1996; Kisner & Colby, 1985).

A stress-strain curve represents the mechanical strength of the tendon, whereby the stretch tension is applied to a tendon resulting in deformation (Alter, 1996; Kisner & Colby, 1985, Zachazewski et al, 1996).

The toe region, within the stress – strain curve, represents the initial straightening out of the normally wavy collagen fibers. This occurs at low levels of tension. Beyond this threshold (two to four percent elongation) further stretching results in deformation (Alter, 1996; Zachazewski et al, 1996). The deformation within this region is not permanent and the tissue is able to return to its original size and shape upon removal of the stress. However, should the tissue continue to undergo additional stress, the elastic limit is reached, which represents the point at which the tissue can no longer return to its original shape and form (Kisner & Colby, 1985, Zachazewski et al, 1996).

As the tissue passes its elastic limit, it enters the plastic range, in which the tissue continues to be strained resulting in permanent length changes, accompanied by microtrauma to the tendon's structural integrity. The deformation may be the result of a single load or the summation of several loads (Alter, 1996; Kisner & Colby, 1985. Zachazewski et al, 1996).

Within the plastic region necking occurs. This is the point at which there is extensive weakening of the tissue. Deformation now results from lesser loads, and tissue failure is quickly approached. Failure is the point at which the tissue ruptures, which occurs at about eight to ten percent elongation from the starting length (Alter, 1996; Kisner & Colby, 1985; Zachazewski et al, 1996).

Viscoelastic Behavior of Muscle

The musculotendinous unit displays both physical and mechanical properties while undergoing deformation. It is these properties that provide the tissue with high tensile stress, allowing it to respond to loads and deformation accordingly (Zachazewski et al, 1996).

Mechanically, the musculotendinous unit functions as a viscoelastic structure. The viscous properties are characterized by time and rate of deformation. The rate of deformation is directly proportional to the force applied when considering the viscous property of the connective tissue. The elastic properties indicate that the deformation of the structure is directly proportional to the load being applied. When the load is removed the structure recovers. Thus the musculotendinous unit combines both of these properties and thereby functions as a viscoelastic structure (Zachazewski et al, 1996).

If the material is stretched and then held at a constant length, the stress at that length gradually declines resulting in stress relaxation. The behavior of the material is considered to be both viscous allowing an increase in overall length, and elastic, because the tissue maintains some degree of tension causing it to shorten somewhat once the tension is removed (Taylor, Dalton, Seaber & Garrett, 1990; Zachazewski et al 1996).

Creep is another viscoelastic property of tissue and is characterized by continued deformation at a maintained load. The deformation depends on both the amount of force and the rate at which the force is applied. Creep occurs with low amounts of stress, usually within the elastic region, over a long period of time (Kisner & Colby, 1985; Taylor et al, 1990; Zachazewski et al, 1996).

Also related to the viscoelastic properties is hysteresis response. This is the amount of relaxation, or load-deformation that occurs within a single cycle of loading and unloading. During this response energy is absorbed by the tissue during the loading phase and released during the unloading phase, resulting in increased tissue temperature (Kisner & Colby, 1985; Taylor et al, 1990, Zachazewski et al, 1996).

Factors Related to the Effectiveness of Stretching

Active Versus Passive Stretching

Two basic methods of stretching exist: active and passive. Active stretching involves contractions produced by the antagonist muscles. For example, to stretch the hamstring muscles, the quadriceps muscles are contracted. Active stretching is facilitated by muscle relaxation via reciprocal inhibition (Hall, 1995).

Passive stretching, however, involves the application of an external force to move the segment to the end range of motion (Hall, 1995). The advantage of passive stretching is that the muscle can be moved through a greater range of motion than occurs with active stretching. However, one has to be cautioned that an increased potential for injury exists (Hall, 1995).

A study by Sady, Wortman and Blanke in 1982 indicated that although passive and active stretched produced significant increases in range of motion, there was no significant difference between passive stretching and active stretching.

Ballistic Versus Static Stretching

Ballistic stretching is a high-intensity, very short duration "bouncing" action. The individual actively contracts the antagonist muscle group and utilizes body weight and momentum to elongate the tight muscle. Although ballistic stretching increases joint range of motion, it is considered to be unsafe because of the lack of control and the susceptibility to microtrauma (Kisner & Colby, 1985; Hall, 1995). During ballistic stretching, the muscle reaches relatively high rates of tension during the fast stretch and then bounces back. The faster stretch rates result in a greater development of tension, and more energy being absorbed (hysteresis) within the musculotendinous unit for a given length of stretch. Therefore, the ballistic stretch, which is performed at a faster rate, has a greater likelihood of producing a muscle strain (Taylor et al, 1990, Zachazewski et al, 1996).

Since the muscle is not held at the higher tension, there is little chance to allow for time-dependent stress relaxation or creep to occur and thereby decrease the tension or increase the length (Taylor et al, 1990). As well, the rapid elongation of the muscle spindle initiates the stretch reflex, thereby increasing tension in the muscle being stretched (Kisner & Colby, 1985; Hall, 1995). When the tension on the muscle is sustained long enough the tension suddenly ceases and the muscle relaxes. This action is known as the inverse myotatic stretch reflex (Ganong, 1991).

Static stretching refers to the slow, passive elongation of a muscle to a new length, maintaining the new length for a period of time and then returning to the starting position (Kisner & Colby, 1985; Bandy, Irion & Briggler, 1994; Magnusson, Simonsen, Aagaard, Gleim, McHugh & Kjaer, 1995; Magnusson, Simonsen, Aagaard & Kjaer, 1996a; Magnusson, Aagaard, Simonsen, Boesen, Johannsen & Kjaer, 1997; Bandy et al, 1998). The static stretch may be divided into two parts: 1) dynamic phase, in which the muscle-tendon unit is passively lengthened, and 2) static phase, in which a constant muscle-tendon length is maintained for some time (Magnusson et al, 1996a; Klinge, Magnusson, Simonsen, Aagaard, Klausen & Kjaer, 1997).

Advocates of static stretching feel that the influence of the stretch reflex is minimized by the gentle motion and the absence of pain (Taylor et al, 1990). However, the inverse stretch reflex does allow for further stretching without the risk of injury. (Ganong, 1991). Static stretching therefore induces relaxation in the muscle, which enables further stretching and subsequently increased flexibility (Strickler et al, 1990; Anderson and Burke, 1991; Smith, 1994). Static stretches are recommended because they are easier to perform, have less associated risk of injury, and are more time efficient than active stretches utilizing proprioceptive neuromuscular facilitation (Taylor et al, 1990; Smith, 1994; Webright, Randolph & Perrin, 1997).

In 1998, Bandy et al conducted a six - week study comparing the effects of static stretching and dynamic range of motion training on hamstring flexibility. Fifty-eight subjects were assigned to one of three groups: Group A performed dynamic range of motion exercises (30 seconds in total) five days per week, Group B performed one 30 – second stretch, five days per week, and Group C was the control group – no stretching. The study indicated a significant difference between the control group and both of the test groups ($p < .015$). Secondly, the static stretching group increased hamstring flexibility significantly greater than the dynamic range of motion group ($p < .05$). Bandy et al (1998) concluded that although both protocols resulted in an increase in hamstring flexibility, the static stretching protocol was favoured over the dynamic range of motion training.

Stretch Duration and Repetitions

In 1994, Bandy and Irion studied the effect of time of a static stretch on the flexibility of the hamstring muscles. Fifty-seven subjects were randomly assigned to four test groups: (1) 15-second stretch, (2) 30-second stretch, (3) 60-second stretch and (4) control group (no stretching activity). The results revealed a significant group by test interaction, indicating that the change in flexibility was dependent on the duration of the stretch. A further *post hoc* analysis revealed that 30 second and 60 second stretching durations were more effective in increasing hamstring muscle flexibility than 15 seconds of stretching or no stretching at all. In addition, there was no significant difference found between 30 and 60 seconds of stretching. The researchers therefore concluded that a duration of 30 seconds is an effective time of stretching for enhancing the flexibility of the hamstring muscle.

In 1997, Bandy et al studied the effect of frequency (repetitions) and time (stretch duration) on hamstring muscle flexibility. One hundred subjects were randomly assigned into five test groups: (1) three 1-minute stretches, (2) three 30-second stretches, (3) one 1-minute stretch, (4) one 30-second stretch and (5) a control group (no stretching activity). Results showed that there was a statistically significant increase in hamstring flexibility amongst all stretching groups (group 1: t=6.79, P < .01; group 2: t=6.70, P < .01; group 3: t=6.43, P < .01; group 4: t=7.23, P < .01), but no significant change in hamstring flexibility in the control groups (t=1.39, P > .01) Secondly, a repeated-measures one-way ANOVA analysis on the post-test scores indicated a statistically significant difference existed across the five groups (F=3.99; df=4,88; P < .05). The Tukey *post hoc* analyses indicated that there was a significant difference between the stretching groups and the control group, but no significant differences were found within the stretching groups. Bandy et al (1997) concluded that one 30-second duration stretch was an effective amount of time for a sustained hamstring muscle stretch in order to increase range of motion. No increase in flexibility occurred by increasing the stretch duration from 30-seconds to 60-seconds or by increasing the frequency of stretching from one to three times.

A study conducted by Taylor et al (1990) evaluated the effects of repeated stretching of muscle –tendon units to tension. Twelve rabbit extensor digitorum longus (EDL) muscle –tendon units were stretched from a starting tension of 1.96 N at a rate of 2 cm/min to a tension of 78.4 N. The final tension of 78.4 N represented a significant deformation in the "elastic" region of the load-deformation curve and did not result in any irreversible injury. Taylor et al indicated that prior studies showed 78.4 N was approximately 65% of the tension required to rupture a passively stretched EDL. Once the tension of 78.4 N was achieved, the stretch was maintained for 30-seconds and then returned to the original tension of 1.96 N. The cycle was repeated ten consecutive times on each specimen. The stretching protocol was designed to simulate the static stretching technique. The results of the study indicated that a significant difference ($P < .05$) existed between the relaxation curve of the first stretch and the relaxation curve of the other nine stretches (Figure 2 – 1). The relaxation curve of the second stretch also showed a significant difference from the remaining eight relaxation curves. Finally no significant difference was noted in the relaxation curves of stretches four through ten. The results of the study indicated that 80% of the length increases of rabbit EDL muscle-tendon units occurred during the first four stretches (Figure 2 – 2). As a result, it appears that a minimal number of stretches (four) would be effective in lengthening the muscle-tendon unit.

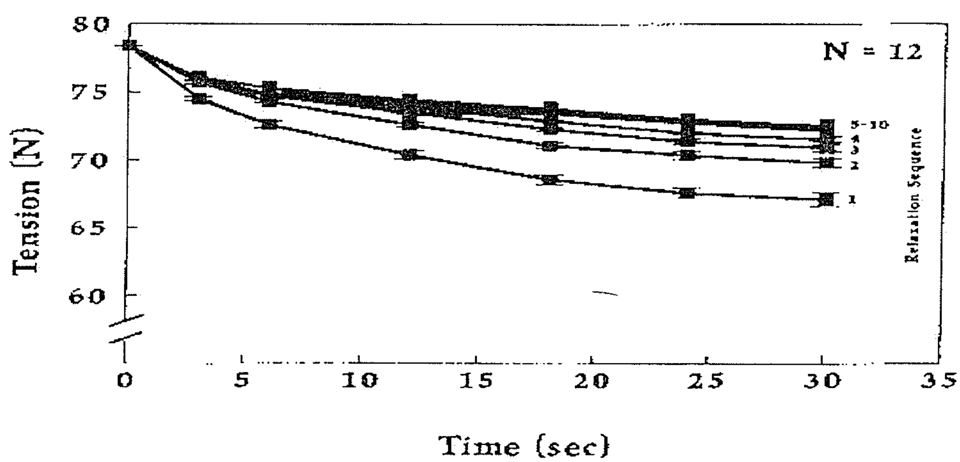

Figure 2 - 1: Relaxation curves for EDL muscle-tendon units stretched repeatedly to 78.4N (Taylor et al, 1990).

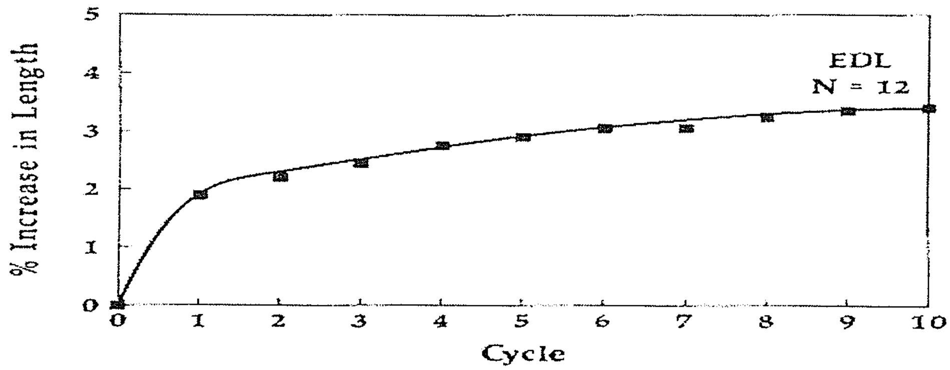

Figure 2 - 2: Graphic representation of EDL lengthening with repeated stretching to the same tension. (Taylor et al, 1990).

Pelvic Tilt Position

It has been recommended that static hamstring stretches be performed in a standing position, with the pelvis in an anterior pelvic tilt position and the hip positioned at 90 degrees (Figure 2 – 3) (Worrell, 1994; Hartig & Henderson, 1999). The anterior pelvic tilt with shoulder retraction minimizes compensation of the cervical, thoracic, and lumbar regions. The anterior pelvic tilt was found to be more effective than the pelvis in the posterior position (Figure 2 – 4) (Sullivan et al, 1992; Worrell, 1994).When individuals flex forward in an attempt to bring their chin to their patella, they are

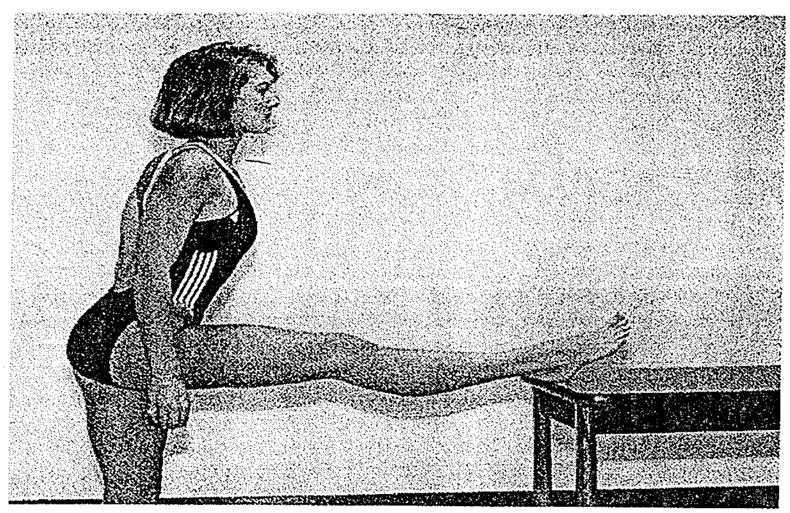

Figure 2 – 3. Anterior pelvic tilt stretching position. (Sullivan, Dejulia & Worrell, 1992).

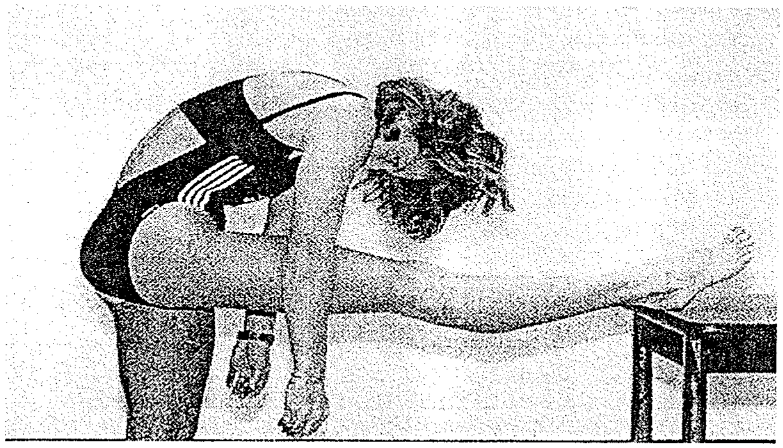

Figure 2 – 4. Posterior pelvic tilt stretching position. (Sullivan et al, 1992).

placing their pelvis in the posterior position, which is ineffective because the ischial tuberosities move forward and closer to the hamstring insertions.

In 1992, Sullivan et al studied the effect of pelvic position and stretching method on hamstring muscle flexibility. Static stretching and proprioceptive neuromuscular facilitation (PNF) techniques were compared while maintaining the pelvis in two test positions: 1) anterior pelvic tilt (APT) and 2) posterior pelvic tilt (PPT).

Twenty subjects were divided and randomly assigned into one of the two test groups, the APT group or the PPT group. The results of the study indicated that the APT group significantly increased hamstring flexibility (P = 0.0375). There was no significant difference found between the static stretch and PNF techniques in the APT position. There was also no significant difference found between stretching techniques in the PPT position. The researchers concluded that the APT position was more important than the stretch technique for increasing hamstring flexibility.

Warm up

Warm up is an activity designed to stimulate blood flow to the peripheral muscles, increase body temperature, and increase muscle extensibility in preparation for vigorous exercise (Anderson & Burke, 1991; Kisner & Colby 1996; Smith, 1994). Stretching is regarded as an important pre-exercise warm up and a necessity for fitness, flexibility and injury prevention. However, it is suggested that a mild warm up period be conducted prior to stretching (Kisner & Colby, 1996). Warmer muscles are more extensible and can be stretched to a greater limit before failing, thereby increasing joint flexibility (Smith, 1994; Kisner & Colby, 1996).

Compliance

Clinically, therapists are routinely expected to provide clients with home programs, which typically consist of stretching and strengthening exercises. "Once the client is discharged from therapy, the rate of continued compliance with the home exercise program has been found to be as low as 35%" (Willy et al, 2001).

In 1993, Sluijs et al, studied the factors related to compliance of prescribed physical therapy programs. They reported that prolonged supervision was a "strong factor in compliance". Also of note, Sluijs et al, 1993 reported that the relationship between the patient and the therapist was considered to be important, and that a closer relationship led to more program satisfaction and adherence.

Protocols for Hamstring Flexibility Testing

Active Knee Extension Test

The Active Knee Extension (AKE) test is believed to represent a measurement of the initial (unstretched) length or resistance point of a muscle (Gajdosik, Rieck, Sullivan

& Wightman, 1993; Halbertsma et al, 1999; Devlin, 2000), and is considered to be an alternative to the straight leg raise (Cameron & Bohannon, 1993).

The AKE test is performed in the supine position on a plinth or mat (Figure 2 – 5). The subject actively extends the test knee, while the test leg is positioned

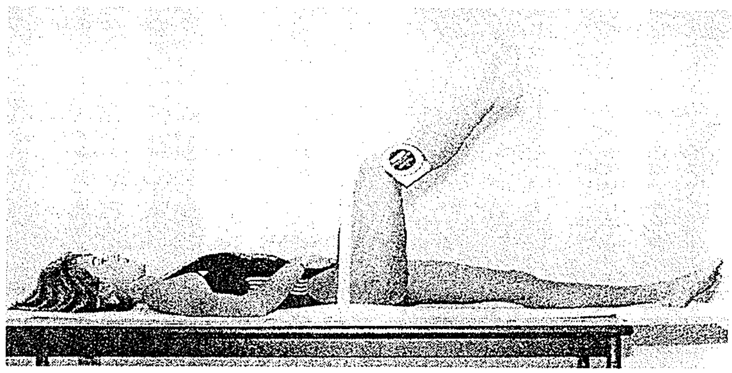

Figure 2 – 5. The Active Knee Extension Test (Sullivan et al, 1992).

in 90 degrees of hip flexion. The hip joint is stabilized in a position of 90 degrees of hip flexion by either the subject (Sutton, 1984), an external device, such as a box (Turl & George, 1998), a frame (Sullivan et al, 1992), or a cradle (Bruce, 1989; Diakow, 2001).

The contralateral leg is usually left in an extended position, but has been flexed when the cradle device was employed (Bruce, 1989). Some researchers have strapped the pelvis and thigh of the non-test leg to avoid excessive movements (Cameron & Bohannon, 1993; Gajdosik et al 1993), while others have left the contralateral leg unstabilized (Sullivan et al, 1992; Webright et al, 1997). In 1993, Webright et al, required the subject to extend the knee beyond the point of initial resistance to stimulate myoclonus (shaking within the muscle). Myoclonus was felt to occur within the range of extensibility of the muscle, or between the initial length and the maximal length. The subject was then asked to flex the knee until the myoclonus was no longer present, or the assumed point of initial resistance (Gajdosik et al, 1993). Other researchers determined the final test position to be the point at which the subject reported that the knee could no longer be extended with a comfortable stretch sensation (Bruce, 1989; Sullivan et al, 1992; Cameron & Bohannon, 1993; Worrell, Smith & Winegardner, 1994; Webright et al, 1997, Diakow, 2001). The angle of knee extension was determined by a goniometer (Gajdosik et al, 1993; Wang, Whitney, Burdett & Janosky, 1993; Bandy & Irion, 1994; Krivickas & Feinberg, 1996; Bandy et al, 1997; Bandy et al, 1998; Hartig & Henderson, 1999; Willy et al,2001), a flexometer/inclinometer attached to the lower leg (Bruce, 1989; Sullivan et al, 1992, Worrell et al, 1994), or by videotape or photographic analysis (Cameron & Bohannon, 1993; Webright et al, 1997, Diakow, 2001).

In 1993, Cameron & Bohannon evaluated the relationship between the AKE test and the active straight leg raise (ASLR) test, as alternatives in indicating hamstring musculotendinous length. Twenty-three subjects were evaluated. The results indicated that a significant relationship ($P < .001$) existed between AKE and ASLR. Cameron and Bohannon concluded that both tests provide the same information, and therefore the AKE test is a valid alternative to the ASLR test.

Sullivan et al (1992) utilized the AKE test in their comparison of static stretch and PNF stretch techniques, while maintaining the pelvis in two test positions: APT and PPT. This study was previously reviewed in the section 'Pelvic Tilt Position'.

In 1994, Worrel et al, evaluated the relationship between hamstring stretching and hamstring muscle performance. Their investigations were two-fold, in that they sought to determine the most effective stretching method for increasing hamstring flexibility, as well as to determine the effects of increasing hamstring flexibility on isokinetic peak torque. Active knee extension was the measurement tool utilized for assessing hamstring muscle flexibility. Nineteen subjects participated in fifteen stretching sessions, either a static stretch or a contract-relax-contract (PNF) stretch, in an anterior pelvic tilt position for a period of three weeks. The results of the study indicated that neither protocol, static stretching nor PNF stretching, produced significantly different increases in flexibility ($p = 0.082$). The researchers therefore recommended static stretching over PNF stretching for increasing hamstring flexibility, since the results indicated that there were no significant benefits in one protocol over the other and the static stretching technique is easier to teach and perform. The researchers also determined that significant increases in hamstring peak torque occurred eccentrically at 60 and 120 degrees/second and concentrically at 120 degrees/second, and therefore concluded that increases in hamstring flexibility produced an increase in selective isokinetic peak torques. Worrel et al (1994) also reported that the active knee extension test showed a high intratester reliability (ICC = 0.93).

Although the active knee extension test has been widely utilized, some limitations should be considered. Such limitations include the method (subject-assisted or an external device) for maintaining the hip in a 90 degree flexed position for the duration of the test. Cameron & Bohannon (1993) reported that the active knee extension test is only applicable to individuals who are unable to achieve complete knee extension. As well, the final testing position is dependent on the subject's tolerance to stretch and the control of the myoclonic reflex (Diakow, 2001).

Passive Knee Extension Test

The Passive Knee Extension (PKE) test is believed to represent a measurement of the maximal length (fully stretched) of a muscle (Gajdosik et al, 1993; Devlin, 2000).

The initial length of the hamstring muscle can be measured by a point of initial resistance to passive stretch, and a point where the muscle can be lengthened maximally, and presents the maximal resistance to passive stretch (Gajdosik et al, 1993).

The passive knee extension test is performed in a supine position with the test leg positioned at 90 degrees of hip flexion (Starring et al, 1988; Anderson & Burke, 1991; Worrell, Perrin, Gansneder & Gieck, 1991; Gajdosik et al, 1993, Magnusson et al 1996a; Bandy et al, 1997; Halbertsma et al, 1999; Hartig & Henderson, 1999; Devlin, 2000; Diakow, 2001) (Figure 2 – 6). In most of the research, the 90 degrees of hip flexion was maintained by the examiner (Worrell et al, 1991; Gajdosik et al, 1993; Bandy & Irion, 1994, Bandy et al, 1997; Bandy et al, 1998, Hartig & Henderson, 1999). In some cases, however, the hands of the subject (Starring et al, 1988), or a frame (Diakow, 2001) have been utilized to maintain hip flexion. The non-test leg has been positioned in 0 degrees of hip flexion (Gajdosik et al, 1993; Bandy & Irion, 1994; Bandy et al, 1997; Hartig & Henderson, 1999), while others have positioned the non-test leg in partial hip and knee flexion to assist with stabilizing the pelvis (Starring et al, 1988). The foot of the test leg is in a plantar flexed position, to rule out the effects of the gastrocnemius muscle (Hartig & Henderson, 1999). The final position was determined by the examiner passively extending the knee until the point of resistance of the hamstring muscle (Starring et al, 1988; Anderson & Burke, 1991; Worrell et al, 1991; Bandy et al, 1997; Hartig & Henderson, 1999).

Figure 2 – 6: Passive knee extension test. (Hartig & Henderson, 1999)

Keeping the low back flat, to avoid a posterior pelvic tilt, is essential for accurate testing (Anderson & Burke, 1991; Gajdosik et al, 1993).

In 1991, Worrel et al compared the isokinetic strength and flexibility measures between hamstring injured and noninjured athletes. Sixteen male university athletes with no history of hamstring injury were compared to sixteen male university athletes with a history of hamstring injury. The athletes were matched for motor dominance, sport, and position. Each subject's hamstring flexibility was measured via the passive knee extension test. The results revealed that a significant difference ($p < .05$) existed between the flexibility of the injured and the noninjured groups, as well as between extremities ($p < .05$). A significant group by extremity interaction ($p < .05$) was found, with a subsequent Tukey post hoc test revealing that the flexibility of the injured extremity was significantly less ($p < .05$) than the noninjured extremity. The researchers concluded that the injured extremity was significantly less flexible than the noninjured extremity within the hamstring injured group, and that the hamstring injured group was less flexible than the noninjured group, thus emphasizing the importance of hamstring flexibility in rehabilitation programs.

In 1988, Starring et al, utilized the passive knee extension test for both their pretest and posttest measurements, in their study comparing cyclic and sustained passive stretching via a mechanical device as a means for increasing the resting length of hamstring muscles. Prior to conducting their study a measurement of intrarater reliability with the passive knee extension test was conducted (right leg: $r = .94$, $p < .01$; left leg: $r = .96$, $p < .01$).

Hartig and Henderson (1999) conducted an intervention study to prove that increasing hamstring flexibility would decrease the number of lower extremity overuse injuries in military infantry basic trainees. Two different companies were evaluated at the beginning and at the end of a thirteen-week training period. The control group ($N = 148$) proceeded through normal basic training. The intervention company ($N = 15$) followed the same fitness program with the addition of three hamstring stretching sessions. The results of the study indicated that the hamstring flexibility of the intervention group increased significantly in comparison with the control group ($p < .0001$). As well, the number of injuries was significantly lower in the intervention group than the control group ($p < .002$). The researchers concluded that increasing hamstring flexibility decreases the risk of lower extremity injuries in military basic trainees.

In another study, Magnusson et al (1996b) examined stiffness, energy, and passive torque in the dynamic and static phases of a stretch in human hamstring muscle in vivo using a test-retest protocol and a repeated stretches protocol. Thirteen males that were free from lower extremity and low back injuries participated in the study. In this study, passive knee extension was used to determine the final stretch position. Stretches were conducted via a KinCom dynamometer. During the test-retest protocol, tests were administered one-hour apart. For the test-retest protocol, stiffness and energy in the dynamic phase and passive torque in the static phase did not differ and resulted in correlations of $r = 0.91$ to 0.99. During the static phase, passive torque declined in both tests ($p < .0001$). The repeated stretches protocol was conducted on a separate occasion. Five consecutive static stretches were administered, with a 30-second rest interval between stretches, followed by a sixth stretch one hour later. Results indicated decreased energy ($p < .01$) and stiffness ($p < .05$) in the dynamic phase and for passive torque ($p < .0001$) in the static phase. The decline in variables returned to baseline within one hour. The researchers concluded that the KinCom dynamometer was a useful tool for measuring energy and stiffness in the dynamic phase, and torque in the static phase of stretching.

Limitations of passive knee extension include the establishment of the final testing position via stretch tolerance, which is very subjective. As well, the examiner's perception of the hamstrings resistance to stretch may be a limiting factor.

Active knee extension versus passive knee extension

In 1993, Gajdosik et al examined four indirect clinical tests for measuring hamstring flexibility: 1) passive straight leg raise (SLR) with the pelvis and opposite thigh stabilized with straps (SLR-SS); 2) passive SLR with the low back flat (SLR-LBF) and if needed, the opposite thigh slightly flexed and supported on pillows; 3) active knee extension (AKE) with the hip flexed to 90 degrees; and 4) passive knee extension (PKE) with the hips flexed to 90 degrees. Thirty male subjects had their right leg tested for this study. The results indicated there was a significant difference between the AKE and the PKE test ($p < .001$). Gajdosik et al, 1993, concluded that the significant difference between the angles for AKE and PKE indicated that the AKE test may represent an initial length, and the PKE test may represent the maximal length.

Importance of Program Compliance

Patients' compliance to prescribed programs has long been a concern of clinicians. When patients fail to comply with their treatment programs, they may exacerbate their condition and nullify the experience and expertise of the health care practitioner. However, when patients do comply with the prescribed treatments, there tends to be dramatic improvements in their condition (Alter, 1996).

When patients fail to comply with their prescribed treatments, there is a potential for a concomitant cost to the health care system and the economy through lost work time, productivity and income. As well, there may be an increased expense for insurance companies, which in turn pass the expenses on to the public in the form of increased insurance premiums (Alter, 1996).

CHAPTER 3

Methods and Procedures

Introduction

The purpose of this study was to evaluate the effects of supervision on a six-week stretching program for hamstring flexibility. A secondary purpose was to compare the effectiveness of a six-week stretching program on the dominant leg versus the non-dominant leg. The null hypotheses for this study were that there would be no significant difference between the effects of a supervised stretching program and an unsupervised stretching program on hamstring flexibility upon completion of a six-week stretching program for hamstrings. There would also be no significant difference found in the effects of the stretching program on the dominant leg versus the non-dominant leg.

Ethics approval for this study was granted from the University of Manitoba Education / Nursing Research Ethics Review Board prior to data collection.

Subjects

Fifty-five healthy female athletes between the ages of 16 and 28 (mean age = 21.66 years) were recruited for this study. The subjects were members of the University of Manitoba women's hockey team, or the Canadian National Ringette team. The Canadian National Ringette team was selected because of the nature of the team's training schedule. The national team athletes are required to train unsupervised, in their respective cities between training camps, which are scheduled once every couple of months. The Canadian Ringette team, therefore, represented an ideal unsupervised group. The University of Manitoba women's hockey team was selected because of the elite abilities of the athletes, and female hockey's similarity to ringette (i.e. incidental contact, skating skills). The University of Manitoba women's hockey team trained on a daily basis and was monitored by student therapists present for all training sessions, and therefore represented the supervised group.

Eight subjects were released from the Canadian Ringette Team prior to the completion of data collection, and were subsequently excluded from this study. Therefore, 47 subjects with a mean age of 21.77 years (SD=3.29, range=16-28), completed the study.

The subjects were recruited by personal communication with the researcher. Those subjects who were willing to participate were placed in their respective groups (Canadian National Ringette team – unsupervised group; University of Manitoba women's hockey team – supervised group). Subjects in the supervised group (N=22) and the unsupervised group (N=25) were actively training for their sport without symptoms and were injury free for at least three (3) months prior to testing.

Subjects were given an informed consent and a written description of the test protocol. The consent form included a guarantee of confidentiality and the option to withdraw from the study at any time (Appendix A). Subjects were also asked for written permission to be contacted for future research that may arise as a result of the current study. Subjects were informed that this research study would have no impact on the team's selection process. Each subject was required to sign the informed consent form to confirm that she had read and understood the testing procedures and her rights as a participant in the study. All subjects who were minors required their parent's signature of consent for their participation in the study. Subjects were asked to wear loose fitting shorts to their testing sessions.

Apparatus

The materials to be used during the subject testing were a digital inclinometer (Cybex EDI 320) (Figure 3-1), a standard measuring tape, and a hip-stabilizing frame Figure 3-2).

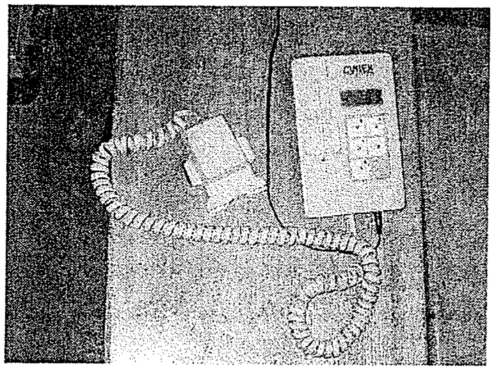

Figure 3-1. Cybex EDI 320 Digital Inclinometer.

The Cybex EDI 320 is an electronic digital inclinometer that uses gravity to indicate motion on a 360 degree scale. A study by Chiarello and Savidge in 1993 compared the Cybex EDI 320 to a fluid goniometer for its interrater reliability. The study indicated that the Cybex EDI 320 exhibited a slightly better interrater reliability ($p<0.01$) than the fluid goniometer and was considered to have acceptable reliability in patients and in normal populations.

A subsequent study by Hunt, Zuberbier, Kozlowski, Robinson, Berkowitz, Schultz, Milner, Crook & Turk in 2001 reported that they used the Cybex EDI 320 for their testing because it was endorsed by the American Medical Association and was reported to possess greater precision than a mechanical inclinometer. It was also considered to be clinically convenient because they automatically calculate true range of motion.

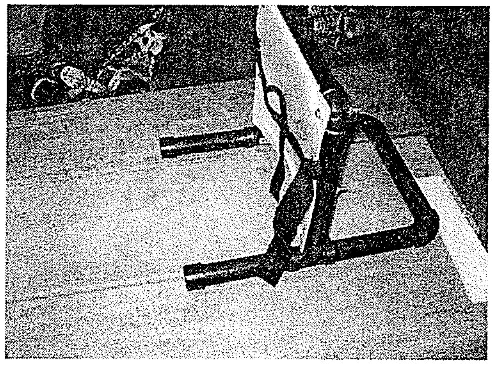

Figure 3-2. Hip Stabilizing Frame.

The hip stabilizing frame was constructed from a polyvinyl carbonate (PVC) material in order to make the frame both sturdy and lightweight for transport across the country. The frame was designed at 90 degree angles to keep the hip in 90 degrees of hip flexion. 90 degree t-shaped connector tubes were used to maintain the 90 degree angle, while also allowing for the frame to be dismantled for transportation. Velcro straps were placed approximately one-third of the distance from the top of the frame. The backboard of the frame was made from a sturdy, yet lightweight plastic.

During the testing procedures, the frame was placed on a stable, wooden table or bench.

Protocol

Upon arrival at their initial testing session, subjects read and signed the Adult Informed Consent form. Subjects who were minors had the consent form sent to their home in hard copy for their parents to sign prior to the testing session. Parents were provided with the researcher's contact information should they have any questions regarding the study. Each subject then completed a subject information sheet (Appendix B). Prior to testing, each subject's anthropometric measurements (height, weight, tibial and femoral lengths) were assessed and the subjects performed the pre-stretching exercise, as described in the next section. All subjects were tested bilaterally. Subjects were randomly assigned a starting limb upon arrival for their testing session, via a coin toss (heads: right leg; tails: left leg). The dominant limb was determined by asking the subject which leg they would use to kick a ball at a target. Time of day of the test was also recorded so that post testing protocols could be performed at a similar time of day.

Anthropometric Measurements

Upon completion of the explanations for the testing procedures, the signing of the adult informed consent form, and the subject information sheet, anthropometric measurements were determined.

The subject's mass, in kilograms, was determined using an electronic scale, which was calibrated prior to the start of each session. Calibration was completed using a five kilogram weight, and a calibration dial on the scale. Each subject's height, in meters, was assessed using a wall scale. The length of the subject's femur, in meters, was measured as the distance between the anterior superior iliac spine and the lateral joint line of the knee. The length of each subject's tibia, in meters, was measured as the distance between the medial joint line and the medial malleolus of the tibia. A standard measuring tape was used to determine the femoral and tibial measurements.

Pre-Test Stretching

Prior to testing, each subject performed four (4) hamstring stretches using a towel assisted passive knee extension technique. Each stretch was held for 30 seconds, and conducted bilaterally. As per Taylor et al (1990), the pre-testing stretches were performed to minimize the effects of an increase in stretch tolerance and, a subsequent increase in range of motion during the initial stretches. The protocol for pre-test stretches was similar to those performed in earlier studies (Gadjosik et al, 1993; Webright et al, 1997; Diakow, 2001).

Stretching Protocols for the Six-Week Stretching Program

All subjects were physically shown the proper technique for the hamstring stretch using the towel assisted passive knee extension technique. Each subject received a diagram and written instructions (Appendix C) regarding the stretching protocol, prior to testing. All subjects were instructed to perform all stretches to the point where they felt a strong, comfortable stretch (pain free). The stretching protocol during the six-week stretching program was the same as that utilized during the testing protocol.

Supervision of Training

Athletic therapy certification candidates who were assigned to the team supervised the University of Manitoba women's hockey team during their training sessions. The certification candidates recorded the athletes' attendance and were permitted to correct any improper stretching techniques (Appendix D). The certification candidates assisting with the supervising of the programs were shown the proper stretching protocol. For the unsupervised group (Canadian National Ringette team), each subject was asked to complete a daily training logbook (Appendix D).

Passive Knee Extension Test

The passive knee extension (PKE) test was conducted in a hip-stabilizing frame, designed to maintain the subject's hip joint at 90 degrees of flexion. With the upper leg secured in the frame at 90 degrees, the knee was placed at 90 degrees of flexion for the starting point, which represented zero degrees of knee flexion for the purpose of this study. The hip-stabilizing frame was similar to that used by Bruce (1989) and Diakow (2001). The test leg was secured to the frame with two Velcro straps, approximately 1/3 from the distal end of the femur. The primary examiner was positioned to the side of the subject to ensure that she was blinded to the reading. The subject was asked to close her eyes during the testing protocol, to eliminate visual perception of the movement and assist in the relaxation of the muscle. The subject was asked to relax the leg. The research assistant positioned the inclinometer on the tibial tubercle, and the inclinometer was activated. The tibial tubercle was selected for the inclinometer placement to ensure consistent landmark placement between the pre-test and the posttest sessions. Starting in a position of 90 degrees of knee flexion, the primary examiner passively extended the subject's knee until the examiner felt resistance to the stretch. This position was considered the end point of the movement, per prior research (Starring et al, 1988; Gajdosik et al, 1993; Bandy & Irion, 1994; Bandy et al, 1997, Diakow, 2001). The knee was held at the end point briefly to allow the research assistant to record the measurement on the inclinometer. The subject's knee was then passively returned to the starting position.

As per Starring et al (1988) and Diakow (2001), four practice trials were performed in a range of motion short of maximal extension to familiarize the subject to the movement, prior to the actual testing. Three maximal range of motion tests were conducted, with a rest period of no more than ten seconds between tests. The average of the three test scores was recorded as the final value. The values were recorded on pre-test and posttest data collection sheets (Appendix E).

Program Compliance

The subjects within the unsupervised group recorded their compliance to the stretching program by completing a logbook (Appendix D). The logbooks were submitted, via email, to the research assistant at the beginning of the following week. The research assistant retained all of the logbooks until the posttest phase was completed.

The subjects within the supervised group had their compliance recorded by the athletic therapy certification candidate that was working with the team. The certification candidate retained the attendance sheets (Appendix D) until the posttest phase was completed. The subjects were given credit for their compliance if they attended the session and completed all repetitions.

Data Analysis

The PKE tests were conducted and recorded manually at the time of the test using an inclinometer by a research assistant, for both the pre-test and post-test scores. With the hip secured in the hip-stabilizing frame at 90 degrees, the knee was placed at 90 degrees of flexion for the starting point, which represented zero degrees of knee flexion for the purpose of this study. A goniometer was used to ensure that both the hip and the knee were in 90 degrees of knee flexion prior to testing. The inclinometer was zeroed at this position, and the flexibility was recorded as the number of degrees of movement. Three trials were completed with the average of the scores utilized as the final test score.

Statistical Analysis

Several statistical analyses were performed to evaluate the effects of supervision on a six-week stretching program for the hamstrings, and to examine limb dominance. For all analyses, mean values were calculated to two decimal places for each test variable. All statistical analyses were performed using the Microsoft 2000 SR-1 Standard Excel program on an IBM computer. Statistical significance levels were set at $p<0.05$.

Supervised Program versus Unsupervised Program

The primary purpose of the study was to evaluate the effects of supervision on a six-week stretching program for hamstrings. One dependent t-test was calculated on the pretest to posttest change for both the unsupervised and the supervised group. The alpha level (0.05) was adjusted with the Bonferroni method by dividing 0.05 by the number of t tests performed (two) to prevent an inflation of the type I error rate. Therefore, in all of the t test analyses the rejection region was $p<0.025$. These dependent t tests were performed to assess if either group had significantly increased their hamstring flexibility following the six-week stretching program.

A single factor ANOVA was calculated to assess whether any significant differences existed in the pretest scores across the unsupervised and the supervised groups. The analysis was performed to assess if any significant differences existed between the groups prior to the six-week stretching program.

A second single factor ANOVA was calculated to assess whether any significant differences existed in the posttest scores across the two groups. The analysis was performed to assess if any significant differences existed between the unsupervised and the supervised groups. Significance for all statistical analyses were accepted at $p<0.05$, unless otherwise indicated.

A third single factor ANOVA was calculated on the gain scores in an attempt to summarize the data for significant difference between the unsupervised and supervised groups.

Non-dominant Limb versus Dominant Limb

The second purpose of the study was to evaluate the effects of a six-week stretching program for hamstrings on limb dominance. One paired t-test was conducted on the gain scores for the non-dominant limb and the dominant limb scores. The dependent t test was performed to assess if either limb had significantly increased its hamstring flexibility following the six-week stretching program.

Three single factor analyses of variances were conducted to see if there was any change across the pre-test score, the post-test score, and if there was any difference between the non-dominant limb and the dominant limb after the six-week stretching program.

A single factor ANOVA was calculated to assess whether any significant differences existed in the pretest scores between the non-dominant limb and the dominant limb. The analysis was performed to assess if any significant differences existed between the limbs prior to the six-week stretching program.

A second single factor ANOVA was calculated to assess whether any significant differences existed in the posttest scores across the two limbs. The analysis was performed to assess if any significant differences existed between the non-dominant limb and the dominant limb.

A third single factor ANOVA was calculated on the gain scores in an attempt to summarize the data for significant difference between the non-dominant limb and the dominant limb. Significance for all statistical analyses were accepted at $p<0.05$, unless otherwise indicated.

Group By Limb Dominance Interaction

A two way ANOVA was conducted to investigate for any group by limb dominance interaction. Significance for the analysis was accepted at $p<0.05$.

Pilot Study

A pilot study was conducted to (1) to provide the primary examiner with practical experience in performing the passive knee extension protocol, (2) to ensure that both the verbal and the written instructions to subjects were clear and concise, and (3) to obtain feedback from the subjects regarding the unsupervised training log. Ethics approval was received from the Education / Nursing Research Ethics Review Board prior to conducting the pilot study.

Subjects

Ten active and healthy subjects (3 female, 7 male) participated in the pilot study. The subjects were recruited by personal communication with the investigator. All of the subjects were free of hamstring injury within the three months prior to the pilot study. The subjects' anthropometric data are given in Table 3 – 1.

Materials

The materials utilized in the pilot study were the same as those listed previously in the chapter.

Protocol

The protocol for the pilot study was the same as the protocol previously described in the chapter. Upon their arrival, the subjects read and signed the Adult Informed Consent form, which was then signed and dated by the Investigator and a witness. Anthropometric measurements (height, weight, femoral length, tibial length) were taken for each subject and each subject performed four (4), bilateral, towel assisted passive knee extensions (30-second duration for each). Each subject was then assessed, bilaterally, via the Passive Knee Extension test.

Table 3 – 1: Anthropometric Data

Subject	Age, yrs	Height, m	Weight, kg	TibFem Ratio (D), m	TibFem Ratio (ND), m
Subject # 1	28	1.75	79	.89	.89
Subject # 2	28	1.68	74	.92	.92
Subject # 3	24	1.67	65	.97	.97
Subject # 4	24	1.63	67	.95	.95
Subject # 5	28	1.80	83	.93	.93
Subject # 6	28	1.75	79	.92	.92
Subject # 7	29	1.62	63	.84	.84
Subject # 8	30	1.62	67	.76	.76
Subject # 9	33	1.86	83	.90	.90
Subject # 10	36	1.89	88	.96	.96

Upon completion of their pre-test measurements, each subject received written explanations regarding their one-week stretching protocol and their one-week logbook.

Data Analysis

The methods of data analysis were the same as those previously described in this chapter. Three trials were conducted, with the average of the three scores being recorded as the final value.

Results

The results of the pilot study are summarized in Table 3 – 2.The final pre-test and post-test scores for the PKE are given for each subject, and for the dominant (D) and non-dominant (ND) limbs.

Table 3 – 2: Pilot Study Raw Data – Range of Motion (degrees)

Subject	**Pre-Test (D)**	**Post-Test (D)**	**Pre-Test (ND)**	**Post-Test (ND)**
Subject # 1	23	25	26	27
Subject # 2	18	21	20	24
Subject # 3	14	17	12	14
Subject # 4	7	10	7	11
Subject # 5	8	9	8	8
Subject # 6	9	12	12	13
Subject # 7	14	17	16	18
Subject # 8	21	22	19	22
Subject # 9	17	17	18	18
Subject # 10	12	14	11	15

Figure 3-1 illustrates the gain in hamstring flexibility, for both the dominant and non-dominant leg, following the completion of the one-week stretching program.

Discussion

An intrarater reliability of the measurement of hamstring muscle flexibility using the passive knee extension test was evaluated using a test – retest (1-week apart) design on the 10 subjects. The intraclass correlation coefficient (ICC[1,1]) was .98 for the dominant leg and .92 for the non-dominant leg, which was considered appropriate for this study.

The data was not further statistically analyzed, as the subject pool was comprised mainly of male subjects and therefore the results could not be compared to the actual

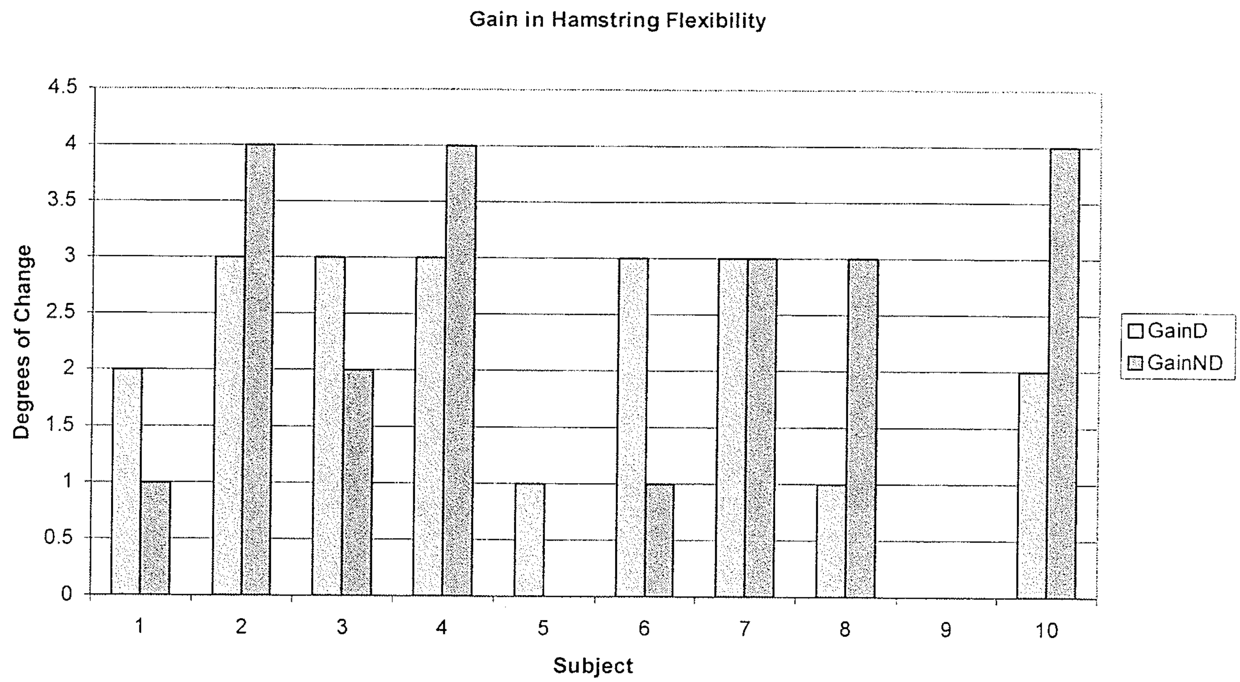

Figure 3-3: Gain in Flexibility.

study group.

While the majority of the subjects showed some gain in flexibility after the one-week stretching period, subject five had zero degrees of gain in flexibility of their non-dominant limb, while subject nine had zero degrees of gain in flexibility in both limbs.

The subjects all reported that the written instructions regarding the stretching program protocol were clear and had no difficulty following the program. As well, the subjects all reported that they had no difficulty completing the daily logbook. Some subjects reported that the logbook served as a useful reminder to complete their stretching program.

CHAPTER 4

Results

Subjects for this study included 47 elite female athletes from either the University of Manitoba women's hockey team or the Canadian National Ringette team. There were 22 subjects in the supervised group, represented by the women's hockey team, and 25 subjects in the unsupervised group, represented by the Canadian National Ringette team. The descriptive data for the subjects are illustrated in Table 4-1.

Table 4-1. Descriptive Subject Data, mean (SD)

Group	Age	Height, m	Weight, kg	BMI*	ND TibFem**	D Tib Fem**
Supervised	19.68 (1.86)	1.66 (0.07)	65.73 (7.07)	39.53 (3.80)	0.72 (0.04)	0.72 (0.04)
Unsupervised	23.60 (3.19)	1.66 (0.06)	63.96 (6.31)	38.67 (3.24)	0.77 (0.04)	0.77 (0.04)

* Body Mass Index
** Non-dominant / Dominant Tibia Femoral Ratio

Six single factor ANOVAs were conducted to determine if any significant differences existed between the unsupervised and the supervised groups for the above anthropometric data. All six analyses revealed that there were no significant differences ($p<0.05$) between the groups regarding their anthropometric data.

Unsupervised and Supervised Group Comparison

The means and standard deviations for the pretest, the post-test, and the gain scores are reported in Table 4-2. These score are reported for the unsupervised and the supervised groups.

Table 4-2.Summary of the single factor ANOVA between supervised and unsupervised training groups.

Test	Group	n	* Mean $\pm$ SD	F value	p value
Pre-test	Unsupervised	50	76.04$\pm$9.12	1.83	0.18
	Supervised	44	73.45$\pm$9.39		
Post-Test	Unsupervised	50	84.86$\pm$7.62	0.02	0.89
	Supervised	44	84.68$\pm$3.48		
Gain	Unsupervised	50	8.84$\pm$8.19	1.71	0.19
	Supervised	44	11.27$\pm$9.87		

* Mean and Standard Deviation for Range of Motion in Degrees.

Three single factor ANOVAs were conducted to determine if any significant differences in hamstring flexibility existed between the unsupervised group and the supervised group prior to and upon completion of the six-week stretching program of the hamstrings. All three analyses revealed that there were no significant differences ($p<0.05$) in the flexibility of the hamstrings between the unsupervised and the supervised groups.

The two dependent t tests calculated (using the Bonferroni correction to avoid inflation of the alpha level) on the pretest to posttest change for the supervised group and the unsupervised group indicated significant increases in the flexibility of the hamstrings in the unsupervised group ($df = 49$, $t = 8.17$, $p<0.025$). There was no significant change in the flexibility of the hamstrings in the supervised group ($df = 43$, $t = 1.00$, $p<0.025$).

Non-dominant and Dominant Limb Comparison

The means and standard deviations for the pretest, the post-test, and the gain scores are reported in Table 4-3. These score are reported for the non-dominant limb and the dominant limb.

Table 4-3. Summary of the single factor ANOVA of hamstring flexibility for dominant and non-dominant limbs.

Test	Group	n	* Mean $\pm$ SD	F value	p value
Pre-test	Non-dominant	47	75.02±9.13	0.040	0.84
	Dominant	47	74.64±9.53		
Post-Test	Non-dominant	47	84.15±6.73	1.02	0.31
	Dominant	47	85.40±5.21		
Gain	Non-dominant	47	9.17±8.29	0.75	0.39
	Dominant	47	10.79±9.76		

* Mean and Standard Deviation for Range of Motion in Degrees.

Three single factor ANOVAs were conducted to assess for any significant differences in flexibility existed between the non-dominant limb and the dominant limb prior to and upon completion of the six-week stretching program for hamstrings. All three analyses revealed that there were no significant differences ($p<0.05$) in the flexibility of the hamstrings between the non-dominant limb and the dominant limb.

The dependent t tests calculated on the gain scores for the non-dominant limb and the dominant limb indicated no significant change in the flexibility of the hamstrings in either the non-dominant limb or dominant limb ($df = 46$, $t = 0.19$, $p<0.05$).

Group and Limb Dominance Interaction

A two-way ANOVA was conducted to investigate any group by limb dominance interaction (Table 4-4). The analysis revealed that there was no significant difference among limb dominance after allowing for the effects of the differences in the groups. As well, there was no significant difference among the groups after allowing for the effects of the differences in limb dominance. Finally, the effect of different levels of limb dominance did not depend on the group, as such there is no statistically significant interaction between the groups and limb dominance ($p<0.05$).

Table 4-4: Summary of Two Way ANOVA for Interaction.

Source of Variation	**Degrees of Freedom**	**SS**	**MS**	**F**	**P**
Dominance	1	68.51	68.51	0.84	0.36
Group	1	138.51	138.51	1.69	0.196
Dominance X Group	1	50.64	50.64	0.62	0.43
Residual	90	7359.36	81.77		
Total	93	7609.96	81.83		

Stretching Program Supervision and Compliance

The means and standard deviations for the stretching program compliance for the unsupervised and the supervised group are reported in Table 4-5. Reasons for missed sessions are also reported. Figure 4.1 illustrates the compliance for all subjects.

Table 4-5. Stretching Program Compliance (%).

Group	n	Mean $\pm$ SD	Reasons for Noncompliance
Unsupervised	25	83.92$\pm$29.51	Lack of time; personal matters / events
Supervised	22	77.86$\pm$15.32	University lecture / lab scheduled during practice; lack of interest / did no feel like doing the stretches

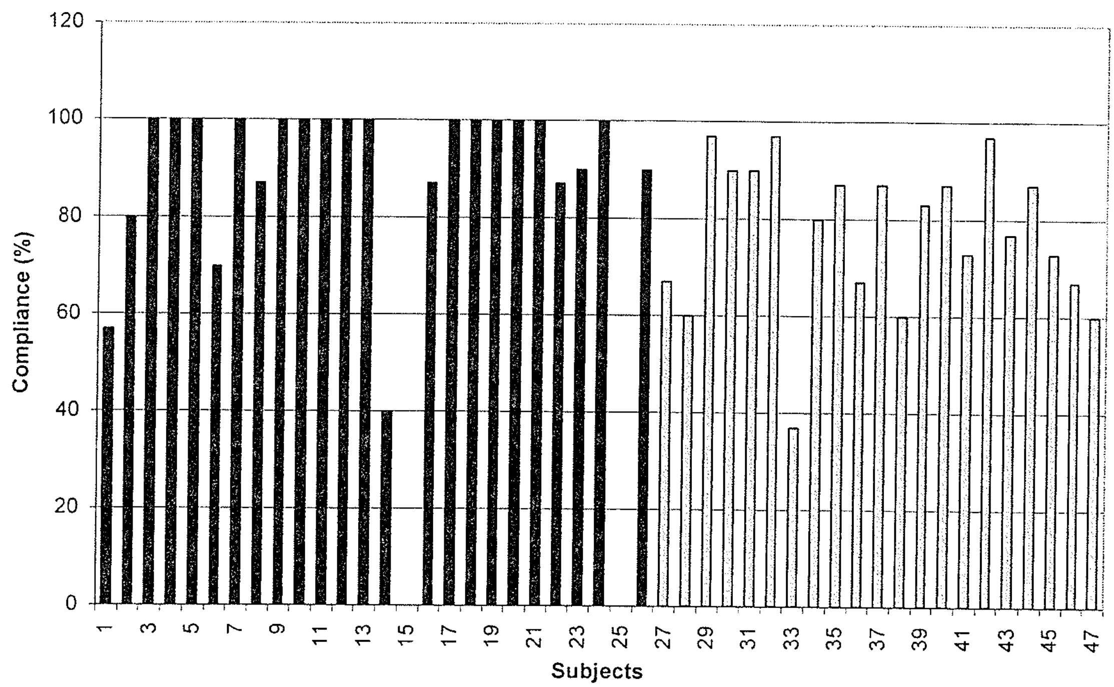

Figure 4.1. Stretching Program Compliance. (Black = Unsupervised; Grey = Supervised)

Three ANOVAs were conducted to assess if there were any significant differences between the unsupervised group and the supervised group regarding their compliance to the six-week stretching program, as well as their gain in flexibility. All three analyses revealed that there were no significant differences ($p<0.05$) between the unsupervised group and the supervised group for program compliance, as well as for gain in flexibility for the non-dominant and the dominant limb as it compared to compliance.

Chapter 5

Discussion

Flexibility has long been considered an integral component of training programs and the regular routine for most athletes, especially those competing at an elite level (Starring et al, 1988, Magnusson et al, 1998). Good muscle flexibility allows the muscle tissue to accommodate to the imposed stresses more easily, thereby allowing for more efficient and effective movements. The increased efficiency and effectiveness in movements assists in the prevention or minimization of injuries and possibly enhanced performance (Bandy et al, 1998).

Clinically, therapists are routinely expected to provide clients with home programs, which typically consist of stretching and strengthening exercises. "Once the client is discharged from therapy, the rate of continued compliance with the home exercise program has been found to be as low as 35%" (Willy et al, 2001). There is a lack of studies evaluating the compliance rates among elite athletes.

The majority of the research studies evaluate the effectiveness of a stretching program on the flexibility of a muscle group. The limb selected for evaluation is randomly chosen, with the right limb typically selected by the researcher. Although Worrel et al (1991) examined the rate of hamstring injury for limb dominance; there is a lack of studies evaluating the effects of a stretching program on the flexibility of the non-dominant and dominant limbs.

The primary purpose of this study was to examine the effects of supervision on a six-week stretching program for hamstrings.

A secondary purpose of this study was to examine if significant differences existed for limb dominance upon completion of a six-week stretching program.

This study will allow therapists to design stretching programs more effectively for their clients by providing information regarding the effects of supervision on client compliance to their programs, as well as indicate the potential need for a focus on limb dominance.

Subjects

Participants in this study included members of the Canadian National Ringette team (N=25) and the University of Manitoba women's hockey team (N=22).
The Canadian National Ringette team was selected because the national team athletes are required to train unsupervised, in their respective cities between training camps, which are scheduled once every couple of months. The Canadian National Ringette team, therefore, represented an ideal unsupervised group. The University of Manitoba women's hockey team was selected because of the elite abilities of the athletes, the sport's similarity to ringette (i.e. incidental contact, skating skills), and the fact that the team trained on a daily basis, with student therapists present for all training sessions, and therefore represented an ideal supervised group.

Analysis of Test Results

Effects of Supervision

Home programs and frequent requests for treatment extensions is a common practice for most therapists providing rehabilitation services. The insurance companies prefer to have clients progressed to home programs. Therapists routinely would like additional time with their clients ensuring that they are performing the exercises appropriately and effectively, so that the client can have the best recovery possible and minimize the recurrence of their injury.

Mean gain flexibility scores for the unsupervised group were 8.84 $\pm$ 8.19 degrees and 11.27 $\pm$ 9.87 degrees for the supervised group. The between group scores were not considered to be significant for this study ($p<0.05$).

The gain scores reported in this study within the unsupervised and supervised groups were comparable to those reported in the literature for six-week stretching programs for the hamstrings, in which subjects stretched five times per week. A study by Willy et al (2001) that evaluated the effects of cessation and resumption of a hamstring muscle stretching program on knee range of motion reported a mean gain of 9.3$\pm$1.7degrees following the initial period of stretching. This gain in the initial stretching period was considered to be significant ($p<0.05$). In 1998, Bandy et al conducted a study to compare the effects of dynamic range of motion training with static stretch on hamstring flexibility. The mean gain scores reported for the static stretch group was 11.42 degrees, which was considered to be significant ($p<0.05$). As well, Bandy et al (1997) evaluated the effect of time and frequency of static stretching on hamstring muscle flexibility. This study appeared to be an expansion of a study conducted by Bandy and Briggler (1994) that examined only the length of time the hamstring muscle should be held in a stretch. The 1997 study reported a mean gain score of 10.05 degrees ($p<0.05$), while the 1994 study reported a mean gain score of 12.50 degrees ($p<0.05$). Although the 1997 and 1994 studies conducted by Bandy and his associates also evaluated other times and frequencies for periods of stretching only those values that matched the present study were reported. All of the above studies were conducted on unsupervised subjects.

Although the results did not show a significant difference between the unsupervised group and the supervised group, they did confirm the effectiveness of the six-week stretching program. It may be important to ensure that the individual fully understands the benefits of their program and are educated on the proper techniques for the components of their program, subsequently increasing their program compliance and its benefits rather than actually supervising the individuals performing the program.

Limb Dominance

As a part of human nature, humans early on in life select a dominant limb, most often referred to as right-handed or left-handed. Similarly, humans also show preference for lower limb dominance in sport (Alter, 1993). Although there is plenty of research evaluating the effectiveness of stretching on the lower limb, most notably the hamstring muscles, there is a lack of research that distinguishes between the dominant limb and the non-dominant limb. In fact, the majority of the research evaluates subjects bilaterally utilizing one leg as the control leg, with the right leg most often randomly selected to be the test leg. This particular protocol for evaluation is typically used because, as reported by Willy et al (2001), "there is no known effect of stretching (one) leg on the (range of motion) of the other leg".

The mean gain scores for this study were 9.17 ± 8.29 for the non-dominant limb and 10.79 ± 9.76 for the dominant limb. These scores were consistent with the literature previously reported on for a six-week stretching program for the hamstring muscles. The between group scores for limb dominance were not significant ($p<0.05$).

Program Compliance

In essence the supervision of the program lends itself to the concept of program compliance. Are clients who are supervised more apt to complete their exercises and complete them appropriately, than their unsupervised counterparts thereby, yielding more significant gains in muscle flexibility? Would the dominant limb of the supervised group have yielded a significant result had the subjects within that group had a greater rate of compliance? In 1993, Sluijs et al, reported that prolonged supervision was a "strong factor in compliance", yet the results of the supervised group were not significantly different from those of the unsupervised group for the current study. Also of note, Sluijs et al reported that the relationship between the patient and the therapist was considered to be important, and that a closer relationship led to more program satisfaction and adherence. Such a relationship may be evidenced in the compliance rate by the unsupervised group, for which the researcher was also the team's athletic therapist. Subsequently the increased compliance may have ultimately played a role in the lack of a significant difference between the two groups. Perhaps if the subjects within the unsupervised group did not have such a strong relationship with the researcher, they may not have been as compliant to their stretching program, and subsequently not attained as great of gains in hamstring flexibility. Although the certification candidates working with their team monitored the supervised group, the actual study was for someone for whom they were not acquainted with. This factor may have affected their rate of compliance and subsequently their scores.

The reality of unsupervised home programs is that some people will comply 100% of the time, some of the people will comply most of the time, and some of the people will only comply some of the time, while others will not complete their program at all (0%). For this reason, those subjects that had zero compliance were retained within the study in order to truly represent an unsupervised home program.

Summary of Discussion

This study was conducted to evaluate the effects of supervision of a six-week stretching program on the flexibility of the hamstring muscles. The effects of limb dominance were also examined. No significant differences were found as a result of a supervised program versus an unsupervised program. As well, no significant effects were noted between the non-dominant limb and the dominant limb groups as a whole, although within the supervised group there was a significant difference only with the non-dominant limb. The present study did confirm that long-term stretching programs are effective for the hamstring muscles, but that the supervision of the program and the dominance of the limb may not be as important as compliance to the program.

Chapter 6

Summary, Conclusion, and Recommendations

Summary

Flexibility and stretching programs have long been a staple of training and rehabilitation programs. The effectiveness of long-term stretching programs for the hamstring muscles in particular is well documented and supported. These studies typically evaluate the effectiveness of the program or the time and / or frequency of the stretches within the prescribed programs. However, the effect of supervision on the success of the stretching program is lacking. As well, there is no research investigating whether or not limb dominance should be factored into one's program.

The purpose of this study was to evaluate the effects of supervision on a six-week stretching program for hamstring flexibility. A secondary purpose was to compare the effectiveness of a six-week stretching program on the dominant leg versus the non-dominant limb.

Fourty-seven subjects participated in this study, including members of the Canadian National Ringette team (N=25) and the University of Manitoba women's hockey team (N=22). The Canadian National Ringette team was selected because the national team athletes are required to train unsupervised, in their respective cities between training camps, which occur once every couple of months. The Canadian Ringette team, therefore, represented an ideal unsupervised group. The University of Manitoba women's hockey team was selected because of the elite abilities of the athletes, the sport's similarity to ringette (i.e. incidental contact, skating skills), and the fact that the team trained on a daily basis, with student therapists present for all training sessions, and therefore represented an ideal supervised group.

Single factor analyses of variance (ANOVA) were conducted to determine if significant differences existed between the unsupervised and the supervised groups, and the non-dominant limb and the dominant limb. There was no significant difference between the unsupervised group and the supervised group ($p<0.05$). As well, there was no significant difference between the non-dominant limb and the dominant limb ($p<0.05$). T tests conducted to evaluate the effect of limb dominance within the unsupervised and supervised groups revealed that significant effects existed within the unsupervised group for both the non-dominant and the dominant limb, and within the supervised group for the non-dominant limb ($p<0.01$). There was no significant effect found within the supervised group for the dominant limb ($p<0.01$).

The results of this study confirm that long-term stretching programs do have a significant effect on the flexibility of the hamstring muscles; however, there is no evidence to support the role of supervision for those programs or the need to modify the program according to the individual's dominant limb.

Conclusions

1) There were no significant differences in the gain scores for hamstring muscles for the unsupervised group and the supervised group. The effect of a stretching program on the hamstring muscles appears to be unrelated to the supervision of the actual program.

2) There were no significant differences in the gain scores for hamstring muscles in the non-dominant limb and the dominant limb. The effect of a stretching program on the hamstring muscles appears to be unrelated to limb dominance.

3) There was a significant difference within each group on the gain scores of the hamstring muscles. The effectiveness of a six-week stretching program on the hamstring muscles continues to be supported by research.

4) Although not statistically supported, there appears to be confirmation of the influence of the relationship between the therapist and the subject regarding program compliance.

Recommendations

The following recommendations have been made based on the current study and may of benefit to future research in similar investigations.

1) Research should continue to evaluate the effects of supervision on the flexibility of the hamstring muscles. However, the primary researcher should not have an established relationship with either group of subjects. This will serve to remove the therapist – subject relationship and therefore its influence on program compliance.

2) Future research in the area of limb dominance should ensure a more balanced grouping within the dominance. I.e. that there be more subjects that are left limb dominant. The majority of the current research randomly selected the right limb for testing, and this study had the vast majority of the dominant limbs represented by the right limb.

3) Future studies should be conducted on the general public, as opposed to elite athletes. This would serve to remove the motivation factor and the already established understanding of the importance of flexibility.

4) Studies utilizing male subjects only or mixed groupings should be conducted. This study included only female subjects, and all other research in the effectiveness of a stretching program on the hamstring has been conducted on mixed groupings.

5) Future studies should adjust the protocol for the stretching program so that the subjects are stretching more than one time per day. This may serve to increase the effects on flexibility.

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Appendix A

Example of Informed Consent Form signed by all participants.

CONSENT TO PARTICIAPTE IN RESEARCH STUDY

TITLE: Flexibility Programs for the Hamstrings
A Comparison of Supervised Versus Unsupervised Flexibility Programs

RESEARCHER: Connie Klassen

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

1. Description of the Study

You have volunteered to participate in a study that will gather information on the effectiveness of supervised stretching programs versus unsupervised stretching programs on hamstring muscles. A secondary purpose to this study is to evaluate the effectiveness of a six – week stretching program on the dominant leg versus the non-dominant leg.

2. Study Procedures

Sixty participants will undergo physical testing. During the initial assessment session, baseline information will be collected regarding physical and anthropometric data (i.e. height, weight, etc.). You will perform five stretches, per leg, followed by the assessment of hamstring flexibility. Each assessment session will be approximately a ½ hour in length.

You will then undergo a six – week stretching program designed to increase your hamstring flexibility. During the course of the stretching program you will a) complete and submit a Daily Personal Stretching Log, or b) attend a supervised stretching session where you will have your attendance recorded.

Following the completion of the stretching program, your hamstring flexibility will be re-assessed (same protocol as for the initial assessment session).

3. Discomfort and Risk

Participants may experience mild discomfort associated with stretching of the hamstring muscles. This discomfort would be like that which you would feel during normal daily physical activity.

4. Recording Devices

A digital inclinometer will be used to record your hamstring flexibility. The inclinometer will record your flexibility in degrees.

5. Confidentiality

The principal investigator and health care providers associated with this study will treat your identity and health information with professional standards of confidentiality. However, certain authorizing agencies, such as the University of Manitoba Health Research Ethics Board, may have the right to inspect any or all of your records relating to this research for the purpose of verifying data. In all cases the identity of participants will be treated in confidence and in accordance with the Personal Health Information Act of Manitoba and the Personal Information Protection and Electronic Documents Act. Any information gathered will be used only for the stated research purposes, and will not be utilized for team selection purposes.

6. Feedback

You will receive written feedback of the results and findings of the study via mail. You will also receive a copy of your personal results.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and / or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

Connie Klassen (Principal Investigator)
Phone: (204) 474-6004
E-mail: klassenc@ms.umanitoba.ca

Dr. Glen Bergeron (Advisor)
Phone: (204) 786-9190
E-mail: g.bergeron@uwinnipeg.ca

This research has been approved by the University of Manitoba's Education / Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above – named persons or the Human Ethics Secretariat at (204) 474-7122, or e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Name of Participant

Signature of Participant

Date

Name of Legal Guardian

Signature of Legal Guardian

Date

Signature of Investigator

Date

Signature of Witness

Date

Appendix B

Subject Information Sheet

Subject Information Sheet

Date: ____________________ Subject ID # ____________________

Name: ____ Age: ________

Address: ____

____

Phone Number: ________________________ Email: ______________________________

SUPERVISED GROUP: _______ UNSUPERVISED GROUP: _______

DOMINANT LIMB: _______

I, ______________________, agree to be contacted for future research that may develop as a result of the current study.

______________________________ ____________________

Signature Date

I, ______________________, DO NOT wish to be contacted for future research that may develop as a result of the current study.

______________________________ ____________________

Signature Date

Subject ID #: _____________

Study Title: Flexibility Programs for the Hamstrings: A Comparison of Supervised Versus Unsupervised Flexibility Programs

Academic Institution: University of Manitoba

Study Coordinator: Connie Klassen

Contact #: (204) 474-6004

Email: klassenc@ms.umanitoba.ca

Appendix C

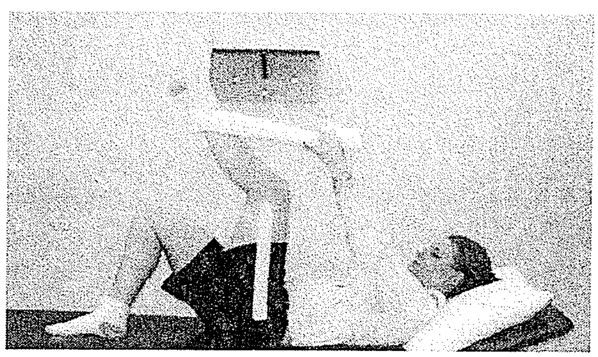
Six-Week Stretching Program

Hamstring Stretch

- This six (6) week stretching program is designed to develop hamstring flexibility.
- It should be carried out five days per week (please complete Daily Stretching Log as attached or check in with session supervisor).
- A 10 minute cardiovascular warm-up is recommended (such as walking, running, and cycling) prior to the start of each stretching session.
- The stretch should be done 4 times on each leg, with each stretch being held for approximately 30 seconds.
- Over the 30 seconds, the stretch you feel should slowly dissipate or decrease.
- The stretch should pain-free.
- A 30 second rest period between stretches.

Key Points:

✓ Start in a lying position, with the opposite leg in a flexed position.
✓ The thigh should be positioned perpendicular to the floor.
✓ Place a towel around your ankle.
✓ Straighten your leg by pulling your ankle forward until a strong, comfortable stretch is felt.
✓ Maintain tight abdominal muscles.
✓ Hold each stretch for 30 seconds.
✓ Repeat 4 times, and then switch legs.



Appendix D

Record of Program Compliance

Unsupervised Group Training Logbook

SUBJECT ID #: ____________________

WEEK ONE:	SESSION DATE:	TIME OF DAY (M / A / E)	REPS COMPLETED (YES / NO)	IF NO, PLEASE EXPLAIN

WERE ALL STRETCHING SESSIONS COMPLETED FOR THIS WEEK? YES / NO

IF NO, PLEASE EXPLAIN: ____________________

PLEASE SUBMIT TRAINING LOG FOR WEEK ONE.

SUBJECT ID #: ____________________

WEEK TWO:	SESSION DATE:	TIME OF DAY (M / A / E)	REPS COMPLETED (YES / NO)	IF NO, PLEASE EXPLAIN

WERE ALL STRETCHING SESSIONS COMPLETED FOR THIS WEEK? YES / NO

IF NO, PLEASE EXPLAIN: ____________________

PLEASE SUBMIT TRAINING LOG FOR WEEK TWO.

Supervised Group Daily Log Sheet

Date: ____________________

SUBJECT ID #	TIME OF DAY (M, A, E)	REPS COMPLETED (Y/N)	IF NO, PLEASE EXPLAIN
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			

Appendix E

Data Collection Sheets

Pre – Test Data Collection Sheet

Date: ____________________ Subject ID #: ____________________

Supervised Group _________ Unsupervised Group _____________

Time: ___________________

ANTHROPOMETRIC MEASUREMENTS:

Height (m): ____________

Mass (kg): ____________

Femoral Length (m): Right _______ Left ________

Tibial Length (m): Right _______ Left ________

PASSIVE KNEE EXTENSION SCORES (deg):

	R	L
Trial # 1:	____________	____________
Trial # 2:	____________	____________
Trial # 3:	____________	____________

Average of the three values: ____________ ____________

Post – Test Data Collection Sheet

Date: ____________________ Subject ID #: ____________________

Supervised Group __________ Unsupervised Group ______________

Time: ____________________

PASSIVE KNEE EXTENSION SCORES (deg):

	R	L
Trial # 1:	____________	____________
Trial # 2:	____________	____________
Trial # 3:	____________	____________

Average of the three values: ____________ ____________

Appendix F

Subject Raw Data

Subject	DOM	Group	Compliance	Pre ND	Post ND	Gain ND	Pre D	Post D	Gain D
1	R	0	57	78	88	10	72	89	17
2	R	0	80	87	89	2	80	85	5
3	R	0	100	80	89	9	63	93	30
4	R	0	100	74	89	15	85	97	12
6	L	0	100	80	89	9	80	88	8
7	L	0	70	79	84	5	79	82	3
8	R	0	100	59	78	19	72	88	16
11	R	0	87	88	89	1	87	87	0
15	R	0	100	74	82	8	77	88	11
16	R	0	100	80	94	14	88	93	5
17	R	0	100	66	82	16	76	86	10
19	R	0	100	78	85	7	70	87	17
20	R	0	100	55	54	-1	82	79	-3
22	L	0	40	53	66	13	78	88	10
23	R	0	0	70	86	16	78	78	0
24	R	0	87	68	85	17	59	77	18
25	R	0	100	85	95	10	87	93	6
26	R	0	100	82	83	1	85	83	-2
27	R	0	100	77	78	1	84	88	4
28	R	0	100	56	88	32	59	88	29
29	R	0	100	84	91	7	83	95	12
30	R	0	87	82	82	0	79	88	9
31	L	0	90	83	88	5	78	81	3
33	R	0	100	74	77	3	72	69	-2
34	R	0	0	79	78	-1	78	84	6
36	R	1	90	79	87	8	76	88	12
37	R	1	67	73	84	11	72	86	14
38	R	1	60	85	88	3	86	88	2
40	R	1	97	82	84	2	84	82	-2
41	R	1	90	76	88	12	78	88	10
42	R	1	90	82	89	7	76	84	8
43	R	1	97	71	87	16	75	88	13
44	R	1	37	83	79	-4	85	81	-4
45	R	1	80	72	78	6	72	78	6
46	L	1	87	63	80	27	47	78	31
47	R	1	67	84	86	2	77	80	3
48	R	1	87	73	81	8	72	82	10
49	R	1	60	82	84	2	72	82	10
50	R	1	83	64	84	20	80	90	10
51	R	1	87	85	88	3	72	87	15
52	R	1	73	74	88	6	59	87	28
53	R	1	97	74	86	12	73	87	14
54	R	1	77	62	82	20	48	87	39
55	R	1	87	75	86	11	58	87	29
56	R	1	73	79	86	7	73	79	6
57	R	1	67	81	82	1	68	83	15
58	R	1	60	56	89	33	74	88	14

Appendix G

Pilot Study Raw Data

Subject	Compliance	PreND	PostND	GainND	PreD	PostD	GainD
1	100	26	27	1	23	25	2
2	100	20	29	4	18	21	3
3	100	12	14	2	14	17	3
4	100	7	11	4	7	10	3
5	100	8	8	0	8	9	1
6	100	12	13	1	9	12	3
7	100	16	19	3	14	17	3
8	100	19	22	3	21	22	1
9	100	18	18	0	17	17	0
10	100	11	15	4	12	14	2

Appendix H

Glossary

Agonist muscle: the muscle acting to cause a movement (Hall, 1995).

Antagonist muscle: the muscle that generates torque opposing that torque which is generated by the agonist muscle (Hall, 1995).

Elasticity: the ability of soft tissue to return to its resting length after passive stretch (Kisner & Colby, 1996).

Flexibility: the ability to move a single joint or a series of joints through an unrestricted, pain-free range of motion (Kisner & Colby, 1996).

Flexometer / Inclinometer: a rotating circular dial marked off in degrees and a pointer counterbalanced to ensure it always points vertically. It is strapped to the appropriate body segment and the range of motion is determined with respect to perpendicular (Anderson & Burke, 1991).

Golgi tendon organ: sensory receptor that inhibits tension development in a muscle and initiates tension development in antagonist muscles (Hall, 1995).

Hamstring flexibility: the number of degrees of range of motion, short of complete knee extension (Hartig & Henderson, 1999).

Hamstring inflexibility: operationally defined as a knee flexion angle greater than 15 degrees (Webright, Randolph & Perrin, 1997).

Muscle spindle: sensory receptor that provokes reflex contraction in a stretched muscle and inhibits tension development in antagonist muscles (Hall, 1995).

Plasticity: the tendency of soft tissue to assume a new and greater length after the stretch force has been removed (Kisner & Colby, 1996).

Range of motion: the amount of angular motion allowed at the joint between two bones (Kisner & Colby, 1996).

Reciprocal inhibition: the inhibition of the antagonist muscles resulting from activation of muscle spindles (Hall, 1995).

Static stretching: slow, passive elongation of a muscle to tolerance and sustaining that position for a period of time (Bandy et al, 1998).

Stretch Reflex: a monosynaptic reflex initiated by stretching of muscle spindles and resulting in immediate development of muscle tension (Hall, 1995).

Stretch tolerance: point where no more muscle stretch could be tolerated, and the passive stretch was stopped (Halbertsma et al, 1999).