AN INVESTIGATION INTO THE EFFECT OF STRETCHING FREQUENCY ON RANGE OF MOTION AT THE ANKLE JOINT.

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CERTIFICATE OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

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ABSTRACT

Stretching is a widely prescribed technique that has been demonstrated to increase range of motion. Consequently it may enhance performance and aid in the prevention and treatment of injury. Few studies have investigated the frequency of stretching on a daily basis. The purpose of this study was to investigate the effect of stretching frequency on range of motion at the ankle joint. The detraining effect was also investigated after a period without stretching.

Thirty-one female subjects participated in this study. They were randomly assigned to either a control group who did not stretch, a group who stretched two times per week (Stretch-2) or a group who stretched four times per week (Stretch-4). The stretching intervention was undertaken over four weeks and targeted the gastrocnemius and soleus muscles. Each stretch was held for a duration of 30 seconds and repeated five times. Prior to the intervention (PRE), dorsiflexion was measured using a weights and pulley system that passively moved the ankle joint from a neutral position into dorsiflexion. After the four-week stretching period (POST), dorsiflexion was measured once again to determine the change following the stretching programme. Following a further four week period where no stretching took place (FINAL), dorsiflexion was measured to determine the detraining effect. Electromyography was used to monitor the activity of the plantarflexors and dorsiflexors during the measuring procedure.

The results of the study showed a significant increase in ankle joint range of motion for the Stretch-4 group ($p<0.05$) when comparing PRE and POST measurements. The Stretch-2 and control groups did not show significant differences ($p>0.05$) between PRE and POST measurements. When comparing the PRE and FINAL measurements of the

Stretch-4 group, no significant differences were recorded (p>0.05). The POST and FINAL measurements were significantly different (p<0.05). After the detraining period the Stretch-4 group lost 99.8% of their range of motion gains.

The present data provide some evidence that the viscoelastic properties of the muscle stretched were unchanged by the four week static stretching programme. The mechanism involved in the observed increase in range of motion for the Stretch-4 group is possibly that of enhanced stretch tolerance of the subject. Further research is required to support this conjecture.

INTRODUCTION

STATEMENT OF THE PROBLEM

Despite the widespread use of various stretching techniques in sports and rehabilitation, there is limited knowledge with respect to efficacy of stretch and the mechanisms behind the observed adaptations to stretch of the human muscle-tendon unit in vivo (Magnusson et al., 1996a). An increase in range of motion is one of the observed effects of stretching (Bandy & Irion, 1994; Bannerman, Pentecost, Rutter, Willoughby, & Vujnovich, 1996; Henricson, Larsson, Olsson, & Westlin, 1983; McNair & Stanley, 1996; Sady, Wortman, & Blanke, 1982; Tanigawa, 1972). Increase in range of motion at a joint is thought to enhance performance through increased ability to absorb forces in the eccentric phase and therefore generate more force during the concentric phase of a muscle contraction (Wilson, Elliot, & Wood, 1992; Worrell, Smith, & Winegardner, 1994). Stretching has also been advocated in the prevention of injury (Ekstrand & Gillquist, 1982), possibly due to a decrease in muscle stiffness being observed after stretching (Rosenbaum & Hennig, 1995). In the rehabilitation setting stretching is useful to prevent and treat chronic muscle shortening and joint contractures due to immobilisation in injured patients (Sapega, Quedenfeld, Moyer, & Butler, 1981).

The mechanism for the increased range of motion that occurs when a muscle is stretched remains ambiguous. The neurophysiological foundations of some stretching techniques are based upon neural inhibition of the muscle undergoing stretch, which in turn causes a decreased reflex activity resulting in reduced resistance to stretch and a subsequent increase in range of motion (Hutton, 1993). Stretching has also been characterized in biomechanical terms in which the muscle-tendon unit is considered to respond viscoelastically during stretching (Taylor, Dalton, Seaber, & Garrett, 1990). More recently "an amplified stretch

tolerance" has been used to describe changes in range of motion that occur with stretching (Halbertsma, van Bolhuis, & Goeken, 1996; Magnusson et al., 1996a; Magnusson, Simonsen, Aagaard, Sorensen, & Kjaer, 1996b). It is thought that the subject's stretch perception changes with the stretch stimulus rather than the properties of muscle tissue.

Important components to a stretch programme are the frequency of stretching sessions performed per week, the duration or time a stretch is held for and the repetition or number of stretches performed in a session. To achieve the optimal outcome from stretching the most effective frequency, duration and repetition of stretch must be determined. Currently many prescriptions for stretching are not based upon sufficient objective information, as there is limited research in this area to justify specific programmes. The effect of more than one session per day has been examined (Bandy, Irion, & Briggler, 1997). The effect of several different durations of stretch within one study has also been investigated (Bandy & Irions, 1994; Borms, Van Roy, Santens, & Haentjens, 1987; Madding, Wong, Hallum, & Medeiros, 1987). The repetition of stretch required to increase range of motion has been studied in animal models (Taylor et al., 1990) and in human muscle (Magnusson et al., 1995; McHugh, Magnusson, Gleim, & Nicholas, 1992). However, there are no studies that compare the frequency of stretching in respect to number of days per week to stretch. The frequency of stretch used in the literature ranges from twice per week (Bannerman et al., 1996; Borms et al., 1987) to seven times per week (Gajdosik, 1991; Toft, Espersen, Kalund, Sinkjaer, & Hornemann, 1989; Webright, Randolph, & Perrin, 1997). There are no studies that compare frequencies across weeks. The lasting effect of stretching on range of motion once a programme has stopped is essentially unknown. Few studies have examined the process of loss in range of motion or the detraining effect (Tanigawa, 1972; Turner Starring, Gossman, Nicholson, & Lemons, 1988; Willy, Kyle, Moore, & Chleboun, 2001). Losses in range

of motion were studied after one week without stretching (Tanigawa, 1972; Turner Starring et al., 1988) and after four weeks without stretching (Willy et al., 2001). The reported losses after one week cessation of stretching were 27.7% (Turner Starring et al., 1988) and 74.6% (Tanigawa, 1972). After four weeks Willy et al. (2001) observed a loss of 77.7% of the increased range of motion from their six week stretching programme.

Purpose of the study

The purpose of this study was:

1) To investigate the effect of stretching two days and four days per week on range of motion at the ankle joint in sedentary females aged 20-40 over a four week period.

Hypothesis:

Stretching the gastrocnemius, soleus muscle and associated ankle joint soft tissue four sessions per week will result in a greater increase in ankle joint range of motion than stretching two sessions per week or no sessions per week.

2) To determine the detraining effect four weeks after the stretching programme has ceased.

Hypothesis:

Range of motion will return to baseline four weeks after the stretching programme has ceased.

Significance of the problem

This study has significance for coaches, trainers, health professionals, athletes and patients who use and/or prescribe stretching to increase range of motion. Examining the frequency of stretching required to increase range of motion at the ankle joint will allow a more accurate prescription of stretching programmes. Through accurate prescription of programmes the desired effects are more likely to be achieved. These effects may lead to the prevention of injury, enhancement of performance and, in the rehabilitative setting, restoration of movement in a damaged joint allowing normal biomechanics.

REVIEW OF LITERATURE

1 INTRODUCTION

This chapter begins by discussing the increase in range of motion that occurs as a result of stretching. The different types of stretching are then discussed and compared. The known effects resulting from stretching are discussed followed by the mechanisms that are thought to occur when tissue is put under stretch. Finally, the prescription of repetitions, frequency and duration of stretch are reviewed as well as the detraining effect.

1.1 INCREASE IN RANGE OF MOTION

Numerous authors have investigated the effects of stretching on range of motion. It has been demonstrated that passive stretching is an effective means of increasing range of motion (Bandy & Irion, 1994, Bandy et al., 1997, Bandy, Irion, & Briggler, 1998; Bannerman et al., 1996; Entyre & Abraham, 1986a; Henricson et al., 1983; McNair & Stanley, 1996; Tanigawa, 1972; Wiktorsson-Moller, Oberg, Ekstrand, & Gillquist, 1983; Williford, East, Smith, & Burry, 1986; Worrell et al., 1994). Increases in range of motion have been observed after a single stretching session demonstrating the short-term effects of stretching (Entyre & Abraham, 1986a; McNair & Stanley, 1996; Wiktorsson-Moller et al., 1983).

Entyre and Abraham (1986a) examined the short-term effects of stretching when comparing the effectiveness of three stretching methods (static, contract-relax and contract-relax-agonist-contract) in producing an increase in dorsiflexion (bent-knee) range of motion. The static stretch involved a passive stretch of the soleus held for nine

seconds. The contract-relax stretch involved passive lengthening of the soleus, followed by isometric plantarflexion in the lengthened position for six seconds followed by an additional three seconds of passive stretch. The contract-relax-agonist-contract was identical to the contract-relax except that the subject assisted the post-contraction dorsiflexion by contracting the tibial muscle. Each of the three techniques was tested on a separate day to minimise influences of a prior technique. Range of motion was measured prior to and immediately after the single stretch session. The results of the study showed a 5.3% increase in range of motion with contract-relax-agonist-contract, a 2.8% increase with contract-relax and a 0.2% decrease with static stretch. McNair and Stanley (1996) also examined the short-term effects of stretching. The study compared the effect of stretching and jogging on series elastic stiffness of the plantar flexors and on the range of dorsiflexion at the ankle joint. The stretching protocol involved five 30 second static stretches. In the running protocol subjects ran on a treadmill for 10 minutes at 60% of maximum age predicted heart rate. In the combined protocol subjects ran first then stretched. The results of the study found the stretching and the combined protocol increased dorsiflexion range of motion by 7.8% and 12.6%. Dorsiflexion was relatively unchanged in the running only protocol. Another group to examine the short-term effects of stretching was Wiktorsson-Moller et al. (1983). Their study compared the effect of warm-up, massage and contract-relax stretching on lower extremity range of motion. Range of motion was measured before and after one stretching session at the ankle joint (knee flexed and knee extended), the hip joint (flexion, extension and abduction) and the knee joint (flexion). The contract-relax stretching session consisted of an isometric contraction lasting 4-6 seconds, followed by full relaxation for two seconds and passive extension lasting for eight seconds. This was repeated five to six times for each muscle group. Ankle joint range of motion increased by 31% with a flexed knee and 26% with

an extended knee. Hip abduction increased by 27%, extension 3%, and flexion 9%. Knee flexion increased by 5 %.

Each of the above three studies examined the ankle joint. The stretching technique of both Entyre and Abraham (1986a) and McNair and Stanley (1996) was static despite a contrast in their results. Entyre and Abraham (1986a) found a 0.2% decrease with static stretch while McNair and Stanley (1996) found a 7.8% increase. Regarding these results one must keep in mind the difference in the details of the stretching programme. McNair and Stanley (1996) had a much longer duration and more repetitions of stretch. Wiktorsson-Moller et al. (1983) utilised a different stretching technique and documented a much larger increase in range of dorsiflexion (31% with a flexed knee and 26% with an extended knee).

Long-term changes in range of motion have been observed after several stretching sessions undertaken over a number of weeks (Bandy & Irion, 1994, Bandy et al., 1997, 1998; Bannerman et al., 1996; Henricson et al., 1983; Tanigawa, 1972; Williford et al., 1986; Worrell et al., 1994). The following studies are reviewed in order of increasing number of weeks. Tanigawa (1972) examined long-term changes in hamstring range of motion over a three week period of stretching comparing PNF and passive stretching techniques. The PNF stretch involved passively elevating the leg to a stretch position followed by an isometric contraction for seven seconds. The passive stretch also involved passive elevation to the stretch position where the leg was held for seven seconds. Both PNF and passive procedures were repeated four times twice per week. Hip flexion increased 45.2% for the PNF group and 22.1% for the static stretch group. Worrell et al. (1994) also observed long term gains in hamstring range of motion over a three week period when studying the effect of stretching on hamstring muscle performance. Static and PNF stretching were compared. The static stretch was held for

15-20 seconds while the PNF stretch involved five seconds of maximal isometric hamstring contraction, five seconds of rest, five seconds of maximal quadriceps contraction and five seconds of rest. Subjects performed four repetitions of stretch five times per week. Static stretching increased range of motion by 21.1% and PNF stretching by 25.7%. Similar increases were observed over a three week stretch period for the static stretch group for Tanigawa (1972) and Worrell et al. (1994) while the PNF group differed considerably despite the duration of stretch being similar.

Long-term gains in ankle joint dorsiflexion range of motion were observed over a five week period by Bannerman et al. (1996). The authors compared static versus ballistic stretching performed twice per week. The static stretches were held for 15 seconds and the ballistic stretches performed at a rate of one bounce per second for a total duration of 15 seconds. The static stretching group increased range of motion by 6.3% and the ballistic stretching group by 6.6%.

Bandy and Irion (1994) examined long term gains in hamstring length measured by increases in knee extension range of motion over a six week period. The study compared the gains for 15, 30 and 60 second durations of static stretch. A single repetition of stretch was performed five times per week. The 15 second group demonstrated a 7.5% increase in range, the 30 second group a 24.2% increase and the 60 second group a 21.7% increase. In a second study also carried out over six weeks Bandy et al. (1997) examined the effect of one versus three repetitions of static stretches on hamstring length. Thirty and 60 second durations of stretch were used. The subjects stretched five times per week. The gain for 30 and 60 second durations, one session per day, was 26.9% and 23.9% and three sessions per day 23.8% and 24.2%. In their most recent study Bandy et al. (1998) compared a single 30 second static stretch with dynamic range of motion on hamstring

length over a six week period. The static stretches and dynamic range of motion were performed five times per week. The range of motion for 30 seconds static stretch increased 27.3% and for the dynamic range of motion 10.7%. The above three studies consistently demonstrated an increase in range of motion over a six week period for the 30 and 60 second duration groups.

Long-term changes observed over a nine week period have been examined by Williford et al. (1986). Williford et al. (1986) studied increases in ankle joint range of motion after two 30 second static stretches were performed twice a week on the gastrocnemius muscle group. A 6.6% gain in ankle joint range of motion was observed. Henricson et al. (1983) studied the effect of stretching on ankle joint range of motion over a 12 week period. Stretching consisted of a maximal contraction for 15 seconds followed by a 15 second passive stretch. Five repetitions were performed three times per week. The dorsiflexion gains observed were 18.5% with an extended knee and 11.5% with a flexed knee.

When examining the above studies, changes in range of motion for the hamstring generally increased range to a greater degree than the ankle joint. The smallest increase in hamstring range was 7.5% after 15 seconds static stretch performed five times per week for six weeks (Bandy & Irion, 1994). The largest increase for static stretch was 27.3% after 30 seconds of five times per week for five weeks (Bandy et al., 1998). The smallest increase at the ankle joint was 6.6% recorded by two authors who both used static stretches twice per week (Bannerman et al., 1996; Williford et al., 1986). The durations differed (15 versus 30 seconds) and the number of weeks (five versus nine). The largest increase recorded was 18.5% over a 12 week period of contract (15 seconds) relax (15 seconds) stretching three times per week.

1.2 TYPES OF STRETCHING

There are many different stretching techniques. The three most commonly used and studied stretching techniques are, static, ballistic and proprioceptive neuromuscular facilitation (PNF).

Static stretching involves slow speed passive movement to the end of the available range, signified as the point of discomfort. This position is held for several seconds. Ballistic stretching is performed by bouncing movements of the limb into the maximally lengthened position of the muscle, followed by the limb returning immediately to the resting position. The most commonly used PNF techniques in the clinical settings are contract-relax and contract-relax-agonist-contract. Contract-relax involves a maximal contraction of the muscles to be stretched, followed by relaxation and stretching of the muscles to the point of limitation. Contract-relax-agonist-contract is performed in the same way as contract-relax, but during the stretch phase the opposite muscle group assists the movement into a stretch position.

When comparing the three techniques the literature is not conclusive as to which is more effective in increasing range of motion. Sady et al. (1982) compared static, ballistic and contract-relax stretching on increases in range of motion at the shoulder, trunk and hamstrings. Contract-relax was found to be the most effective. Static and ballistic showed similar gains in range. Entyre and Abraham (1986a) found contract-relax-agonist-contract to be superior to contract-relax, which was superior to static stretch, when comparing the effectiveness of these three techniques in producing an increase in dorsiflexion (bent-knee) range of motion. Moore and Hutton (1980) when comparing static, contract-relax and contract-relax-agonist-contract on increases in hamstring range of motion, also found contract-relax-agonist-contract to be more effective than static

stretch but static stretch was found to be more effective than contract-relax. Conversely Condon and Hutton (1987) when investigating the effect of static stretching, contract-relax and contract-relax-agonist-contract on ankle joint dorsiflexion gains found no significant difference in range achieved when comparing these three techniques. Bannerman et al. (1996) compared ballistic and static stretching on increases in ankle joint dorsiflexion. Ballistic stretching was found to cause similar gains in muscle length as static stretching.

Static stretching has been shown to produce the least amount of tension in muscle (Moore & Hutton, 1980) and has been reported to cause the least amount of discomfort when compared to other techniques (Condon & Hutton, 1987; Moore & Hutton, 1980). Moore and Hutton (1980) found the level of EMG activity with static stretch to be very low and frequently approaching zero in their study. Condon and Hutton (1987) and Moore and Hutton (1980) revealed that the PNF procedure of contract-relax-agonist-contract was ineffective in minimizing EMG activity as was previously thought to occur. When questioning their subjects on the most effective stretch, Moore and Hutton (1980) found there was a definite tendency towards the technique that produced the least EMG and pain. The authors suggested that the contract-relax-agonist-contract technique was the most preferred for achieving a maximum gain in range of motion when subjects were experienced, well motivated and had sufficient time to practice the procedure. If comfort and limited training time are major factors the static stretching was recommended.

1.3 PERFORMANCE

Improvement in performance is assumed as a positive effect of stretching due to increases in range of motion. A limited range of motion is thought to impede the development of the muscle's contractile potential as well as increase the stress on the muscle imposed

during passive or active movements (Taylor et al., 1990). Eccentric contraction followed by concentric contraction occurs during gait and running. During an eccentric contraction mechanical work is absorbed by the series elastic component of the muscle as potential energy, which is used during the immediate concentric contraction, this being the basis behind stretch-shortening cycle exercises. The factors that determine the amount of energy absorbed by the muscle are the speed of contraction and the length of the muscle. Thus, if the length of a muscle can be increased, more forces will be absorbed during the eccentric contraction and more forces will be generated during the concentric contraction (Worrell et al., 1994).

Worrell et al. (1994) and Wilson et al. (1992) both studied the relationship between "flexibility" and force production. Worrell et al. (1994) examined the effects of increasing hamstring flexibility on isokinetic peak torque. They compared a static stretch held for 15 to 20 seconds and repeated four times with a PNF stretch. The PNF stretch involved five seconds maximal isometric hamstring contraction, five seconds rest and five seconds maximal hamstring contraction and five seconds rest and was repeated four times also. The results showed a significant increase in torque of the flexors of the knee joint under eccentric load conditions at velocities of 60°/sec and 120°/sec and under concentric load conditions at 120°/sec. The authors attributed the increases in eccentric force production to increases in hamstring muscle flexibility and increases in the compliance of the series elastic component that resulted in a greater ability to store potential energy. Improvements in concentric peak torque production at 120°/sec were attributed to increased storage of potential energy during eccentric loading which is used in the subsequent concentric muscle contraction.

Wilson et al. (1992) studied stretch-shortening cycle performance enhancement through flexibility training in 16 male powerlifters. The athletes stretched their glenohumeral joints twice a week for eight weeks. The results demonstrated a 7.2 % decrease ($p<0.05$) in muscle series elastic component (SEC) stiffness in the training group. This reduction in SEC stiffness increased the potential of these subjects to store and release elastic strain energy facilitating initial concentric performance. Consequently during the post-training rebound bench press lift, a 20.1% increase in initial work enabled a 5.4% greater load to be lifted.

Hortobagyi, Faludi, Tihanyi, & Merkely (1985) examined the effect of intense stretching on the mechanical profile of the knee extensors and on range of motion of the hip joint. Twelve male subjects passively stretched their knee extensors and hip joints three times per week for seven weeks. The results showed significant improvements in hip flexibility after stretching and a higher stride frequency rate during running. In respect to strength, there was a significant improvement in fast isometric force development and speed of concentric contractions when low loads were to be overcome. Maximal voluntary contraction remained unaltered.

Handel, Horstmann, Dickhuth, & Gulch (1997) studied the effects of a contract-relax stretching programme on muscular performance and flexibility of the knee joint. The stretching programme was performed three times per week over an eight week period. Apart from significant improvements in active and passive flexibility (up to 6.3° in range of motion), an improvement in maximum torque (up to 21.6%) and work (up to 12.9%) was observed and these were especially pronounced under eccentric load conditions.

1.4 PREVENTION AND TREATMENT OF INJURY

Stretching has been recommended as a method of preventing injury (Beaulieu, 1981; Ciullo & Zarins, 1983; Ekstrand & Gillquist, 1983b; Glick, 1980; Hubley-Kozey & Stanish, 1990). Studies on connective tissue indicate that if loaded sub-maximally, connective tissue will increase in strength and conversely if immobilised or only worked in a limited range, it will become shorter and less compliant (Tardieu & Tabary, 1982). This research provided a rationale for exercising a muscle in the range that it is required to work in to ensure sufficient compliance of the muscle. For many sporting activities the required range is less than that used by stretching techniques, but there is always a risk when playing sport that a joint will be moved past the usual range of motion by either intrinsic or extrinsic forces. Ekstrand and Gillquist (1982) studied past injuries, persisting symptoms from past injuries, and muscular tightness in the lower extremities of 180 male soccer players. They found that muscle strains of the thigh and calf were related to poor muscle flexibility. Ekstrand and Gillquist (1983b) also studied the avoidability of muscle strains in soccer by documenting pre-season range of motion and muscle strength in the lower extremities, as well as all injuries over a one year period, of 180 male soccer players. Sixty-three percent of the players had muscle tightness and strains more commonly affected players with muscle tightness. A programme for prevention of muscle injuries that included adequate training with warm-up and stretching and appropriate rehabilitation for recovery from injury was implemented. The results showed a 75% reduction in injuries in the trained group compared to the control group.

Not all research supports the inclusion of warm-up and stretching within injury prevention programmes. Van Mechelin, Hlobil, Kemper, Vorn, & Dejongh (1993) evaluated the effect of a health education intervention on running injuries. Four hundred

and twenty one male recreational runners were matched for age, weekly running distance and general knowledge of the prevention of sports injuries. The subjects were randomly split into a control and an intervention group. The intervention consisted of information on and the subsequent performance of a standardized warm-up, cool-down, and stretching exercises. During a 16 week period both groups kept a daily diary of their running distance and time, and reported all injuries. The intervention group were also asked to document their compliance with the programme. The results showed that the intervention was not effective in the prevention of injuries. A reason for this finding may be that only 46.6% of the subjects performed the stretching part of the programme as prescribed.

Rosenbaum and Hennig (1995) studied the acute effects of warm-up and static muscle stretch on the electromyographic and force output associated with mechanically elicited triceps surae reflexes. Their results showed a reduction in the stiffness of the musculotendinous unit after stretching. This observation was consistent with the notion that after stretching the muscles and tendon are more "pliable", and therefore perhaps less likely to be damaged by additional excessive forces. A reduction in the peak force and rate of force development caused by a passive stretch of the muscles, (e.g. during sporting activities) may diminish the risk of a strain injury, as the muscles sustain a reduced peak stress.

Stretching is also advocated in the rehabilitation of patients after injury or surgery to prevent chronic muscle shortening and joint contractures. Following trauma or surgery the connective tissue involved in the body's reparative processes frequently impedes normal function, because it limits the range of joint motion (Sapega et al., 1981). Scar tissue, adhesions, and fibrotic contractures are common types of pathological connective

tissue that occur post injury (Sapega et al., 1981). Immobilization through casts or braces is often necessary post injury or surgery and has been shown to increase joint stiffness (Butler, Grood, Moyes, & Zernicke, 1978) and decrease muscle strength by reducing the number of sarcomeres in parallel (Gossman, Sahrmann, & Rose, 1982). Animal studies have demonstrated that during immobilization, excessive connective tissue builds up in the joint and joint recesses and with time forms mature scar tissue that creates intra articular adhesions (Tardieu & Tabary, 1982). Stretching is therefore advocated (Becker, 1979; Glazer, 1980; Sapega et al., 1981) in the rehabilitation of patients after injury or surgery to prevent chronic muscle shortening and joint contractures.

1.5 MECHANICAL AND NEUROPHYSIOLOGICAL CHANGES ASSOCIATED WITH STRETCHING

1.5.1 Introduction

The response of muscle to stretching has been attributed to neurophysiological (Hutton, 1993) and mechanical mechanisms (Taylor et al., 1990). It is thought that both the muscle contractile tissue and the related connective tissue are affected when stretch is applied to a joint (Sapega et al., 1981).

Tension in a muscle can be considered to be comprised of active and passive components. The active contractile components are the myofibrillar elements that are part of a muscle's structure. These elements are comprised of actin and myosin and are controlled neurally. Any stretching effects mediated by the reflex activity must involve these active components. The passive resistive component is made up of the structures such as tendon, which is in series with the contractile elements and also parallel connective tissue elements that provide a framework for the active contractile

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components. When stretched, these structures exhibit biomechanical behaviour and react viscoelastically (Taylor et al., 1990). The literature has not established how each of these structures react to stretch or how much each contribute to increases in range of motion. Some authors conclude that increases in range of motion are due to viscoelastic responses (Magnusson et al., 1996c; McHugh et al., 1992; Taylor et al., 1990). Others assume that increases in muscle compliance occur when electromyographic activity is decreased allowing greater passive elongation of muscle fibres (Sady et al., 1982; Tanigawa, 1972). Some authors disagree with this conjecture. For instance Condon and Hutton (1987) examined soleus muscle EMG activity and dorsiflexion range of motion during four stretching procedures and concluded that muscle relaxation was unrelated to the degree of range of motion achieved.

1.5.2 Viscoelastic Properties

Muscle behaves viscoelastically. The viscoelastic response is thought to provide the basis for passive stretching and has been demonstrated in humans and animals (Magnusson et al., 1995; McHugh et al., 1992; Taylor et al., 1990). Taylor et al. (1990) states that gains in muscle length from stretching are due to changes in the viscoelastic properties of the passive components of muscle. The viscoelastic properties are characterised as time-dependent and rate change-dependent, where the rate of deformation is directly proportional to the applied forces or loads. Elasticity is represented by Hooke's model of the perfect spring, where the reversible nature of the spring is solely dependent on the applied forces. The viscous elements can be described by Newton's model of the hydraulic piston known as the dashpot, where rate and duration of the application of forces influence the length changes (Taylor et al., 1990).

Certain properties are characteristic of viscoelastic materials. These are stress relaxation, creep and hysteresis. Stress relaxation is evident if a viscoelastic material is stretched and held at a constant length. The stress or force at that length gradually declines. This behaviour is both viscous, because tension decreases with time, and elastic, because the specimen maintains some degree of tension. Static stretching according to Taylor et al. (1990) is actually a clinical example of stress relaxation. Viscoelastic stress relaxation in vitro has been characterised as having an initial fast and subsequent slow decline in force (Cavagna, 1993).

Creep is characterised by continued deformation at a fixed load. The material will approach a new length depending on the viscoelastic elements of the material (Taylor et al., 1990). Hysteresis is the variation in the load -deformation relationship that takes place between loading and unloading a specimen. For viscoelastic materials, greater energy is absorbed during loading than is dissipated during unloading (Taylor et al., 1990). Strain rate dependence is another viscoelastic property where tissue exhibits higher tensile stresses at faster strain rates. Slower strains allow for greater relaxation to take place within the tested material. Faster stretch rates result in greater tensions and more absorbed energy within the muscle tendon unit for a given length of stretch (Taylor et al., 1990).

Taylor et al. (1990) developed an experimental model that was based upon the above mentioned viscoelastic characteristics. It was designed to evaluate clinically relevant biomechanical stretching properties in an entire muscle tendon unit. Rabbit extensor digitorum longus and tibialis anterior muscle-tendon units were evaluated using methods designed to simulate widely used stretching techniques. The study was divided into three parts. Part I examined the characteristics of repeated stretching of the muscle-tendon

units to 10% beyond resting length. This was similar to a cyclic stretching technique with a stretch to the same length, e.g. toe touching. In part II, muscle tendon units were stretched repeatedly to the same tension. This paradigm is similar to some static stretching procedures. In part III, the researchers explored how varying the stretch rates and denervating the muscles affected the viscoelastic characteristics of the muscle-tendon unit.

Time dependency of the load deformation relationship was demonstrated in both parts I and II of the study. In part I, where repeated stretching of the muscle-tendon units to 10% beyond resting length was performed, the decline in peak tension with each stretch showed that the stretching history is relevant to the stretched muscle-tendon unit. The decline in peak tension occurred because the viscoelastic property of stress relaxation leads to an internal change in structure of a specimen during each stretch. This decline in peak tension results in reduced tensile stress on the stretched muscle-tendon unit. Both peak tensile force and absorbed energy were dependant upon the rate of stretch applied. Slower stretches allow for a greater degree of stress relaxation to occur, resulting in lowered peak forces. In part II, where the muscle tendon units were stretched repeatedly to the same tension and held at a fixed length stress relaxation was demonstrated. The amount of stress relaxation that took place after the initial 12 to 18 seconds appeared to be much less significant than the changes during this initial 12 to 18 seconds of the stretch. In part III, where the researchers studied the effect of varying the stretch rates and denervating the muscles on stretching of the muscle-tendon unit, the innervated and denervated muscles responded similarly for all parameters observed and the stretch reflex did not appear to make any significant force contributions. It was hypothesised that it may have been due to the rabbit's nervous system being depressed by the anaesthetic. Based upon the results of this part of their study Taylor et al. (1990) commented that the

behaviour of muscle in response to stretch can be explained by viscoelastic properties alone exclusive of stretch reflex.

Researchers have examined the response noted by Taylor et al. (1990) in humans. For instance McHugh et al. (1992) measured resistance to stretch, hip flexion range of motion and reflex contractile activity of the hamstring muscle group measured during a passive straight leg raise. The testing protocol involved a first stretch to the maximum tolerated range of motion with the lower extremity held at that point for 45 seconds. The point at which EMG activity occurred was noted. A second straight leg raise stretch was performed to a range of motion five degrees below the range of motion at which the onset of EMG activity occurred in test 1. The stretch was held at this point for 45 seconds. The results showed a significant decrease in EMG activity during the relaxation period, which was not significantly correlated to the decrease in force. The decrease in force over time in test 2 represented viscoelastic stress relaxation independent of detectable EMG activity.

A later study by Magnusson et al. (1995) also investigated the viscoelastic response in humans. The aim of the study was to evaluate the reproducibility of a new method of measuring resistance to stretch in the human hamstring muscle group in vivo, using a test re-test protocol. The effect of repeated stretches was also examined. Passive resistance to stretch offered by the hamstring muscle group during knee extension was measured as knee flexion moment of force (Nm) using a KinCom dynamometer with a modified thigh pad. The test re-test protocol involved two tests (tests 1 and 2) administered one hour apart. Test 1 consisted of one static stretch manoeuvre held for 90 seconds. Test 2 involved the same process and was performed 60 minutes after test 1. To measure the effect of repeated stretches five consecutive static stretches were administered (stretches 1-5). Each stretch was held for a 90 second duration. The stretches were separated by a

30 second interval. Sixty minutes after the last stretch one last stretch was performed (Stretch 6). Passive resistance, joint range of motion, velocity and hamstring EMG were continuously recorded over the entire stretch event. The test re-test protocol demonstrated that one 90 second stretch was without effect one hour later, as evident by the lack of difference in resistance between test 1 and test 2. The repeated stretches protocol produced viscoelastic changes that were still statistically significant one hour later. The decline in resistance was less as more stretches were performed. The EMG response to stretch was unrelated to a 29% decrease in resistance to stretch, confirming previous work by McHugh et al. (1992). The authors concluded that the observed decline in resistance was largely mechanical in nature, i.e., viscoelastic.

1.5.3 Neural mechanism

The contractile components response to stretch is muscle activation of voluntary and/or reflexive origin. Improvements in range of motion produced by specific muscle stretching techniques are often attributed to a decrease in active resistance produced by reflexively or voluntarily induced inhibition or both to motoneurons of the muscle to be stretched (Condon & Hutton, 1987). Therefore it has been suggested (Condon & Hutton, 1987; Hutton, 1993) that when electromyographic activity is decreased, the muscle fibres will have greater passive elongation resulting in increased muscle compliance and increased range of motion. This theory is questionable. An early study by Moore and Hutton (1980) used electromyography (EMG) and examined the relative level of hamstring muscle relaxation achieved during the application of static, contract-relax and contract-relax-agonist-contract stretch procedures. The results demonstrated that the contract-relax-agonist-contract technique produced significantly greater hamstring EMG activity post stretching. Static stretch had a very low level of hamstring EMG activity that frequently approached baseline. The contract-relax-agonist-contract technique

showed greater gains in ROM than static stretch and contract-relax. In view of the findings the authors concluded that full muscle relaxation was not imperative for effective stretching of muscle.

Condon and Hutton (1987) examined soleus muscle EMG activity and dorsiflexion range of motion (ROM) during four stretching procedures. The purpose of the study was to compare the effects of PNF stretching on alpha motoneuron excitability (as measured by the Hoffman reflex amplitude) and active resistance of the muscle being stretched, ROM achieved, and on the subject's perception of the stretch. Four stretching techniques were studied, a static stretch plus three PNF techniques. The first PNF technique involved a static contraction of the muscle being stretched then a relaxation phase (hold-relax). The second technique involved the opposite muscle group to the group being stretched assisting the static stretch (agonist-contract). The third technique combined the first and second techniques (contract-relax-agonist-contract). The authors hypothesised that 1) a static contraction of the muscle being stretched then a relaxation phase would result in increased alpha motoneuron excitability of the muscle being stretched, more activity of this same muscle, and less ROM than performance of a static stretch alone; 2) the opposite muscle group to the group being stretched assisting the static stretch would result in decreased alpha motoneuron excitability of the muscle being stretched, less activity of this same muscle, and more ROM than static stretch alone; and 3) the combination of the two techniques would result in increased alpha motoneuron excitability of the muscle being stretched, more activity of this same muscle, and less ROM than a static stretch assisted by a contraction of the opposite muscle group alone. The results for ROM showed no significant difference between the four stretching procedures. In regard to EMG, the static stretch and hold-relax procedures were associated with significantly lower levels of soleus muscle EMG activity than the

agonist-contract and hold-relax-agonist-contract procedures. They found H-reflex amplitudes were significantly larger during the static stretch and hold-relax stretching procedures than agonist-contract and hold-relax-agonist-contract. This suggests that reciprocal inhibition was operative but masked by other sources of excitatory current to the soleus motoneuronal pool. As found in the previous investigation on hamstring musculature (Moore & Hutton, 1980) the PNF procedure of hold-relax-agonist-contract was ineffective in minimizing EMG activity through putative "successive induction" or "autogenic inhibition" (Condon & Hutton, 1987).

More recently Vujnovich and Dawson (1994) hypothesised that the mechanism responsible for increases in muscle flexibility as a consequence of PNF and other stretches may not depend upon the delivery of the stretch to the connective tissue but instead may depend upon the neural response to the stretch induced afferent activity. The purpose of their study was to compare the sequential application of static and ballistic muscle stretch with static muscle stretch alone, using the electrically elicited Hoffman reflex as a measure of excitability of homonymous motoneurons. The results of their study demonstrated a significant effect ($p<0.05$) of passive muscle stretch on decreasing the activity of neurons within the L5-S1 spinal segment, with ballistic stretch producing greater inhibition than static stretch when applied sequentially to the same subjects. The authors concluded that since reductions in alpha-motoneuron pool excitability correlated with increased flexibility, ballistic stretch applied following static stretch appears more effective than static stretch alone.

An alternate explanation has been proposed for the increase in range of motion observed from stretching. Halbertsma et al. (1996) and Magnusson et al. (1996a; 1996b) have suggested that an "amplified stretch tolerance" is responsible for the increased range of

motion adaptations rather than a change in the mechanical or viscoelastic properties of the muscle. This premise is based upon the results of three studies. In the first of these studies Halbertsma and Goeken (1994) measured hamstring extensibility, stiffness, and electromyographic activity of the hamstring muscles following a daily four week stretching programme. The results showed a significant increase in the extensibility of the hamstrings accompanied with a significant increase of the stretching moment tolerated by the passive hamstring muscles. The elasticity remained the same. Halbertsma and Goeken (1994) concluded that stretching exercises do not make short hamstrings any longer or less stiff, but only influence the stretch tolerance.

In the second study Magnusson et al. (1996a) examined EMG activity, passive torque and stretch perception during static stretch and contract-relax stretch. A constant angle protocol (where subjects were taken to a predetermined position) and a variable angle protocol (where subjects were extended to the onset of pain) were tested on the hamstring muscle group during passive knee extension. In the constant angle protocol contract-relax and static stretch did not differ in passive torque or EMG response. In the variable angle protocol maximal joint angle and corresponding passive torque were significantly greater in contract-relax compared with static ($p<0.01$), while EMG did not differ. The authors concluded that the variable angle protocol demonstrated that PNF stretching altered stretch perception.

The third study (Magnusson et al., 1996b) investigated the effect of a long term stretching regimen (carried out over three weeks) on the tissue properties and stretch tolerance of human skeletal muscle. Resistance to stretch (in Nm) by the hamstring muscle group during passive knee extension was examined, while EMG activity, knee joint angle and velocity were continuously monitored during a standardized stretch

manoeuvre. Two protocols were used. The first involved a slow stretch to a predetermined angle and the second involved a stretch taken to the point of pain. The results from the first protocol showed no significant difference in stiffness, energy or peak torque as a result of the training programme. In the second protocol the angle to which the knee could be extended significantly increased as a result of the training. This was accompanied by a comparable increase in peak torque and energy. EMG activity was small but unaffected by the training. Magnusson concluded that the reflex EMG activity does not limit the range of motion during slow stretches and that the increased range of motion achieved from training is a consequence of increased stretch tolerance on the part of the subject rather than a change in the mechanical or viscoelastic properties of the muscle.

1.6 FREQUENCY OF STRETCH

The frequency of stretch can be defined as the number of days stretched per week. Few studies have compared different stretch frequencies. Most studies have used different durations of stretch and numbers of repetitions or sets. Therefore a comparison of the effect of stretching two or four times per week is difficult given the difference in duration, sets and repetitions used across studies. The frequencies of once per week, four times per week and six times per week have not been discussed as no studies have been found that used these frequencies.

A frequency of twice per week has been used by three studies (Bannerman et al., 1996; Borms et al., 1987; Williford et al., 1986). Bannerman et al. (1996) compared the difference between static and ballistic stretching on ankle joint dorsiflexion. The subjects stretched for a 15 second duration twice per week for a period of five weeks. The results found stretching twice per week for five weeks (10 sessions) significantly improved

ROM by 6.3% in the static group and by 6.6% in the ballistic group. Williford et al. (1986) studied the effects of static stretching performed twice per week for nine weeks (18 sessions) on ankle joint range of motion. The stretches were held for 30 seconds and repeated twice. The observed gain in range of motion was 6.6%. Borms et al. (1987) used a frequency of twice per week in their study that examined a 10 second versus 20 second versus 30 second duration of static stretch on hip flexibility. The results found that hip flexibility improved significantly after 10 weeks of stretching (20 stretching sessions). The 10 second group increased range of motion by 18.6%, the 20 second group by 20% and the 30 second group by 22.5 %. The results of Bannerman and Williford are comparable in terms of the recorded increase in ankle range of motion for static stretching of 6.3% and 6.6%. Borms et al. (1987) results showed three times as much increase at the hip joint. The reason for this difference in gains is not readily apparent.

In the following two studies a frequency of three times per week was used. Sady et al. (1982) examined the difference between static, ballistic and PNF stretches on range of motion at the shoulder, trunk and hip. The stretches were performed three times per week over six weeks (18 sessions). Only the PNF group showed an increase of 9.7% in hip joint ROM. Henricson et al. (1983) studied the effect of stretching on ankle joint range of motion. The stretching frequency was three times per week for a 12 week period (36 sessions). Stretching consisted of a maximal contraction for 15 seconds followed by a 15 second passive stretch. This was repeated five times. The gains in dorsiflexion were 18.5% with an extended knee and 11.5% with a flexed knee. Thus, the results of Sady et al. (1982) and Henricson et al. (1983) differ when using a frequency of three times per week. These differences may reflect the total number of sessions undertaken and the joints measured. The results of other studies (Bandy & Irions, 1994, Bandy et al., 1997,

1998; Borms et al., 1987; Gajdosik, 1991) consistently show the hamstring to increase by a greater percentage than the ankle joint.

A frequency of five times per week has been used by Bandy & Irions (1994) and Bandy et al. (1997; 1998). The first study (Bandy & Irion, 1994) used a frequency of five times per week for six weeks (30 sessions) when examining 15, 30 and 60 second durations of static stretch on hamstring ROM. The 15 second group demonstrated a 7.5% increase in range, the 30 second group a 24.2% increase and the 60 second group a 21.7% increase.   The second study (Bandy et al., 1997) also used a frequency of five times per week for six weeks (30 sessions). The effect of one versus three repetitions of static stretches on hamstring length was examined. Thirty and 60 second durations of stretch were used. The gain for 30 and 60 second durations, one session per day, was 26.9% and 23.9% and three sessions per day 23.8% and 24.2%. The most recent study by Bandy et al. (1998) also used a frequency of five times per week over a six week period (30 sessions). The effect of a single 30 second static stretch was compared with dynamic range of motion on hamstring length. The range of motion for the 30 second static stretching group increased 27.3% and for the dynamic range of motion group 10.7%. In summary Bandy and co-workers demonstrated in these three studies a consistent increase in hamstring range of motion (between 21.7-27.3%) when using a frequency of five times per week over a six week period for the thirty and sixty second duration groups.

A frequency of seven times per week for a three week period (21 sessions) was used by Gajdosik (1991). The effect of static stretching on maximal hamstring length and resistance to passive stretch was examined. The stretches were held for 15 seconds and repeated 10 times. After three weeks the stretching group demonstrated an increase in straight leg raise of 21.9%. This is consistent with the increases found by Bandy. Halbertsma and Goeken

(1994) also used a frequency of seven times per week when studying the effect of stretching on short hamstrings over a four week period. Stretching was performed for 10 minutes in a long sitting position. The duration of stretching or repetitions was not reported. A 7.1% increase in hip flexion was observed.

No obvious pattern for increases in range of motion when a greater frequency was used has emerged for the hamstring group. The smallest increase of 7.1% was recorded after a frequency of seven times per week (Halbertsma & Goeken, 1994). The greatest increase of 27.3% occurred after a frequency of five times per week (Bandy et al., 1998). The ankle studies reviewed all used a frequency of either twice (Bannerman et al., 1996; Williford et al., 1986) or three times per week (Henricson et al., 1983). The smallest increase was 6.3% recorded with a twice per week frequency (Bannerman et al., 1996) and the largest increase was 18.5% (Henricson et al., 1983) with a frequency of three times per week. Although two different studies may have used a similar frequency one must take into account the difference in types of stretching techniques and the duration and repetitions of stretch in each study.

1.7 DURATION OF STRETCH

The duration of stretch is the length of time a muscle is held on stretch. Durations of stretch suggested for increasing range of motion range from six to 120 seconds. Sady et al. (1982) used a duration of six seconds when comparing static, ballistic and PNF stretching techniques. Only the PNF stretching group showed a significant increase in flexibility. Gajdosik (1991) reported an increase in hamstring ROM as measured by a straight leg raise when holding a static stretch for 15 seconds. Williford et al. (1986) examined the effect of warm up and static stretching on increases in joint range of motion at the ankle, trunk, shoulder and hamstring. A 30 second duration of stretch was utilised. The stretching

programme was carried out twice per week for nine weeks. A significant gain in range was observed at all joints for the stretch group.

Borms et al. (1987) conducted a study to determine the effect of different durations of static stretching exercises on hip flexibility. The three subject groups either stretched for a duration of 10, 20 or 30 seconds. The results of the study showed no significant difference in hip flexibility between the three subgroups. The authors suggested that 10 seconds static stretching was sufficient for improving hip flexibility. Madding et al. (1987) studied three different durations of passive stretch on hip abduction range of motion (15 seconds, 45 seconds and 2 minutes). Each subject was stretched only once. The results showed a significant increase in hip abduction range of motion with all three durations of stretch. The authors concluded that as 15 seconds is just as effective as two minutes it made sense to just stretch for 15 seconds. Bandy and Irion (1994) examined effects of hamstring muscle stretching comparing the durations of 15, 30 or 60 seconds. The results showed that stretching for 15 seconds was no more effective than not stretching. Stretching for 30 and 60 seconds showed similar increase in range of motion. The authors questioned the use of longer duration of stretch and concluded that 30 seconds was the most effective duration to hold a stretch. In a second study, Bandy et al. (1997) studied frequency and time of static stretch on hamstring flexibility. The results confirmed their 1994 study that 30 seconds was an effective length of time to sustain a hamstring stretch.

1.8 REPETITION OF STRETCH

The repetition of stretch is the amount of times a stretch is repeated in a session.

In an animal study to investigate the viscoelastic properties of a muscle-tendon unit by using repeated stretching to a constant length, Taylor et al. (1990) found that the greatest changes in muscle-tendon units occurred in the first four stretches for both cyclic and static

stretching regimes. In the static stretching regime 80% of the length increases occurred during the first four stretches, with the most elongation occurring during the first stretch. These observations were confirmed in a human model by McHugh et al. (1992). The purpose of their study was to demonstrate viscoelastic stress relaxation in human skeletal muscle. The response of the hamstring muscle group during a passive straight leg raise was studied. The passive stretch was held for 45 seconds at maximum tolerated ROM for test 1. In test 2 the straight leg raise was brought to five degrees below the ROM at which the onset of EMG activity occurred in test 1 and held at this point for 45 seconds. The results showed a significant decline in force over the 45 second relaxation period for both tests. Magnusson et al. (1995) also investigated the force relaxation response in hamstring muscles. Ten male subjects were studied in the test re-test protocol, which involved two 90 second stretches being administered one hour apart. The repeated stretches protocol also had ten male subjects and involved 5 consecutive static stretches held for 90 seconds with a 30 second rest period between each of the one to five stretches. A sixth stretch was performed one hour later. The results of the test re-test protocol showed a decline in resistance in both test 1 and 2. Mean resistance declined significantly over the 90 second stretch period with no significant decline after 40-45 seconds. The results of the repeated stretches protocol showed a decline in resistance with each subsequent stretch, complementing the findings of Taylor et al. (1990). The decline in resistance diminished in magnitude with each subsequent stretch. Viscoelastic changes were still statistically significant one hour later. The test re-test protocol demonstrated that one 90 second stretch was without effect one hour later, showing that repeated stretches were necessary to produce lasting (1 hour) viscoelastic changes.

1.9 DETRAINING EFFECT

The detraining effect in the context of stretching is the loss in range of motion that can be observed once stretching has stopped. Only three studies have examined the detraining effect following stretching. Tanigawa (1972) compared the effects of PNF hold-relax and passive mobilisation on hamstring muscle length over a three week period of stretching. The range of motion increased by 45.2% for the hold-relax group. The passive mobilization group gained range by 22.1%. Following the three week stretching programme Tanigawa examined the effect of seven days without stretching. A loss of 38.9% occurred during the seven days without stretching for the hold-relax group and 74.6% for the passive stretch group.

Turner Starring et al. (1988) compared the effects of cyclic versus sustained passive stretching with a mechanical device on resting hamstring muscle length. The hamstrings were stretched on five consecutive days for 15 minutes. The observed mean gains in range of motion were 27.7% for the cyclic stretch group and 24.0% for the sustained stretch group. A follow-up examination was incorporated one week after the finish of the stretching programme to test the detraining effect. The cyclic stretching group had a 34.4% loss in range after the week without stretching. The sustained stretching group had a 40.3% loss of range.

Willy et al. (2001) evaluated the effect of six weeks of static hamstring stretching, four weeks with cessation from stretching, and six weeks with resumption of stretching on knee range of motion. The hamstring stretching consisted of two 30 second stretches per day for five days per week. The mean knee range of motion increase after the initial stretching period was 6.3 %. The range of motion loss after the cessation period was

77.7%. The range of motion increase following the resumption of stretching was not different from the initial gains (6.2%).

1.10 SUMMARY OF KEY FINDINGS

Stretching has been shown to be an effective method of increasing range of motion. Short-term increases in range of motion have been observed after a single stretch session and long-term changes after several stretching sessions undertaken over a number of weeks.

The three most commonly used and studied stretching techniques are, static, ballistic and proprioceptive neuromuscular facilitation (PNF). When comparing the three techniques the literature is not conclusive as to which is more effective in increasing range of motion.

Increases in muscular performance observed following a stretching programme have been attributed to range of motion gains. Stretching has also been recommended as a method for prevention and treatment of injury following surgery and immobilisation.

The response of muscle to stretching has been attributed to neurophysiological and mechanical mechanisms. More recently it has been suggested that an "amplified stretch tolerance" is responsible for the increased range.

The frequency of stretch, defined as the number of days stretched per week, varies in the literature from twice per week to seven times per week. Significant increases in range of motion have been observed with all these varying frequencies. The duration of stretch is the length of time a muscle is held on stretch. The suggested durations of stretch range from six to 120 seconds. A duration of 30 seconds has been found to be as effective as

60 seconds and 15 seconds not significantly effective. The repetition of stretch is the amount of times a stretch is repeated in a session. The literature has shown that the most changes occur in the first four repetitions.

The detraining effect is the loss of range of motion that is observed with cessation of a stretching programme. There is limited research in this area and further research is needed to confirm the findings of the few studies that do exist. After one week cessation reported losses in gained range of motion for static stretching have ranged from 40.3% to 74.6%. After four weeks cessation reported losses have been 77.7%.

MATERIALS AND METHODS

2.1 STUDY DESIGN

A randomised trial design was utilised. Subjects were randomly assigned to control and experimental groups and the dependant variable, ankle joint dorsiflexion, was examined prior to, immediately after an intervention, and four weeks following the end of intervention. The intervention for the experimental groups was a four week stretching programme of either two stretching sessions per week (Stretch-2) or four stretching sessions per week (Stretch-4), followed by a detraining period of four weeks where no stretching was performed.

2.2 SUBJECTS

Thirty-one sedentary female subjects, aged 20-40 years were included in this study. The number of subjects required was established from pilot work and a power analysis. It was based upon a 10 percent change in the dependant variable (ankle dorsiflexion angle), with the alpha level set at 0.05 and the beta at 0.2.

All subjects were volunteers recruited by a posted advertisement describing the procedures of the experiment (appendix IV). The advertisements were placed in the QE 2 complex and nearby crèche in Christchurch.

The inclusion criteria for the study were: female subjects aged 20-40, who were not involved in any competitive physical activity and agreed to maintain their current level of activity over the study period.

Subjects were excluded if they had an existing injury or history of an orthopaedic or arthritic condition to their back, knee, foot, ankle joint or plantar flexion complex. Furthermore subjects with neurological problems or those involved in any competitive sporting activity were excluded.

Subjects could withdraw from the study at any time for any reason. Withdrawal from the study was without prejudice. Subject data was withdrawn from the study if the subject had not achieved greater than 75% compliance with the stretching programme, or had not maintained their activity at a similar level for the duration of the study.

2.3 EQUIPMENT AND PROCEDURES

All of the procedures were approved by the Auckland University of Technology ethics committee. All subjects signed a document of consent to participate (appendix 1).

2.3.1 Testing procedure

The subjects undertook the following procedures at the same time of the day, prior to the intervention, immediately after the intervention, and four weeks thereafter. Dorsiflexion range of motion of the left ankle was assessed using a weights and pulley system. The size of the weights used with this measuring device was 1.8 kg for the first five weights added then .9 kg for the following four.
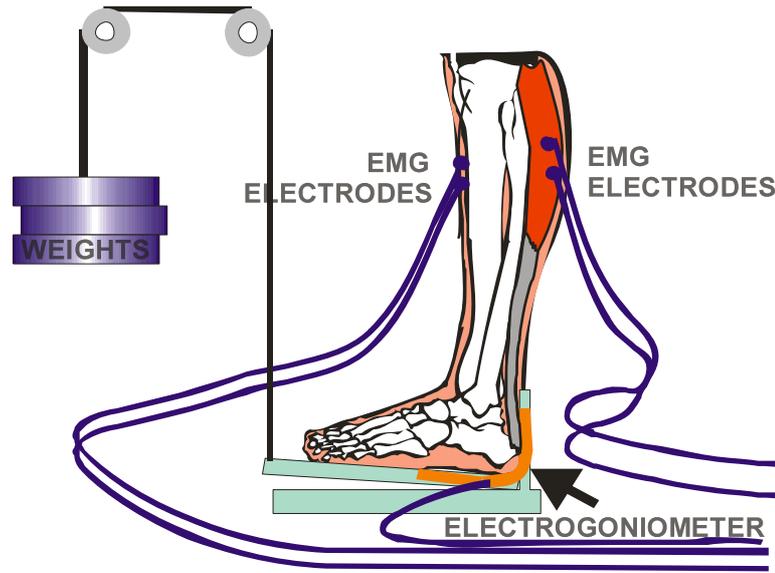
Figure 1. A schematic representation of the apparatus used to measure dorsiflexion range of motion of the ankle.

This equipment was similar to that used by McNair and Stanley (1996). The subject was positioned in sitting with the knee and ankle at 90 degrees. They were asked to relax their lower leg muscles. The left foot was then placed on a hinged footplate. The correct position was checked by using a block to line the medial border of the foot with the medial edge of the hinged footplate and the posterior aspect of the foot with the back of the hinged footplate. The medial malleolus of the ankle was positioned directly under the medial epicondyle of the knee. The right foot was in line with the left foot. A strap attached to the apparatus was fastened across the mid femur of the left leg to hold the limb in place. The subject sat stationary for five minutes prior to testing. The ankle was then passively dorsiflexed by adding weights to the pulley system at five second intervals. An electrogoniometer (Penny and Giles Ltd, Gwent, England) measured the ankle joint angle as each weight was added. A digital display allowed these measurements to be recorded immediately. The final ankle joint dorsiflexion position

was determined as being when the ankle did not dorsiflex any further with the adding of weight and the subject's heel remained in contact with the footplate.

The test-retest reliability of these procedures was examined by measuring 11 subjects twice, with a six day interval between tests. The three trials of data were averaged on each day. The results showed that the technique was reliable with an intraclass correlation (Shrout & Fleiss, 1979) of 0.97.

A two channel EMG unit (Chattanooga Group Inc., Tennessee, USA) was used to measure the tibialis anterior and the soleus muscle activity during passive dorsiflexion. Voltage levels were measured during the addition of weights in each trial. The skin was prepared for electrode placement by shaving and rubbing with alcohol wipes. The electrode placement was a bipolar configuration, with one set of the electrodes placed over the tibialis anterior adjacent to the fibula head (see figure 2) and the other set were placed over the soleus below the medial head of gastrocnemius (see figure 3) (McNair & Stanley, 1996).

Figure 2. Placement of tibialis anterior electrode.

Figure 3. Placement of soleus electrode.

Data were sampled at 500 Hz, amplified 1000 times and relayed to a digital display.

The level of EMG activity above which data were excluded from analyses was 1% of a

maximal voluntary contraction obtained in the position of testing at the completion of a

session.

2.3.2 Intervention

Stretch-2 group performed two stretching sessions per week and the Stretch-4 group

performed four stretching sessions per week. The control group did not stretch. The

stretching programme was undertaken for four weeks. A stretching session consisted of

five 30 second static stretches. There was a 10 second rest interval between each stretch.

The subjects were instructed to stretch the muscles until they felt a "strong stretching

sensation that was not painful". This instruction has been used by previous researchers

who have shown range of motion improvements following their stretching programmes

(Bandy & Irion, 1994; Turner Starring et al., 1988; Zito, Driver, Parker, & Bohannon,

1997). All subjects were shown how to perform the soleus and gastrocnemius stretches

and questions related to the instructions were answered. The stretches were performed at

the same time of the day and each session was recorded on a grid chart. Subjects were

instructed not to stretch the day before or the day of testing to ensure the short term or

acute effects of stretching were eliminated. The soleus stretch was performed by placing

the left foot, at the level of the first metatarsal phalangeal joint, on the edge of a phone

book with the heel still on the ground (see figure 4). The knee was then flexed over the

toes until the above mentioned stretching sensation was elicited (see figure 5). This

stretching technique has been used by a number of researchers (Bannerman et al., 1996;

McNair & Stanley, 1996) who have noted increases in range of motion following the use

of this technique.

Figure 4. Specific foot placement

for the soleus stretch.

Figure 5. Soleus stretch technique.

The gastrocnemius stretch was performed by putting both hands on a wall, the left leg was placed posteriorly with the knee straight and the right foot anteriorly. The right knee was flexed until the above mentioned stretching sensation was elicited (see figure 6). This stretching technique has also been used previously by other researchers (Williford et al., 1986) who have noted increases in range of motion following the use of this technique.

Figure 6. Gastrocnemius stretch position.

All subjects completed a log of their activity levels throughout the time of the study.

2.4 DATA ANALYSIS AND STATISTICS

Three trials of data were collected at each assessment point: pre-treatment (PRE), post-treatment (POST) and 4 weeks after the intervention ceased (FINAL). The mean of these trials was used in the statistical analysis.

Three variables were examined:

1. Firstly, it was of interest whether the angle measured at the final increment of weight changed across the three testing times (PRE, POST and FINAL). This was termed "greatest angle".

2. Secondly, it was of interest to determine whether the angle attained at the greatest common weight recorded pre-treatment changed at POST and FINAL tests. The greatest common weight was determined by the greatest weight increment that was common to PRE, POST and FINAL tests. For example if a subject had four weight increments at PRE-testing but only three at POST and FINAL, the greatest common weight was third weight. This angle was termed "angle at greatest common weight".

3. Finally, the average of the angles measured from the first weight increment to the greatest common weight were examined PRE, POST and FINAL. This angle was termed "average angle".

Statistical analyses were undertaken using the software programme SPSS (SPSS Inc., Michigan, Illinois, USA). One way analysis of variance tested equivalence of the groups for each dependant variable at baseline. Two factor repeated measures analysis of

variance compared the effects of the stretching programmes. In the latter analyses, group (3 levels: control, Stretch-2 and Stretch-4) was a between subjects factor: and time (3 levels: pre-treatment (PRE), post-treatment (POST), 4 weeks follow-up (FINAL)) was a within subjects factor. For all tests the alpha level was set at 0.05. Bonferroni adjustments were undertaken to correct for the chance of incurring a type 1 error.

RESULTS

3.1 SUBJECTS

The mean age of the subjects in the control, Stretch-2 and Stretch-4 groups was 31.2 yr (6.03), 31.3 yr (4.88), 32.4 yr (5.10) respectively. An examination of the subjects' activity levels showed that seven were non-active and the remaining 24 were involved in non-competitive social sports activities. Five of the seven non-active subjects were in the Stretch-4 group. The other two subjects were in the control group. All subjects maintained their activity levels throughout the time of the study.

3.1.1 Compliance

Eight of the 10 subjects in the Stretch-2 group achieved a compliance level of 100%. The remaining two subjects in this group had compliance levels of 87.5% and 75%. Of the eleven subjects in the Stretch-4 group seven achieved 100% compliance, three 93.8% and one 80% compliance. All subjects in the control group achieved 100% compliance as they maintained their normal level of activity.

3.2 DORSIFLEXION RANGE OF MOTION RESULTS

The data from all subjects (n=31) was included in the analysis of range of motion.
A one way ANOVA for each of the three dependant variables revealed no significant differences (p>0.05) between the three groups at baseline.

For the greatest angle achieved (see Fig 7) a repeated measures ANOVA showed a significant time (p=0.002) and group (p=0.033) interaction. Tests for simple effects revealed a significant time effect for the Stretch-4 group (p=0.002), but not for the

control or Stretch-2 groups. Bonferroni adjusted pair-wise comparisons between the Stretch-4 means revealed significant differences between PRE and POST (p=0.002), and POST and FINAL (p=0.004), but not between PRE and FINAL. The magnitude of the increase in range of motion for the Stretch-4 group was 21.5%. Tests for simple effects of group at each level of time did not reach significance (p>0.05).

Repeated measures ANOVAs on the angle at greatest common weight (see figure 8) and the average angle (see figure 9) revealed no significant main or interaction effects.

Figure 7: Greatest angle achieved at PRE, POST and FINAL tests

for control, Stretch-2 and Stretch-4 groups. Data are means and standard deviations.

Figure 8: Angle at greatest common weight achieved at PRE, POST and FINAL tests for
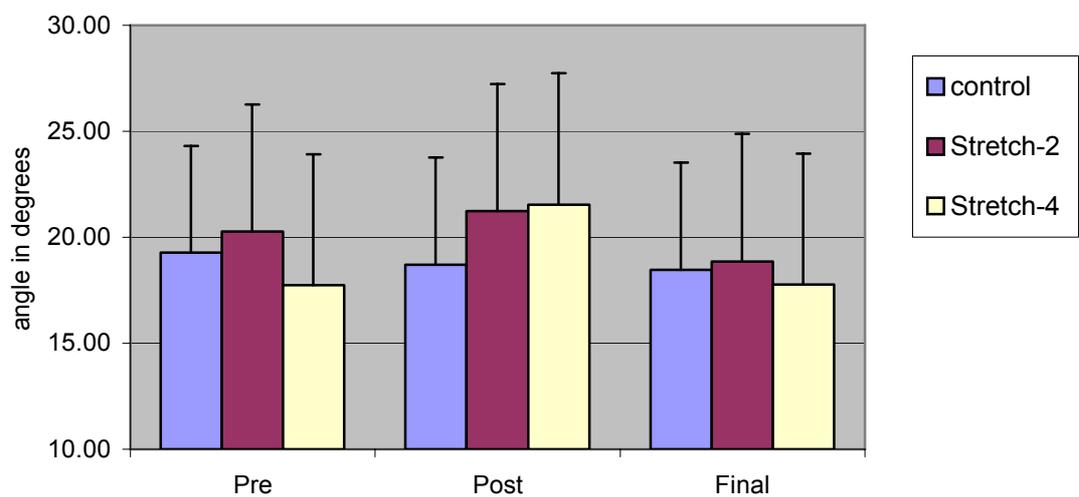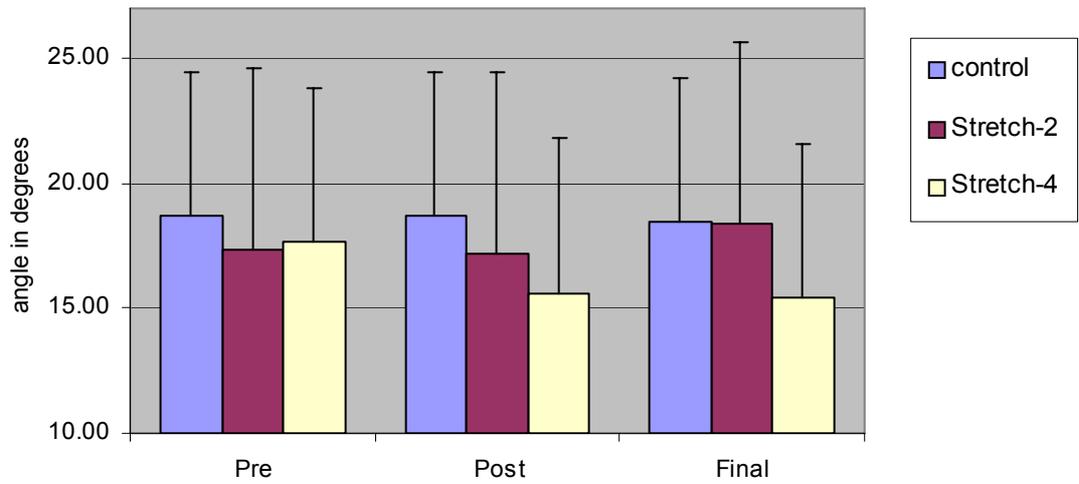control, Stretch-2 and Stretch-4 groups. Data are means and standard deviations.
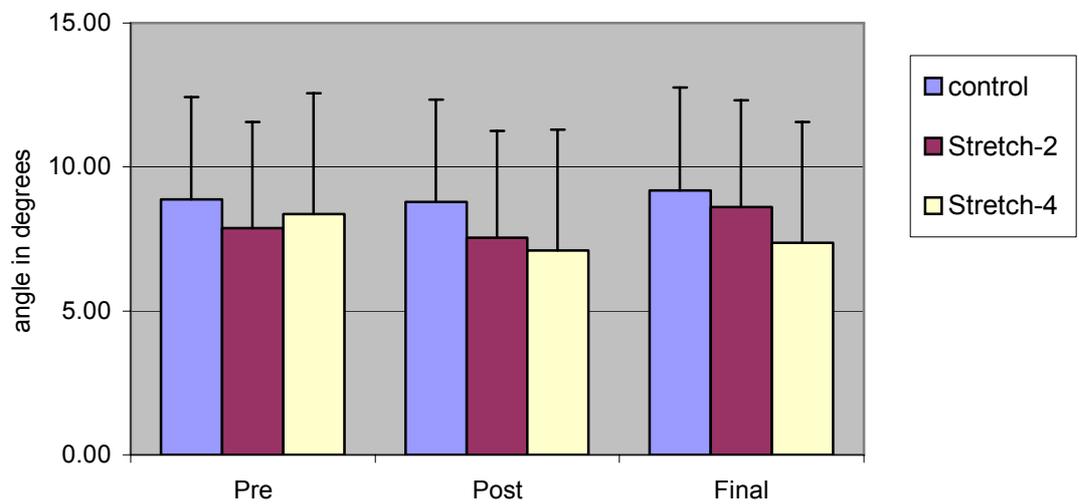

Figure 9: Average angle achieved at PRE, POST and FINAL tests for control, Stretch-2
and Stretch-4 groups. Data are means and standard deviations.

Typical subject data for a member of the control and experimental groups is presented in Figures 10 and 11 respectively. They show the angle changes that occurred PRE, POST and FINAL as each weight was added to dorsiflex the ankle. Measurements taken PRE, POST and FINAL in the control group subject were very similar across testing sessions. In contrast an increase in range of motion is shown after the stretching programme in the stretch group subject. However, after the four week detraining period the FINAL data has returned to pre-training levels.
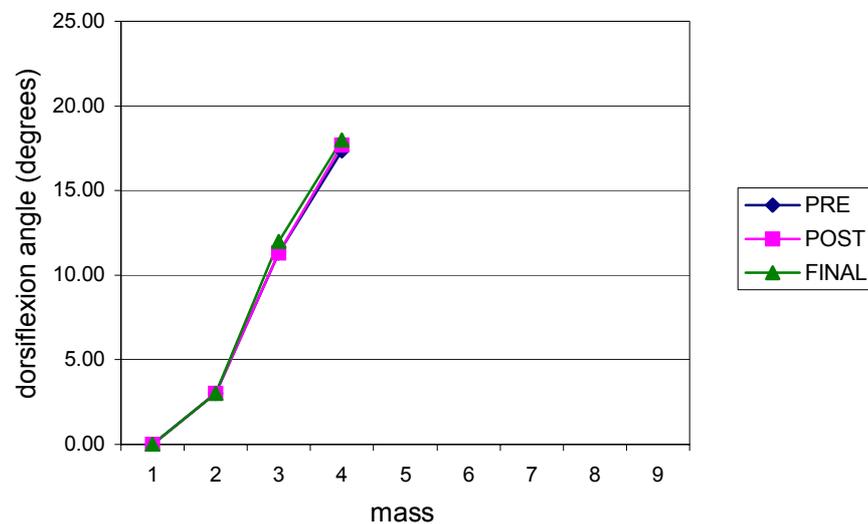

Figure 10: Graph of a typical subject from the control group showing

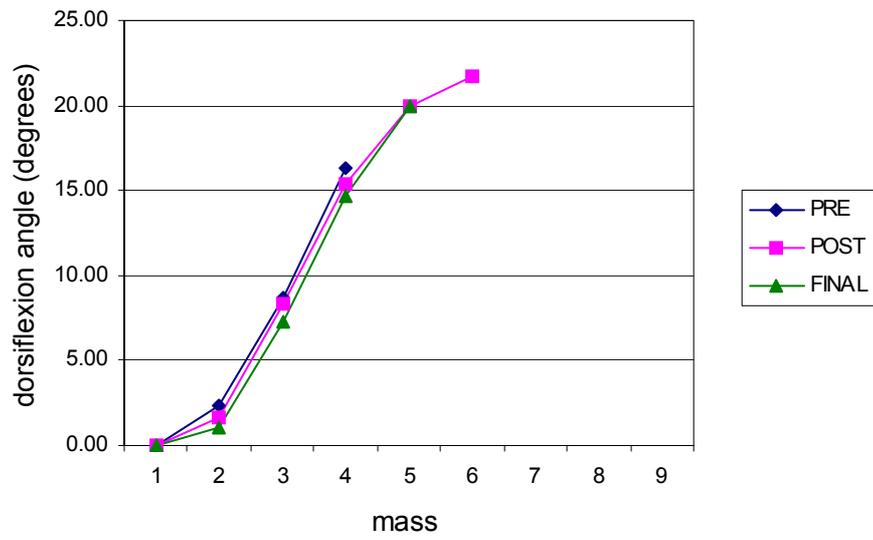PRE, POST and FINAL measurements. Data are means and standard deviations.

Figure 11: Graph of a typical subject from the Stretch-4 group showing PRE,

POST and FINAL measurements.

DISCUSSION

Stretching has been demonstrated to increase joint range of motion (Bandy & Irion, 1994; Bandy et al., 1997, 1998; Bannerman et al., 1996; Entyre & Abraham, 1986 a; Henricson et al., 1983; Tanigawa, 1972; Wiktorsson-Moller et al., 1983). Stretching has also been linked to a decreased incidence of injury (Ekstrand & Gillquist, 1983b; Ekstrand, Gillquist, & Liljedahl, 1983a) and to enhanced performance (Wilson et al., 1992; Worrell et al., 1994). For these reasons, stretching is prescribed as a preventative measure for injury and to enhance performance. However, a review of the literature revealed that there were gaps related to issues concerning the prescription of stretching programmes. This study focused upon two issues. Firstly the frequency of stretching and secondly the detraining effect.

The results of the study demonstrated that dorsiflexion stretches performed four times per week led to a significant increase in ankle joint dorsiflexion (21.5%). A frequency of twice weekly stretches was not sufficient to show significant gains (4.8%). In relation to the detraining effect, after four weeks of no stretching, the ankle joint dorsiflexion measurements returned to those taken at baseline for the experimental groups.

When reviewing the literature there were no stretching studies, which examined increases in ankle joint dorsiflexion over a four week intervention period. There were also no studies which compared the effect of different frequencies of stretching per week although individual studies have employed stretching frequencies of twice per week, three times, five times and seven times per week.

The finding that twice weekly stretches did not elicit gains was surprising, and in contrast to other research which examined the ankle joint dorsiflexion. For instance Bannerman et al. (1996) showed a significant increase in dorsiflexion with static and ballistic stretching over a five week period, stretching twice per week with a 15 second duration of stretch. Bannermann's range of motion showed a 6.3% increase from baseline to post-intervention for the static stretch group. The current study had a non- significant 4.8% increase from pre- to post-intervention testing for the Stretch-2 group. The subjects in both studies were of a similar age but the subjects in the current study were females with a lower level of activity than Bannerman's being male rugby players. Bannerman used a universal goniometer to measure their subjects using surface landmarks. This method is less likely to get a significant change than the method used in the current study. Williford et al. (1986) also showed a significant increase in range of motion when using the stretching frequency of twice per week. The study examined increases in ankle joint range of motion after static stretching for nine weeks with a 30 second duration of stretch. The 6.6% gain in range was comparable to the gains observed by Bannerman but greater than those of the Stretch-2 group in the current study. Williford's study population were of a similar age to the current study but were physically active. The number of weeks (4 in the current study) may be a factor that is worthy of consideration. However, others have shown that ROM changes can occur within the time period used in the current study.

Henricson et al. (1983) also examined ankle joint dorsiflexion. Their frequency of stretch was three times per week for a 12 week intervention period with a 15 second duration. They measured the gains at two, four, eight and 12 weeks but unfortunately only presented the 12 week gains in their paper. The significant gains at 12 weeks were 11.5% when measured with a flexed knee (as was used in the current study) and 18.5%

when measured with an extended knee. The gains observed by Henricson were greater than the current study's Stretch-2 group but less than the Stretch-4 group's 21.5% gain although the time frame used was three times greater. When comparing the subjects from Henricson's study with those of the current study the age group and activity level were quite different. Henricson's subjects were girls and boys 17-18 years of age and actively involved in 10-15 hours per week of badminton.

A number of studies examined the effects of twice per week stretching frequencies on other muscle groups. Borms et al. (1987) used a frequency of twice per week, for ten weeks, when studying different durations of stretch on hip flexibility. The gains observed were 18.6%, (10 second duration), 20% (20 second) and 22.5 % (30 second). The subjects in the study by Borms were similar to the current study being sedentary females aged 20-30 years. The increase in range of motion for the 20 second duration of 20% and the 30 second duration of 22.5% is similar to the current study's Stretch-4 gain of 21.5%. Tanigawa (1972) also used a frequency of twice per week when studying the effect of a passive stretching programme on the hamstring muscles length over a three week period. Range of motion increased by 22.1%. This gain was again comparable to the Stretch-4 groups gain. The subjects in Tanigawa's study were males of similar age to the current study. Borms used a goniometer to measure the range of motion and Tanigawa used a mathematical method involving the calculation of the sine of a right angle triangle.

In respect to the equipment used in the current study, the range of motion measures were collected using standardised weights to passively move the ankle into dorsiflexion. The resulting degrees of motion achieved were measured using an electrogoniometer. Traditionally methods of measuring range of motion have only taken into account the

range of motion, not the forces required to produce motion. Few other studies have used the technique of the current study. Most have used goniometers that usually have a resolution of five degrees (Godges, MacRae, Longdon, Tinberg, & MacRae, 1989; Henricson et al., 1983; Wiktorsson-Moller et al., 1983). The baseline measurements for this study showed a mean peak angle of 19.04 (SD 4.99) degrees dorsiflexion. Using a very similar technique, McNair and Stanley (1996) recorded angles of 18.8 (SD 6.6) and 18.3 (SD 6.2) degrees dorsiflexion.

A question of interest is the mechanism behind the observed changes in range of motion in the current study. The effectiveness of stretching has been attributed to neurophysiological (Hutton, 1993) and biomechanical mechanisms (Taylor et al., 1990). The neurological foundations of some stretching techniques are based on neural inhibition of the muscle undergoing stretch, with decreased reflex activity resulting in reduced resistance to stretch, which results in further gains in joint range of motion. Studies on humans contradict this theory as they have shown that the stretching exercises that produce the greatest improvements in joint range of motion can yield the largest EMG response (Osternig, Robertson, Troxel, & Hansen, 1990, 1987). The biomechanical mechanism suggests that stretching causes a change in the mechanical properties of the muscle (Taylor et al., 1990). The muscle tendon unit is considered to respond viscoelastically when stretched (Magnusson et al., 1996c; Taylor et al., 1990). Another theory that has more recently been proposed is that acute and chronic adaptations may be attributed to an amplified stretch tolerance (Magnusson et al., 1996a; Magnusson et al., 1996b). Rather than a change in elasticity occurring in the muscle as a result of a stretch stimulus, it is proposed a subject's tolerance to the stretch increases allowing more range to be achieved. The role of these mechanisms in stretching of the human skeletal muscle in vivo remains unclear. Most studies have only investigated the

range of motion changes that occur with stretching (Bandy & Irion, 1994; Williford et al. 1986; Wilson et al., 1992). Some have also taken into account EMG activity (Condon & Hutton, 1987; Hutton, 1993). For improved understanding of the mechanism the tensile loading of the structures should be measured as well as the range of motion (Halbertsma & Goeken, 1994; Magnusson et al., 1996a; Magnusson et al., 1996b; McHugh et al., 1992; McNair & Stanley, 1996). In the current study the amount of load necessary to increase the ROM of the ankle joint was recorded prior to and after a stretching regime. The results provided some evidence that viscoelastic changes were not occurring. That is, if the changes observed in the current study were of a viscoelastic nature and the tissues became more compliant, the angle associated with a certain load pre-intervention would be more post-intervention. This did not occur. The variable "greatest angle" was significantly increased in the Stretch-4 group and the load associated with that angle was increased. The "angle at the greatest common weight" and "the average angle" measured across baseline weights were unchanged post intervention. These findings are similar to those of Magnusson et al. (1996b) who also noted no change in viscoelastic characteristics following a three week training programme. Like the current study, these authors noted increased range of motion and increased resistance to stretching. Thus the load-ROM curve was extended directly from the baseline measures and was unchanged at loads recorded at baseline. These findings provide evidence for a mechanism other than that related solely to viscoelasticity. Magnusson et al. (1996b) suggested that this mechanism might be an increased tolerance to stretch, a mechanism that has received increasing attention recently.

Follow-up measures recorded four weeks after the cessation of training provided a measure of the detraining effect. In the current study, the Stretch-4 group increased range of motion by 21.5% after four weeks of stretching. After the four week detraining

period a loss of 99.8% of the gains was observed, that is the range returned virtually to baseline. Few studies have examined the effects of detraining. Tanigawa (1972) incorporated a follow up session one week after stopping stretching of the hamstring muscles. During the three week stretching programme the hold-relax group gained 45.2% in range, while the passive stretch group gained 22.1%. The detraining effect showed a loss of 38.9% of the observed gains for the hold-relax group and 74.6% for the passive stretch group. Tanigawa believed the loss in range of motion may have been due to fibrous changes, which occurred during the no stretch week initially caused by possible muscle damage to the hamstring muscles when doing the stretching programme. Turner Starring et al. (1988) also incorporated a follow up examination one week after the finish of a five day stretching programme. The study examined the effect of cyclic and sustained passive stretch on the hamstring muscles. The cyclic stretching group showed a 27.7% increase in knee flexion. After no stretching a 34.4% loss of the range gained was documented. The sustained stretching group showed an increase in knee flexion of 24.0%. The loss after no stretching was 40.3% of the increase that was gained from the stretching programme. Willy et al. (2001) evaluated the effect of six weeks of static hamstring stretching, four weeks with cessation from stretching, and six weeks with resumption of stretching on knee range of motion. The hamstring stretching consisted of two 30 second stretches per day for five days per week. The mean knee range of motion increase after the initial stretching period was 6.3 %. The range of motion loss after the cessation period was 77.7%. The range of motion increase following the resumption of stretching was not different from the initial gains (6.2%).

The pattern of loss in range of motion over specific weeks cannot be determined in the current study. It is apparent from the above studies that gains can become significantly diminished after only one week of detraining. Such findings have ramifications for

clinical practice. It may be that those people who are suffering from range of motion deficits as a result of injury or degenerative conditions may have to maintain levels of stretching permanently. These thoughts remain speculative until further research can be undertaken.

All subjects who participated in the current study were included in the statistical analysis (n=31). A level of compliance of at least 75% was achieved by all subjects. This is lower than the levels used by other authors. Williford et al. (1986) examined increases in ankle joint range of motion after static stretching was performed twice per week for nine weeks. They excluded subjects from their study if they missed more than two sessions therefore all subjects achieved a level of 88% or greater compliance. Sady et al. (1982) compared the effects of static, ballistic and PNF stretching techniques on the range of motion at the shoulder, trunk and hamstring muscles performed three times per week for six weeks. Subjects were excluded from the study if they missed more than one stretching session equating to a 94% level of compliance. Magnusson et al. (1996b) investigated the effect of a three week daily stretching regimen on the tissue properties and stretch tolerance of human skeletal muscle. The subjects completed 94 +/- 1% of the stretch sessions. In the current study, the average level of compliance was 90% for Stretch-4 and 81% for Stretch-2. Perhaps this lower level of compliance was a factor in the lack of significant findings in the Stretch-2 group.

4.1 LIMITATIONS OF STUDY

A number of limitations in the current study need to be considered:

1) This study was limited to the effects of stretching the calf muscle complex on ankle joint dorsiflexion. The results obtained using this protocol on ankle joint range of motion may be different when tested on other muscle groups at other joints. The reason for

possible differences when stretching other muscles mainly relates to different joint architecture and muscle type and function. Further studies using the same protocol are required to determine how different muscle groups would respond to this stretching protocol.

2) The subjects in this study were all female therefore the response to the protocol may be different in a male population. Though the evidence is conflicting and far from conclusive, it appears that females are generally more flexible than males (McHugh et al., 1992). The reasons are unknown, however, it seems likely that structural differences in the muscle and tendon may be responsible (Goldstein, Armstrong, Chaffin, & Matthews, 1987).

3) The subjects involved in this study were 20-40 years of age. Conclusions from this study should only be applied to similar age groups, and future research is needed on subjects in other age groups.

4) The subjects were either sedentary or involved in non-competitive exercise. To be able to relate this study's findings to other activity levels further research would need to look at either particular sports with similar activity levels or each sport individually.

5) This study could not be double blinded (neither the subjects nor the researcher knowing who was in each study group) as due to the nature of the intervention the subjects knew which group they were in. It was also not single blinded (researcher not knowing who was in each group) as only one researcher was involved in conducting the study therefore tester bias cannot be excluded. However, resources were limited and this bias would be typical of many projects undertaken for a Masters thesis.

SUMMARY AND CONCLUSIONS

This study is unique in that no other studies have examined the effects of a long term stretching programme as well as a period of detraining on viscoelastic parameters acting on the ankle joint in humans. The findings of the study support the use of static stretching to increase range of motion. However, the results indicated that stretching four times per week for four weeks produced a significant change in range of motion but stretching twice per week did not show a significant change. The results indicate that the mechanism responsible for the increase in range of motion may be due to increased stretch tolerance by the subject not biomechanical changes. If the stretching regime is stopped, a detraining effect occurs where range of motion is lost. In this study after four weeks without stretching, the Stretch-4 group lost 99.8% of the gains they had made with the stretching programme.

5.1 FUTURE WORK

There are a number of questions that have arisen while undertaking the current study. To answer these questions, further research needs to be conducted. Ideally a similar protocol or methodologies should be used to be able to compare the results. Firstly, did the change in range of motion occur before four weeks? The subjects would need to be followed week by week to show if changes happened earlier than four weeks. If a significant change occurred earlier, this would allow shorter stretching programmes to be prescribed. Conversely if an individual continued a stretching programme for longer than four weeks would the increase in range continue or would it level off?

The detraining effect, which is often not studied, is an area of great importance as it allows the length of time to be measured that individuals could rest from a stretching

programme before they lost their gains. Measuring the detraining effect at closer

intervals, perhaps week by week, would give more information on this aspect of

stretching.

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APPENDICES
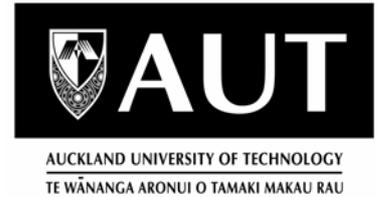
TITLE: AN INVESTIGATION INTO THE EFFECT OF STRETCHING FREQUENCY ON RANGE OF MOTION AT THE ANKLE JOINT.

INVESTIGATOR: Vanessa Trent

SUPERVISORS: Dr Peter J. McNair & Mr Maynard Williams

PURPOSE OF THE RESEARCH

Stretching is performed before and after exercise to prevent injury by allowing the joints to move more freely. It is also prescribed in the rehabilitation of injuries to help speed up recovery. There is much that is still unknown about stretching, for example how many sessions per week do you need to stretch. This study will address this question by looking at how many stretching sessions per week are needed to increase ankle joint range of motion. Finding out these details about stretching will enable a clearer picture of the effects and benefits of stretching. This will enable health professionals to prescribe effective stretching programmes for their clients. It will also help people participating in physical activity to prevent injuries.

If you decide to participate in this study the following "explanation of procedures" outlines what is involved.

EXPLANATION OF PROCEDURES

This research project is an eight week clinical trial. It involves stretching your calf muscles for a period of four weeks then not stretching for a further four weeks. The range of motion of the ankle joint will be tested before you commence the stretching programme, after four weeks, which is the end of the stretching programme, and finally at eight weeks once you have not stretched for four weeks. This last testing is to see if the stretching effect lasts once you stop stretching.

You will be randomly assigned to one of three groups. Group one will stretch two sessions per week, group two four sessions per week and group three acts as a control and does not stretch.

Testing procedure for ankle joint dorsiflexion.

You will be seated on a chair with your knees bent to approximately 90 degrees and your bare left foot positioned on a wooden platform beneath your left knee. A seat belt will be put across your knee to keep you in this position. You will have an electrode put on your shin and one on your calf muscle to test the EMG activity in your muscles. You will sit quietly for five minutes prior to testing. The testing consists of a weights and pulley system moving your foot gently into dorsiflexion. Once your foot stops moving the angle of your foot to your leg will be measured by an electrogoniometer, which is attached to the frame of the stretching rig. The testing will take less than ten minutes.

Stretching session

Once you have been tested you will be shown how you are to stretch your calf muscles for this particular study.

The stretches are for your gastrocnemius (long calf muscle) and your soleus (short calf muscle). The session consists of five stretches, each held for 30 seconds. When moving

into the stretch position stop and hold the position once you feel a "strong stretching sensation that is not painful". You will be given a log book to record your stretching sessions. You will need to do the stretches at the same time of the day and the frequency per week will depend on the group to which you are randomly assigned.

As mentioned above you will stretch for four weeks then stop for the next four weeks, except the control group who will not stretch at all in the eight weeks. You will be tested for ankle joint range of motion at zero, four and eight weeks. You will need to keep your activity level the same for the whole eight weeks, i.e. not increase the amount you are doing or participate in any competitive sport.

POSSIBLE RISKS AND DISCOMFORTS

There are no obvious risks involved with this study if you closely follow the instructions given to you. If you do not follow the instructions and stretch past discomfort into pain you may injure your calf muscle. The testing procedure does not pose any risks and has been thoroughly tested with volunteers prior to testing you.

CONFIDENTIALITY

Each subject's information and test results will be treated as confidential and no personal identification will be used in any publication. The subjects will remain anonymous. The data will be stored on a computer belonging to the researcher and only the researcher and the supervisors will have access to the information. Once the study has been completed, it is a requirement that the subject records be preserved for 10 years after the study is completed. These will be held under lock and key by the investigator.

Appendix II

AUCKLAND UNIVERSITY OF TECHNOLOGY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

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SUBJECT CONSENT FORM

TITLE: AN INVESTIGATION INTO THE EFFECT OF STRETCHING FREQUENCY ON RANGE OF MOTION AT THE ANKLE JOINT.

INVESTIGATOR: Vanessa Trent

SUPERVISORS: Dr Peter J. McNair & Mr Maynard Williams

DECLARATION OF CONSENT

I, the undersigned………………………………………….(full name)

of……………………………………………………..…….(address)

Phone number   (H)…………………(W)………………

Consent to be a subject in this research study. I have read the "subject information form" and understand the consequences associated with participation. I have had the procedures explained to me and the investigator has answered my questions concerning the procedures involved in this study. I may withdraw from the study at any time without compromise.

I also agree that the results of this research study can be used for the purpose of publication in scientific journals on the understanding that anonymity will be fully preserved.
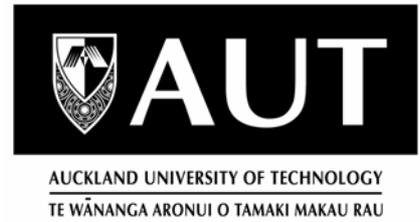
Signature…………………………………………………..Date……………….

Witness…………………………………………………………Date……………….

I have explained the research procedures to which the subject has consented to participate.

Researcher………………………………………………… Date………………

Appendix III

INCLUSION QUESTIONNAIRE

To participate in this study it is necessary that you meet certain criteria. By filling out this

form the researcher can decide whether you can be included in this study.

Circle the correct answer.

1) Are you between the ages of 18-40?   YES / NO

2) Do you participate in any sporting activity?   YES / NO

If yes, explain what type of activity and how often (eg walking 3x week for 45 mins).

3) Have you ever had any major illnesses?   YES / NO

4) Have you ever had a neurological problem?   YES / NO

5) Have you had any injuries to your back or legs in the last three months?   YES / NO

6) Do you have a history of orthopaedic problems or arthritis that have affected your back,

hips, knees, ankles or feet?   YES / NO

7) Do you have any loss of function in your legs due to previous trauma or congenital

abnormality?   YES / NO

We need you!!

Would you like to participate in a stretching study being carried out at SportsMed QE 2?

The aim of the study is to determine how many times a week you need to stretch your calf muscles to increase ankle joint range of motion.

The study runs for eight weeks and involves a stretching programme for the calf muscles for the first four weeks followed by four weeks of no stretching to measure how quickly the effects of stretching are lost. Before you start the stretching programme your ankle joint movement will be measured with a passive dorsiflexion device (this is painless). The movement will be remeasured at four weeks and at eight weeks after four weeks of no stretching. So you only need to come for testing three times. Testing takes about 10 minutes.

To register your interest either ring SportsMed QE 2 on 3836290 or call in at the reception and leave your name and contact number.

If you participate in the study you will be in to win a $100 dinner at a restaurant of your choice (only 30 people will be involved so you have a 1/30 chance of winning).