

**THE FREQUENCY OF HAMSTRING
STRETCHES REQUIRED TO MAINTAIN
KNEE EXTENSION RANGE OF MOTION
FOLLOWING AN INITIAL SIX-WEEK
STRETCHING PROGRAMME**

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Attestation 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 (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degrees or diploma of a university or other institution of higher learning.”

Signed.....

Date.....

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The Auckland University of Technology Ethics Committee (AUTEK) granted ethical approval for Study 1 and 2 on 06th November 2011 (Ethics Application Number 11/153).

ABSTRACTS

Objective: The objective of this study was to determine the frequency of on-going hamstring stretching required to maintain knee extension ROM following an initial stretching programme.

Study Design: A test-retest randomised control trial with repeated measures was undertaken with 63 university-aged males as participants.

Background: Stretching exercises are commonly prescribed during warm-up and cool-down, and within training and rehabilitation programmes with a common aim to improve muscle extensibility and joint range of motion. Previous research has demonstrated that stretching the hamstring muscle group once a day, five days a week for a six-week period improves knee extension range of motion. However, it has been demonstrated that this improvement is short-lived and starts to reduce once the stretching intervention is ceased. To maintain the improvement in range of motion gained following an initial stretching programme, an on-going stretching programme may be required. There is, however, little research to demonstrate the optimal frequency of on-going stretching required to maintain the range of motion once the initial improvements have been achieved.

Method: Participants were randomly assigned to two intervention groups and a control group. The two intervention groups both stretched for 30 seconds three times, once per day, five days a week, for an initial six weeks. The intervention was an active knee extension static hamstring stretch in a supine position. After the six-week initial stretching programme, participants allocated to intervention group one continued stretching with the same stretching routine once a day, three days per week, and

participants in intervention group two once a day, for one day per week, for a further six weeks. Participants in the control group did not stretch over the 12-week intervention period. Knee extension range of movement was assessed by an active knee extension test using an electronic goniometer at baseline, week six and week 12.

Results: Following the initial six-week stretching programme there was a significant ($p < 0.05$) improvement in knee extension range of motion (mean- 16.2 degrees) in both intervention groups. Over the further six-week on-going stretching programme those participants in intervention group one (stretched three days a week) maintained their improvement in range of motion, whereas those in intervention group two (stretched one day per week) did not. The difference between the groups was significant ($p < 0.05$). No significant difference ($p > 0.05$) was observed in knee extension range of motion in the control group.

Conclusion: The findings of this study were consistent with previous research that has demonstrated a six-week static hamstring stretching programme significantly improves the knee extension range of motion. The on-going hamstring stretching programme with the frequency of three times a week was required to maintain the initial improvement in knee extension ROM for 6 weeks. This finding may be useful to maintain the benefits of stretching exercises with minimal effort, and therefore potentially improve compliance with on-going stretching exercises.

Chapter 1

Introduction

1.1 Statement of the problem

Stretching exercises are commonly prescribed during warm-up and cool-down protocols, and training and rehabilitation programmes with the aim of improving muscle extensibility and joint range of motion (ROM) (Smith, 1994; Chan, Hong & Robinson, 2001; Willy, Kyle, Moore & Chleboun, 2001; Small, McNaughton & Matthews, 2008). The benefits of stretching exercises include preventing musculoskeletal injuries, improving muscular performance, mobility and posture, recovery from muscle strain, and alleviating muscle soreness (Worrell & Perrin, 1992; White & Sahrman, 1994; Worrell, Smith & Winegardener, 1994; Gleim & McHugh, 1997; Shrier, 1999; Kerrigan, Xenopoulos, Sullivan, Lelas, J. & O'Reilly, 2003; Malliaropoulos, Papalexandris, Papalada & Papacostas, 2004; O'Sullivan, Murray & Sainsbury, 2009).

Stretching exercises can be classified by duration or technique. The three most common types of stretching based on a duration of stretching are; acute, periodic and chronic stretches (Liebesman & Cafarelli, 1994). An acute stretch is one that is completed in a single session, a periodic stretch is performed several times each week for a given period of time, and a chronic stretch is a form of continuous stretch usually attained by immobilisation such as casting (Bandy & Irion, 1994; Liebesman & Cafarelli, 1994; Depino, Webright & Arnold, 2000; Weppler & Magnusson, 2010). There are also a range of common stretching techniques and these are ballistic, static and proprioceptive neuromuscular facilitation (PNF) stretch. Ballistic stretching refers to repetitive bouncing and rhythmic movements in the muscle's lengthened position while static stretch is a slow stretch sustained at the point of maximum

tolerable tension. PNF stretch refers to a technique utilising maximum relaxation of the muscle following a maximum isometric contraction of the muscle (Liebesman & Cafarelli, 1994; Smith, 1994).

During a stretching intervention, a muscle extends against the passive resistance of the internal connective tissues. The internal connective tissues that contribute to the passive resistance consist of the series elastic components and the parallel elastic components. The principal components of these elastic components are endomysium and perimysium respectively (Magnusson, 1998). The primary aim of a stretching intervention is therefore to overcome this passive resistance of the internal connective tissues and by doing so increases joint ROM. The passive resistance of a muscle is related to its muscle extensibility as the muscle extends (McNair & Stanley, 1996). Muscle extensibility is defined as the ability of a muscle to extend and this could be measured in muscle stiffness (Magnusson, 1998; Reid & McNair, 2004). An examination of muscle stiffness allows you to demonstrate whether structural changes are occurring with changes in ROM following stretching exercises (Reid & McNair, 2004). However, increased muscle extensibility could also be demonstrated by an increase in ROM (Weppeler & Magnusson, 2010). Although a measurement of ROM does not examine possible structural changes following stretching exercises, it is a measurable outcome for increased muscle extensibility. A number of studies have confirmed that increases in muscle extensibility following stretching exercises are accompanied by an increase in ROM (Magnusson, 1998; Reid & McNair, 2004; Weppeler & Magnusson, 2010).

To explain the increase in ROM following stretching exercises, two theories have been proposed; the mechanical and neurophysiological theories (Magnusson, 1998; Weppeler & Magnusson, 2010). The mechanical theory describes structural changes associated

with increased joint ROM and proposed mechanisms include viscoelastic deformation, plastic deformation of connective tissues, and an increase in the number of sarcomeres in series (Liebesman & Cafarelli, 1994; Weppeler & Magnusson, 2010). Whilst these mechanisms have been proposed based on observations from animal studies, the same phenomena is yet to be confirmed in human studies (Goldspink, Tabary, Tabary, Tardieu & Tardieu, 1974; Taylor, Dalton, Seaber & Garrett, 1990; Gajdosik, 1991; Liebesman & Cafarelli, 1994; Smith, 1994; Magnusson, Simonsen, Aagaard, Sorensen & Kjaer, 1996b; Magnusson, Aagaard & Neilson, 2000; McNair, Dombroski, Hewson, Stanley, 2001; Reid & McNair, 2004; Ryan et al., 2008; Weppeler & Magnusson, 2010; Esposito, Limonta & Cè, 2011).

The neurophysiological theory for increased ROM suggests that involuntary contraction of muscles, evoked by a stretch reflex, can limit the muscle under stretch from excessive elongation. The overall effect is limitation of joint ROM (Liebesman & Cafarelli, 1994; Smith, 1994; Magnusson, 1998; Weppeler & Magnusson, 2010).

However, the evidence from experimental studies does not support this theory (Moore & Hutton, 1980; Osternig, Robertson, Troxel & Hansen, 1990; Magnusson, Simonsen, Aagaard & Kjaer, 1996a; Magnusson et al., 1996b; Magnusson, 1998). Paradoxically, PNF stretching techniques have been shown to be associated with an elevated electromyogram (EMG) of a muscle under stretching while joint ROM still increases (Moore & Hutton, 1980; Osternig et al., 1990). Other studies have demonstrated no significant changes in EMG activity of the stretched muscles and yet ROM improved after stretching (Magnusson et al., 1996a; Magnusson et al., 1996b; Magnusson, 1998). These conflicting findings suggest that changes in neural activity in muscles may not be related to increases in ROM.

A more recent explanation for increases in ROM is the sensory theory. This theory suggests that increases in ROM after stretching is due to an alteration of the subject's stretch tolerance, rather than increases in muscle length or altered mechanical properties (Halbertsma & Goëken, 1994; Magnusson et al., 1996a; Nelson & Bandy, 2004). The increased ROM associated with an increase in stretch tolerance, without a change in mechanical properties, has been confirmed by a number of studies (Gajdosik, 1991; Halbertsma & Goëken, 1994; Magnusson et al., 1996a; Nelson & Bandy, 2004; Reid & McNair, 2004; Folpp, Deall, Harvey & Gwinn, 2006; Ben & Harvey, 2010).

With respect to the optimal frequency and duration of static stretching programmes, previous research has demonstrated that a stretching programme consisting of 15-60 seconds, one to three repetitions per day, five days a week, for six weeks is sufficient to elicit significant changes in ROM (Bandy & Irion, 1994; Bandy et al., 1997; Willy et al., 2001; Reid & McNair, 2004; Davis, Ashby, McCale, McQuain, & Wine, 2005; Decoster, Cleland, Altieri & Russell, 2005; Yuktasir & Kaya, 2009; Russell, Decoster & Enea, 2010). While the majority of the research has been carried out in the calf and hamstring muscle groups, the previously mentioned parameters are generally considered to be effective for all muscle groups (American College of Sports Medicine Position Stand, 1998; Prentice, 2002).

Whilst the previously mentioned parameters have been advocated to improve ROM, there is evidence suggesting that improvements gained from stretching programmes are short-lived. A small number of studies have examined how long improvements in ROM last following acute stretching interventions (Depino et al., 2000; Spernoga, Uhl, Arnold & Gansneder, 2001; de Weijer, Gorniak & Shamus, 2003; Ford & McChesney, 2007). These studies suggested that improvements in ROM following acute stretching

interventions lasted anywhere between 3 minutes to 24 hours after following the cessation of stretching. Similar results have been reported following periodic stretching programmes. Following one to six weeks of periodic hamstring stretching programmes it is demonstrated that improvements in ROM were retained for three to four weeks, and then start to diminish following the cessation of stretching (Rubley, Brucker, Knight, Ricard & Draper, 2001; Willy et al., 2001). Regardless of duration of a stretching intervention it would appear that improvements gained from a stretching programme are temporary, maximum of four weeks, once the stretching programme is stopped. This leads to the concept that an on-going stretching programme would be necessary in order to maintain the benefits gained following an initial stretching programme.

Research has demonstrated that too many exercises given to patients can reduce compliance (Haynes, 1979; Schneiders, Zusman & Singer 1998; Henry, Rosemond & Eckert, 1999). In addition, once the patients are discharged from therapy, the rate of continued compliance with the home exercise programme has been found to be low (Sluijs, Kok & van der Zee, 1993). Therefore, the ability to determine the minimum number of stretches required to maintain ROM may also help to improve compliance with the on-going stretching interventions.

The current literature is unclear on what the optimal weekly frequency of stretching is in order to maintain ROM improvement after an initial stretching programme. More specifically, no randomised controlled trials have examined the frequency of hamstring stretches required to maintain knee extension range of motion once the initial improvements have been achieved.

1.2 Purpose of the study

1. To investigate the effect of a six-week hamstring stretching programme on the knee extension ROM.
2. To investigate what frequency of stretching is required to maintain improvement in ROM after an initial six-week stretching programme.

1.3 Significance of the problem

The study will have significance for coaches, trainers, health professionals and athletes in the maintenance of improvement in ROM following stretching programmes. By examining the effects of varying frequencies of an on-going hamstring stretching programme on knee extension ROM, this study will provide information on the minimum number of stretches required to maintain improvement gained following an initial stretching programme. This will be of interest in terms of maintaining the benefits of stretching exercises with minimal frequency, and therefore potentially improving compliance with on-going stretching exercises. The findings gained from the study will provide a guideline for stretching prescriptions following an initial stretching programme and therefore may help in the prevention and rehabilitation of injuries related to reduced muscle extensibility and joint ROM.

Chapter 2

Review of literature

Introduction

This chapter is composed of three sections. Firstly, there is a description of the various types of stretching, together with the recommendations on duration and frequency for a stretching programme and for maintenance of the improvement gained following an initial stretching programme. Secondly, a systematic review of the literature pertaining to static and periodic stretching interventions of the hamstring muscles and a long-term effect of stretching after cessation is presented. Thirdly, the literature relating to the reliability of the knee extension ROM measurement is reviewed.

2.1 Types of Stretching

There are various types and techniques of stretching presented in the literature. The three most common types of stretching utilised based on the duration of stretching are; acute, periodic and chronic stretches (Liebesman & Cafarelli, 1994, Wepler & Magnusson, 2010). An acute stretch is completed in a single session and the effect usually lasts for only a few minutes (Depino et al., 2000). A periodic stretch refers to a protocol when subjects perform a particular stretch several times each week for a given period of time (Bandy & Irion, 1994). Lastly, a chronic stretch is a form of continuous stretch, attained by immobilisation through techniques such as casting and may last for several weeks (Liebesman & Cafarelli, 1994, Wepler & Magnusson, 2010).

Other common stretching techniques described in the literature are ballistic and static stretching, and proprioceptive neuromuscular facilitation (PNF) (Liebesman & Cafarelli, 1994; Smith, 1994). Ballistic stretch involves repetitive bouncing, rhythmic

movements in the muscle's lengthened position. There are conflicting findings in the literature as to the effects of ballistic stretch. A reason for these is a relatively high level of tension produced in the muscles during ballistic stretching and therefore a higher risk of injury compared to other stretching techniques (Holt, Travis & Okita, 1970; Ciullo & Zarins, 1983; Zebra & Rivera, 1985; Noakes & Granger, 1990; Vujnovich & Dawson, 1994; Covert, Alexander, Petronis & Davis, 2010).

Static stretch refers to a slow stretch applied to the muscles to the point of maximum tolerable tension. This stretch can be performed either passively or actively and is commonly held for 5-60 seconds (Bandy & Irion, 1994; Bandy, Irion & Briggler, 1997; Roberts & Wilson, 1999; Willy et al., 2001; Reid & McNair, 2004; Decoster et al., 2005; Russell et al., 2010). Static stretching has been suggested to cause less tensional force in the muscles, bringing a reduction in stretch reflexes and therefore the risk of injury (Liebesman & Cafarelli, 1994, Smith, 1994).

PNF is a technique derived from the concept that a maximum isometric contraction of the muscle leads to maximum relaxation of the same muscle (Liebesman & Cafarelli, 1994). Although PNF has been recognised for its beneficial effect of improving ROM, some disadvantages have been suggested when comparing this technique to other stretching techniques (Wallin, Ekblom, Grahn & Nordenborg, 1985; Ostering et al., 1990; Liebesman & Cafarelli, 1994; Smith, 1994). These include the fact that subjects must be highly motivated and need a partner in most cases to perform the proper technique, and a high degree of pain and tension associated with certain PNF techniques, and therefore movements must be supervised to avoid possible soft tissue injury (Moore & Hutton, 1980).

2.2 Frequency and duration of stretching

Research has demonstrated that a stretching programme consisting of 15-60 seconds with one to three repetitions per day, five days a week, for six weeks is required to elicit significant changes in ROM (Bandy & Irion, 1994; Bandy et al., 1997; Willy et al., 2001; Reid & McNair, 2004; Davis et al., 2005; Decoster et al., 2005; Yuktasir & Kaya, 2009; Russell et al., 2010). While the majority of the research has been carried out in the calf and hamstring muscle groups, the previously mentioned parameters are generally considered to be effective for all muscle groups (American College of Sports Medicine Position Stand, 1998; Prentice, 2002). When research supports the effect of stretching, it has been suggested that improvements gained from stretching programmes are short-lived. A number of studies examined the maintenance effect following acute stretches (Depino et al., 2000; Spernoga et al., 2001; de Weijer et al., 2003; Ford & McChesney, 2007). The acute stretches employed in the studies varied from PNF to static stretching, with between three and five repetitions of 30 to 40 seconds in duration. These studies suggested that improvement in ROM following acute stretches was lasted anywhere between three minutes to 24 hours after cessation of stretching. Similar results were reported following periodic stretching programmes. Rubley et al. (2001) determined the retention of increased hamstring length by measuring sit-and-reach test in 33 college students. Passive static hamstring stretching was performed in a standing position for 30 seconds, three times a day for five consecutive days. At the end of the stretching programme, there was a 22.4% improvement in the sit-and-reach test in the stretch group and this improvement was retained for at least three weeks. Willy et al. (2001) evaluated the effect of six weeks of initial hamstring stretching, followed by four weeks of cessation of stretching, and six weeks of resumption of stretching in 18 college students. The main variable was knee extension ROM and it was measured by a supine active knee extension test. Passive static hamstring stretching was performed in a

standing position for 30 seconds twice a day, five days a week. Following six weeks of an initial stretching programme, there was approximately 9 degrees improvement in knee extension ROM. After a four-week cessation period, ROM returned to baseline values. On resumption of hamstring stretching for six weeks, ROM increased again by approximately 11 degrees. The authors concluded that improvement gained from the six-week stretching programme was lost in the four weeks after cessation of stretching, and therefore a continuous stretching programme is required to maintain the initial improvement.

In the current literature, it is yet unclear as to how often an on-going stretch needs to be performed each week to maintain an initial improvement in ROM. Only two studies were identified as investigating the effect of on-going stretching following an initial stretching programme (Wallin et al., 1985; Rancour, Holmes & Cipriani, 2009). Wallin et al. (1985) investigated the effect of 30 days of PNF and ballistic stretching, and 30 days of on-going PNF stretching with different stretching frequencies. The authors suggested that on-going stretching of once per week frequency was sufficient to maintain the initial improvement. Rancour, Holmes and Cipriani (2009) performed a similar study examining the effect of an on-going stretching programme following a four-week static hamstring muscle stretching programme. The results indicated that on-going stretching of two to three times a week is sufficient to maintain the initial improvement. Both studies, however, did not have a control group who did not stretch at all and therefore their methodological qualities are not high. Currently, there is a gap in the literature on the effects of on-going stretching, specifically regarding the frequency of on-going stretching protocol, to maintain the improvement gained following an initial stretching programme.

2.3 Review of stretching intervention

There are a number of published studies that have investigated a change in ROM of the knee joint following stretching interventions to the hamstring muscles (Bandy & Irion, 1994; Bandy et al., 1997; Willy et al., 2001; Reid & McNair, 2004; Rancour et al., 2009; Covert et al., 2010). Of these, only a few studies directly compared the effects of different durations and frequencies of on-going stretching, or investigated a long-term effect of the ROM gained following cessation of the stretching interventions (see Table 2.2). Given the limited resources in the literature, a review of hamstring stretching interventions was undertaken based on the following criteria:

2.3.1 Types of studies

Randomised controlled trials (RCT) were included in the review. Studies must have a control group that did not stretch throughout the study.

2.3.2 Types of participants

Studies involving healthy participants with tight hamstring muscles, as assessed by reduced knee or hip extension ROM (defined by authors' own criteria), of either gender, and without a history of lower back or lower limb injuries were selected for review.

2.3.3 Types of intervention

Stretching interventions had to be self, static and periodic (greater than three weeks of duration) hamstring stretches. Studies using any other stretching techniques or assisted by any form of instruments were excluded.

Studies had to have intervention groups directly comparing different durations or frequencies of hamstring stretching, or examining a long-term effect following an initial stretching programme.

2.3.4 Outcome measurements

Outcome measurements of the studies had to include ROM of the knee or hip joints, measured in degrees. These were passive and active knee extension, and passive hip flexion measured by the straight leg raise technique.

2.3.5 Search strategy

The studies to be reviewed were selected from CINAHL, Cochrane, MEDLINE, Scopus, SportDiscus and PEDro for the years 1981-2011, 1957-2011, 1966-2011, 1985-2011 and 1953-2011, respectively. The following key words and combinations of these words were used in the search: stretch, stretching, muscles, hamstring, flexibility, extensibility, range of movement, periodic and static.

The initial search identified 140 publications. Through the screening of eligibility and exclusion criteria, a total of 10 studies were selected for review (see Figure 2.1 and Table 2.2).

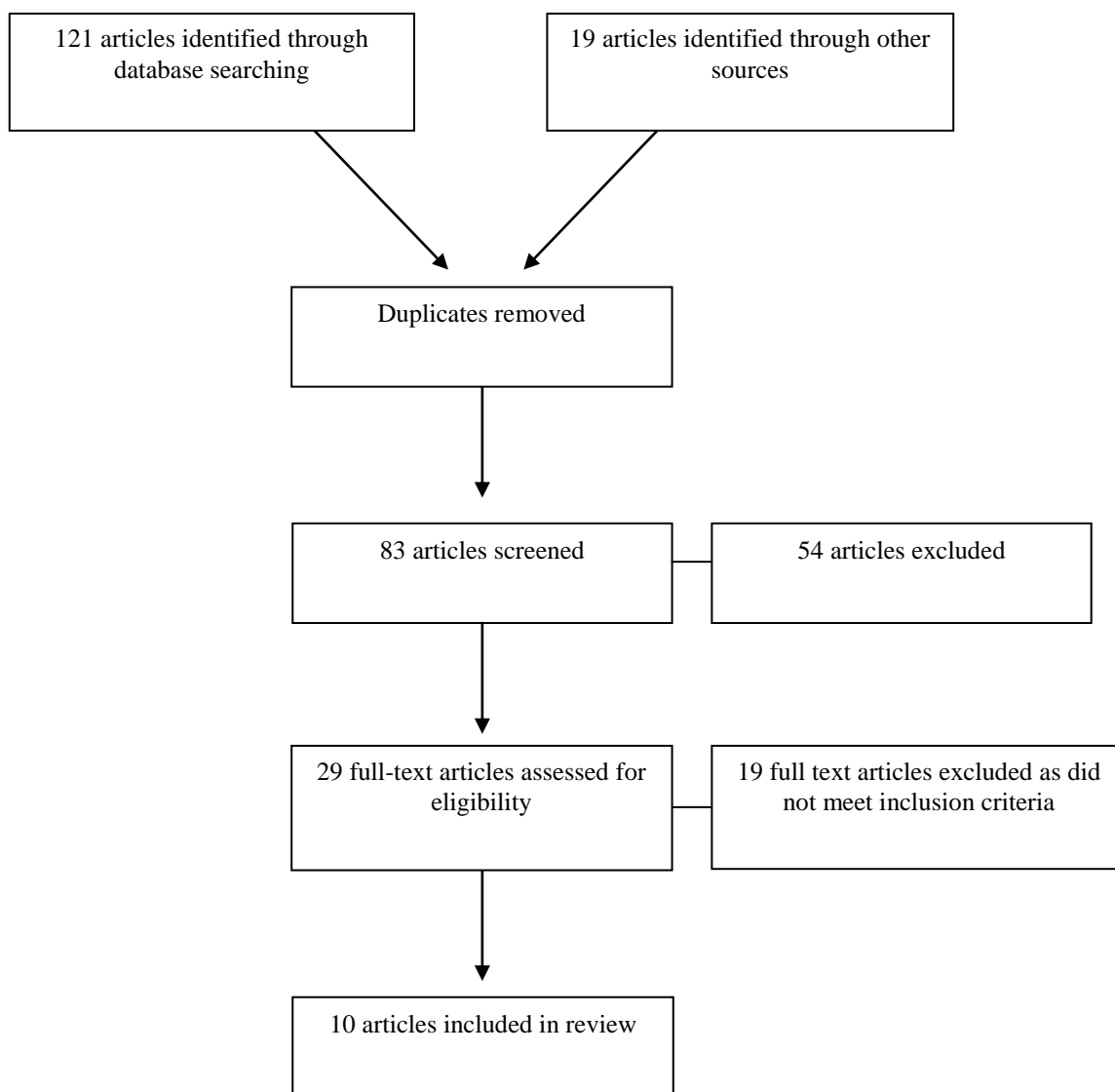


Figure 2.1 Flow diagram of the selection process of the studies

2.3.6 Assessment of the methodological quality of the publications

Assessing the methodological quality of publications is an essential process for evidence-based practice by achieving the integration of clinical expertise with the best available external clinical evidence from systemic reviews of research (Sackett, 1998). In this study, the PEDro scale was utilised to assess the methodological quality of the selected papers (see Appendix 1).

The PEDro scale is a validated 11-item scale developed by the Centre of Evidence - Based Physiotherapy, based on the Delphi list, to rate the methodological quality of RCTs for the PEDro database (Clark et al., 1999; Maher, Sherrington, Herbert, Moseley & Elkins, 2003; Ellis, Hing & Reid, 2007). This scale was chosen as various criteria of the scale covers different aspects of RCT analysis including external validity (criterion 1), internal validity (criteria 2-9) and statistics (criteria 10-11). An overall score of methodological quality, quality score (QS), was calculated by adding up the positive scores of criteria 2-11, giving a total score of 10. Item one was not used to calculate the QS. In addition, an internal validity score (IVS) was calculated for each study by adding the seven criteria of the PEDro scale (criteria 2, 3, 5, 6, 7, 8 and 9) that relate to internal validity (see Table 2.1). Reid and Rivett (2005), and Ellis, Hing and Reid (2007) have suggested that when a review consists of heterogeneous studies, the IVS can be calculated to allow a qualitative assessment of the evidence. The following levels of evidence were used to interpret the overall strength of the evidence (Reid & Rivett, 2005; Ellis et al., 2007).

- Level 1: Strong evidence- when provided by generally consistent findings in multiple RCTs of high quality (IVS = 6-7);
- Level 2: Moderate evidence- when provided by generally consistent findings in one RCT of high quality (i.e. IVS = 6-7) and one or more lower-quality RCTs (i.e. IVS ≤ 5);
- Level 3: Limited evidence- when provided by generally consistent findings in one RCT of moderate quality (i.e. IVS = 4-5) and one or more lower-quality RCTs (i.e. IVS ≤ 3);
- Level 4: Insufficient evidence- when provided by generally consistent findings of one or more RCTs of limited quality (i.e. IVS ≤ 3), no RCTs available or conflicting results.

‘Consistent findings’ were defined as >75% of the trials reporting the same trend in findings across each of the main variables (Furlan et al., 2005).

The methodological quality of selected studies, as assessed by the PEDro scale and IVS, are detailed in table 2.1. The mean QS for the reviewed studies was 6.4/10 (range 5-7). All of the reviewed studies satisfied the criteria of the PEDro scale relating to random allocation of subjects, intention to treat analysis, results of between group comparisons being present for at least one key outcome, and both point measures and measures of variability for at least one key outcome. However, all 10 studies failed to meet criteria 5 on subject blinding, demonstrating that it is not possible to blind subjects from stretching interventions. In addition, only one study (Sainz de Baranda & Ayala, 2010) met criteria 3 and one (Feland et al., 2010) criteria 6, relating to therapist blinding and concealed allocation respectively, indicating the criteria to improve in future for overall quality of the evidence.

There was limited, or level 3, evidence for the effectiveness of hamstring stretching to improve knee or hip range of movement. This result is based on the above qualitative assessment system whereby five studies (Bandy & Irion, 1994; Ford, Mazzone & Taylor, 2005; Ayala & Sainze de Barranda, 2010; Ayala, Sainze de Barranda & De Ste Croix, 2010; Sainz de Baranda & Ayala, 2010) were of moderate quality (IVS = 4-5) and five studies (Bandy et al., 1997; Roberts & Wilson, 1999; Chan et al., 2001; Willy et al., 2001; Feland et al., 2010) were of low quality (IVS \leq 3). All of the studies reviewed demonstrated a positive effect of hamstring stretching intervention and therefore there are consistent findings in favour of the stretching intervention.

Table 2.1 Summary of PEDro scores of selected studies

Study	PEDro Score Criteria											QS	IVS
	1	2	3	4	5	6	7	8	9	10	11	/10	/7
Ayala and Sainz de Baranda (2010)	1	1	0	1	0	0	1	1	1	1	1	7	4
Ayala et al. (2010)	1	1	0	1	0	0	1	1	1	1	1	7	4
Ford et al. (2005)	1	1	0	1	0	0	1	1	1	1	1	7	4
Sainz de Baranda and Ayala (2010)	1	1	1	1	0	0	1	0	1	1	1	7	4
Bandy and Irion (1994)	1	1	0	0	0	0	1	1	1	1	1	6	4
Chan et al. (2001)	1	1	0	1	0	0	0	1	1	1	1	6	3
Feland et al. (2010)	1	1	0	1	0	1	0	0	1	1	1	6	3
Bandy et al. (1997)	1	1	0	1	0	0	0	1	1	1	1	6	3
Roberts and Wilson (1999)	0	1	0	1	0	0	1	0	1	1	1	6	3
Willy et al. (2001)	1	1	0	1	0	0	0	0	1	1	1	5	3

Note: IVS, Internal validity score; QS, Quality Score.

2.3.7 Effect size

The effect size is often used to measure the magnitude of a treatment effect (Cohen, 1988). The effect sizes for the selected studies were calculated by taking the mean difference of experimental and control group changes and dividing this figure by the pooled standard deviation of the experimental and control groups (Cohen, 1988). Cohen has defined effect sizes as ‘small’ (0.2), ‘medium’ (0.5) and ‘large’ (0.8).

The effect sizes could be calculated for all selected studies except one study due to the standard deviations for main outcome measurements not being presented (see Table 2.2). The effect sizes for main outcome measures, knee or hip joint ROM, in the reviewed studies ranged from a small effect (0.35) to a large effect (4.31). However, all selected studies, excepting one, demonstrated a large effect size of hamstring stretch on improving knee or hip ROM.

Table 2.2 Summary of randomised controlled trials investigating the effect of hamstring stretching on knee extension range of movement

Study	Technique	Duration/ comparison groups	Protocol	Outcome	ROM Gain (deg)	Result	Effect Size Experiment	Effect Size Control
Bandy and Irion (1994)	Passive SS Hamstrings	15 sec 30 sec 60 sec	5/wk, 6 wk	PKE	3.8 12.5 10.9	All durations sig improved ROM. 30 sec and 60 sec stretches were more effective	0.62 1.28 2.21	0.04
Bandy et al. (1997)	Passive SS Hamstrings	3 × 1 min 3 × 30 sec 1 × 1 min 1 × 30 sec	5/wk, 6 wk	PKE	10.5 10.1 10.5 11.5	A single 30 sec duration was sufficient to improve ROM	1.26 0.99 1.51 1.12	0.01
Roberts and Wilson (1999)	Active SS Hamstrings	3 × 15 sec 3 × 3 × 5 sec	3/wk, 5 wk	AKE PKE	7.8 4.6 5.8 5.3	SS for 15 sec sig improved ROM, greater than 5 sec	3.28 1.83 1.87 1.89	0.17 0.09
Chan et al. (2001)	Passive SS Hamstrings	1 × 30 sec 2 × 30 sec	3/wk, 8 wk 3/wk, 4 wk	PKE	7.9 5.6	Both protocols equally improved ROM	4.31 3.18	0.13 0.14
Willy et al. (2001)	Passive SS Hamstrings	2 × 30 sec	5/wk, 6 wk	AKE	9.3	SS sig improved ROM. Gains were retained for < 4 weeks of cessation	0.84	*
Ford et al. (2005)	Passive SS Hamstrings	1 × 30 sec 1 × 60 sec 1 × 90 sec 1 × 120 sec	7/wk, 5 wk	PKE	3.6 1.9 2.6 2.2	All groups sig improved ROM but no sig difference among the groups	0.54 0.35 0.60 0.54	0.71

Table 2.2 Continued

Study	Technique	Duration/ comparison groups	Protocol	Outcome	ROM Gain (deg)	Result	Effect Size Experiment	Effect Size Control
Ayala et al. (2010)	Passive SS Hamstrings	6 × 30 sec	3/wk, 8 wk	PSLR	21.1	Stretch sig improved ROM. Gains were retained for > 2 weeks	2.50	0.05
Ayala and Sainz de Baranda (2010)	Passive SS Hamstrings	12 × 15 sec 6 × 30 sec 4 × 45 sec	3/wk, 6 wk	PSLR	19.9 20.4 21.4	All 3 durations equally improved ROM	1.67 1.44 2.19	0.18
Feland et al. (2010)	Passive SS Hamstrings	5 × 30 sec	5/wk, 4 wk	PKE	8.7 (SS) 13.1 (SV)	SS and SV both sig improved hamstring ROM. Gains were retained for < 3 weeks	*	*
Sainz de Baranda and Ayala (2010)	Passive SS Hamstrings Active SS Hamstrings	12 × 15 sec 6 × 30 sec 4 × 45 sec 12 × 15 sec 6 × 30 sec 4 × 45 sec	3/wk, 12 wk	PSLR	20.8 18.4 14.6 17.9 12.9 14.6	Both groups sig improved but no sig difference among durations and techniques	2.88 2.85 1.91 2.17 1.52 1.98	0.01

Note: ADF, Active Dorsiflexion; AKE, Active Knee Extension; PKE, Passive Knee extension; PSLR, Passive Straight Leg Raise; ROM, Range of Movement; Sig, Significantly; SS, Static Stretch; SV, Static stretch + Vibration; *, insufficient to calculate effect size.

2.4 Parameters associated with stretching regimes

2.4.1 Duration of holding a stretch

In this review, there was a wide variation on the duration of holding a stretch. The duration of stretching in studies reviewed varied from 15-60 seconds (Bandy & Irion, 1994; Bandy et al., 1997; Roberts & Wilson, 1999; Chan et al., 2001; Willy et al., 2001; Ford, Mazzone & Taylor, 2005; Ayala & Sainze de Barranda, 2010; Ayala, Sainze de Barranda & De Ste Croix, 2010; Feland et al., 2010; Sainz de Baranda & Ayala, 2010). Bandy and Irion (1994) investigated the effect of different durations of hamstring stretch on knee extension ROM. Fifty-seven healthy subjects with tight hamstring muscles were divided into three experimental groups of 15, 30 and 60 seconds durations of stretching, and a control group that did not stretch at all. The stretching intervention was passive static hamstring stretch in a standing position and it was performed daily, five days a week for six weeks. The passive knee extension test was used to measure the knee extension ROM and the results of experimental groups indicated 3.8, 12.5 and 10.9 degrees improvements in ROM, respectively, after six weeks of the hamstring stretching programme. The authors suggested that hamstring muscle stretch of 30 seconds in duration is sufficient to increase knee extension ROM. Other studies support this finding by demonstrating that a single 30-second duration hamstring stretching is effective to elicit a significant change in knee extension ROM (Chan et al., 2001; Ford et al, 2005).

There were five studies that examined the effect of repeated stretches with a short interval between stretches (Bandy et al., 1997; Roberts & Wilson, 1999; Ayala & Sainze de Barranda, 2010; Sainz de Baranda & Ayala, 2010). Bandy et al. (1997) compared the durations of a single 30-second and a one minute hamstring stretch to three repetitions of

30 seconds and one minute stretches with 10 seconds rest between stretches. The results showed that a single 30 seconds stretch is as effective as the other repeated stretches. Roberts and Wilson (1999) investigated the effect of total time spent on stretching on joint ROM. Two experimental groups equally performed a total of 45 seconds of passive hamstring stretch, three times a week for five weeks. However, while one group performed three repetitions of 15 seconds stretches, another group performed nine repetitions of five seconds stretches, in order to equalise the total time spent on stretching. The results demonstrated that, given the same total time spent on stretching, those performed stretches of 15 seconds in duration made greater improvement in knee extension ROM than those performed stretches of five seconds in duration. This concept of total time spent on stretching has been tested by two other studies and the overall consensus was that a 15 seconds duration stretch with 3-12 repetitions, in total 45-180 seconds per day is effective to improve joint ROM (Ayala & Sainze de Barranda, 2010; Sainz de Baranda & Ayala, 2010).

2.4.2 Frequency of stretch

In regards to the frequency of stretching performed, most reviewed studies adopted a stretching frequency of either three times or five times a week (Bandy & Irion, 1994; Bandy et al., 1997; Roberts & Wilson, 1999; Chan et al., 2001; Willy et al., 2001; Ayala et al., 2010; Ayala & Sainze de Barranda, 2010; Feland et al., 2010; Sainz de Baranda & Ayala, 2010). All these studies reported significant improvement in joint ROM with a large effect size via the given stretching frequencies. In comparison, Ford et al. (2005) examined the effect of four different durations of hamstring stretching on passive knee extension ROM in 35 healthy college students. Participants were randomly assigned to four

experimental groups with 30, 60, 90 and 120 seconds durations and a control group that did not stretch. Experimental groups performed seated passive static hamstring stretching once a day, seven days a week for five weeks. The passive knee extension test was used to measure passive knee extension ROM. The results demonstrated an average 2.6 degrees improvement in knee extension ROM, with a medium effect size, in all experimental groups. No significant difference existed among the experimental groups. The improvement in ROM gained following everyday stretching did not provide any greater improvement.

The length of the stretching programme was varied from 4-12 weeks across the studies reviewed. Six studies utilised a stretching programme of between four and six weeks, and all these studies have demonstrated significant increases in knee ROM following stretching interventions (Bandy & Irion, 1994; Bandy et al., 1997; Roberts & Wilson, 1999; Willy et al., 2001; Ayala & Sainze de Barranda, 2010; Feland et al., 2010). In contrast, Sainz de Baranda and Ayala (2010) examined the effect of a hamstring stretching programme over 12 weeks. They demonstrated consistent increases in hip flexion ROM over the 12 weeks period. This evidence suggests that stretching improves joint ROM proportional to the length of the stretching programme. However, it was not possible to make a direct comparison on the effect of the length of a stretching programme among the reviewed studies, because of heterogeneity in the outcome measures utilised.

2.4.3 Long-term effect of stretch after cessation

There were three studies that investigated the long-term effects of stretching programme after cessation of stretching intervention (Willy et al., 2001; Feland et al., 2010; Ayala et

al., 2010). Willy et al. (2001) evaluated the effect of cessation and resumption of static hamstring muscle stretching on knee extension ROM in 18 college students. The initial and resumption hamstring stretching consisted of two 30 seconds stretches per day, five days per week for six weeks. The intervention was passive static hamstring stretch in a standing position and the outcome measure was the active knee extension test. There was a four-week cessation period between the initial programme and resumption of stretching. In the results, the mean knee extension ROM significantly increased by 9.3 degrees after the initial stretching period but during cessation period it decreased to the baseline. Then it increased again following the resumption of stretching and it showed no difference from the initial gains. The authors concluded that the initial gains in knee extension ROM after the initial stretching period were lost during the four-week cessation period, and increased again following the resumption of stretching. Similar results were obtained from other experimental studies. Ayala et al. (2010) investigated the effect of an eight-week hamstring stretching programme and a retention of four weeks following the initial programme, in 18 female professional futsal players. Subjects in the experimental group performed four different passive static hamstring stretching exercises, two in sitting and two in standing positions, a total of six repetitions of 30 seconds, three days per week. Passive hip flexion ROM was measured by the passive straight leg raise test. At the end of 8 weeks intervention, subjects gained a 21.1 degrees increase in hip flexion ROM. However, by four weeks following cessation of the stretching programme, this increase had significantly decreased. In addition, Feland et al. (2010) demonstrated an 8.7 degrees increase in knee extension ROM after four weeks of a static hamstring stretching programme, in 34 college students. The static hamstring stretching programme consisted of five repetitions of 30 seconds passive static hamstring stretches while standing, five days per week. Changes in

knee extension ROM was measured by the passive knee extension test. After three weeks of cessation period, knee extension ROM decreased to the baseline.

The consistent findings from the above studies suggest that the effects following an initial stretching programme may only last for three to four weeks after cessation of stretching. In order to prevent this loss of improvement following an initial stretching programme, an on-going stretching programme may be required. However, at this point in time, there are no studies in this review that investigated a frequency or duration of on-going stretching protocol to maintain improvement following an initial stretching programme.

2.5 Measurement of knee extension range of motion

In the studies reviewed, there are three different methods utilised for measuring knee joint ROM after stretching. These include the active and passive knee extension test, and the straight leg raise test.

2.5.1 The passive straight leg raise test

In the passive straight leg raise (PSLR) test, the subject is positioned in supine with the contralateral leg and the pelvis fixed to the bed. The subject's leg is then raised passively by an examiner into hip flexion until the end-point, which is determined by firm resistance perceived by the researcher and subject's expression of significant stretching pain. The PSLR test was utilised in three of the reviewed studies (Alyala et al., 2010; Ayala & Sainz de Baranda, 2010; Sainze de Baranda & Ayala, 2010). Although in these studies the PSLR test was utilised as means of measuring hip flexion ROM and hamstring muscle length, it is also commonly used in the diagnosis of lumbar nerve root compression due to associated pelvic movement (Bohannon, Gajdosik & LeVeau, 1985). Bohannon, Gajdosik and

LeVeau (1985) tested the relative contributions of pelvic and lower limb motion during the PSLR test in 17 healthy subjects. They demonstrated that pelvic rotation begins within 9° of the beginning of PSLR and that the relative contribution of pelvic rotation increases as the angle of PSLR increases. The authors suggested that when interpreting the PSLR test results the contribution of pelvic rotation needs to be taken into consideration. Therefore the pelvis needs to be restricted in range to have a true measurement of hamstring muscle length using the PSLR test.

2.5.2 Reliability of passive straight leg raise test

Reliability of the PSLR test has been demonstrated by a number of stretching studies (Rancour et al., 2009; Alyala et al., 2010; Ayala & Sainz de Baranda, 2010). Alyala et al. (2010) and Ayala and Sainz de Baranda (2010) carried out a pilot study and evaluated the reliability of the PSLR test using a test-retest design. The authors reported a high reliability coefficient ($r=0.95$ and 0.96) and demonstrated that the PSLR test is reliable in measuring hip flexion ROM. Another study also verified the reliability of the PSLR test (Rancour et al., 2009). In a pilot study, they examined intra-tester reliability by measuring the hip flexion of 15 subjects twice on the same day, using the PSLR test. The study determined good intra-tester reliability for the PSLR test and a high ICC value (0.95).

2.5.3 The knee extension test

The knee extension test was the most popular test for measuring joint ROM and utilised in seven of the studies reviewed (Bandy & Irion, 1994; Bandy et al., 1997; Robert & Wilson, 1999; Chan et al., 2001; Willy et al., 2001; Ford et al., 2005; Feland et al., 2010). Most of these studies used a similar testing procedure, with only minor modifications, from the

active knee extension test described by Gajdosik and Lusin (1983). The subjects were positioned in supine with the hip and the knee flexed at 90°. This position is then secured with a seat belt over the anterior pelvis and the non-testing thigh. Each subject is asked to actively extend the knee to the point at which they perceived significant stretching discomfort. At this terminal knee extension, ROM is taken. For the passive knee extension test, the testing procedure is identical, except that someone else passively extends the subject's knee up to the end-point.

2.5.4 Reliability of the knee extension test

The knee extension test, both active and passive, has been suggested to be reliable for measuring knee extension ROM. In a pilot study by Willy et al. (2001), determined intra-tester and inter-tester reliability of the active knee extension test in 13 subjects and three examiners, using a test-retest design. They reported high intra-tester and inter-tester reliability with an Intra-class Correlation Coefficient (ICC) of 0.88 and 0.87, respectively. Reliability of the active knee extension test has been supported by other studies, with high ICC values (0.91-0.98) (William et al., 1997; Bazett-Jones, Gibson & McBride, 2008). The passive knee extension test has also been shown to be reliable in several studies, with high ICC values (0.91-0.98) (Gajdosik, 1991; Bandy & Irion, 1994; Bandy et al., 1997; Hartig & Henderson, 1999; Ford et al., 2005; Feland et al., 2010). One study utilised both active and passive knee extension tests for measuring knee extension ROM during a five-week hamstring stretching programme (Roberts & Wilson, 1999). In the study, changes in both active and passive knee extension ROM for intervention groups were measured by active and passive knee extension tests, before and after the stretching programme. The results demonstrated that both active and passive knee extension tests were able to detect

significant changes in joint ROM after stretching, and the values at the same measurement point were similar between the two tests.

All studies in this review utilised a goniometer or inclinometer as the measurement tools. Whilst goniometric measurement allows a measurement of joint angle within one degree of precision, the inclinometer allows two decimal point precision. However, studies using both measurement tools have shown to be reliable with their testing results (Bandy & Irion, 1994; Bandy et al., 1997; Willy et al., 2001; Ford et al., 2005; Alyala et al., 2010; Ayala & Sainz de Baranda, 2010; Feland et al., 2010).

2.6 Summary

This review of the literature has highlighted the following key issues. Given a wide variation in the literature, a recommended protocol for a stretching programme is 15- 60 seconds, one to three repetitions per day, five days a week, and for six weeks for a measurable change. The majority of studies using this stretching protocol have demonstrated a significant improvement in knee extension range of movement. However, the improvement following stretching programmes was shown to be temporary and only lasted for three to four weeks after cessation of stretching. The active or passive knee extension test and the straight leg raise were commonly utilised as a measure of hamstring muscle length.

Two studies have examined the effects of on-going stretching following an initial hamstring stretching programme but their methodological quality has been weakened due to a lack of a control group. No randomised controlled trials were identified that examine

the effect of different frequencies of an on-going stretching programme following an initial stretching programme.

Chapter 3

Materials and Methods

Introduction

The current study investigated the effects of a hamstring muscle stretching programme on knee extension ROM. The intervention was a six-week initial stretching programme, followed by a six week on-going stretching intervention of differing frequencies. The sample of interest was healthy males from the university student population.

3.1 Study Design

A randomised control trial was undertaken for this study.

3.2 Subjects

Based on previous research by Bandy et al. (1997), to detect an initial 10° change in knee extension ROM, with 80% power and $p < 0.05$, a sample size of approximately 90 participants was deemed appropriate, with 30 in each group. In the current study, sixty three subjects (Mean age, 22.9 ± 5.1 yrs; Height, 178.6 ± 7.5 cm; Weight, 76.3 ± 12.1 kg) were recruited from the student population of the Auckland University of Technology (AUT). Only male participants were recruited for the study as there are gender differences that affect ROM measures (Shephard, Berridge & Montelpare, 1990; Cornbleet & Woosley, 1996). Prior to data collection, written and verbal explanations of the experimental procedures (Appendix 2) were provided to the subjects, and written consent (Appendix 3) was gained. Subjects were included in the study if they were between the ages of 18-40 years of age and had tight hamstring muscles defined as having greater than

20° loss of knee extension ROM (Nelson & Bandy, 2004). The subjects were excluded from the study if they had injuries in the lower limb, current history of low-back pain or had been participating in a stretching regime over the past three months. All subjects were randomly assigned using a computer-generated random number table to one of three groups: a control group and two experimental (stretch) groups. Data collection was performed at the Health and Rehabilitation Research Institute (HRRI) at AUT University. This study was approved by the AUT Ethics Committee (Reference number 11/153).

3.3 Equipment and procedures

3.3.1 Knee extension ROM

The active knee extension test (Gajdosik & Lusin, 1983; Willy et al., 2001) was used as the dependent variable. The knee extension ROM was assessed using an electronic goniometer (Penny and Giles Blackwood Ltd., Gwent, UK). The active knee extension test has been shown to be highly reliable for measuring hamstring muscle tightness (Gajdosik & Lusin, 1983; Willy et al., 2001).

Knee extension ROM was measured at baseline, and then at week six and week 12. The measurement was performed following a standardised warm-up on a stationary bike for five minutes on the same load (50 Watts). The subjects were then positioned in supine with the right hip and the knee flexed at 90°. This position was secured with a seat belt over the anterior pelvis and left thigh. The right thigh was maintained in contact with a crossbar placed above the iliac crest (See figure 3.1-2). An electronic goniometry was placed along a line between the greater trochanter of femur and the lateral femoral epicondyle, and a line between the lateral femoral epicondyle and lateral malleolus (See figure 3.3-4). Each

subject was asked to actively extend the knee to the point at which they perceived significant stretching discomfort. At this terminal the knee extension ROM was taken. Lateral deviation or rotation at the hip or pelvic joints was closely monitored by the assessor. The measurement was repeated three times with a 10 seconds rest in between. The measurement was taken only from the right side as the stretching was performed only on the right side hamstring muscles.

3.3.2 Measurement reliability

Prior to data collection, a pilot study assessing the reliability of the active knee extension test for measuring knee extension ROM was undertaken. Ten subjects (Mean age, 24.8 ± 4.3 yrs; Height, 172.9 ± 6.1 cm; Weight, 68.0 ± 16.7 kg) from a sample of convenience were participated in the reliability study. Using the data-collection procedures outlined earlier, two sets of measurements of active knee extension were completed on two separate occasions with 10 minutes intervals (Depino et al., 2000; Spernoga et al., 2001). The intraclass correlation coefficient (ICC) for the paired data was 0.99, establishing excellent test-retest reliability (Bandy & Irion, 1994; Bandy et al., 1998; Ford et al., 2005).

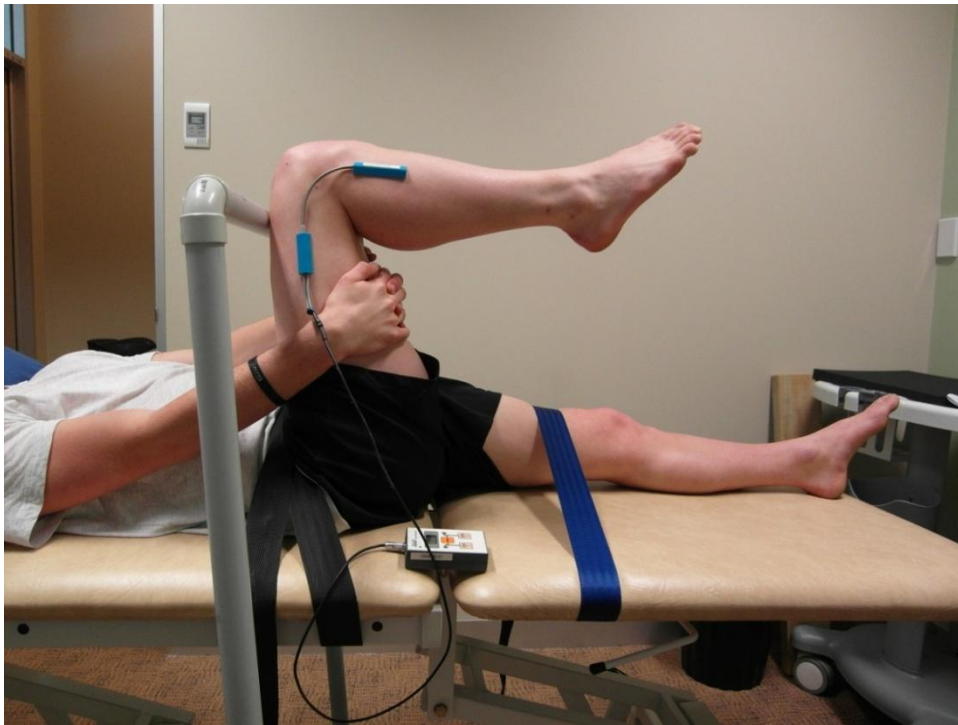


Figure 3.1 The start position of the active knee extension test

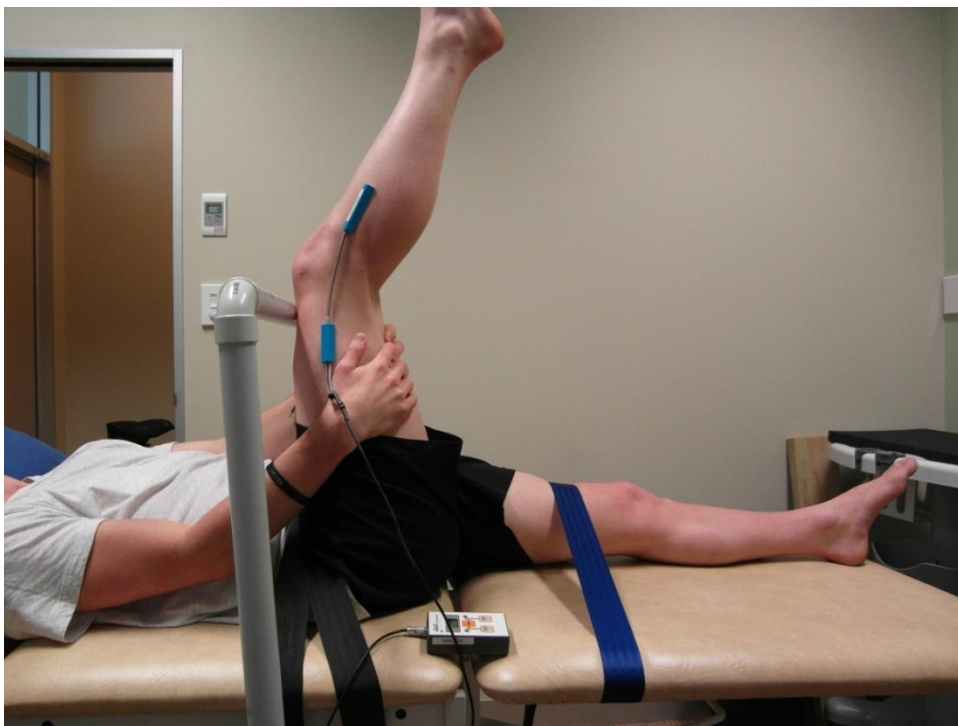


Figure 3.2 The finish position of the active knee extension test

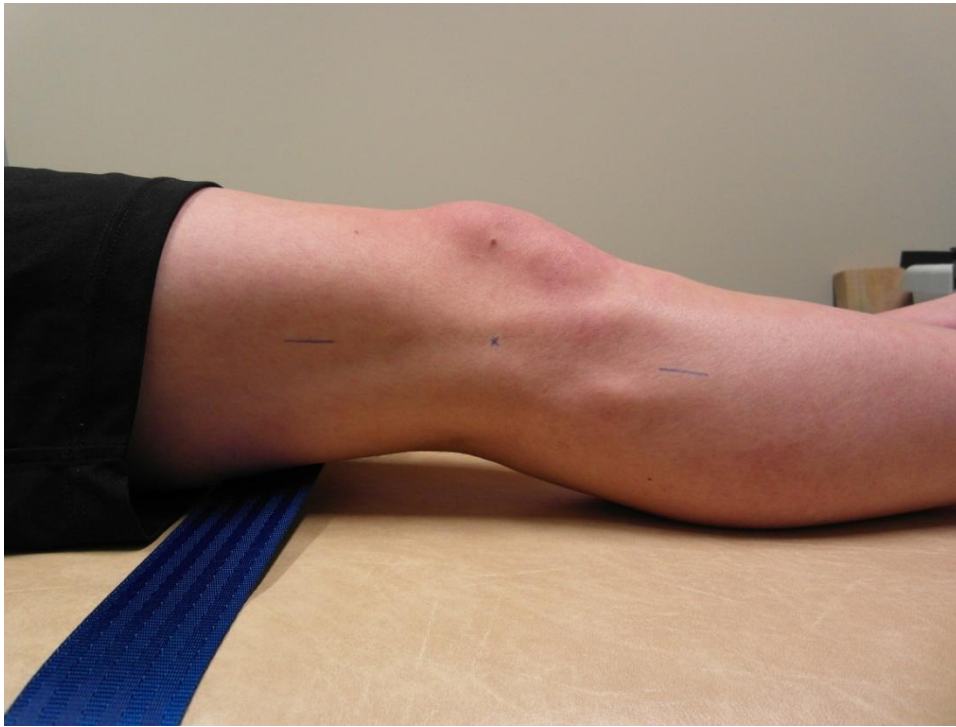


Figure 3.3 The anatomical landmarks for electronic goniometer

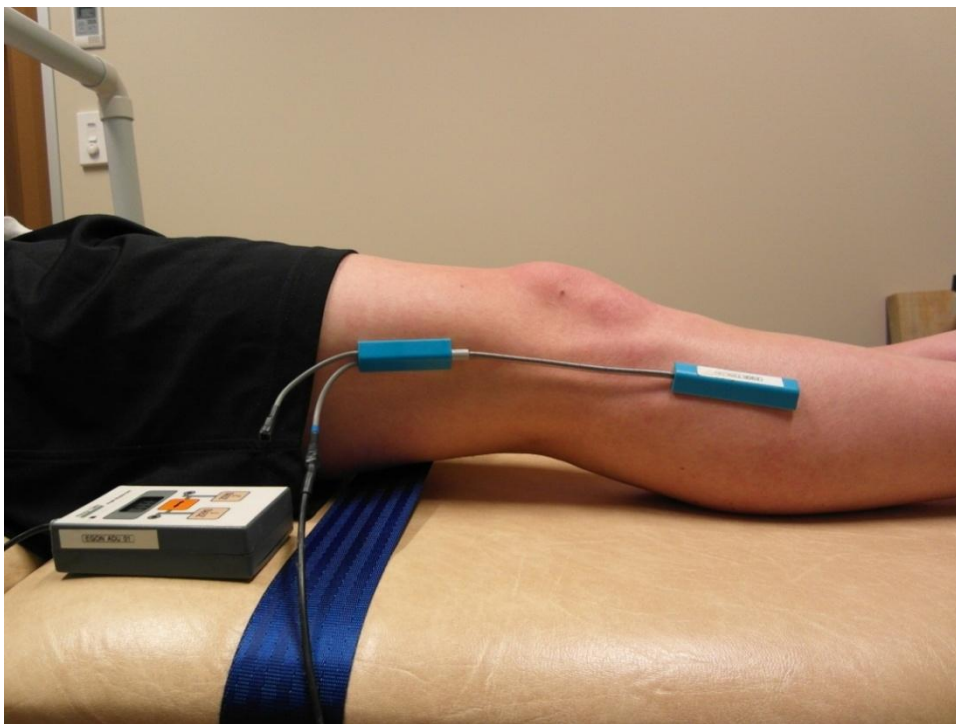


Figure 3.4 The placement of electronic goniometer

3.4 Stretching programme

3.4.1 Intervention group

The stretching intervention was undertaken in two stages. Those participants randomly allocated to the stretching groups performed active static stretch of the right side hamstring muscles, 3×30 seconds with 30 seconds intervals once a day, and five days a week for six weeks. This programme was performed in the same manner as the AKE test described above.

Following this initial stretching period, participants in group one (21 subjects) reduced their frequency of stretching to three times per week and group two (21 subjects) stretched once a week for a further six weeks. All participants in the stretching groups were educated with the stretching technique by a single researcher at the baseline.

To ensure compliance with the stretching protocol, participants in both stretching groups kept a diary of the stretches and other physical activity, and the researcher contacted participants through email or text messages every three weeks.

3.4.2 Control group

The control group (21 subjects) did not stretch throughout the intervention period but had their knee extension ROM measured from the start and to the end of the trial. The measurement points were at the baseline, week six and week 12. All participants in the study were instructed not to alter their activity of daily living regimes throughout the study.

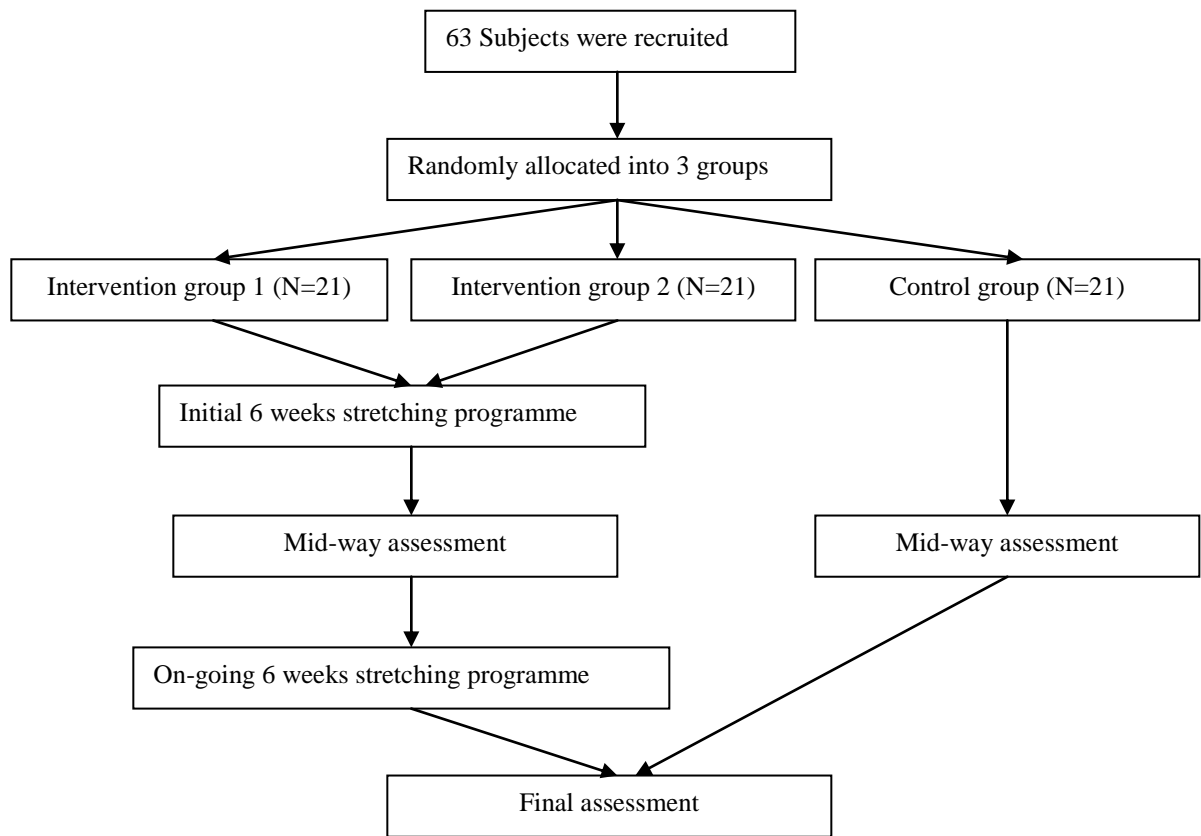


Figure 3.5 Flow diagram of randomisation, intervention and assessment process

3.5 Statistical analysis

Descriptive statistics were analysed to determine the appropriateness of utilising parametric analysis. A two-factor (time and group) repeated ANOVA was utilised to determine the significant changes in knee extension ROM over time and to compare ROM differences between the three groups over time. The participant diaries were assessed for compliance via descriptive statistics. Statistical analysis was performed using SPSS statistical analysis software version 18 (SPSS Inc. Chicago, IL). The alpha level was set at 0.05.

Chapter 4

Results

Introduction

This chapter presents the main findings of the investigation. Firstly, it provides a description of the subjects that participated in the study. Secondly, the results of the active knee extension tests that assessed changes in range of motion over a six week initial hamstring stretching intervention and following a six-week on-going stretching intervention are presented.

4.1 Subjects

The target sample size of 90 subjects was not achieved and only 63 subjects were recruited. Data from 63 subjects were collected. They were all males aged between 18 and 40 years of age (mean 24.8 ± 4.3). At the baseline, no significant difference was found between groups regarding the variables of age, height or weight ($p < 0.05$). Four subjects in the intervention group one, three subjects in the intervention group two and two subjects in the control group did not complete the programme. These subjects withdrew at various stages of the intervention or control period. The main reason for the withdrawal from the study was time constraint due to personal reasons. The data from these subjects was dealt via an intention to treat analysis.

The overall subject's compliance to the hamstring stretching in the intervention group was approximately 93%. However, one subject in the intervention group two showed 43% compliance during the initial stretching programme that improved to 100% during last six

weeks follow-up. A qualitative examination of the subjects' diaries indicated that no subjects had undertaken additional physical activities that may have affected the results.

Descriptive characteristics of the subjects are presented in Table 4.1.

Table 4.1 The subjects' age, height and mass. Data are means and standard deviations

Groups	Number	Age (years)	Height (cm)	Mass (kgs)
Control	21	23.0 ± 5.4	179.0 ± 6.7	77.7 ± 13.3
Stretch 1	21	23.2 ± 5.7	177.1 ± 8.0	76.4 ± 13.2
Stretch 2	21	22.5 ± 4.3	179.6 ± 7.7	74.8 ± 10.1
Overall	63	22.9 ± 5.1	178.6 ± 7.5	76.3 ± 12.1

Table 4.2 The subjects' compliance with the intervention

Groups	Initial stretching intervention	On-going stretching intervention
Stretch 1	91.04%	92.36%
Stretch 2	93.16%	97.06%

4.2 Changes in active knee extension range of motion

With respect to knee extension range of motion, there was a significant effect for time ($p < 0.05$) and group, and a significant interaction between time and group ($p < 0.05$). Figure 4.1 displays the mean knee extension range of movement for the intervention groups and the control group. The start angle for the test movement was 90 degrees knee flexion and zero degree was determined as full knee extension. The data represents the point at which the subjects voluntarily stopped the active knee extension test which was determined as the maximal hamstring stretch sensation by the subjects. At the baseline, subjects in the intervention group one were a mean 36.65 (± 9.87) degrees short of full knee extension and they improved significantly to 17.55 (± 11.83) after the initial six-week stretching intervention ($p < 0.05$). This corresponded to 19.10 degrees improvement. After six weeks of on-going stretching with reduced frequency (three times a week), subjects in the

intervention group one remained at 17.73 (\pm 11.68) degrees. This difference was not significant ($p > 0.05$). Therefore subjects in this group maintained the ROM gained after the initial stretching period. In the intervention group two, subjects had a mean of 32.33 (\pm 9.93) and they improved significantly to 18.87 (\pm 7.17) after the initial six week stretching intervention ($p < 0.05$). This corresponded to a 13.35 degrees improvement in ROM. Following the six weeks on-going stretching intervention, subjects in the intervention group two (once a week) reduced to 23.46 (\pm 10.34) degrees. This represented a 4.59 degrees reduction in ROM. This difference was significant ($p < 0.05$). Therefore those subjects in group two did not maintain the gains in ROM. Subjects in the control group had a mean 31.95 (\pm 8.54) degrees short of full knee extension at the baseline, 31.53 (\pm 7.80) at week six and 29.91 (\pm 8.5) at week 12. These differences were not significant ($p > 0.05$).

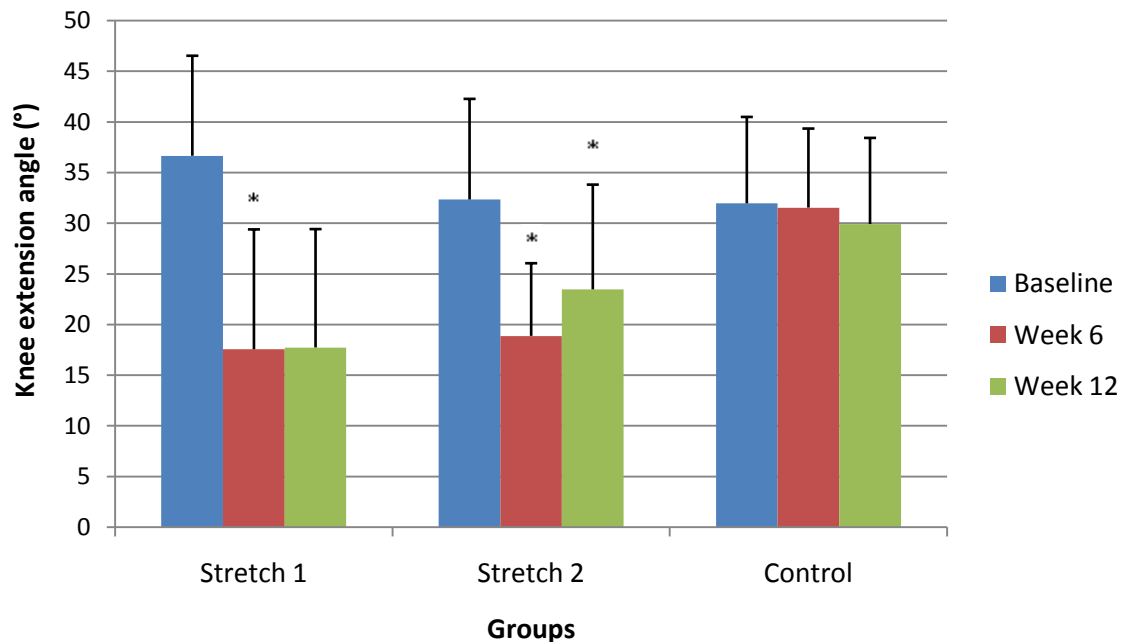


Figure 4.1 The extension range of movement for the intervention groups and the control group at baseline, week 6 and week 12. Data are means and standard deviations. * $P < 0.05$

4.3 Effect size

The effect sizes of the initial hamstring stretching intervention were calculated by taking the mean difference of intervention and control group changes in knee extension ROM and dividing this figure by the pooled standard deviation of the experimental and control groups (Cohen, 1988). The stretch group one and two both revealed a large effect, 1.75 and 1.56 respectively, during the initial stretching intervention. These results demonstrated that a six-week initial hamstring stretching intervention was effective on improving knee extension ROM in both intervention groups. The control group showed a small effect for the initial stretching intervention.

Table 4.3 The effect sizes of the initial stretching intervention for each group

Groups	Effect sizes
Stretch group 1	1.75
Stretch group 2	1.56
Control group	0.05

Chapter 5

Discussion

The results of this study demonstrated that a six-week static hamstring stretching programme significantly improved knee extension ROM and this finding is consistent with previous stretching studies (Bandy et al., 1997; Roberts & Wilson, 1999; Reid & McNair, 2004; Russell et al., 2010). To maintain this initial improvement in knee extension ROM for six weeks, the frequency of stretching required was three times a week. The on-going stretching frequency of once a week was not sufficient to maintain the initial improvement for six weeks, yet the final knee extension ROM of this group was still greater than that of the control group.

5.1 Effect of the hamstring stretching intervention

In the current study, the initial six-week active static hamstring stretching programme significantly improved knee extension ROM compared to the control group. Following the initial stretching intervention, active knee extension ROM was increased by an average of 16.2 degrees with a large effect size (average 1.66) in the experimental groups. This improvement is a relatively large treatment effect compared to other stretching studies. Bandy et al. (1997) investigated the effect of a six-week hamstring stretching programme on knee extension ROM. Experimental groups performed passive static hamstring stretches in a standing position with one or three repetition of a 30-second or one minute hold, once a day, five days a week, for six weeks. The results showed that passive knee extension ROM was improved by an average of 10.7 degrees with a large effect size (average 1.22) in the experimental groups. In particular, one of the experimental groups performed the same intensity of hamstring stretching as the initial stretching protocol of the current study (three

repetitions of a 30-second hold) and the group demonstrated a 10.1 degrees improvement in ROM with a large effect size (0.99). Although Bandy et al. (1997) utilised similar frequency and duration of hamstring stretching to the current study, the improvement in knee extension ROM of the study (average 10.7 degrees) was less than that of the current study (average 16.2 degrees). There are two possible reasons for the difference; the participants' age and gender differences. Participants in the study had a mean age of 26.2 ± 5.1 years, compared with a mean age of 22.9 ± 5.1 years in the current study. Research has shown that connective tissues lose extensibility as part of the ageing process due to an increase in the crystallinity of the collagen fibres and increases their diameter (Mazzeo et al., 1998; Maharam, Bauman, Kalman, Skolnik & Perle, 1999). This implies that the tissues will be stiffer with increasing age and hence reduce ROM. However the age differences in these two studies is only four years so this may not be that significant. In the Bandy et al. (1997) study 32 of 93 participants were females where as only male participants were recruited in the current study. Females are known to have a greater hamstring length than males and this gender difference may affect the improvements gained in ROM (Shephard, Berridge & Montelpare, 1990; Cornbleet & Woosley, 1996). Roberts and Wilson (1999) examined the effect of active static hamstring stretches on the active and passive knee extension ROM in 24 university students. The intervention was the active hamstring stretch that performed three repetitions of 15 seconds or nine repetitions of five seconds, three days a week for five weeks. The control group did not stretch over this study period. The active and passive knee extension ROM was measured before and after the intervention. The results revealed that active knee extension ROM was improved by an average of 6.2 degrees with a large effect size (average 2.56) and passive ROM was also improved by an average of 5.6 degrees with a large effect size (average 1.88). The hamstring stretching

technique, the outcome measure, and the age of the participants (20.5 ± 1.4) of the study were similar to the current study. Despite these similarities, the improvement in the active knee extension ROM of this study (average 6.2 degrees) was less than that of the current study (average 16.2 degrees). This difference in the improvement may be related to the difference in the frequency and duration of the hamstring stretching interventions. In Roberts and Wilson (1999) the active hamstring stretching was performed either three repetitions of 15 seconds or nine repetitions of five seconds, three days a week for five weeks, compared with three repetitions of 30 seconds, five days a week for six weeks in the current study. Regardless of the amount of improvement in ROM, the stretching protocols of both studies resulted in the large effect sizes on improving the knee extension ROM. This means that the optimal frequency and duration of hamstring stretching has yet to be determined.

5.2 Long-term effect of stretching exercises

The results of the current study demonstrated that muscles are constantly adapting in response to changes in the amount of stretching applied to muscles. During a six-week initial hamstring stretching programme, both stretch groups improved in knee extension ROM in response to stretching interventions. In comparison, the control group did not make any changes in ROM without stretching. More importantly, whilst the stretch group one successfully maintained the initial improvement with an on-going stretching frequency of three times a week, the stretch group two lost ROM with an on-going stretching frequency of once a week.

A number of studies have suggested that improvement in ROM following a stretching programme is short lived (a maximum of four weeks) and starts to diminish following the

stretching intervention (Depino et al., 2000; Rubley et al., 2001; Willy et al., 2001; Ford & McChesney, 2007). Moreover, Willy et al. (2001) examined the effect of cessation and resumption of static hamstring muscle stretching on knee ROM. They demonstrated that initial improvement in ROM after an initial stretching programme decreased to the baseline during a four-week cessation period, and it was increased again only to the level of initial improvement after the resumption of stretching.

5.3 Frequency of the on-going stretching programme

The current study indicated that three times a week is the optimal frequency of on-going stretching to maintain the initial improvement in ROM. After the six-week on-going stretching programme, the stretch group one successfully maintained the initial improvement in knee extension ROM (17.55 to 17.73, $p > 0.05$) by performing the stretching three times a week while the stretch group two lost an average 4.59 degrees ($p < 0.05$) by performing the stretching once a week.

In the current literature, there are two other studies on the frequency of on-going stretching. Wallin et al. (1985) investigated the effect of 30 days of PNF and ballistic stretching, followed by 30 days of on-going PNF stretching in 48 university students. Stretching interventions were performed on the following four muscles groups; ankle plantar flexors with straight and flexed knee, and hip adductors and extensors. All PNF stretches were performed in a standing position with seven seconds of muscle contractions followed by seven seconds of stretching with two to five seconds rest in between, this was repeated five times. Ballistic stretches were performed in standing and sitting positions with a total time of one to two minutes of stretching. Passive plantar flexion and hip adduction and

extension angles were measured at the baseline, and after 14, 30 and 60 days. In the initial stretching programme, three groups performed PNF stretching and one group performed ballistic stretching, three times a week for 30 days. Following the initial stretching programme, there was an average 8.3 degrees improvement in different joint angles with PNF stretching and a 2.5 degrees improvement with ballistic stretching. After the initial stretching, three former groups performed the same PNF stretching protocol once, three or five times a week, respectively, for another 30 days. The results showed that all groups showed no change or significantly increase in ROM following 30 days of on-going PNF stretching. They suggested that on-going stretching of once a week is sufficient to maintain the initial improvement in ROM. The current study demonstrated that on-going stretching of once a week was not sufficient to maintain the initial improvement and a minimum three times a week of stretching was required. This difference in the optimal frequency of on-going stretching could be due to the differences in the stretching techniques used, in the initial improvement gained and the duration of on-going stretching programmes. In the Wallin et al. (1985) study participants performed a PNF stretching technique, compared with an active static stretching technique in the current study. Therefore the results of two studies are not directly comparable. Following the initial stretching programme, an average 8.3 degrees improvement was gained in the study and these figures are less than an average 16.2 degrees in the current study. These initial improvements were expected to be maintained for 30 days in the study, compare with for six weeks (i.e. 42 days) in the current study. This means that the on-going stretching programme of the study was required to maintain a smaller amount of the improvement for a shorter period than that of the current study. Rancour et al. (2009) performed a similar study examining the effect of on-going stretching following a four-week static hamstring stretching programme. Subjects were

randomly assigned to one of two groups and both groups performed passive static hamstring stretching in a standing position two repetition of 30 seconds, twice a day, seven days per week, for four weeks. After the initial stretching programme, one group reduced the frequency of hamstring stretching to two to three times a week while another group ceased stretching, for another four weeks. The passive straight leg raise was used to measure hip flexion ROM. The results demonstrated that both groups significantly improved, by an average 19.9 degrees, in hip flexion ROM after four weeks of the initial stretching programme. The improvement in hip flexion ROM was greater than the initial improvement in knee extension ROM of the current study (average 16.2 degrees). One reason for the difference could be more frequent stretches performed daily and weekly (twice a day and seven days a week) in the study than in the current study (once a day and five days a week). For a further four weeks, the group performing on-going stretching maintained the improvement in ROM while the group that ceased stretching lost an average 6.7 degrees in ROM. The authors concluded that on-going stretching with a frequency of two or three times a week is sufficient to maintain the initial improvement in ROM. However, the study did not provide a set frequency of on-going stretching but instead allowed the subjects to decide whether to stretch two or three times a week. For this reason, based on the results of the study it is difficult to conclude whether the optimal frequency of on-going stretching is two or three times a week. With regards to the optimal frequency of on-going stretching, the results of the study are consistent with the current study. To maintain an initial improvement in ROM, three times a week of on-going stretching is required. Finally, in comparison to the current study, both Rancour et al. (2009) and Wallin et al. (1985) did not have a true control group who did not stretch and therefore the methodological qualities of these studies may have been weakened.

5.4 Subjects' compliance with on-going stretching programme

From a clinical and practical perspective, an on-going stretching programme with reduced frequency allows maintenance of the benefits of stretching exercises with minimal effort and potentially improves subjects' compliance with on-going stretching exercises.

Although we commonly prescribe stretching exercises in clinical practice, research has shown that once a client is discharged from therapy compliance rate with the home exercise programme is low and too many exercises can reduce compliance (Haynes, 1979; Sluijs et al., 1993; Schneiders et al., 1998; Henry, Rosemond & Eckert, 1999). Based on these findings, the reduced frequency of on-going stretching may improve compliance with on-going stretching exercises and in turn maintain the benefits of stretching exercises.

Particularly, it would be beneficial for athletes to reduce the risk of re-injury following discharge from therapy and maintenance of ROM gains during the off-season (Rancour et al., 2009). In the current study, both stretching groups maintained a high compliance, averaging 94.72%, throughout the study. Possible reasons for this may include the reduced frequency of stretching required, clear written and verbal instruction, and continuous reminders and regular follow-up. Research has shown that written and illustrated instructions, continuous reminders and regular follow-up are good strategies to improve compliance with exercises (Schneiders et al., 1998; Jacobs et al., 2004; Eakin, Lawler, Vandelanotte & Owen, 2007).

5.5 Limitations of the study

There are a number of limitations that were associated with the current study. Recruitment of subjects for this study was primarily carried out within a university setting and only

healthy and university-aged subjects were included in the study. The findings of this study, therefore, may not be directly applicable to injured or older populations.

With respect to the power of the study, we expected a sample size of approximately 90 participants in total for 80% power and $p < 0.05$ (Bandy et al., 1997). Although the current study did not meet the expected percentage of power with only 63 participants, the data from this study still yielded statistically significant results.

Despite regular reminders and follow-up, nine of the 63 participants withdrew from the study. The data from these participants was dealt via an intention to treat analysis and thus these drop outs did not affect the statistical significance of the results.

A further limitation of this study concerns the blinding of assessor and participant. In the current study the assessor and the participants were not blinded to the interventions. Due to the nature of stretching intervention, it was not possible to blind the control group from the interventions.

Finally this study only measured knee extension ROM and no other variables such as force or muscle stiffness were measured (Gajdosik, 1991; Magnusson, 1998; Reid & McNair, 2004). Therefore the results of this study does not allow any conclusion to be drawn on the effect of stretching on the structural changes in the musculotendinous complex, but probably support the stretch tolerance theory. Moreover, the current study was interested in the frequency of on-going stretching to maintain initial improvement in ROM following a stretching programme, but not in the reasons for the improvement or maintenance. By

measuring knee extension ROM, this study was intended to be as practical and clinical as possible in respect to measurement and stretch method, thus the results would be easily utilised in clinical practice.

5.6 Future research

Future research examining structural changes associated with static stretching and whether these changes are maintained through on-going stretching is required. Static stretching increases the maximum ROM and decreases the passive torque, also decreasing the muscle-tendon unit stiffness (Magnusson et al, 1996a; Ryan et al., 2008). It is suggested that to demonstrate structural changes occurring with changes in ROM, a measurement of muscle stiffness is required (Reid & McNair, 2004; Nakamura, Ikezoe, Takeno & Ichihashi, 2011). Several studies have adopted ultrasonography to measure changes in muscle-tendon unit stiffness and length before and after stretching intervention (Kubo, Kanehisa & Fukunaga, 2002a; Kubo, Kanehisa & Fukunaga, 2002b; Burgess, Graham-Smith & Pearson, 2009; Nakamura et al., 2011). It would be interesting to observe structural changes utilising ultrasonography following the initial hamstring static stretching intervention and whether these changes are maintained by the on-going stretching protocol.

The current study investigated the maintenance effect of static hamstring stretching only. However, future studies need to look at that whether different types of stretching (e.g. PNF versus static stretching) or stretching of different muscle groups have different effect on maintenance.

As the results of the current study are limited to a healthy university-age population, the effect of on-going stretching protocol of this study needs to be confirmed in different clinical populations such as elderly and females, and those with diseases that affect joint ROM such as osteoarthritis and muscle injury.

5.7 Summary and Conclusion

The purpose of this study was to determine the frequency of on-going hamstring stretching required to maintain knee extension ROM following an initial stretching programme. The results of the current study demonstrated that on-going hamstring stretching of three times a week was required to maintain the initial improvement in knee extension ROM for 6 weeks. This finding may assist clinicians, coaches and trainers in prescribing an on-going stretching programme following an initial stretching programme to maintain improvements in ROM and therefore maintain the benefits of stretching exercises. The reduced frequency of on-going stretching may also improve patients and athletes' compliance with on-going stretching exercises.

Appendix1

PEDro scale criteria and operational definitions for the criteria (Maher et al., 2003).

The following 11 criteria were used to assess the methodological quality:

1. Eligibility criteria were specified.
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received).
3. Allocation was concealed.
4. The groups were similar at baseline regarding the most important prognostic indicators.
5. There was blinding of all subjects.
6. There was blinding of all therapists who administered the therapy.
7. There was blinding of all assessors who measured at least one key outcome.
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups.
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by “intention to treat”.
10. The results of between-group statistical comparisons are reported for at least one key outcome.
11. The study provides both point measures and measures of variability for at least one key outcome.

The PEDro scale was administered using the following operational definitions:

All criteria Points are only awarded when a criterion is clearly satisfied. If on a literal reading of the trial report it is possible that a criterion was not satisfied, a point should not be awarded for that criterion.

Criterion 1 This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study.

Criterion 2 A study is considered to have used *random allocation* if the report states that allocation was random. The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion.

Criterion 3 *Concealed allocation* means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for these criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was “off-site”.

Criterion 4 At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups’ outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables

alone, by a clinically significant amount. This criterion is satisfied even if only baseline data of study completers are presented.

Criterion 4, 7-11 *Key outcomes* are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure.

Criterion 5-7 *Blinding* means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be “blind” if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind.

Criterion 8 This criterion is only satisfied if the report explicitly states *both* the number of subjects initially allocated to groups *and* the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time.

Criterion 9 An *intention to treat* analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated.

Criterion 10 A *between-group* statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group \times time interaction). The comparison may be in the form hypothesis testing (which provides a “p” value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval.

Criterion 11 A *point measure* is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. *Measures of variability* include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quartile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group.

Appendix 2

Participant Information Sheet



Date Information Sheet Produced:

17/ 07/ 2011

Project Title

The frequency of hamstring stretches required to maintain knee extension range of motion following an initial six week stretching programme.

An Invitation

My name is Joshua Kim. I am undertaking a Masters degree at AUT University under the supervision of Assoc Professor Duncan Reid. You are invited to take part in a study being undertaken at the Department of Physiotherapy, AUT University, Akoranga campus related to the optimal frequency of an on-going stretching programme. This information sheet provides details of the study which will enable you to decide if you wish to participate. Your participation is entirely voluntary and even if you agree to participate, you are free to withdraw at any stage without needing to give a reason. You will not be disadvantaged if you decide to withdraw from the research and in the event that you do, the information about you will be destroyed. You are welcome to ask questions and seek clarification about any part of the research that you do not understand at any time.

What is the purpose of this research?

Stretching exercises in sports and the activities of daily living have been widely used by clinicians aiming to prevent injuries, and improve recovery and performance. Previous research has found an optimal frequency and duration of hamstring stretching exercises. There has been, however, limited research examining the frequency of stretching required to maintain the lasting effects of such stretching programmes following an initial stretching period.

This research aims to identify an optimal frequency of an on-going stretching programme for maintenance of knee extension range of motion via a hamstring muscle stretching programme following an initial six week stretching programme.

How was I identified and why am I being invited to participate in this research?

AUT University Akoranga campus was selected to be the main pool of participants as there are a large number of healthy and active students on the campus.

To be part of the study you need to be:

- A healthy male
- Aged between 18-40
- Able to understand the English language
- Have tight hamstring (back of thigh) muscles
- You will be excluded from the study if the principal researcher Duncan Reid, has taught or supervised you and/or if you have injuries in the lower limbs, a current history of low-back pain or have been participating in a stretching regime over the past 3 months

What will happen in this research?

If you agree to participate in this research you will be contacted by the principal researcher to determine if you meet the inclusion criteria stated above. You will be required to attend a testing session to gather baseline measurements of your knee's range of motion and hamstring flexibility. This session will last approximately 15 minutes to enable the above measurements to take place. You will need to wear comfortable shorts during the session. Once the baseline measurements have been taken you will be randomly allocated into one of three groups; two groups will be allocated a different frequency of an on-going stretching programme and one group will not need to stretch at all other than during the test sessions. The details of the procedures are outlined below. You will be given advice and instruction in the stretching programme. You will need to undertake a first session of stretching exercises for six weeks. At the end of this time you will need to return for another assessment session. A final assessment session will be required after a further six weeks. The testing laboratory is screened off from the public ensuring your privacy at all times. Each measurement session will involve the following steps:

1. Warming up for 5 minutes on a stationary bike to prepare your body for exercise.
2. Lying on the plinth and having the electronic goniometry fixed along the leg, centred on the knee joint, with adhesive tape. The goniometer is a measurement device that can accurately measure the change in knee angle. It is battery powered but you will not be able to feel any current when it is attached to your leg.
3. Moving the hip to 90° which position will be maintained using a cross bar. While maintaining this hip position, you will be encouraged to actively extend the knee until you feel significant stretching discomfort in the hamstring muscles (Figure 1). The tension in the hamstring muscle prevents any further knee movement. At this point the knee extension angle will be measured.

4. You will be required to perform this active knee extension movement three times and the average knee extension angle will be recorded. If there is an error with the recording equipment, you may be asked to repeat the movements again.
5. The electronic goniometry will be removed following the testing.



Figure1. The active knee extension test and stretch

The test procedure and the stretch are the same. To do this stretch you need to lie on your back, pull the hip up to 90°, hold this position and then try to straighten your knee. As you reach the limit of the movement there is usually some discomfort in the back of the thigh and behind the knee. Sometimes the leg starts to shake. You then need to relax a little and once the shaking has stopped, hold this position for 30 seconds. You then relax the knee and repeat the procedure twice more. You need to follow the same sequence when you do the stretch at home.

After the baseline measurement, you will be asked to select a random number which will determine which of the three groups you will be allocated to, either one of two stretching groups or to a control group.

1. Both stretching groups will perform 3×30 sec stretches once a day for 5 days a week for an initial 6 weeks (Figure 1).
2. After the initial 6 weeks, one group will reduce their frequency of stretching to 3 times per week and the other group will stretch once a week for a further 6 weeks. The control group will not be required to stretch during the study.

To ensure compliance with the procedures of the study you will be required to keep a diary of your level of physical activity and, for those in the stretching group, the frequency of the stretch. I will provide you with the diary to complete. It will be collected at the end of the study. If you are in one of the stretching groups you will be reassessed for compliance with the stretching programme every two weeks by phone or email. Clear written instructions will be given to those in the stretching group and you will also be given physical instruction on how to do the stretches once you have completed the baseline measurements. If there are any problems understanding how to do these stretches you will be welcome to see me at a time of mutual convenience for a refresher.

What are the discomforts and risks?

For the duration of the measurement, you will have electronic goniometry fixed to your skin using adhesive tape and, although unlikely, some people may experience skin irritation from this.

On rare occasions it is possible to injure yourself or feel tolerable discomfort when you perform the hamstring stretch.

If you experience discomfort or have any concerns, please notify the researcher as soon as this occurs.

How will these discomforts and risks be alleviated?

You will complete a screening questionnaire prior to entering the study to ensure you are healthy and capable of performing the hamstring stretch, thereby minimising the risk of injury.

To minimise the risk of skin irritation, the skin will be cleaned with hypoallergenic wipes following the testing procedure.

To minimise the risk of injury you will be asked to warm up your body, before completing the measurement, on a stationary bike. In the unlikely event that you injure yourself, ice and a first aid kit will be on hand and the researcher is a qualified physiotherapist who will be able to administer care.

What are the benefits?

You, the participant, may improve your hamstring muscle length and knee joint range of movement after the regular stretching programme. This research will also serve to inform the clinicians about the optimal frequency of an on-going stretching programme they can prescribe to patients to maintain the beneficial effects from an initial stretching programme.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Your privacy will be protected at all times and the information you provide will be kept strictly confidential and securely locked in the Physiotherapy Department at AUT for a period of ten years. After ten years the information will be destroyed. The data collected from your stretching tasks will be assigned a numbered code so that it remains anonymous in any publication of the research.

What are the costs of participating in this research?

The total time involved will be three measurement sessions (baseline, week 6 and week 12) of approximately 15 minutes duration, two reassessments via phone or email (week 3 and

week 9) of approximately 2 minutes duration, and daily stretching of approximately 3 minutes duration, 5 days a week for 12 weeks. There are no other monetary or time costs involved in this research and you will be reimbursed for travel expenses incurred.

What opportunity do I have to consider this invitation?

From the time you receive this information sheet, you will be given one week to consider if you would like to participate in the study and return your completed consent form to the receptionist at the Physiotherapy Department on AUT's Akoranga campus or contact me personally.

How do I agree to participate in this research?

If you wish to participate in the research, please complete the consent form and return this to the receptionist at the Physiotherapy Department on AUT's Akoranga campus within one week of receiving this information. Following this you will be contacted by the researcher to arrange a time to have the measurement and education session.

Will I receive feedback on the results of this research?

Please indicate on your consent form if you wish to receive information regarding the results of the research.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be addressed in the first instance to the Project Supervisor, Assoc Professor Duncan Reid, duncan.reid@aut.ac.nz .

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, madeline.banda@aut.ac.nz, 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Joshua Kim

Email: kimsu819@hotmail.com ***or phone:*** 021 371 019

Project Supervisor Contact Details:

Duncan Reid

Email: duncan.reid@aut.ac.nz ***or phone:*** 09 921 9999 ext 7806

Approved by the Auckland University of Technology Ethics Committee on 06/07/2011, AUTEK Reference number 11/153.

Appendix 3

Participant Consent Form



Project title: The frequency of hamstring stretches required to maintain knee extension range of motion following an initial six week stretching programme.

Project Supervisor: Assoc Professor Duncan Reid

Researchers: Joshua Kim, Duncan Reid

- I am a male aged between 18 and 40 years
- I have read and understood the information provided about this research project in the Information Sheet dated 17 July 2011.
- I have had an opportunity to ask questions and to have them answered.
- I understand that I may withdraw from the study at any time and any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- I may be excluded from the study if the principal researcher (Duncan Reid) has taught or supervised me and if I have injuries in the lower limbs, a current history of low-back pain or have been participating in a stretching regime over the past 3 months.
- I wish to receive a copy of the report from the research (please tick one):
Yes No

Participants Name : Signature:

Date :

Approved by the Auckland University of Technology Ethics Committee on 06/07/2011 AUTEK Reference number 11/153.

Note: The Participant should retain a copy of this form.

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