THE EFFECTS OF ACUTE AND PERIODIC STRETCHING INTERVENTIONS ON KNEE EXTENSION RANGE OF MOTION AND HAMSTRING MUSCLE EXTENSIBILITY IN INDIVIDUALS WITH OSTEOARTHRITIS OF THE KNEE

Duncan Reid

School of Rehabilitation and Occupation Studies

Supervisor

Peter McNair PhD

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CERTIFICATE OF AUTHORSHIP

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

Signed………………………………………………………….

Date…………………………………………………………….

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The Auckland University of Technology Ethics Committee (AUTEC) granted ethical approval for Study 1 and 2 on 17th November 2006 (Ethics Application Number 06/189 and 06/190 respectively) (See Appendices 2 and 3).

ABSTRACT

Background: Osteoarthritis (OA) of the knee is a common condition. The condition causes pain and swelling in the knee joint and as a consequence knee range of motion, particularly knee extension, can be decreased. While a number of studies have indicated increases in knee extension range of motion (ROM) can be achieved following stretching interventions, these studies have been undertaken in young healthy populations mostly. To date, there have been no investigations of stretching as a single intervention in people with OA knee.

Review of Literature: To gain an appreciation of the literature in this area, three structured literature reviews were undertaken. The first examined the efficacy of acute stretching interventions on lower limb joint ROM in young and elderly subjects, the second examined the efficacy of periodic muscle stretching interventions on lower limb joint ROM in elderly subjects and the third examined the efficacy of periodic muscle stretching interventions on ROM in subjects with OA of the knee joint. The results of the first review indicated that there is strong evidence for acute stretching interventions to increase joint ROM in the lower limb of young and elderly subjects. The results of the second review indicated that there is strong evidence for periodic stretching interventions to increase joint ROM in the lower limb of elderly subjects. The result of the third review indicated that there is limited evidence for stretching interventions alone to improve ROM in the lower limb in subjects with OA of the knee joint. As consequence of these findings two studies were designed to investigate the effects of acute and periodic stretching in people with OA of the knee joint.

Study 1

Objective: The objective of this study was to investigate the effects of an acute hamstring-stretching programme on knee extension range of motion in individuals with osteoarthritis (OA) of the knee and compare them to individuals of a similar age without OA of the knee.

Study Design: A cross sectional study design was used.

Participants: Thirty one subjects (16 male and 15 female) with OA of the knee were recruited from the local population (mean age 67.8 yrs SD: 5.0, mass 81.4 kg, SD: 15.2, height 168.5 cm, SD 11.1). Thirty one subjects of a similar age (9 male and 23 female) were also recruited who were otherwise fit and healthy and did not have OA of the knee (mean age 68.8 yrs SD: 5.2, mass 71.4 kg, SD: 13.2, height 163.8 cm, SD 8.1).

Method: Hamstring extensibility was assessed by a passive knee extension test using a Kincom® isokinetic dynamometer. Subjects undertook two trials of maximum knee extension. The Kincom® then stretched the hamstrings to a point determined as 80% of the initial maximum knee extension test. Three sets of 60 seconds stretching were undertaken with 60 seconds rest between sets. Two further maximal knee extension tests were performed after the stretching intervention. The variables of interests were maximal knee extension, peak passive torque and stiffness.

Analysis: A 2-factor repeated measures ANOVA model was utilised. The alpha level was set at 0.05.

Results: There was a significant main effect by time for knee extension ROM, peak passive torque and stiffness ($p<0.05$). There was no interaction effect between groups across time ($p>0.05$). Knee extension range of motion (ROM) in the OA group increased significantly from 75.6 (SD: 17.2) degrees to 80.5 (SD: 22.3) degrees after the intervention

($p<0.05$). Subjects in the non OA group increased significantly from 77.5 (SD: 15.5) degrees to 81.9 (SD: 18.2) degrees after the intervention ($p<0.05$). The knee extension ROM recorded at 50% of the peak torque level pre intervention for the OA group was 60.3 (SD: 18.7) degrees and this increased significantly to 67.2 (SD 16.7) degrees post intervention ($p<0.05$). For the non OA group, knee extension ROM at 50% of peak torque increased significantly from 60.1 (SD: 15.2) degrees to 65.8 (SD 16.0) degrees ($p<0.05$). Peak passive torque in the OA group increased significantly from 18.1 (SD: 9.6) Nm to 22.5 (SD: 12.9) Nm after the intervention ($p<0.05$). Subjects in the non OA group increased significantly from 21.05 (SD: 11.6) Nm to 22.05 (SD: 12.8) Nm after the intervention ($p<0.05$). For stiffness, there was a significant interaction effect ($p <0.05$) between groups across time. The OA group increased significantly from 0.70 (SD: 0.35) Nm/deg to 0.89 (SD: 0.5) Nm/deg after the intervention ($p<0.05$). Subjects in the non OA group increased significantly 0.78 (SD: 0.36) Nm/deg to 0.82 (SD: 0.42) Nm/deg after the intervention ($p<0.05$).

Conclusions: The study demonstrated that knee extension ROM, passive resistive torque and stiffness increased with a single bout of stretching. These results indicate that both elderly subjects and those with degenerative joint disease are able to demonstrate immediate tissue adaptations with acute stretching interventions. This is important as clinicians often prescribe acute stretching exercises in the preparation for other activities such as strengthening and walking programmes. Improving joint range of motion prior to other subsequent activities may be beneficial to those people with OA in particular, as management guidelines for these populations recommend regular exercise to reduce the deterioration of the condition.

Study 2

Objective: The purpose of this study was to investigate the effects of a six week stretching intervention to the key muscles of the lower limb, in people with osteoarthritis (OA) of the knee joint and compare them to individuals of a similar age without OA of the knee. A 12 week follow up was undertaken to see if these effects were maintained following the intervention. This study builds on the effects of an acute stretching intervention as demonstrated in Study 1.

Study Design: A randomised control trial design was used.

Participants: Forty three subjects (24 OA and 19 non OA) were recruited from the local population (mean age 68.8 yrs SD: 5.0, mass 79.5 kg, SD: 14.6, height 166 cm, SD 9.8). Subjects were randomly allocated by condition to either a stretch group or a control group.

Methods: Hamstring extensibility was assessed by a passive knee extension test using a Kincom® isokinetic dynamometer at baseline, following the intervention and at a 12 week follow-up. Subjects in the intervention groups stretched the main lower limb muscles 3 x 60 seconds, 5 days a week for 6 weeks. The control groups did not stretch but received a placebo intervention of interferential current. The variables of interest were maximal knee extension, peak passive torque and stiffness. The following outcome measures were also used to assess activity levels: the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), the Lower Limb Task Questionnaire (LLTQ) and the Aggregated Locomotor Functional (ALF) score.

Analysis: A 3-factor (group x condition x time) repeated measures ANOVA model was utilised. The alpha level was set at 0.05.

Results: There was a significant main effect for time and a significant interaction effect for group (stretch and control) by time for knee extension ROM, peak passive torque and stiffness ($p<0.05$). There was no significant interaction for condition (OA vs non OA) ($p>0.05$). Subjects in the stretch group had 68.9 (SD: 15.5) degrees of knee extension before the intervention and this increased significantly to 76.8 (SD: 14.4) degrees after the intervention ($p<0.05$). At the 12 week follow up assessment, subjects had a mean of 72.5 (SD: 20.51) degrees. This difference was not significant when compared to the post intervention assessment ($p>0.05$). Subjects in the control group were not significantly different for knee extension ROM following the intervention or at the 12 week follow up ($p>0.05$). For the knee extension ROM at 50% of the maximum torque level, there was a significant main effect for time ($p<0.05$) but no significant interaction effect between groups across time ($p >0.05$). The mean knee extension ROM recorded at 50% of the peak torque level for the stretch group pre intervention was 55.9 (SD: 15.0) degrees and this decreased significantly to 50.8 (SD 12.3) degrees post intervention ($p<0.05$). The mean knee extension ROM recorded at 50% of the peak torque level pre intervention for the control group was 60.2 (SD: 11.4) degrees and this decreased significantly to 57.1 (SD 11.0) degrees post intervention ($p<0.05$).

With respect to peak passive torque subjects in the stretch group were 13.2 (SD: 7.7) Nm before the intervention and increased significantly to 19.7 (SD: 9.5) Nm after the intervention ($p<0.05$). At the 12 week follow up assessment, the subjects in the stretch group generated a mean peak torque of 20.2 (SD: 11.5) Nm. This difference was not significant when compared to the post intervention assessment ($p>0.05$).

With respect to stiffness, subjects in the stretch group were 0.62 (SD: 0.3) Nm/deg before the intervention and this increased significantly to 0.84 (SD: 0.3) Nm/deg after the intervention ($p<0.05$). At the 12 week follow up time point, the subjects in the stretch group had a mean stiffness of 0.88 (SD: 11.5) Nm/deg. This increase was not significant when compared to the post intervention assessment ($p>0.05$). Subjects in the control group were not significantly different for peak passive torque or stiffness following the intervention or at the 12 week follow up.

There was no significant difference for time or condition for the WOMAC or LLTQ scores. There was a significant main effect for time for both groups for the ALF score ($p<0.05$), however there was no significant interaction for time by condition ($p>0.05$). Subjects in the stretch group had a mean ALF score of 23.1 (SD: 3.9) seconds pre intervention and this reduced significantly to 19.8 (SD: 5.4) seconds post intervention ($p<0.05$). Subjects in the control group had a mean AFL score of 24.8 (SD: 3.1) seconds pre intervention and this reduced significantly to 22.3 (SD: 3.0) seconds post intervention ($p<0.05$).

Conclusions: The study demonstrated that knee extension range of motion, peak passive torque and stiffness increased in those subjects who undertook the six week stretching programme. Knee extension ROM was not maintained at the 12 week follow up assessment, however peak passive torque and stiffness were. These results indicate that both elderly subjects and those with degenerative joint disease are able to demonstrate long term adaptations with periodic stretching interventions. Functional improvements were also observed following the intervention in the stretch groups and the control groups. As previous studies investigating exercise interventions in subjects with OA of the knee joint have combined stretching and strengthening exercises, this study has provided a clear picture of the effects of stretching alone in this population. However, to gain a more obvious change in function in subjects with OA of the knee joint, the combination of stretching with other exercises such as strengthening, may be required in future studies.

Key Words: Osteoarthritis, Range of Motion, Knee Extension, Flexibility

CHAPTER 1

Introduction

1.1 Statement of the problem

Arthritis has been identified as a common cause of disability (Hofman, Grobbee, De Jong, & Van Den Ouweland, 1991; Mathers, Vos, Stevenson, & Begg, 2001; Thomson, Lewis, Didham, Harrison, Rudge, Jones et al., 2005). In New Zealand it is estimated that 16.2 % of the population or around one in six persons aged fifteen or over, will be living with one form of arthritis and this prevalence is expected to grow to 19.2% by the year 2020 (Thomson, Lewis, Didham, Harrison, Rudge, & Jones, 2005). A recent analysis of the direct and indirect economic cost related to arthritis in New Zealand was found to be $2.35 billion. With respect to osteoarthritis (OA) in particular, the community prevalence for this condition is currently 7.7% (Thomson, Lewis, Didham, Harrison, Rudge, & Jones, 2005). In New Zealand, OA ranks as the 6th leading cause of years lost to disability (after depression, anxiety, asthma, diabetes and chronic obstructive airways disease) (Taylor, Smeets, Hall, & McPherson, 2004). Whilst OA can affect any joint in the body, it is common in the knee and hip (Zhang et al., 2008).

OA has often been termed a "wear and tear" disease, however research has demonstrated that in fact it is an active disease process (Dieppe, 1999). While the dominant pathological feature of an osteoarthritic joint is focal loss of damaged articular cartilage, the disease affects many structures within the joint (Dieppe, 1999). At a macroscopic level, the key characteristics of the OA joint are swelling, fibrillation, erosion and eventual loss of articular cartilage, together with remodelling of the underlying bone resulting in subchondral bone sclerosis, bone cysts, an increase in the metaphysial bone and the development of osteophytes. The end point is eburnation in which the focal loss of cartilage on the articulating surface of bone becomes exposed and subject to increased localised overloading (Dawson, Fitzpatrick, Flectcher, & Wilson, 2005). With respect to the knee joint, such changes have been noted to lead to alterations in knee joint laxity, varus or valgus knee alignment and proprioception (Felson, 2000). Other physical impairments associated with OA of the knee joint include pain, loss of joint motion and reduced quadriceps strength (Fitzgerald, Childs, Ridge, & Irrgang, 2002; Messier, Loeser, Hoover, Semble, & Wise, 1992) and subsequent reductions in functional activites such as walking and stair climbing (Kaufman, Hughes, Morrey, Morrey, & Kai-Nan, 2001; Messier et al., 1992).

The Osteoarthritis Research Society International (OARSI) evidence based guidelines for the management of OA of the knee and hip (Zhang et al., 2008), provides a strong consensus recommendation (85% consensus) that individuals with OA of the knee and hip should be encouraged to undertake regular aerobic exercise, muscle strengthening and range of motion exercises. Hurley (2003) has commented that there is an increasing amount of evidence that demonstrates the benefits of exercise in the management of patients with OA knee. A number of studies have investigated the effects of exercise on the OA knee (Deyle et al., 2005; Deyle et al., 2000; Fitzgerald et al., 2002; Fransen, Crosbie, & Edmonds, 2001; Law, 2001; Rogind et al., 1998; van Baar et al., 1998). These programmes have involved a range of exercises including strengthening, stretching and general activities such as mobility and coordination (Deyle et al., 2005; Deyle et al., 2000; Fitzgerald et al., 2002; Fransen et al., 2001;

Law, 2001; Rogind et al., 1998; van Baar et al., 1998). Following these programmes patients have improved with regard to pain (Deyle et al., 2005; Deyle et al., 2000; Thomas et al., 2002), increased walking distance, reductions in the use of medication (Deyle et al., 2000), improved walking speed and strength (Rogind et al., 1998). However a key component of the exercise programmes, namely stretching, has received limited attention in the literature.

In people with OA of the knee joint, the flexion and extension range of motion in particular is reduced. This can be due to damaged articular cartilage, pain avoidance, loss of extensibility of the capsule surrounding the joint and loss of extensibility of the muscles acting over the joint (Dieppe, 1999). Trudel and Uhthoff (2000) commented that arthrogenic changes occur in the knee with increasing periods of immobility leading to the development of a contracture. These authors stated that recovery from the contracture may be possible if the adaptive shortening in the muscles around the joint is addressed by a specific treatment regime. With regard to the loss of knee extension, the hamstring muscles in particular may play a role in this limitation. The implications of the loss of range of motion are that individuals with these restrictions have been shown to increase the loading rates on the joint immediately before heel strike (Messier et al., 1992). This exaggerated loading rate may also contribute to the progression of the disease process (Radin, Yang, Riegger, Kish, & O'Connor, 1991).

In the area of physical rehabilitation, stretching exercises are used to improve joint range of motion (Bandy & Irion, 1994; Bandy, Irion, & Briggler, 1997; Gajdosik, 1991; Magnusson, Simonsen, Aagaard, Sorenson, & Kjaer, 1996; Reid & McNair, 2004), improve function after muscle injury (Malliaropoulos, Papalexandris, Papalada, & Papacostas, 2004), and reduce the effects of chronic disease on joint range of motion (Deyle et al., 2000; Fitzgerald et al., 2002). With respect to the prescription for stretching, Liebesman and Caffarelli (1994) have defined three types of procedures: acute, periodic and chronic. An acute stretch is brief, completed in one session and lasts only a few minutes. Periodic stretching refers to a training programme where subjects repeat a particular stretch several times a week for several weeks. Both of these procedures would have notable benefits for those with OA of the knee joint. For instance, these acute stretching exercises are often prescribed as part of a warm up routine to prepare the muscles and joints for other types of exercises for individuals with OA of the knee, such as strengthening programmes.

Stretching exercises delivered in an acute or single session in non OA groups have demonstrated increases in knee extension ROM, in both young (De Pino, Webright, & Arnold, 2000; de Weijer, Gorniak, & Shamus, 2003; Ford & McCesney, 2007; Magnusson, Simonsen, Per Aagaard et al., 1996; Nordez, Cornu, & McNair, 2006; Whatman, Knappstein, & Hume, 2006) and elderly populations (Feland, Myer, & Merrill, 2001; Zakas, Balaska, Grannatikopoulou, Zakas, & Vergou, 2005). At this time there are no studies that have specifically investigated the effects of an acute hamstring stretching programme on knee extension range of motion in subjects with OA of the knee.

Periodic stretching programmes may also be of value to ameliorate the long term changes in joint range of motion associated with the disease progression. Periodic stretching programmes to the hamstring muscle group in non OA groups, have demonstrated an improvement in knee extension range of motion in young (Bandy & Irion, 1994; Bandy et al., 1997; Magnusson, Simonsen, Aagaard, Sorenson et al., 1996; Reid & McNair, 2004) and elderly populations (Feland, Myrer, Schulthies, Fellingham, & Meason, 2001; Girouard & Hurley, 1995; Raab, Agre, McAdam, & Smith, 1988). A small number of studies have utilised stretching exercises to the hamstring muscles in combination with strengthening programmes in subjects with OA of the knee joint (Deyle et al., 2005; Deyle et al., 2000; Fransen et al., 2001; van Baar et al., 1998). However the design of these studies has prevented a good understanding of the relative merits of stretching exercises. Thus, a study designed to address a number of gaps in the current knowledge and specifically investigate the long term effects of hamstring stretching to improve knee extension ROM and function in this population, will be valuable.

1.2 Purpose of the study

The purpose of this research was to undertake two studies:

1. To investigate the effect of an acute hamstring-stretching intervention on knee extension range of motion in subjects with and without OA of the knee. Specifically, the following variables were of interest: the peak knee extension angle, peak passive torque, and stiffness, measured with the Kincom® isokinetic dynamometer during a passive knee extension test.

2. To investigate the effect of a six week hamstring and general lower limb stretching intervention on knee extension range of motion in subjects with and without OA of the knee and examine if these effects are maintained at a 12 week follow up. Specifically the following variables were of interest: the peak knee extension angle, peak passive torque, and stiffness, measured with the Kincom® isokinetic dynamometer during a passive knee extension test. A secondary aim of this study was to investigate the effects of the stretching

intervention on activities such as walking, sit to stand transfers and stair climbing.

1.3 Significance of the problem

The study's findings will have significance for health professionals, people with osteoarthritis of the knee and health funding bodies engaged in improving the long term management of a chronic and debilitating disease process. Health care delivery in New Zealand is guided by a key government document, the NZ Health Strategy (King, 2001). The strategy outlines 13 major population health objectives including increasing levels of physical activity, reducing obesity, diabetes, cardiovascular disease and smoking. Whilst arthritis is not an explicitly targeted disease in the NZ Health Strategy, it still affects as many as 30% of the population over 45 years of age (Taylor et al., 2004). Osteoarthritis of the knee however, could have an effect on people's ability to deal with some of the other specifically targeted diseases. If one has OA of the knee joint, being able to undertake exercise programmes that include activities such as walking, to help reduce obesity and cardiovascular disease for example, is going to be a challenge. Examining specific exercise regimes such as stretching that may help to improve joint mobility and therefore the ability to engage in exercise, is of importance.

Examining the effects of a hamstring-stretching and lower limb muscle stretching programme on knee extension range of motion, peak passive torque and stiffness, will provide new knowledge concerning the potential changes in these variables in pathological populations. The study will also allow comparisons with people without pathology but of a similar age range. This will provide important information for an aging population who may require increasing amounts of health care services in the future. The information gained from the study may lead to alterations in acute and periodic stretching prescriptions for both the elderly and people with OA of the knee joint. Such changes to these programmes may be a key component to maintaining independence and reduce the burden of health care, the effects of progressive joint deterioration and aging.

CHAPTER 2

Review of Literature

Introduction

This chapter is divided into six sections. Firstly, the chapter begins with a brief review of the mechanisms associated with changes in range of motion (ROM) following stretching interventions. Secondly, the literature related to the effects of acute stretching interventions in the lower limbs of both young and elderly populations is reviewed. Thirdly, the literature investigating the effects of periodic hamstring stretching interventions in elderly populations is reviewed. Fourthly, periodic stretching programmes in populations with OA of the knee joint are reviewed and fifthly, the literature investigating the effects of osteoarthritis on gait is reviewed. The chapter concludes with a review of the outcome measures relevant to the measurement of changes in function in people with OA of the knee joint.

2.1 Mechanisms associated with changes in ROM

Although the current research is not investigating mechanisms, the interpretation of the data requires some understanding of the possible underlying factors responsible for adaptations found following stretching regimes. The primary aim of stretching interventions is to increase joint range of motion (ROM) or to improve tissue compliance (reduce stiffness). Extensibility of soft tissues is related to the resistance of tissue as it lengthens (McNair and Stanley 1996). The ability of a muscle to lengthen could also be measured in terms of its' 'stiffness' (or it's reciprocal compliance) to movement (Magnusson 1998). Stiffness can be defined as the ratio of the change in force to the change in length of the tissue (McNair and Stanley 1996). It should be noted at this point that 'stiffness' is also a term used by people with joint conditions such as OA as a sensation of restriction of movement or slowness as defined by Bellamy et al., (1988) in the development of disease specific questionnaires such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). This is a different interpretation than the physiological description provided above.

The proposed mechanisms associated with changes in ROM following stretching regimes include neurophysiological and mechanical phenomena (Hutton, 1993; Moore & Hutton, 1980; D. Taylor, Dalton, Seaber, & Garrett, 1990). Increases in musculotendinous length, increased stretch tolerance, alterations in muscle stiffness, viscoelastic stress relaxation and reflexes have been observed (Halbertsma, Ludwig, & Goeken, 1994; Hutton, 1993; Magnusson, 1998; Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996; Magnusson, Simonsen, Per Aagaard et al., 1996; McHugh, Magnusson, Gleim, & Nicholas, 1992; McNair & Stanley, 1996; Moore & Hutton, 1980; D. Taylor et al., 1990; Toft, Espersen, Kalund, Sinkjaer, & Hornemann, 1989).

Gajdosik (2001) has suggested that the resistance in muscle that occurs when passively stretching is influenced by both intramuscular and extra-muscular components. The intra-muscular (series elastic) components include the active muscle components (actin and myosin) and the non contractive proteins such as titin and desmin. The extra-muscular (parallel elastic) components, made up of connective tissue (endomysium, perimysium and epimysium), are located within and surrounding the muscle bellies. Of these components it is the perimysium that undergoes the most mechanical deformation particularly when the tissue reaches it terminal range (Purslow, 1989).

When an acute or single stretch is undertaken, the observed immediate changes in ROM are thought to be due to a number of mechanisms. These include a redistribution of the more mobile constituents of the tissues, such as the polysaccharides and water (McNair, Dombroski, Hewson, & Stanley, 2001) uncrimping and slippage of collagen tissues (de Weijer et al., 2003; Magnusson, Simonsen, Per Aagaard et al., 1996; Stromberg & Wiederielm, 1969) and breakage of bonds between actin and myosin filaments (Proske & Morgan, 1999).

In periodic or long-term stretching regimes, the suggested mechanisms for these increases in ROM are changes in the tissue properties of the muscle. These include increases in muscle fibre length and through the addition of sarcomeres in series, primarily at the distal end of the contractile elements (Herbert & Balnave, 1993; Williams & Goldspink, 1973). Goldspink Tabary and Tabary et al (1974) also suggested that such changes were a local response to increased tension in the muscle undergoing stretch.

Increases in musculotendinous length have also been examined with particular attention to the tendon. Some studies (Herbert, Moseley, Butler, & Gandevia, 2002; Kawakami, Kanehisa, & Fukunaga, 2008) have demonstrated that while changes occur in the muscle fascicles with passive stretching there is also significant lengthening of the tendon (Herbert et al., 2002; Morse, Degens, Seynnes, Maganaris, & Jones, 2008). Other researchers have demonstrated that different types of periodic stretching (static or ballistic), effect the passive properties of the muscle-tendon unit (Mahieu et al., 2007), with static stretching reducing the passive resistive torque of the muscle and ballistic stretching, the tendon stiffness.

An alternative mechanism for inducing an increase ROM following stretching is a change in stretch tolerance. Some researchers (Folpp, Deall, Harvey, & Gwinn, 2006; Klinge et al., 1997; Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, Sorenson et al., 1996) have suggested that the adaptations to stretching may be due to an “amplified stretch tolerance” rather than to changes in the tissue properties. The stretch tolerance of a muscle is determined as the maximum limit of stretch or elongation that a subject will tolerate during a passive stretching procedure (Halbertsma, Bolhuis, & Goeken, 1996). Gajdosik et al (2004) commented that this phenomena is a subjective limitation of joint range and may not reflect the true mechanical end point of joint range of motion.

In summary, the changes in biomechanical properties that occur after a single bout of stretching are likely to be transitory and involve a combination of frictional and viscoelastic factors. In contrast, changes in range of motion after periodic stretching are more to reflect a combination of structural and perceptual factors. The relative contribution of these factors is unknown.

2.2 Search strategy

The papers reviewed were selected from three structured searches, one aimed at examining the efficacy of acute stretching interventions on ROM in lower limb muscles in young and elderly populations, one aimed at examining the efficacy of periodic stretching interventions on ROM to the lower limb muscles in the elderly and one aimed at examining the efficacy of periodic stretching interventions on ROM in those with OA of the knee joint. These searches utilised the following key electronic data bases; Ovid (including Pub Med, Cinahl), EBSCO databases (including Biomedical Reference Collection: Basic, Clinical Reference Systems, Health Source - Consumer Edition, Health Source: Nursing/Academic Edition, MEDLINE, SPORTDiscus with Full Text), Cochrane Library, Physiotherapy Evidence database (PEDro), and Scopus, from 1966 to July 2008. The key words for each search are presented in the relevant following sections.

2.3 Methodological quality

Assessing the methodological quality of publications is an important part of evidence-based practice (Sackett, 1998). There are varying methods of assessing the methodological quality of publications that may be used in systematic reviews and these include tools such as the Physiotherapy Evidence Database Scale (PEDro Scale) (Herbert, 1999), the Delphi list (Verhagen et al., 2000) and the Cochrane Collaborative schemes. In the current review, where the literature was focused upon randomised controlled trials, the methodological quality of each study was assessed with the latter evaluation tool. Thus, a scoring system of twelve aspects of internal and external validity was examined. A score of 2 was given if the criteria assessed were ‘clearly yes”, 1 for ‘not sure’ and 0 for ‘clearly no’. A maximum score of 24 was possible. A copy of the criteria is presented in Appendix 1. The total out of 24 was deemed to be the overall Quality Score (QS) of the studies reviewed. Although the reliability and validity of this method has not been established, it is based on common features of other methods of review. Eight of the twelve criteria are derived from the Delphi list (Verhagen et al., 2000) and the Delphi list also includes eight of the ten criteria present in the PEDro Scoring system (Herbert, 1999). The effect size (ES) is often used to measure the magnitude of a treatment effect (Cohen, 1988). Cohen (1988) has defined effect sizes as "small" (.2), "medium" (.5)" and "large" (.8). The effect sizes for the reviewed 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 at baseline.

2.4 Levels of evidence

Having assigned an overall quality score, a qualitative analysis of the overall strength of the scientific evidence was achieved using the following criteria based on Van Tulder (2003):

Level 1: Strong evidence- provided by generally consistent findings in multiple higher quality Randomised Controlled Trial's (RCT).

Level 2: Moderate evidence- provided by generally consistent findings in one higher quality RCT and one or more lower quality RCT's.

Level 3: Limited evidence –provided by generally consistent findings in one or more low quality RCT's.

Level 4: No evidence - if there were no RCT's or if the results were conflicting.

The trials were considered to be of 'higher quality' if they scored 50% or more on the quality score (van Tulder, Furlan, Bombardier, & Bouter, 2003), while 'consistent findings' were defined as >75% of the trials reporting the same findings (Furlan et al., 2008).

2.5 Acute stretching interventions in the lower limb

An acute stretch is defined as brief, completed in one session often with effects lasting only a few minutes (Liebesman & Cafarelli, 1994). There are a number of cross sectional studies that have examined the effects of acute stretching interventions on joint range of motion and other viscoelastic parameters in the lower limb (Halbertsma, Mulder, Goeken, & Eisma, 1999; Magnusson, Aagaard, & Nielsen, 2000; Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996; Nordez et al., 2006; Whatman et al., 2006; Zakas et al., 2005). However, in order to determine the efficacy of acute stretching interventions to improve range of motion in the muscles of the lower limb, there is a need to review randomised controlled trials rather than cross sectional studies. An initial search focussing on elderly populations (defined as over 60 years of age) only elicited a small number of studies (N=3); therefore to gain a greater appreciation of the topic, the search was expanded to include younger populations.

2.5.1 Key words

For the acute lower limb stretching studies the following key words or combinations of key words were used;

1. “static stretch*” or “passive stretch* or extensibility or flexibility or range of motion”

2. “hamstring*” or “calf*” or “knee extension” or “ankle dorsiflexion” or “lower limb*” or “lower extremit*” or “hip”

These key words and combinations of key words were adapted as required to narrow the search to the relevant topic areas. Hand searching and cross referencing was also undertaken with identified systematic reviews and the reference lists of relevant articles. Once articles were retrieved, a review of the title and abstract was undertaken to determine if the articles met the inclusion criteria.

2.5.2 Study selection

Inclusion criteria: The following criteria were used to select relevant papers to be included within this review:

Type of participant: Human participants of either gender. Trials examined only those subjects who did not have orthopaedic conditions such as arthritis or neurological conditions such as stroke.

Type of study design: Randomised controlled trials.

Type of intervention: Acute static stretching intervention to lower limb muscles, in particular the hamstrings and calf. Studies were excluded if static stretching was combined with other modalities such as heat, cold or strengthening exercises.

Outcome measurements: Studies had to include at least one of the following outcome measurements: Range of motion or passive torque or stiffness measured with a goniometer, an electronic inclinometer or isokinetic dynamometer, in weight bearing or non weight bearing conditions.

Exclusion criteria: The following criteria were used to eliminate papers from this review: Papers written in non-English languages; and those studies utilising animals.

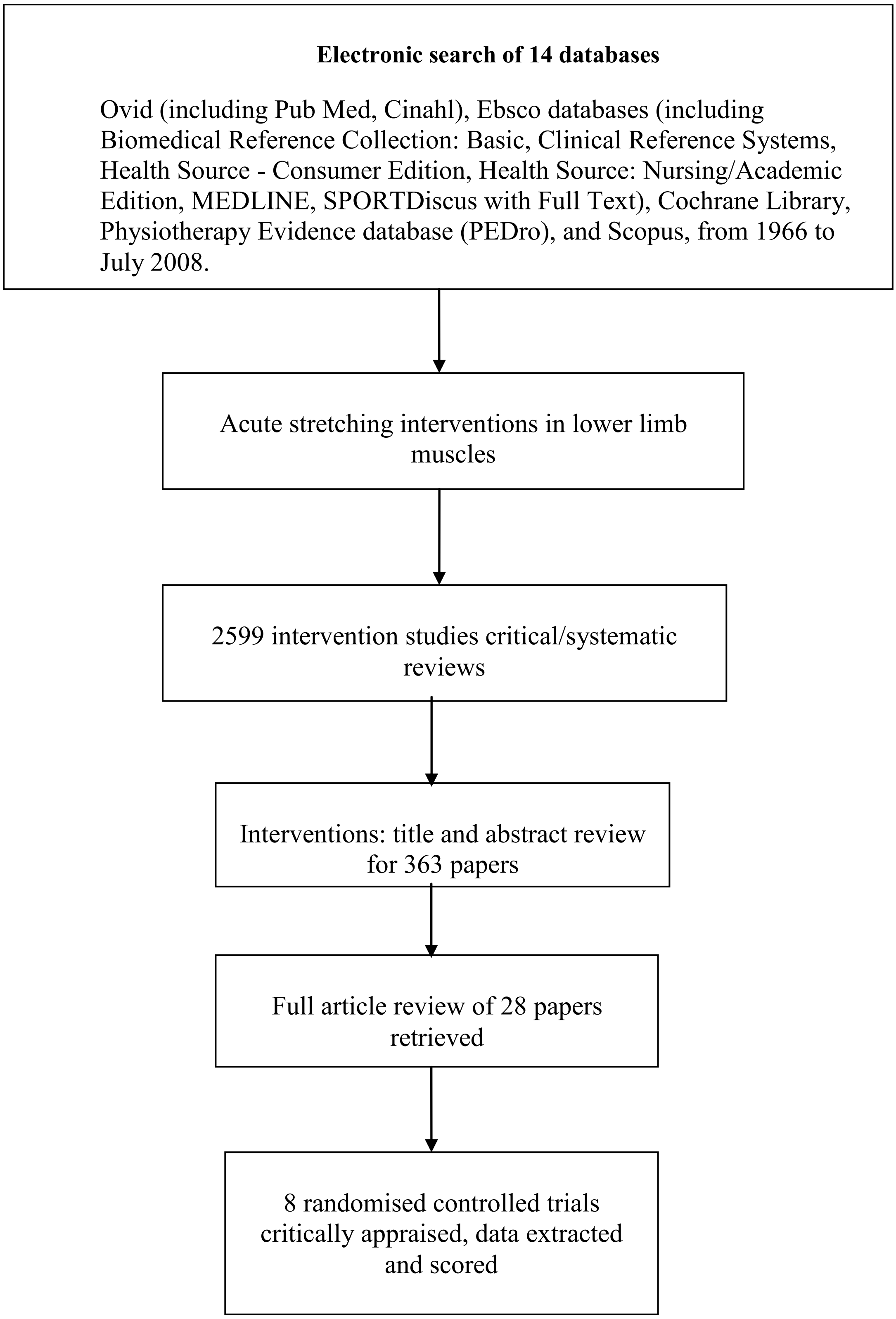


Figure 2.1: Flow diagram of the acute stretching search strategy.

2.5.3 Results

A total of eight studies met the inclusion criteria (De Pino et al., 2000; de Weijer et al., 2003; Feland, Myer et al., 2001; Ford & McCesney, 2007; Hubley, Kozey, & Stanish, 1984; Muir, Chesworth, & Vandervoort, 1999; Zakas, 2005; Zakas, Doganis, Zakas, & Vergou, 2006) The methodological quality of the reviewed studies is displayed in Table 2.1 and a summary of the key features of the studies in Table 2.2.

The methodological quality scores (QS) of the studies ranged from 13-20. The majority of studies failed to score well in the areas of assessor blinding, subject blinding and blinding of treatment providers to assignment status. Only De Weijer et al (2003) provided blinding of outcome assessors. In the studies reviewed, the effect size (ES) varied from -0.05 to 1.5. In two studies, the ES could not be calculated due to insufficient data or data not presented in such a way as to allow the calculations to be undertaken (Feland, Myrer et al., 2001; Muir et al., 1999).

A significant increase in range of motion following acute static stretching interventions was demonstrated in all studies. These increases ranged from four (Feland, Myer et al., 2001) to 14 degrees (de Weijer et al., 2003). These positive results were achieved with varying volumes of stretch duration, ranging from 32 seconds (Feland, Myer et al., 2001) to 900 seconds (Hubley et al., 1984). Only three of the studies specifically investigated these acute effects in elderly subjects (Feland, Myer et al., 2001; Zakas et al., 2005; Zakas et al., 2006). In these particular studies, the stretching durations varied from 32 seconds (Feland, Myer et al., 2001) to 60 seconds (Zakas et al., 2005; Zakas et al., 2006). Three studies used subjects of mixed genders (de Weijer et al., 2003; Feland, Myer et al., 2001; Ford & McCesney, 2007), while the remaining studies used subjects of single genders. As all the reviewed studies rated greater than 50% on the quality score and greater than 75% (seven of the eight studies) demonstrated a consistent result, it was concluded that there is strong evidence for acute stretching interventions to improve lower limb range of motion in both young and elderly subjects.

Table 2.1 Methodological quality of acute stretching studies assessed using the Cochrane Musculoskeletal Injuries Group (CMSIG) tool

First Author (year)	A	B	C	D	E	F	G	H	I	J	K	L	QS/24
Hubley (1984)	2	2	0	2	0	0	2	0	2	2	2	2	**16**
Muir (1999)	2	2	0	2	0	0	2	2	2	2	2	2	**18**
Feland (2001)	1	2	0	0	0	0	2	2	2	2	2	2	**15**
De Pino (2000)	2	2	0	2	0	0	2	2	2	2	2	2	**18**
De Weijer (2003)	2	2	2	2	0	0	2	2	2	2	2	2	**20**
Zakas (2005)	1	0	0	0	0	0	2	2	2	2	2	2	**13**
Zakas (2006)	1	0	0	0	0	0	2	2	2	2	2	2	**13**
Ford (2007)	2	2	0	2	0	0	2	2	2	2	2	2	**18**

Key: QS = Quality Score.

Notes:

A= assignment of treatment adequately concealed

B= outcomes of participant who withdrew included in intention to treat analysis

C= blinding of outcome assessors to treatment

D= comparability of treatment and control group at entry

E= blinding of subjects to assignment status

F= blinding of treatment providers to assignment status

G= identical care programmes

H = inclusion and exclusion criteria clearly defined

I= intervention clearly defined

J= outcomes clearly defined

K= diagnostic tests clinically useful

L=duration of surveillance active and clinically relevant

Table 2.2 Summary of key variables of studies investigating acute stretching interventions in the lower limb

Quality Score	Authors	Sample (N), gender and mean age	Stretch prescription and location	Total stretch duration (seconds)	ROM gained	ES	Results
20	de Weijer et al (2003)	N=56 (male and female) 28.8 yrs	Gp1: 3 x 30s+WU Gp2: 3 x 30s Gp3: WU only Gp4: Control Hamstrings	90	Gp1: 14° Gp2: 13.1° Gp3: 1.2° Gp4: -0.3°	1.5 1.4 0.09	Significant ROM increases for stretch groups. Improvements in ROM were maintained 24 hours post stretch.
18	DePino et al., (2000)	N=30 (males) 20 yrs	Gp1: 4 x 30s Gp2: Control Hamstrings	120	Gp1: 6.8° Gp2: -2.9°	0.3	Significant ROM increases for stretch groups. These were maintained for 1 and 3 minutes post stretch.
18	Ford & McChesney (2007)	N= 32 (male and female) 22 yrs	Gp1: 4 x 12s PNF Gp2: 5 x 30 s static Gp3: Active control 10 x 10s Gp4: Control Hamstrings	Gp1: 48 Gp2: 150 Gp3: 100	Gp1: 4.9° Gp2: 6.7° Gp3: 7.2° Gp4: 0°	0.6 0.6 0.8	Significant ROM increases for stretch groups maintained for 25 minutes. No significant difference between stretch groups.
18	Muir et al (1999)	N=20 (males) 26 yrs	Gp:1 4 x 30s Gp:2 Control Calf	120	ROM not stated	*	No significant difference in peak torque between the groups.
16	Hubley et al (1984)	N= 30 (male and female) 14-60 yrs	Gp1: Cycle Gp2: Cycle/rest Gp3: Cycle/stretch Gp4: Stretch/rest Gp5: Control Hip Flexion	900	Gp1: 8° Gp2: 2° Gp3: 1° Gp4: 9° Gp5: 2°	0.3 0.01 -0.05 0.2	Significant increase in hip flexion ROM for stretch only and cycle only groups. Gains in ROM maintained for 15 mins.

Quality Score	Authors	Sample (N), gender and Mean age	Stretch prescription and location	Total stretch duration (seconds)	ROM gained	ES	Results
15	Feland et al (2001)	N=97 (male and female) 55-75 yrs	Gp1: 1 x 32s static Gp2: 1 x 30s PNF Gp3: Control Hamstrings	32s	Gp1: 4° Gp2: 5° Gp3: 1°	*	Significant increase in ROM immediate post stretch for both types of stretch.
13	Zakas et al (2006)	N=22 (females) 76.5yrs	Gp1: WU (control) Gp2: WU + 3 x 60 s Gp3: 3 x 60 s All major lower limb muscles including Hamstrings and Calf	180	Hip flexion Gp1: 0° Gp2: 6.4° Gp3: 7° Ankle DF Gp1: 1.8° Gp2: 4.5° Gp3: 3.9°	 0.7 0.7 0.7 0.5	Significant increase in ROM stretch and warm up group's Warm up only group significant increase in ROM in ankle dorsiflexion.
13	Zakas et al (2005)	N=20 (females) 65-85 yrs	Gp1: 1 x 60s (control) Gp2: 2 x 30s Gp3: 4 x 15s All major lower limb muscles including Hamstrings and Calf	60	Hip flexion Gp1: 7.5° Gp2: 7.1° Gp3: 7.5° Ankle DF Gp1: 4.5° Gp2: 4.7° Gp3: 4.3°	 -0.05 0 0.08 0.09	Significant increases in ROM for all stretch groups.

Key: WU= warm up, ES = Effect Size, ROM = range of motion, DF = dorsiflexion * = insufficient data to calculate ES

2.6 Key features associated with acute stretching programmes

Biomechanically, muscle tendon units behave as a viscoelastic material. This means that when a stretching force is applied to it, the relationship between length and tension changes with time (Herbert, 1988). In the acute stretching situation, depending on the frequency and duration of the stretching intervention, a number of different phenomena have been observed. These include stress relaxation (Duong, Low, Moseley, Lee, & Herbert, 2001; Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996; McHugh et al., 1992), creep (Herbert, 1988) and hysteresis (Magnusson et al., 1995; McHugh, Kremenic, Fox, & Gleim, 1998; McNair et al., 2000). The measurement of human flexibility has predominately been undertaken by recording total passive joint range of motion with devices such as the goniometer and this has been the methodology of choice in the majority of the studies in this review. The purpose of this section of the literature review was to determine the efficacy of acute stretching interventions to the lower limb muscles of young and elderly subjects. Whilst all studies demonstrated a positive increase in ROM, direct comparison was difficult as a range of variables such as the duration of the stretch, the use of warm up, comparisons with proprioceptive neuromuscular facilitation(PNF), the lasting effects of acute stretches and passive resistive torque, were assessed.

2.6.1 Range of motion in elderly subjects

Three studies were identified that examined acute changes in ROM in elderly populations (Feland, Myer et al., 2001; Zakas et al., 2005; Zakas et al., 2006). Feland, Myer and Merrill (2001) (QS 17) investigated the acute changes in knee extension range of motion in a group of senior athletes (mean age 65 years). Ninety seven athletes attending the World Senior Games participated and were randomly allocated to one of three groups; a static stretch group, a PNF stretch group or a control group that did not stretch. The stretches were performed by the researchers. The static group was given a 1x 32 seconds stretch. The PNF group was given a six second contraction followed by a 10 second stretch. This sequence was repeated three times. The control group had their range of motion measured once, then again after a 32 second rest. The results of the study indicated that the static stretch group improved by four degrees and the PNF group by five degrees. The control group had no significant change. The authors of this study concluded that a single bout of stretching provided an acute increase in hamstring flexibility in these senior athletes and this may be beneficial in improving activities of daily living and improving quality of life.

Zakas, Balaska, Grannitakopoulou et al (2005) (QS 13) investigated the acute effects of stretching duration and numbers of repetitions on lower limb and trunk ROM in elderly women. Twenty sedentary women (age 65-85 years) participated in the study. All participants were randomly allocated to one of three static stretching protocols, 1 x 60 second, 2 x 30 second and 4 x 15 second stretches. As the authors were interested in the effects of the different durations of stretch they stated that the 1 x 60 second group would serve as the control group. Ten second rest intervals were given between repetitions. The participants independently performed specific static stretches for the adductors, iliopsoas, hamstrings,quadriceps, soleus and erector spinae muscles. Trunk flexion, knee flexion, ankle dorsiflexion and hip flexion, extension and abduction ROM were measured immediately before and after each stretching protocol. The results indicated that all three stretching protocols temporarily increase ROM in the lower limbs and trunk of older women. With respect to the hamstring muscle group, hip flexion increased by 7.5° with the 60 second stretch duration. The authors concluded that a single 60 second stretch was adequate when aiming to temporarily improve ROM in the elderly population. These results indicated that a longer duration of stretch (60 seconds) improved range of motion by three degrees more than the study by Feland et al (2001)(1 x32 seconds for a four degree increase).

Zakas et al (2006) (QS 13) compared the effects of a warm up routine versus static stretching and a combination of the two. Twenty two elderly women (mean age 76 yrs) were randomly allocated to a warm up group (20 minutes walking and cycling), a warm up and static stretch group and a static stretch only group. The warm up group served as a control. Subjects in the stretching groups undertook a series of stretches to the calf, hamstring, hip adductors, quadriceps and trunk muscles, stretching each area for three repetitions of sixty seconds. The results of the study indicated that all muscle groups that had been stretched demonstrated a significant increase in range of motion. With respect to the hamstring group, a 6.4° increase in knee extension ROM was observed in the combined group and a 7° increase in the static stretch only group. No change in ROM was observed across muscle groups for the warm up only group, except for ankle dorsiflexion, which increased significantly by 1.8°. The authors of this study concluded that undertaking a warm up alone did not provide a sufficient stimulus to increase joint range of motion in this elderly population, and that joint ROM was more effectively improved with static stretching. These results were consistent with McNair and Stanley (1996) who compared dynamic activities such as jogging and static stretching in young subjects.

2.6.2 Range of motion in young subjects

The remaining five studies examined the effects of acute stretching interventions in young populations (De Pino et al., 2000; de Weijer et al., 2003; Ford & McCesney, 2007; Hubley et al., 1984; Muir et al., 1999). Four of these studies had positive increase in ROM (De Pino et al., 2000; de Weijer et al., 2003; Ford & McCesney, 2007; Hubley et al., 1984; Muir et al., 1999). The following sections will review the effect of warm up, the lasting effects of acute stretching, and changes in passive resistive torque following acute stretching in young subjects.

2.6.3 Warm up

Acute stretching interventions are often used as part of a pre exercise warm up procedure in an endeavour to maximise the available joint range of motion. Equally warm up activities have been used prior to stretching to reduce muscle stiffness and increase range of motion (McNair & Stanley, 1996). Given these different actions, two studies investigated the effects of warm up and acute stretching interventions on joint ROM (de Weijer et al., 2003; Hubley et al., 1984). De Weijer, Gorniak and Shamus (2003) (QS 20) compared the effects of static stretching and warm up on knee extension ROM over a twenty four hour period in 56 young subjects (mean age 28.8 years). The subjects were randomly allocated into four groups; a warm-up (stair climbing machine for 10 minutes) followed by static stretch group, a static stretch only group, warm-up exercise only group, and a control group who received no intervention. Three thirty second static stretches using a passive knee extension test were performed. Knee extension measurements were recorded immediately, at 15 minutes, 60 minutes, four and twenty four hours post stretch. The results of this study demonstrated significant improvements in ROM immediately post stretch for the warm-up exercise and stretch group (10°), and stretch alone group (7°). The ROM increases were maintained up to the twenty four hour point. These results suggest that static stretching of the hamstring muscles results in improvements in flexibility, maintained for twenty four hours regardless of warm up exercise being performed prior to stretching.

Hubley, Kozey and Stanish (1984) (QS 16) compared the immediate and retained effects of static stretching exercises and stationary cycling on hip ROM. Thirty subjects (age 14-60) were randomly allocated to one of five groups; a cycle/cycle group, a cycle/rest group, a stretch/cycle group, a stretch/rest group and a control group. The intervention involved either 15 minutes cycling or 15 minutes stretching to the quadriceps and hamstring muscles. This was followed up with either another period of cycling or rest from the exercise. Hip joint flexion and extension ROM were measured at baseline and then following the above five conditions. The results of this study found that the individual application of stretching and cycling significantly improved hip ROM immediately, and that these gains were maintained for 15 minutes after the intervention. However, combinations of stretching and cycling did not show any significant difference in ROM. Surprisingly, the authors of the study commented that the increases in ROM with both interventions were due to increased muscle temperature improving the compliance of the muscle tissue.

2.6.4 Lasting effects of acute stretching interventions

The acute effects of stretching on joint ROM have been shown to return to baseline within a short period of time (Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996). Two studies investigated the lasting effects of acute stretching on ROM. (De Pino et al., 2000; Ford & McCesney, 2007). De Pino, Webright and Arnold (2000) (QS 18) investigated the lasting effects of an acute static stretching routine to the hamstrings. Thirty healthy male subjects (mean age 19 years) were recruited for the study. The subjects were randomly allocated to a stretching group (n=15) or control group (n=15). All subjects performed six active knee extension movements before the stretching intervention with the sixth movement used as the baseline measure. Subjects in the stretch group then undertook 4 x 30 second stretches to the hamstrings with 15 seconds rest between stretches. The control group did not stretch. Following the intervention measurements of knee extension ROM was taken at one, three, six, nine, 15 and 30 minutes. The results of the study indicated that the subjects in the stretch group had a significantly improved knee extension ROM of 6.8°. This increase in range of motion returned to baseline measure after six minutes. The control group declined in ROM from baseline testing. The authors of the study suggested that the inability to maintain the increased range of motion beyond three minutes indicated that a temporary creep effect occurred in the viscoelastic component of the hamstring, but the stimulus was not sufficient to make permanent changes in the tissue.

Ford and McChesney (2007) (QS 18) examined the lasting effects of an acute hamstring stretching programme on knee extension ROM in 32 healthy subjects (mean age 22 yrs). Subjects were randomly allocated to a PNF stretch group, a static stretch group, an 'active control' stretch group and a control group who did not stretch. The subjects in the PNF group stretched using four cycles of six second contract, six second stretch. The static stretch group undertook 5 x 30 seconds of static in a hurdlers stretch position. The active control stretch group stretched the hamstrings in a sitting active knee extension position for 10 x10 seconds. Following the stretching interventions the active knee extension ROM was measured at 0, 3, 7, 12, 18 and 25 minute intervals. The main findings indicated that in all the stretch groups there was a significant increase in knee extension range of motion and this was maintained for 25 minutes post stretch. The authors of this study stated that these results demonstrated increases in ROM do last for a significant time irrespective of the stretch used and this lends support to the use of stretching exercises as part of a warm up procedure.

2.6.5 Passive resistive torque

The ability to measure other parameters associated with increases in ROM such as passive resistive torque require the use of devices such as isokinetic dynamometers (Magnusson, Simonsen, Aagaard, Sorenson et al., 1996; Reid & McNair, 2004) and load cells (Halbertsma et al., 1996; Halbertsma et al., 1994; Halbertsma et al., 1999; McHugh et al., 1999; McHugh et al., 1998). The advantage in measuring torque compared to measuring joint ROM alone is that it allows quantification of the passive resistance throughout the range of motion (Muir et al., 1999). In doing so, indirect evidence of the physiological mechanisms associated with the stretching procedures can be appreciated.

Only one of the reviewed studies measured changes in torque associated with range of motion following an acute stretching intervention. Muir, Chesworth and Vandervoort (1999) (QS 18) investigated the effects of static calf stretching on resistive torque during passive ankle dorsiflexion in 20 healthy men (mean age 26yrs). Subjects were randomly allocated a stretching group and a control group. The stretching procedure was a static calf stretch for 30 seconds, repeated four times. A Kincom® dynamometer was used to measure torque while moving from 10° plantar-flexion to 10° dorsiflexion. A series of six cycles were performed before and after the intervention. Peak to peak torque (10° plantar-flexion to 10° dorsiflexion) and torque at the mid-position (zero degrees) was evaluated. The results of the study indicated no difference in peak to peak torque or the torque at the mid position for the intervention or control leg. The authors of the study concluded that static stretching did not produce a significant reduction in torque and therefore did not support the hypothesis that static stretching would reduce the passive resistance of the connective tissue surrounding the calf muscles. A possible reason for the lack of change may be reflective of the methodology used. The torque was measured through a range of motion where little resistance is observed, and not at the terminal range of motion where changes in passive resistance are more often observed following acute stretching interventions (Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996).

2.6.6 Summary

In summary, the majority of acute stretching hamstring programmes have been undertaken in young subjects (age range 14-26) with a smaller number examining stretching in the elderly. The total stretch duration has varied from 32 to 900 seconds. The gains in range of motion have varied from 5-14 degrees. Some studies found the effects of acute stretching interventions to be short term with changes lasting less than an hour, with others finding a more lasting effect of up to twenty four hours. The majority of studies measured ROM only and not passive torque or stiffness associated with changes in range of motion. No studies examined acute stretching interventions in subjects with OA of the knee joint.

2.7 Periodic stretching interventions in elderly populations

Periodic stretching involves the repetition of a stretch over a period of days or weeks. There has been a notable amount of research undertaken on this topic and a number of systematic reviews, analysing the efficacy of the stretching programmes to lower limb muscles in younger populations, have been undertaken (Decoster, Cleland, Altieri, & Russell, 2005; Harvey, Herbert, & Crosbie, 2002; Radford, Burns, Buchbinder, Landorf, & Cook, 2006). The results of these reviews indicate there is low to moderate levels of evidence for periodic stretching programmes to improve joint

ROM in young subjects However, this review was particularly interested in periodic lower limb stretching programmes applied to elderly populations only.

2.7.1 Key words

For the periodic stretching studies in elderly the following key words or combinations of key words were used;

1. "static stretch*" or "passive stretch*" or extensibility or flexibility or range of motion"

2. "hamstring*" or "calf*" or "knee extension" or "ankle dorsiflexion" or "lower limb*" OR "lower extremit*" or "hip"

3. "old*" or "elder*" or "aged"

These key words and combinations of key words were adapted as required to narrow the search to the relevant topic areas. Hand searching and cross referencing was also undertaken with identified systematic reviews and the reference lists of relevant articles. Once articles were retrieved, a review of the title and abstract was undertaken to determine if the articles met the inclusion criteria.

2.7.2 Study selection

Inclusion criteria: The following criteria were used to select relevant papers to be included within this review:

Type of participant: Participants were defined as elderly with a mean age 60 years and older, of either gender. Trials examined only those subjects who did not have orthopaedic conditions such as arthritis or neurological conditions such as stroke.

Type of study design: Randomised controlled trials.

Type of intervention: Static stretching intervention to key muscles groups in the lower limb, calf, hamstring, or hip flexors.

Outcome measurements: Studies had to include at least one of the following outcome measurements: Range of motion, or passive torque or stiffness, with a goniometer, an electronic inclinometer or isokinetic dynamometer, , in weight bearing or non weight bearing conditions.

<u>Exclusion criteria:</u> The following criteria were used to eliminate papers from this review: Papers written in non-English languages, non-RCT's; stretches that were not static such as PNF, however a comparison with a PNF stretching technique was accepted.

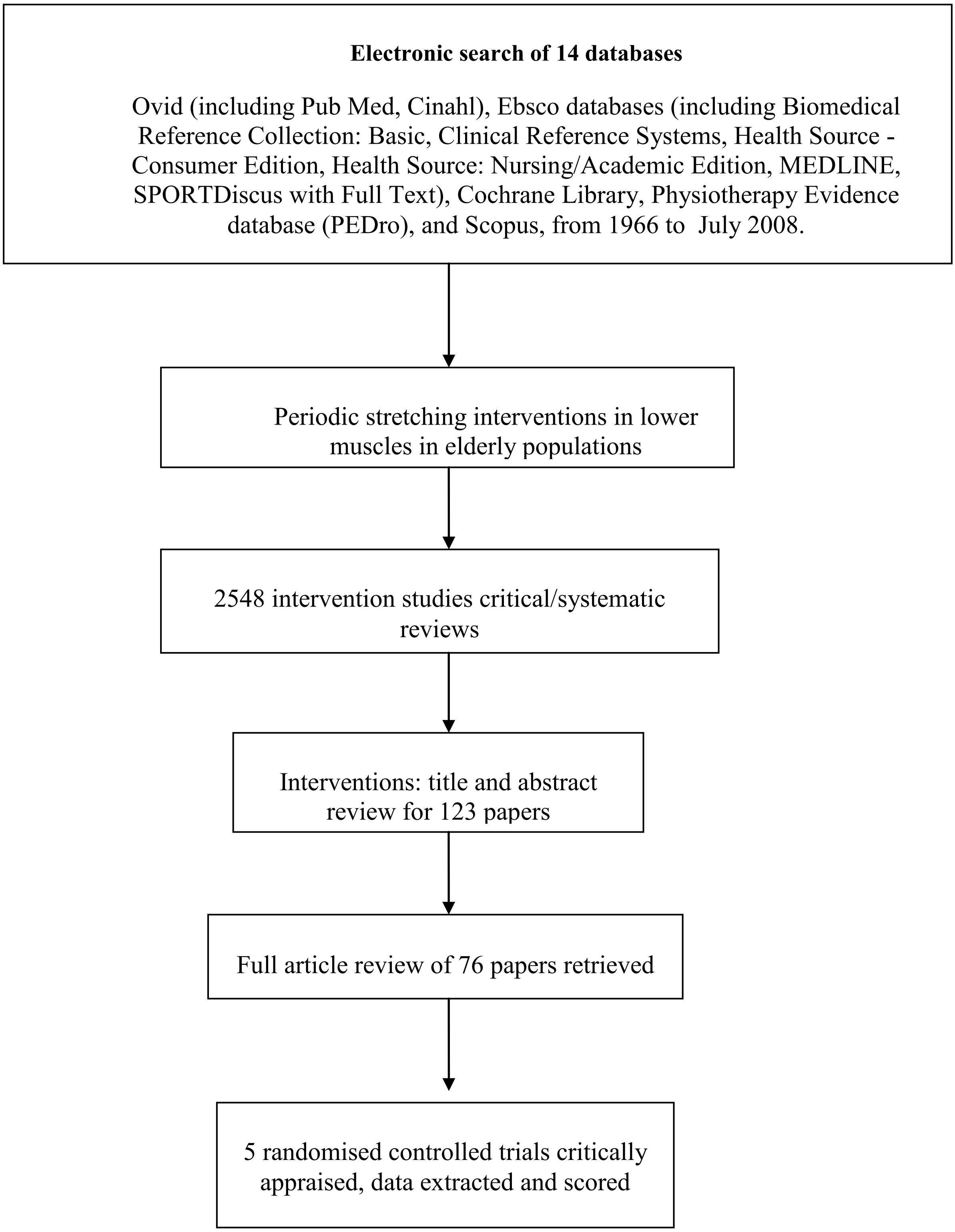


Figure 2.2: Flow diagram of the periodic stretching search strategy in elderly.

2.7.3 Results

A total of five studies met the final inclusion criteria (Feland, Myer et al., 2001; Gajdosik, Vander Linden, McNair, Riggin et al., 2005; Girouard & Hurley, 1995; Kerrigan, Xenopoulos, Sullivan, Lelas, & O'Reilly, 2003; Raab et al., 1988). The methodological quality of the reviewed studies is displayed in Table 2.3 and a summary of the key features of the studies in Table 2.4. The overall methodological quality score of the six studies ranged from 13 - 19. The majority of studies failed to score in the areas of assessor blinding, subject blinding and blinding of treatment providers to assignment status. Only two studies provided blinding of outcome assessors (Feland, Myrer et al., 2001; Kerrigan et al., 2003) and one study addressed blinding of subjects to assignment status (Gajdosik, Vander Linden, McNair, Williams, & Riggin, 2005). The effect sizes ranged from 0.1 to 2.6. In two studies, the ES could not be calculated due to insufficient data or data not presented in such a way as to allow the calculations to be undertaken (Feland, Myrer et al., 2001; Raab et al., 1988).

The five studies reviewed have demonstrated increases in range of motion following the stretching interventions ranging from two degrees to 14°. These increases were achieved with varying stretch durations from 1500 seconds (Raab et al., 1988) to 16,800 seconds (Kerrigan et al., 2003). The overall time frames for the studies varied from six weeks (Feland, Myrer et al., 2001), to 25 weeks (Raab et al., 1988). Two studies used female subjects only (Gajdosik, Vander Linden, McNair, Williams et al., 2005; Raab et al., 1988) and the remainder used subjects of both genders. Two studies provided stretching regimes to a range of lower limb muscle groups (Girouard & Hurley, 1995; Raab et al., 1988), two studies compared upper limb stretches to lower limb stretches (Girouard & Hurley, 1995; Kerrigan et al., 2003), one study stretched the calf muscles only (Gajdosik, Vander Linden, McNair, Williams et al., 2005), and one the hamstring group only (Feland, Myrer et al., 2001). Only one study measured passive resistive force related to stretching (Gajdosik, Vander Linden, McNair, Williams et al., 2005). As all the reviewed studies rated greater than 50% on the quality score, and all demostrated consistent findings (>75%), it can be concluded that there is strong evidence for periodic stretching interventions to improve knee joint and ankle joint range of motion in elderly populations.

Table 2.3 Methodological quality of periodic stretching studies assessed using the Cochrane Musculoskeletal Injuries Group (CMSIG) tool

First Author (year)	A	B	C	D	E	F	G	H	I	J	K	L	QS/24
Giroud (1995)	0	2	0	0	0	0	2	1	2	2	2	2	**13**
Raab (1988)	1	1	0	2	0	0	2	2	2	2	2	1	**15**
Feland (2001)	1	1	2	2	0	0	2	2	2	2	2	2	**18**
Kerrigan (2003)	2	0	2	1	0	0	2	2	2	2	2	2	**17**
Gajdosik (2005)	2	2	0	2	1	0	2	2	2	2	2	2	**19**

Key: QS = Quality Score. Notes:

A= assignment of treatment adequately concealed

B= outcomes of participant who withdrew included in intention to treat analysis

C= blinding of outcome assessors to treatment

D= comparability of treatment and control group at entry

E= blinding of subjects to assignment status

F= blinding of treatment providers to assignment status

G= identical care programmes

H = inclusion and exclusion criteria clearly defined

I= intervention clearly defined

J= outcomes clearly defined

K= diagnostic tests clinically useful

L= duration of surveillance active and clinically relevant

Table 2.4 Summary of key variables of studies investigating periodic stretching interventions in elderly populations

Quality Score	Authors	Sample (N) and mean age	Stretch prescription and location	Total stretch duration (seconds)	ROM	ES	Results
19	Gajdosik et al (2005)	N= 19 (females) 74.2 yrs	Gp1: 10 x 15s 1 x day 3 x week, for 8 weeks Gp2: Control Calf muscles	Gp1: 3600	Gp1: 5.1° Gp2: no change	1.2	Significant increase in stretch group in passive dorsiflexion ROM. Stretch group increased 10m walk and agility test.
18	Feland et al (2001)	N= 60 (male and female) 84 yrs	Gp1: 4 x 15s Gp2: 4 x 30s Gp3: 4 x 60s 5 x week for 6 weeks Gp4: Control Hamstrings	Gp1: 1800 Gp2: 3600 Gp3: 7200	Gp1: 3.6° Gp2: 7.8° Gp3: 14.4° Gp4: no change	*	Significant increase ROM in all stretch groups Longer duration = greater increase in ROM.
17	Kerrigan et al (2003)	N= 96 (males and females) 65yrs	Gp1: 4 x 30s 2 x day for 10 weeks Hip flexors Gp2: Control 4 x 30s 2 x day for 10 weeks Shoulder abductors	Gp1: 16,800 Gp2: 16,800	Gp1: 2° Gp2: no change	0.1	Significant increase in static hip extension ROM and dynamic peak hip extension with stretch group.

Quality Score	Authors	Sample(N) and Mean age	Stretch prescription and location	Total stretch duration (seconds)	ROM	ES	Results
15	Raab et al (1998)	N=49 (female) 70.9 yrs	Gp1: 1 x 20s 3 x week for 25 weeks Gp2: stretch + weights Gp3: Control Cervical spine, Shoulder, Wrist, Ankle & Hip	Gp1: 1500 Gp2: 1500	Gp1: 14.1° Gp2: 8.8° Hip Gp1: 0° Gp2: 1.1° Ankle Gp3: no change	*	Significant increase in ROM for stretch groups. The addition of weights reduced ROM gained.
13	Girouard et al (1995)	N= 31 (male and female) 62 yrs	Gp1: Strength and stretches Gp2: 3x 30 sec 3 x week, for 10 weeks Gp3: Control Hamstrings and Shoulder	Gp2: 1800	Gp1: 4° hip flexion Gp2: 10° hip flexion Gp3: no change	0.1 2.6	Significant increase in hip flexion and shoulder abduction for stretch groups only.

Key: ES=Effect Size, ROM = range of motion, * = insufficient data to calculate ES

2.8 Key features of periodic stretching programmes in elderly

The pupose of this section of the literature review was to determine the efficacy of periodic stretching interventions to the lower limb muscles of elderly subjects. Of the five studies indentified all demonstrated a positive increase in ROM.

2.8.1 Duration of stretch

Feland Myer, and Schulthies et al (2001) (QS 18) compared three durations of static hamstring stretching in elderly subjects. Sixty subjects (mean age 84.7 years) were recruited to the study and randomly assigned to one of four groups, 1 x 15 second stretch group, 1 x 30 second stretch group and 1 x 60 second stretch group, or a control group. The subjects recieved hamstrings stretches from a research assistant using the straight leg raise stretch five days a week, over a ten week time frame. The results of this study indicated that those subjects in the group that stretched for 60 seconds had the greatest rate of improvement (2.4° per week), whereas those in the 30 second group increased by 1.3° per week, and the 15 second group by 0.6° per week. The authors concluded that longer durations of hold result in greater improvement in range of motion and particularly in elderly populations when compared with similar stretching studies in younger populations.

In comparison to the other reviewed studies, the actual time a single stretch was held was variable with 15 seconds (Feland, Myrer et al., 2001; Gajdosik, Vander Linden, McNair, Williams et al., 2005), 20 seconds (Raab et al., 1988 430), and 30 seconds (Girouard & Hurley, 1995) being used. This variation would indicate that at this time the optimal stretch duration has not been identified to provide a consistent increase in range of motion following stretching programmes in elderly subjects.

2.8.2 Stretching and strengthening

Two of the studies reviewed compared the effects of strength training on gains in flexibility in elderly subjects (Girouard & Hurley, 1995; Raab et al., 1988). Girouard and Hurley (1995) (QS 15) compared stretching and strengthening interventions to see if the strength gains would inhibit the gains in range of motion. Fourteen male subjects (mean age 59 yrs) were randomly assigned to a strengthening and flexibility (SF) group and 10 male subjects (mean age 63 yrs) were randomly assigned to the flexibility only (FO) group. Seven subjects served as a control group and did not exercise. With respect to the stretching intervention the subjects stretched the major muscles groups in the shoulder region and in the lower limbs, including hamstring muscles. The subjects stretched for 30 seconds, 3 times per week for a 10 week period. The SF group also undertook a range of upper and lower body strengthening execises using resistance machines. The results demonstrated that the FO group had a 10-degree increase in hip flexion compared to four degrees in the SF group. With respect to the shoulder region the FO group had a 20-degree increase in shoulder abduction, compared to 5 degrees in the SF group. The FO group had statistically greater gains in range of motion than the SF group, indicating that strengthening exercises undertaken at the same time as flexibility exercises inhibit the gains in range of motion.

Raab, Agre and McAdam et al (1988) (QS 15) investigated if weighted or unweighted exercise would increase range of motion in 49 elderly women (age range 69-85 yrs). Subjects were randomly allocated to an exercise group with no weights and an exercise group with weights and a control group who did not exercise. The exercise groups participated in an organised exercise session for 60 minutes, three days per week, for 25 weeks. With respect to the stretching programme, both exercise groups undertook passive stretches held for 20 seconds, as well as slow circling movements to the target areas. The cervical spine, shoulders, wrists, ankles and hamstrings were stretched. At the conclusion of the programme, range of motion had improved significantly in both exercise groups compared to the control group. The areas of greatest increase in range of motion were shoulder flexion (7.4°) shoulder abduction (8.4°) and cervical rotation (6.4°). Whilst hip flexion range of motion altered by 11.4 degrees in the exercise groups and 8.8 degrees in the control group, this difference was not significant. The results did demonstrate a trend for the non weight group to have greater improvements in range of motion than the weight training group. In that sense, these results support the findings of Girouard and Hurley(1995), however this programme was lengthy (25 weeks) and greater than most other stretching programmes in this review (Feland, Myer et al., 2001; Gajdosik, Vander Linden, McNair, Riggin et al., 2005; Girouard & Hurley, 1995). The results of these studies would also indicate that providing stretching exercises in isolation is more effective in improving joint range of motion than combining the exercises with strengthening programmes.

2.8.3 Functional improvements

Gajdosik, Vander Linden, and McNair et al (2005) (QS 19) investigated the effects of an eight week stretching programme to the calf muscles on functional activities such as walking in 19 elderly women. These women all had reduced dorsiflexion ROM of less than or equal to 10 degrees. The subjects were randomly allocated to either the stretch group or a control group who did not stretch. The investigators in this study examined whether a stretching programme would increase the dorsiflexion ROM and also improve function. Three functional tests were used, a timed agility course, a timed 10 metre fast walk and a standing functional reach test. The stretching intervention was a static calf stretch held for 15 secs, repeated 10 times for a total stretching duration of 150 secs. The stretches were repeated three times a week for a total of eight weeks.The results of the study demonstrated that maximal passive doriflexion angles significantly increased in the intervention group by a mean of 5.1 degrees. No change was seen in the controls. The total range of ankle ROM also increased significantly (13°). These changes in ROM were also accompanied by increases in passive resistive force. Subjects in the stretch groups increased their maximal passive dorsiflexion force significantly from 76.2N before the intervention to 122.5N after the intervention. The control group did not significantly change. With respect to the functional tests, the agility test and the 10 metre walk tests were significantly improved in the stretching group. There was no difference in the functional reach test between the two groups. This study is of interest with respect to elderly populations as it has demonstrated a significant increase in ROM and also that functional activities, particularly agility can be improved with an eight week stretching programme. It was also the only study to measure ROM and associated passive resistive force and stiffness.

Kerrigan et al (2001) (QS 17) investigated the effects of a 10 week hip flexor stretching programme on gait in 96 elderly subjects (65 years or older). Subjects were randomly allocated to either a hip flexor stretch group or a control group who stretched the shoulder abductors. Subjects stretched for 30 seconds, four repetitions daily for 10 weeks as a home programme. The results of this study indicated that the stretching group increased the range of hip extension by two degrees whereas the control group had no change in hip extension. The improvement in hip extension also resulted in an increase in normal walking speeds in the stretching group. Therefore, these results support the work of Gajdosik et al (2005), demonstrating important changes in function following a lower limb stretching programme. It was of interest that the Kerrigan et al study, the longest stretch duration (16,800 secs) was applied to the subjects and yet this only achieved a small increase in hip extension range of motion. Much greater increases in range of motion have been achieved with smaller stretch durations in elderly populations (Feland, Myrer et al., 2001).

2.8.4 Summary

In summary, periodic stretching programmes to the lower limb muscles of elderly subjects have seen a positive increase in range of motion. The total stretch duration in these studies has varied from 1500 – 16,800 seconds. The gains in range of motion have varied from 2-14 degrees. Combining strengthening exercises with stretching had a negative effect on ROM gains. The majority of studies only measured ROM and not passive torque or stiffness associated with changes in range of motion.

2.9 Periodic lower limb stretching interventions in people with OA of the knee joint

2.9.1 Key words

The same search words were used as per the previous two searches but the addition of the following key words or combinations of key words was required to identify the periodic stretching studies in OA knee joint populations.

1. "knee osteoarthr*"

2. "exercise therapy"

These key words and combinations of key words were adapted as required to narrow the search to the relevant topic areas. Hand searching and cross referencing was also undertaken with identified systematic reviews and the reference list of relevant articles. Once articles were retrieved, a review of the title and abstract was undertaken to determine if the articles met the inclusion criteria.

2.9.2 Study selection

Inclusion criteria: The following criteria were used to select relevant papers to be included within this review:

Type of participant: participants were defined as elderly with a mean age 60 years and older, of either gender. Trials examined only those subjects who had osteoarthritis of the knee joint.

Type of study design: Randomised controlled trials.

Type of intervention: static stretching intervention to key muscles groups in the lower limb, calf, hamstring, or hip flexors.

Outcome measurements: to include at least one of the following outcome measurements: Range of motion or passive torque or stiffness, with a goniometer, an electronic inclinometer or isokinetic dynamometer in weight bearing or non weight bearing conditions.

Exclusion criteria: The following criteria were used to eliminate papers from this review: Papers written in non-English languages.

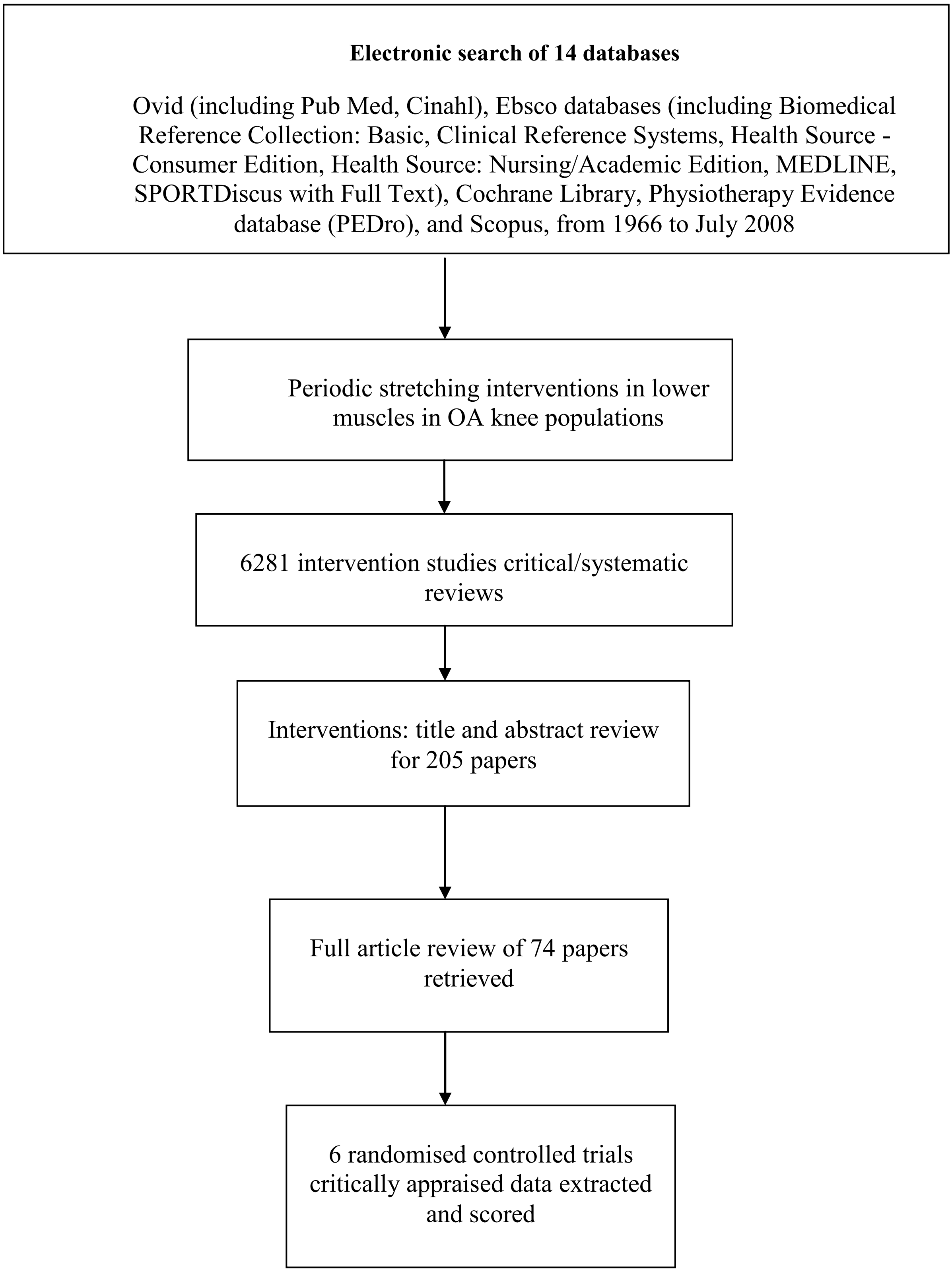


Figure 2.3: Flow diagram of the periodic stretching search strategy in OA knee populations.

2.9.3 Results

A total of six studies met the final inclusion criteria (Borjesson, Robertson, Weidenhielm, Mattson, & Olsson, 1996; Minor, Hewett, Webel, Anderrson, & Kay, 1989; Peloquin, Bravo, Gauthier, & Billiard, 1999; Petrella, 2000; Rogind et al., 1998; van Baar et al., 1998). The methodological quality of the reviewed studies is displayed in Table 2.5 and a summary of the key features of the studies in Table 2.6. The methodological quality scores ranged from 14 – 21. All studies scored poorly in the areas of subject blinding and treatment provider blinding. The effect sizes could only be calculated in two studies (Borjesson et al., 1996; Peloquin et al., 1999) and these were both calculated at 0.3. In the remaining studies the ES could not be calculated due to insufficient data or data not presented in such a way as to allow the calculations to be undertaken (Petrella & Bartha, 2000; Rogind et al., 1998; van Baar et al., 1998).

In all of the studies reviewed, the stretching and/or range of motion interventions have been provided to subjects with OA of the knee joint in conjunction with strengthening exercises. Only three studies demonstrated a significant increase in range of motion following the stretching regime (Minor et al., 1989; Peloquin et al., 1999; Petrella & Bartha, 2000). The improvements in range of motion were achieved with varying volumes of stretch duration, from a small stretch stimulus of 750 seconds (Borjesson et al., 1996) to a large stimulus of 720 minutes (Petrella & Bartha, 2000). These stretch durations resulted in alterations in range of motion from two degrees (Rogind et al., 1998) to 18 degrees (Petrella & Bartha, 2000). In all but one of the studies (van Baar et al., 1998), the stretching regimes were provided to the key lower limb muscle groups of quadriceps, calf and hamstrings. The overall time frames for the studies varied from five weeks (Borjesson et al., 1996), to 12 weeks (Minor et al., 1989; Peloquin et al., 1999; Rogind et al., 1998; van Baar et al., 1998). All the subjects in the reviewed studies were of mixed gender. While all the reviewed studies rated greater than 50% on the quality score, only two studies demonstrated a positive result with respect to increasing joint ROM (consistency <75%) , therefore it was concluded there is limited evidence for periodic stretching interventions to improve range of motion in populations with OA of the knee joint.

Table 2.5 Methodological quality of periodic OA stretching studies assessed using the Cochrane Musculoskeletal Injuries Group (CMSIG) tool

First Author (year)	A	B	C	D	E	F	G	H	I	J	K	L	QS/24
Minor (1989)	1	1	0	1	0	0	2	2	2	2	2	1	**14**
Borjesson (1996)	1	2	2	2	0	0	2	2	2	2	2	1	**18**
Rogind (1998)	2	2	2	2	0	0	2	2	2	2	2	2	**20**
Van Baar (1998)	2	1	2	2	0	0	2	2	2	2	2	1	**18**
Peloquin (1999)	2	1	2	2	0	0	2	2	2	2	2	1	**18**
Petrella (2000)	2	2	2	2	0	0	2	2	2	2	2	1	**21**

Key: QS = Quality Score Notes:

A= assignment of treatment adequately concealed

B= outcomes of participant who withdrew included in intention to treat analysis

C= blinding of outcome assessors to treatment

D= comparability of treatment and control group at entry

E= blinding of subjects to assignment status

F= blinding of treatment providers to assignment status

G= identical care programmes

H = inclusion and exclusion criteria clearly defined

I= intervention clearly defined

J= outcomes clearly defined

K= diagnostic tests clinically useful

L= duration of surveillance active and clinically relevant

Table 2.6 Summary of key variables of studies investigating periodic stretching interventions in OA knee populations

Quality Score	Authors	Sample (N) andmean age	Stretch prescription & location	Total stretch duration (seconds)	ROM	ES	Results
21	Petrella and Bartha (2000)	N= 179 (male and female) 73.7 yrs	Gp1: 5-10 mins, 3x per session, 3 x weeks for 8 weeks Gp2: Control Hamstrings	43,200	Gp1: 18° Gp2: 5°	*	Significant increase ROM in the stretch group.
20	Rogind et al (1998)	N= 25 (male and female) 71.1 yrs	Gp1: 1x day, 2 days week, 12 weeks Gp2: Control Low back, Chest Calf, Quadriceps, Adductors, Hamstrings, Gluteals	Not stated	Gp1: 1 5°- 3° Gp2: 1 - 2°	*	No significant difference in ROM observed between groups.
18	Van Baar et al (1998)	N= 201(male and female) 65.7 yrs	Gp1: 30 mins, 3 x week for 12 weeks Gp2: Control Knee and Hip	Not stated	Gp1: Range 115.4° to 0.1° Gp2: Range 115.5° to 0.0°	*	No significant differences between groups for total range of knee flexion to extension.

Quality Score	Authors	Sample (N) and mean age	Stretch prescription & location	Total stretch duration (seconds)	ROM	ES	Results
18	Borjesson et al (1997)	N= 68 (male and female) 64+ yrs	Gp1: 5 x 10s 3x week for 5 weeks Gp2: Control Quads & Hamstrings	750	Gp1: 2° Gp2: -4°	0.3	No significant difference in ROM between groups.
18	Peloquin et al (1999)	N= 137 (male and female) 66 yrs	Gp1: 3 x 15s 3 x week, 12 weeks Gp2: Control Quads & Hamstrings	1620	Gp1: 2.89° Gp2: 1.6°	0.3	Significant improvement in ROM in the stretch group.
14	Minor et al (1989)	N= 120 (male and female) 63.8 yrs	Gp1: Pool exercises Gp2: Walking exercises Gp3: 10 mins stretching, 3 x week for 12 weeks Shoulders, Trunk and Ankle	21,600	Gp1: 3.6 cm Gp2: 3.9 cm Gp3: 5. 5 cm	*	Significant increased trunk ROM in all groups, no significant difference between groups.

Key**:** ES=Effect Size, ROM = range of motion, cm = centimeters* = insufficient data to calculate ES

2.10 Key features of periodic stretching for OA of the knee joint

The purpose of this section of the review was to investigate the efficacy of lower limb stretching interventions in subjects with OA of the knee joint. Two of the identified studies demonstrated a positive increase in knee joint ROM (Peloquin et al., 1999; Petrella & Bartha, 2000), and one demonstrated an increase in trunk ROM but direct measurements of knee joint ROM were not undertaken (Minor et al., 1989). The remaining three studies did not demonstrate a change in knee joint ROM (Borjesson et al., 1996; Rogind et al., 1998; van Baar et al., 1998). In all of these studies the stretching intervention was combined with other interventions so direct comparison of the effectiveness of stretching alone was not possible.

Petrella and Bartha (2000) (QS 21) compared the effects of a progressive home based exercise programme and treatment with non steriodal anti inflammatory drugs (NSAID's) with NSAID's alone in the management of OA knee. One hundred and eighty four patients were recruited for the study. The subjects were randomly allocated to the progressive exercise group (mean age 72.9 years) and a control group (mean age 74.6 years). With respect to the progressive exercise regimes, subjects in the exercise group undertook a range of exercises that included resistance exercises for the quadriceps, closed kinetic exercises such as wall slides, stretching, and range of motion exercises. One of the stretches was a knee unloading exercise that required the subjects to sit on the edge of a table with a 1-2 kg weight suspended from the foot. Subjects held this position for 5-10 minutes alternating from one knee to the other until they had completed 3 repetitions. The range of motion exercises included knee extension and knee flexion exercises. The exercises were included in the 10 minute warm up each session and repeated three times a week for eight weeks. The control group undertook the joint unloading stretch and the range of motion exercises, but did not do the progressive exercises. The outcome measures for this study were pain as measured with the VAS, the WOMAC score, the self paced walk and the self paced step tests. The results of the study indicated that both groups improved with respect to all variables but the exercise group was significantly improved compared to the control group. With respect to range of motion, the exercise group improved significantly by 18° in total knee range of motion and the control group improved by five degrees. The increases in range of motion in this study are the largest when compared to the other reviewed studies. This may be reflective of the sustained nature of the stretching procedure (5 -10 minutes) as this was different to the other stretching studies that employed stretching regimes of a much shorter duration (see Table 2.6).

Rogind, Bibow-Neilson and Jensen et al (1998) (QS 20), investigated the effects of a physical training programme on 25 patients (aged 69-73 years) with bilateral OA of the knee. Patients were randomly assigned to either an intervention or control group. The intervention consisted of both stretching and strengthening exercises twice a week for a 12 week period. With respect to the stretching component of the intervention, participants stretched the calf muscles, quadriceps, hip adductors, hamstrings, glutues maximus, lower back and pectoral muscles. Stretches were performed once a day for two days of the week over the duration of the study. The duration of holding the stretch in this study was not stated. The results showed a change in knee range of motion of three to five degrees for the intervention group and two degrees for the control goup. These differences were not significant. Of interest in this study was that following the intervention, the walking speed of those who received the stretching and strengthening programme increased from 1.18 m/s at baseline to 1.33 m/s at the 12 month follow up. Given that strength was shown to improve more than flexibility in this study, these improvements could be more related to the strength increases.

Van Baar, Dekker, Oostendorp, and Bijl et al (1998) (QS 18) compared the effectiveness of exercise therapy in 201 patients with OA of the hip or knee joint. The subjects were randomly allocated to a supervised exercise group (mean age 68.3 years) and a control group (mean age 67.7 years). The exercise group was prescribed exercises to improve muscle function, muscle length and strength in a physiotherapy session, three times a week for 30 minutes, over a 12-week period. The control group was given patient education and medication as required. The primary outcome measures were pain, medication use and observed disability. The results showed a significant difference in the key outcomes of pain and observed disability between the exercise group and the control group at 12 weeks post intervention. With respect to the stretching component of the programme, there was no significant difference or improvement in range of motion at the hip or knee in either group.

In a follow up to the study van Baar et al (2001) assessed the same cohort of patients at 12, 24 and 36 weeks following the intervention. The assessments at 12 and 24 weeks indicated that there was a slow decline in the beneficial effects of the exercise programme resulting in a similar status between the exercise group and the control group. The authors concluded that the results of this study indicate that measures must be undertaken to maintain the beneficial effects of the exercise regimes.

Borjesson, Robertson, Weidenhielm et al (1996)(QS 18) investigated the effects of a strengthening and stretching programme on a group of OA knee patients scheduled for surgery. Sixty eight subjects (aged 55-70 years) were randomly allocated to the exercise group and the control group. The control group was evaluated before and after the five week intervention period but did not exercise. The exercise group undertook a programme consisting of a warm up on an exercycle, resisted knee flexion and extension, stretching to the quadriceps and hamstrings, and passive knee extension exercises. With respect to the stretching programme subjects stretched the relevant muscles for 10 seconds and repeated these five times. The intervention was undertaken three times a week for five weeks. The subjects also stretched at home twice a week. The other outcomes measured were pain during walking, muscle strength via a dynamometer and the ability to step up and down. The results showed that the exercise group had a difference in knee joint ROM of two degrees and the control group reduced ROM by four degrees. These differences were not statistically significant. The authors concluded that while the exercises made the patients feel better there was no measurable objective change. The severity of the patients OA in this trial may also have been a factor. Both groups had knee flexion contractures of five - seven degrees prior to surgery.

Peloquin Bravo and Gauthier et al (1999) (QS 18) examined the effects of a three month cross training exercise programme on 137 patients with OA in one or both knees. The subjects were randomly allocated to the exercise group (mean age 65.4 years) or the control group (mean age 66.4 years). The control group received advice on OA but did not exercise. The subjects in the exercise groups were supervised in the exercise programme for one hour three times a week for three months. The programme was divided into three parts, a warm up period including a brisk walk, a progressive strengthening programme for the quadriceps and hamstrings and stretches to the same muscles. With respect to the stretching intervention, subjects stretched 3 x 15 seconds per muscle per session. Specific measurements of changes in range of motion were provided but were more global in nature and were not directly aimed at the knee joint. Flexibility was measured via the sit and reach test. At the conclusion of the trial the exercise group had improved in the sit and reach test by 2.89 inches (a 15% increase) and this was significantly different from the control group. The authors of this study noted that this increase in range of motion was greater than the increase demonstrated by Minor et al (1989) who recorded a maximal increase of 1.9 inches (5.5cms). However, it should be noted that the sit and reach test may not accurately measure specific improvements in hamstring ROM and some of this improvement could be attributed to increased lumbar spine mobility.

Minor, Hewitt, Webel, et al (1989) (QS 14) conducted a study comparing two forms of aerobic exercises (pool activity and walking) with a control group who undertook a stretching regime. One hundred and twenty patients with either rheumatoid arthritis (RA) (mean age 54.3 years) or OA (mean age 63.8 years) were eligible for the 12-week programme. All subjects participated in a similar exercise routine with respect to the isometric strengthening exercises and the stretching exercises. The aerobic pool group undertook an additional 30 minutes of aerobic exercise, while the walking group had a progressive walking programme increasing from 10 to 30 minutes over the 12 weeks. All groups completed a ten minute period of stretching and range of motion exercises at the conclusion of the treatment sessions. The authors did not explicitly state which muscle groups were being stretched. Flexibility was measured using the sit and reach test. At the conclusion of the programme all groups demonstrated improved trunk, shoulder and ankle flexibility. Trunk motion improved by 3.6 cm in the pool group, 3.9 cm in the walking group and 5.5 cm in the stretching only group. These improvements were significant from baseline, but there was no difference in these improvements between the groups. The improvements were maintained at three and nine month follow-ups in all groups.

2.10.1 Summary

In summary, due to the variations in frequency, duration, methods of measurement and the associated interventions within the studies that have included stretching regimes, it is not possible to get a clear picture of whether stretching interventions alone have a beneficial effect on patients with OA of the knee joint.

2.11 Changes in gait in subjects with and without OA of the knee joint

A number of studies have investigated the changes in gait in subjects without OA of the knee and those with OA of the knee (Al-Zahrani & Bakheit, 2002; Gok, Egin, & Yavuzer, 2002; Kaufman et al., 2001; Messier et al., 1992; Oberg, Karsznia, & Oberg, 1993). The main findings of these studies with respect to the spatial temporal parameters of walking velocity, stride and step length are presented in Table 2.7.

In the non OA knee population Oberg, Karsznia and Oberg (1993) investigated the basic gait parameters in 240 male and female subjects aged from 10 -79 years of age. Subjects in this study were examined whilst walking over a ten meter walkway past two photocells spaced five meters apart. The basic temporal gait parameters of gait speed, step length and frequency were examined. Subjects were asked to walk at a slow speed, a normal speed and a fast speed. The study found statistically significant reductions in gait speed and step length particularly at the normal and fast speeds in the elderly subjects compared to younger subjects. In the elderly subjects aged 60 to 70 years, the mean gait speed for men at normal speed was 127.7 cm/s and this increased to 163.9 cm/s at fast speeds. For men aged 20-29 normal and fast gait speeds were 122.7 m/sec and 162.6 cm/s respectively. For women, the mean walking speed was 115.7cm/s at normal speeds and increased to 155.5cm/s at fast speeds. For women aged 20-29 the normal and fast walking speeds were 124.1 cm/s and 169.3cm/s respectively. The mean step length in the men was 65cm at normal speeds and increased to 73cm at fast walking speeds. For men aged 20-29 the mean step length at normal and fast speeds was 61.6 cm and 71.2 cm respectively. For the women the mean step length was 55cm at normal speeds and increased to 62cm at fast speeds. For women aged 20 -29 years the mean step length at normal and fast speeds was 59.1cm and 66.7cm respectively. Having an understanding of these normative values is of interest when comparing these to subjects with OA of the knee joint.

Messier, Loeser, and Hoover et al (1992) examined the effects of OA of the knee joint on gait, strength and flexibility. Thirty subjects (mean age 58 years) were divided into an OA knee group and a control group. In the OA group, affected and unaffected legs were matched with the ipsilateral leg of the respective control subjects. The subjects walked along a 22 metre walkway at a speed of 1.12- 1.34 metres per second, while the kinetic and kinematic data was collected. The results of this study revealed that knee flexion and extension ROM was significantly less in the OA group than the control. There was a ten-degree difference in the overall knee flexion ROM between control and OA knee subject and a 25-degree difference in knee extension. It was also noted that the OA knee subjects walked more slowly than the control subjects (walking velocity 1.09 m/s versus 1.29 m/s respectively) and also had a shorter step length (1.19m versus 1.3m respectively). An interesting finding of the study with respect to ROM was that even the unaffected leg of the OA subjects also had a reduced ROM. The authors commented that therapeutic interventions aimed at improving ROM should therefore focus on affected and unaffected limbs.

Kaufmann, Hughes and Morrey et al (2001) investigated the gait characteristics of 139 patients (mean age 57 years) with OA of the knee joint. Twenty normal subjects of similar age were used as controls. The subjects were analysed using a video motion analysis system during level walking and ascending and descending stairs. The subjects were required to walk along a 12 metre walkway and also ascend and descend a flight of four steps 18 cm high. The results of this study indicated that subjects with OA knee walk significantly slower than normal age matched subjects on a flat surface (1.09 m/s versus 1.17 m/s respectively) and when descending stairs (0.59 m/s versus 0.71 m/s). During level walking, patients with OA of the knee had six degrees less peak knee flexion and extension motion. The authors commented that subjects with OA knee compensate to reduce the knee extensor moment, and consequently the knee joint loading, perhaps in an attempt to reduce the pain associated with weight bearing activities.

Gok, Ergin and Yavuzer (2002) compared the mechanics of gait in thirteen elderly women with medial knee joint OA (mean age 57) with 13 women of the same age without knee OA (mean age 58). Gait analysis was undertaken using a 3D motion analysis system. Subjects in the study were asked to walk at a natural pace over a walkway until the speed was consistent. Gait velocity, stride length and cadence as well as ground reaction forces, were measured and analysed. The results of the study indicated that in subjects with OA, walking velocity, stride length and cadence were all less than those without OA. Subjects with OA of the knee had a walking velocity of 0.9m/s compared to 1.0m/s for non OA knee subjects. The overall length of time spent in the stance phase of gait was also longer for OA knee subjects compared to those without OA of the knee (64% versus 62% of the stance phase respectively). The authors concluded that changes in gait are present in subjects even with early signs of OA of the knee.

Al Zahrani and Bakheit (2002) compared gait characteristics in subjects with chronic OA of the knee with those without OA of the knee of a similar age. Fifty eight OA knee subjects (mean age 69 years) and 25 without OA of the knee (mean age 71 years) were recruited for the study. Subjects gait characteristics were measured using video analysis of limb movement. The results of the study found that subjects with OA walked slower than those without OA of the knee (walking velocity 0.5 m/s versus 1.17 m/s respectively), had a shorter stride length and delayed mid stance phase of gait. Another important finding of the study was that subjects with OA of the knee also had reduced ranges of motion in the hip, knee and ankle joints. The authors commented that these changes in gait parameters may be due to instability in the knee joint and lack of normal proprioception as a consequence of the arthritic knee.

In summary, patients with OA of the knee walk slower than those without OA of the knee, have greater difficulty in walking downstairs, spend a greater amount of time in the stance phase of gait, and use less of the normal range of knee motion, particularly knee extension prior to heel strike.

Table 2.7 Summary of spatial and temporal gait characteristics non OA subjects and OA knee subjects

Authors (year)	Subjects and age	Walking velocity	Stride (step) length	Stance phase
Oberg et al (1993)	Male 60-70yrs Female 60-70yrs (All non OA)	Normal speed: 1.27m/s Fast: 1.63m/s Normal speed: 1.15m/s Fast: 1.55m/s	Normal speed: 0.65m Fast: 0.73 Normal speed: 0.55m Fast: 0.62m	Not reported
Messier et al (1992)	Male and female 74 yrs (OA and non OA)	Control: 1.29m/s OA: 1.09 m/s	Control: 1.30 m OA: 1.19m	Control: 64% of full cycle OA: 61% of full cycle
Kaufmann et al (2001)	Male and female 30-82 yrs (OA and non OA)	Control: 1.17m/s OA :1.09 m/s	Not reported	Not reported
Al- Zahrani et al (2002)	Male and female 69-71yrs (OA and non OA)	Control: 1.17 m/s OA: 0.55m/s	Control: 1.27m OA: 0.75m	Control: 30.05% of full cycle OA: 34.16% of full cycle
Gok et al (2002)	Women only 57-58 yrs (OA and non OA)	Control: 1.0 m/s OA: 0.9 m/s	Control :1.1 m OA: 1.1 m	Control: 63% of full cycle OA: 64% of full cycle

2.12 Outcome Measures

Outcome measures are tools or questionnaires that can be used to measure the effectiveness (or not) of a health intervention. Such measures in themselves have to have robust psychometric properties, in particular reliability, validity and responsiveness (Horner & Larmer, 2006). When measuring the effects of an intervention on a condition such as OA of the knee a relevant outcome measure is required. Some outcome measures are generic to a range of disease populations such as the Short Form-36 (SF-36) which generates a profile of eight dimensions and for which there is some evidence for validity in OA patients (Bombardier et al., 1995). However, there are also a number of knee specific outcome measures such as the Knee Pain Scale (Rejeski et al., 1995), the Knee injury and Osteoarthritis Outcome Score (KOOS) (Roos, Roos, Lohmander, Ekdahl, & Beynnon, 1998), the Arthritis Impact Measurement Scale (AIMS) (Meenan, Mason, Anderson, Guccione, & Kazis, 1992), the Aggregated Locomotor Function (ALF) score (McCarthy & Oldham, 2004) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Bellamy, Buchanan, Goldsmith, Campbell, & Stitt, 1988). The WOMAC is commonly used in research in OA knee populations (Deyle et al., 2005; Deyle et al., 2000; Fitzgerald et al., 2002; Fransen et al., 2001; Law, 2001). However, in the current review of literature there was variation in the outcome measures used. One study used the WOMAC; (Petrella & Bartha, 2000), two studies used the AIMS (Minor et al., 1989; Peloquin et al., 1999), two studies used the Visual Analogue Scale (Borjesson et al., 1996; van Baar et al., 2001) and one study has used the Algofunctional Index (Rogind et al., 1998). The next section reviews the main psychometric properties of the three outcome measures to be used as part of this research.

2.12.1 WOMAC

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was developed specifically for patients with lower extremity arthritis (Bellamy et al., 1988). The WOMAC Index was designed to measure pain and functional loss in patients with OA (Bellamy et al., 1988). There are five questions relating to pain, two questions relating to stiffness and 17 questions relating to physical function.

In a review of literature of the utility and measurement properties of the WOMAC McConnell, Kolopak and Davis (2001) have demonstrated it is reliable, valid and responsive with respect to pain and physical function in a range of patient groups with OA in the lower limb and with respect to the interventions they received. The stiffness subscale did not demonstrate good measurement properties. Although it had good internal consistency, the test-retest reliability was below expected levels. The authors suggested that this was a consequence of there only being two questions in the stiffness subscale and that small variances in the scores may result in lower levels of reliability.

A study by Angst, Aeschlimann, Steiner et al (2001) compared the WOMAC with the SF-36 in 258 patients with OA of the hip or knee undergoing a comprehensive rehabilitation intervention. The patients undertook a physical rehabilitation programme consisting of both active and passive therapies (strengthening and stretching exercises as well as hydro and electrotherapy) over a four week period. The patients were encouraged to reduce their medication use over the course of the intervention. Patients completed the WOMAC and the SF 36 four weeks before the intervention programme, on the day of entry to the programme, the day of discharge and three months after the conclusion of the programme. The results of the study demonstrated that from the start to the end of the intervention period, the pain scale was the most responsive and that the WOMAC and the SF 36 had comparable values (WOMAC SRM= 0.72) (SF 36 SRM= 0.52). While there is no direct scale comparison possible for stiffness in this domain the WOMAC's responsiveness was 0.39 (SRM). This is relatively low and may reflect the comments of McConnell et al (2001) that the stiffness domain is less responsive as a measure. The WOMAC however was much more responsive with respect to the physical functioning characteristics (WOMAC SRM= 0.63, SF 36 SRM=0.25). The authors concluded that while both instruments capture improvement in pain equally well, the WOMAC is better at detecting changes in functional improvement.

2.12.2 The Aggregated Locomotor Function (ALF) score

As well as questionnaires there is a need to have tests that measure functional change in patients with OA of the knee. One such test is the Aggregated Locomotor Function (ALF) score. The ALF score is a simple measure of observed locomotor function, using timed walking, stairs and transfers, developed by McCarthy and Oldham (2004). It takes less than ten minutes to administer and the score for the test is the aggregated total time for the three activities.

McCarthy and Oldham (2004) have investigated this measure for the following characteristics; intra-tester reliability, criterion-related validity and responsiveness in a sample of patients with knee OA. Two hundred and fourteen patients with knee OA were recruited for inclusion in a randomized controlled trial investigating two methods of exercise provision. The ALF was compared with the WOMAC and the SF

36 before treatment, and after the testing sequences of the timed 8 m walk, ascending and descending a set of gymnasium stairs and transferring in and out of a chair. A group of 15 patients also undertook a test-retest reliability study of the above outcome measures. The results of the study indicated that the ALF demonstrated excellent intra-tester reliability, (ICC, 0.99; 95% CI 0.98-0.99), low standard error of measurement (0.86 s), and smallest detectable difference (9.5%) values. Criterion-related validity with the physical function dimensions of the WOMAC and SF-36 were reasonable, with correlation coefficients of 0.59 and - 0.53 respectively. The authors concluded that the ALF can be used as a measure of physical function status and as a means of quantifying treatment response in patients with OA of the knee.

2.12.3 The Lower Limb Task Questionnaire (LLTQ)

The LLTQ is a 10 item functional questionnaire that has been recently developed by McNair, Prapavessis, Collier et al (2007). It has not been used extensively in populations with OA of the knee joint, but has been developed to measure functional change in a range of lower limb pathologies. The questionnaire has been developed for two domains, activities of daily living and recreational activities that require use of the lower limbs. There are 10 questions in each of the two domains. Each question has a five point scale and subjects rate the activity from no difficulty (4 points) to unable to do (0 points). The total score for the test is out of forty. Patients are also asked to rate the importance of each activity on a Likert scale (1-4) with a score of four rated as very important and a one as not important.

The reliability of this questionnaire has been examined and shown to be high (ICC 0.96 (lower CI 0.93) and 0.98 (lower CI 0.97)) for the ADL and recreational activity domains respectively. The responsiveness of the questionnaire for activities of daily living was also high with the effect size, the standardised response mean and the responsiveness statistic reported as 1.5, 1.4 and 5.3, respectively. For the recreational questionnaire, the same statistics were 1.6, 1.3 and 5.8, respectively. With respect to the Minimal Important Difference (MID) for the ADL questionnaire the MID was determined as 2.6 points and for the recreational questionnaire the MID was 2.2 points. Overall the authors comment that this questionnaire is both reliable and responsive and has low MID change scores, with the questionnaire being easy to administer and score.

2.13 Summary

In summary, the effects of both acute and periodic stretching programmes undertaken in both young and elderly populations produce increases in range of motion of a similar range (5-14 degrees). These increases are brought about with varying durations of stretch, however longer durations (60 seconds compared to 30 seconds) in elderly populations appear to demonstrate larger increases in ROM. The periodic stretching interventions in elderly subjects may also have a positive effect on functional activities such as walking speed. In the case of periodic stretching regimes applied to subjects with OA of the knee, while increases in range of motion are observed, because of the variation in the duration of the stretching regimes the methods of measurement and the associated interventions, it is not possible to get clear picture of whether stretching alone has a beneficial effect on subjects with OA knee. At this time no studies have investigated the viscoelastic characteristics of hamstring muscles in subjects with OA knee with acute or periodic stretching interventions. No studies have investigated the specific effects of periodic stretching interventions to the lower limb, on functional activities, such as walking and stair climbing in this group.

CHAPTER 3

METHODS

Introduction

This chapter contains the methods for the two studies undertaken in this project. In the first study, the subjects of interest were elderly with and without OA of the knee joint, and the variables of interest were knee extension range of motion, peak passive torque and stiffness prior to and following a single stretching intervention.

In the second study, the subjects of interest were elderly with and without OA of the knee joint, and the variables of interest were knee extension range of motion, peak passive torque and stiffness, prior to and following a six week stretching intervention, with a 12 week follow up. A second objective was to investigate the effects of the stretching intervention on functional activities as measured via the ALF score.

3.1 Study 1

3.2 Study design

A cross sectional trial was undertaken for this study.

3.3 Subjects

In response to a local newspaper advertisement and in accordance with the requirements of the Auckland University of Technology (AUT) Ethics Committee (see Appendix 2), 100 subjects from the community applied to participate in the study. Sixty two subjects met the inclusion criteria. With respect to the selection criteria, subjects with OA of the knee joint had to meet the Altman Criteria (Altman, 1991) or Kellgren Lawrence criteria (Kellgren, Jeffery, & Ball, 1963).

The clinical criteria for diagnosis was based on Altman (1991) and was as follows; Subjects with the examination findings consistent with any of the three categories below were considered to have knee arthritis (sensitivity= 89%, specificity = 88%. (Altman, 1991)).

1. Knee pain and crepitus with activity and morning stiffness < 30 minutes and age >38 years
2. Knee pain and crepitus with active motion and morning stiffness > 30 minutes and bony enlargement
3. Knee pain and no crepitus and bony enlargement

The Kellgren and Lawrence system grades OA of the knee joint based on radiographic evidence of the pathology (Kellgren et al., 1963). There are four grades:

Grade 1: (doubtful) Minute osteophytes evident on x ray

Grade 2: (minimal) Definite osteophytes, no loss of joint space

Grade 3: (moderate) Moderate loss of joint space

Grade 4: (severe) Joint space loss with sclerosis of subchondral bone

The subjects had to be free of any other lower limb pathology and were not eligible for the study if they were currently participating in physiotherapy treatments for the knee joint. Subjects were also excluded if they had cardiovascular or neurological disease that would affect their ability to exercise. Subjects were allowed to continue with their usual medication (such as non steroidal anti-inflammatory drugs) for the knee. Those subjects who did not have OA of the knee had to be fit and well, have no history of lower limb orthopaedic conditions or injuries, neurological conditions or significant cardiovascular conditions, which would prevent them from undertaking the testing.

Prior to testing all subjects read the participant information sheet (See Appendix 4) and when any relevant questions were answered, signed a written consent form (See Appendix 6). The subjects were also required to complete the Physical Activity Readiness Questionnaire (Par Q) (see Appendix 8). Subjects were cleared to participate by their General Practitioner if any areas of concern were found following the completion of this questionnaire.

All subjects completed the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (see Appendix 11) (Bellamy et al., 1988), and the Lower Limb Task Questionnaire (LLTQ) (see Appendix 10) (McNair et al., 2007) to gain an appreciation of their functional capacity and level of disability.

Based on Feland et al (2001) a 5° change in knee extension range of motion was considered clinically significant, therefore with 80% power, $\alpha = 0.05$, a sample size of 20 in each group was required to detect a difference of 4.3° between groups. Data collection was performed at the Health and Rehabilitation Research Centre of the Auckland University of Technology.

3.4 Equipment and Procedures

3.4.1 Knee extension range of motion

A passive knee extension test using the Kincom® dynamometer (Kinetic Communicator, II 500H, Chattex Corp., Chattanooga, TN, USA) was utilised to measure knee extension range of motion. These methods were similar to those used by other investigators (Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, Sorenson et al., 1996; Reid & McNair, 2004). In accordance with the manufacturer's instructions, the limb weight of subjects was gravity corrected with subjects in a sitting position and the limb to be tested resting on the load cell at a knee joint angle of 60° from full extension. A firm lumbar roll was placed in the low lumbar spine (L2-L4 level) to maintain the lumbar lordosis and reduce the likelihood of the pelvis rotating posteriorly during the stretching procedure. The subjects were secured in the sitting position with a Velcro strap across the chest and a seat belt over the anterior aspect of the pelvis. The thigh to be tested was placed on a specially constructed pad that created an angle of 25 degrees to the horizontal. The height of the pad was adjustable so that during the stretching procedure the leg was unable to reach full knee joint extension. The thigh was secured with a Velcro strap to the pad. The knee joint was positioned with the axis of rotation in line with the axle of the lever arm of the Kincom®. Once the subject was ready, the limb to be tested was moved to the starting position at 80 degrees of knee flexion. A blind-fold was placed over the subject's eyes and they were asked to relax the muscles about the knee joint throughout the motion and to concentrate on the sensation of the stretch (see Figure 3.2). The Kincom® dynamometer extended the knee passively at 10 degrees per second. Subjects used an emergency stop switch to halt knee extension at the point when they perceived the maximum tolerable stretch in the hamstring muscles (see Figure 3.3). This terminal position was then designated as the point of maximal passive knee extension range of motion.

Following a familiarization to the procedure, two trials were undertaken. Two further trials were undertaken following the stretching intervention. An average of the two trials before and after stretching was used for data analyses. The reliability of these procedures has been determined in other studies using a similar methodology (Reid & McNair, 2004). The following dependent variables were of interest; maximal knee extension ROM, peak torque, range of motion at 50% of baseline peak torque, and stiffness in the final 10% of the knee extension ROM. Peak torque and range of motion were analysed in the following ways (See Figure 3.1). At point A, the peak torque pre intervention, and maximal knee extension ROM was compared to point B post intervention. At Point C, 50% of the baseline peak torque level, knee extension ROM pre intervention was compared with point D post intervention. Point E, the post intervention peak torque and maximum ROM was compared to point A pre intervention. Stiffness was calculated using a computer programme by the differentiation of the torque and angle arrays which were then divided (torque change/angle change), and thereafter the men stiffness was calculated. This was then measured in the final 10% of the ROM at baseline and post intervention.

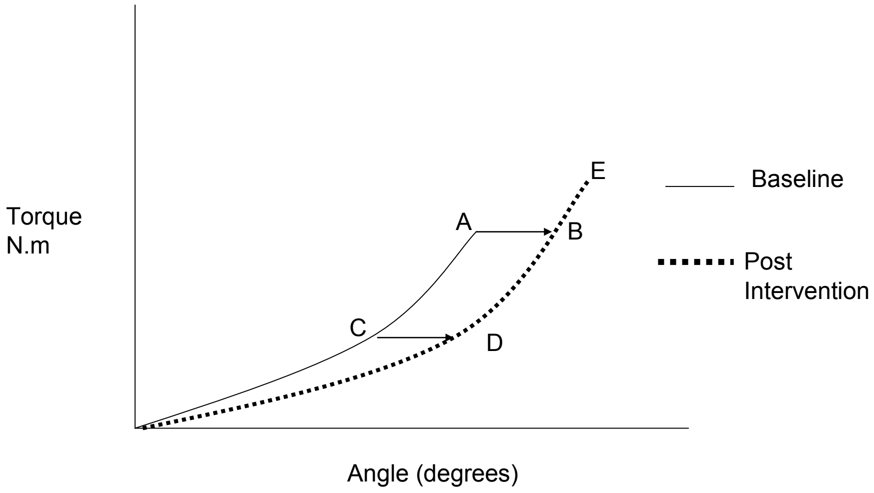


Figure 3.1: Calculation of torque and knee extension ROM data.

3.4.2 The intervention

Based on the findings of Zakas et al (2005), the stretching intervention involved three repetitions, each held for 60 seconds. A 60 second rest was undertaken between stretches. The subjects remained seated in the Kincom® as described above and the machine was programmed to deliver the required stretch intervention. The subjects were moved to a position of 80% of their maximal perceived knee extension range of motion for the intervention following a similar protocol to Nordez, Cornu and McNair (2006). The 80% of maximal range of motion was chosen to reduce the possible increase in EMG activity when stretching procedures are taken to maximal passive range of motion as noted by these authors.

3.4.3 Electromyography of quadriceps and hamstring muscles

Electromyographic activity was recorded using Norotrode 20 TM bi polar surface electrodes (Myotronics Noromed Inc Tukwila WA, USA). Data were sampled at 500Hz, amplified 1000 times, band-pass filtered (20-450Hz) and relayed to a computer based data acquisition and analysis system (Superscope, GW Instruments, Washington, USA). The common mode rejection ratio at 60 Hz is > 80dB for the Norotrode 20 TM bi polar electrodes. The electrode sites were prepared by shaving and cleaning the area with alcohol. The electrodes were orientated approximately parallel to the direction of the fibres of the muscles of interest in accordance with SENIAM guidelines (Hermens et al 2000) . With respect to the rectus femoris muscle, the electrodes were placed over the upper third of the muscle belly (see Figure 3.4). With respect to hamstring muscles the electrodes were placed posteriorly midway between the gluteal fold and the knee joint (see Figure 3.5). The EMG data were recorded simultaneously with signals from the Kincom®'s load cell and potentiometer at a sampling frequency of 500 Hz, and relayed to a computerised data acquisition system for subsequent processing. Data collection occurred continuously throughout the 12-second passive knee extension test performed by the Kincom®. The surface electromyographic activity from the rectus femoris and the lateral hamstring muscles was monitored to ensure that subjects complied with the request to relax during the stretching procedures. The root mean square (RMS) of muscle activity was normalised to a maximum voluntary isometric contraction recorded at the completion of each test. The EMG activity could then be expressed as a percentage of the activity recorded during their maximum isometric voluntary contraction. If a subject's EMG data were greater than one percent of a maximum voluntary contraction, then that subject's data were discarded.

Figure 3.2: The start position for the passive knee extension test.

Figure 3.3: The finish position for the passive knee extension test. This was the position at which the subject voluntarily depressed the cut out switch, at the point of perceived maximal tolerable stretch.

Figure 3.4: The typical placement of the rectus femoris electrodes. The placement of the earth electrode can be seen on the proximal tibia.

Figure 3.5: The typical placement of the hamstring electrodes.

3.5 Statistical analysis

Descriptive statistics were analysed to determine the appropriateness of utilising parametric analyses. Normality of the data were assessed via the Kolmorgorov-Smirnov test. A two factor (time and group) ANOVA was utilised for this study. The 2 factors were time (pre and post intervention), which was the repeated measure, and group (OA and non OA). The statistical analysis was undertaken using Statistical Package for Social Sciences Version 14.0 (Chicago, Illinois). The alpha level was 0.05. The results for Study 1 are presented on page 91.

3.6 Study 2

3.7 Study design

A randomised controlled trial with a 12 week follow up was undertaken for this study. See Figure 3.6 for a flow chart of the selection process.

3.8. Subjects

Of the sixty two subjects who had participated in study one, thirty nine subjects agreed to participate in study two. A further four subjects from the original 100 applicants, who did not want to participate in the first study, agreed to participate in the second study. In accordance with the Auckland University of Technology (AUT) Ethics Committee (see Appendix 3), forty three subjects met the inclusion criteria. Prior to testing all subjects read the participant information sheet (See Appendix 5) and when any relevant questions were answered, signed a written consent form (see Appendix 7). The subjects were also required to complete the Physical Activity Readiness Questionnaire (Par Q) (see Appendix 8). Subjects were cleared to participate by their General Practitioner if any areas of concern were found following the completion of this questionnaire. The criteria for selection into this study were the same as Study 1. Based on Gajdosik et al (2005), a 5° change in knee extension range of motion was considered clinically significant, therefore for 80% power, $\alpha = 0.05$, a sample size of 10 in each group was required to detect a difference of 5.5°.

3.9 Randomisation

Following baseline testing, all subjects were randomly allocated to one of four groups via a sealed envelope. The process of randomisation was carried out by two allied staff within the University who were unaware of the study and not aware of the group allocation indicated in the sealed envelope. The four groups were: a stretching group of subjects with OA of the knee (N=14), a group of subjects with OA knee who were controls (N=10), a group of non OA knee subjects who stretched (N=8) and a group of non OA knee subjects who acted as controls (N=11) (see Figure 3.6).

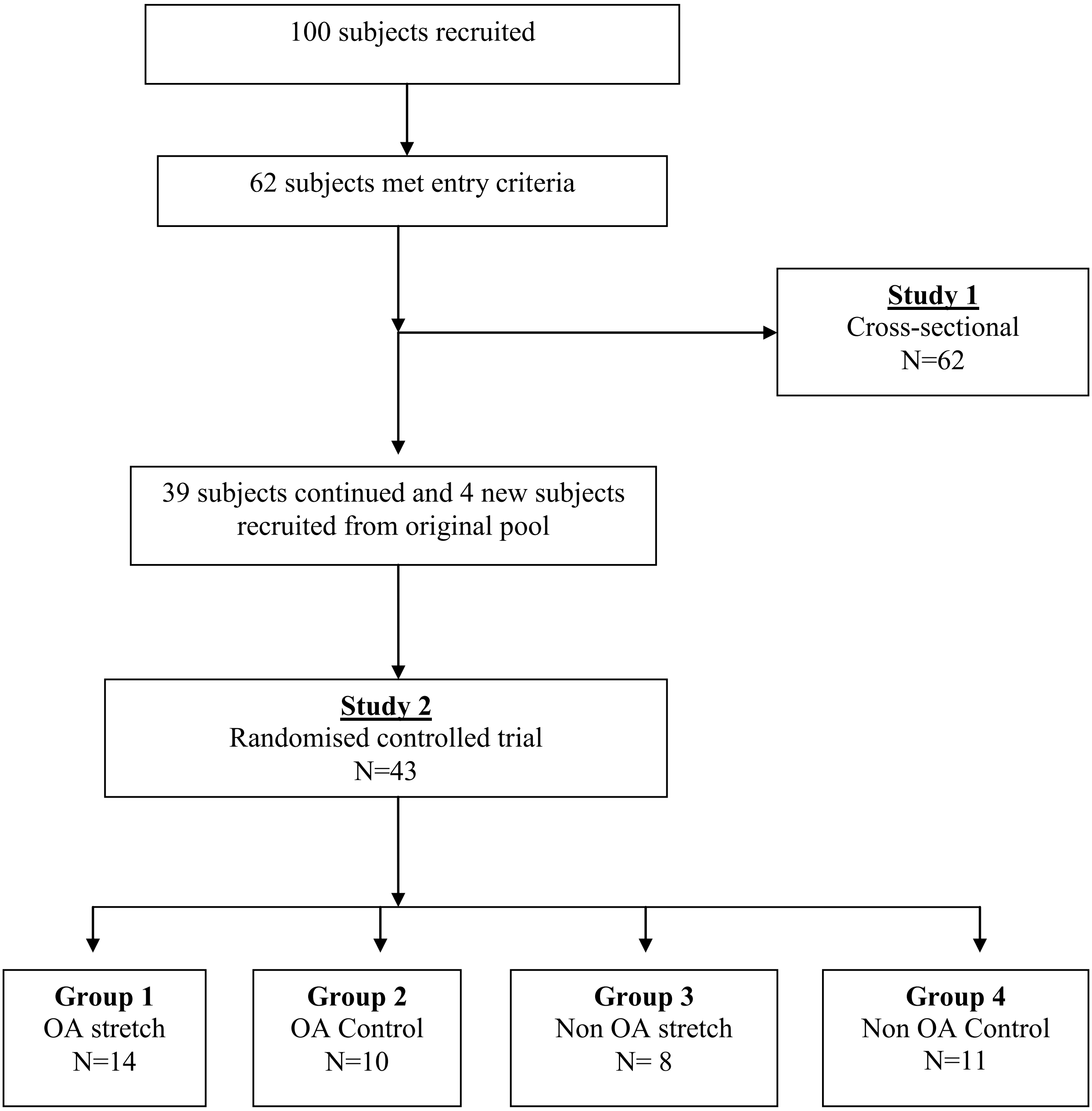


Figure 3.6: The selection process of the subjects in Study 2.

3.10 Blinding

A number of levels of blinding were included in the study. The principal investigator (DR) was blinded to the allocation of the subjects in the four groups and took no part in the assessment of the subjects or the delivery of the interventions. The two research assistants, who undertook the Kincom® assessments, the WOMAC, LLTQ and gait assessments, were blinded to the group allocation. The two research assistants, who supervised the stretching intervention and interferential current placebo treatment delivery, were blinded to the assessment procedures. Blinding of the subjects to the intervention was not possible due to the nature of the intervention.

3.11 Equipment and Procedures

3.11.1 Knee extension range of motion.

A passive knee extension test using the Kincom® dynamometer (Kinetic Communicator, II 500H, Chattex Corp., Chattanooga, TN, USA) was utilised to measure knee extension range of motion, in the same way as Study 1. Following familiarization to the procedure, two trials were undertaken. Two further trials were undertaken following the stretching intervention and at the 12 week follow up. An average of two trials was used for data analyses. The reliability of these procedures has been determined in other studies using a similar methodology (Reid & McNair, 2004).

The following dependent variables were of interest; maximal knee extension ROM, peak torque, range of motion at 50% of baseline peak torque, and stiffness in the final 10% of the knee extension ROM. Peak torque and range of motion were analysed in the following ways (See Figure 3.1). At point A, the peak torque pre intervention, and maximal knee extension ROM was compared to point B post intervention. At Point C, 50% of the baseline peak torque level, knee extension ROM pre intervention was compared with point D post intervention. Point E, the post intervention peak torque and maximum ROM was compared to point A pre intervention. Stiffness was calculated in the final 10% of the ROM at baseline and post intervention.

3.11.2 Electromyography of quadriceps and hamstring muscles

Electromyographic activity of the quadriceps and hamstring muscles was recorded during the trials, in the same way as Study 1.

3.11.3 Functional outcome measures

To examine whether the stretching intervention made a difference to activities of daily living, all subjects completed the following outcome measurements at baseline, post intervention and at the 12 week follow up; The Aggregated Locomotor Function score (McCarthy & Oldham, 2004), the Western Ontario and McMaster Universities Osteoarthritis Index (Bellamy et al., 1988), and the Lower Limb Task Questionnaire (McNair et al., 2007). For information on the reliability and validity of these outcomes please refer to Chapter 2, pages 59-61 of the literature review.

3.11.4 Aggregated Locomotor Function (ALF) score

This score, developed by McCarthy and Oldham (2004), has three components.

1. An eight metre timed walk
2. A timed stair climb and descent, one flight of stairs or seven steps
3. A timed chair sit and stand

The outcome score was calculated by summing the mean times across the three trials of the above mentioned tasks. In the current study, these tasks were modified slightly.

- The eight metre walk test was extended to 10 metres. The reason for this change was to accommodate a data collection system, the Gait Mat II® (E.Q., Inc Chalfont, PA, USA). The system allowed accurate collection of the following temporal-spatial parameters; stride length, step length and walking velocity. Subjects were asked to walk as quickly as possible across a 10-metre distance, turned around and then returned to the starting point. The timing for the test was undertaken using timing lights (Speedlight Swift Performance Equipment, Lismore, Australia). Three repetitions of the test were undertaken and the mean of the three tests calculated (see Figures 3.7 and 3.8).

- The sit to stand test. Subjects were asked to sit in a chair then stand and walk a distance of two metres as quickly as possible, turn and walk back to the chair and sit down. This exercise was timed with the timing lights. The test was repeated three times and the mean calculated (see Figure 3.9).

- The stair ascent and descent test. Subjects were asked to ascend and then descend seven steps as quickly as possible. The subjects were instructed not to use the handrails. This exercise was timed with the timing lights. Three repetitions were completed and the mean time calculated (see Figure 3.10).

All subjects were measured at baseline, following the intervention period and at the 12 week follow up.

Figure 3.7: The set up for the walk test. The Gait Mat® is shown in the centre section of the walk. The timing lights are positioned at the start of the walkway.

Figure 3.8: A typical subject undertaking the 20 metre walk test.

Figure 3.9: A typical subject undertaking the sit to stand and two metre walk.

Figure 3.10: A typical subject descending the stairs.

3.12 Patient global assessment of change

In order to gain an appreciation of the subjects' impressions of how the stretching and placebo interventions had affected the overall status of the arthritic knee, a patient global assessment was used. Such assessments are helpful in detecting clinically relevant changes following a given intervention (Jaeschke, Singer, & Guyatt, 1989; Salaffi, Stancati, Silvestri, Ciapetti, & Grassi, 2004). These assessment and other questionnaires have been developed and validated in subjects with chronic and disabling conditions (Farrar, Young, laMoreaux, Werth, & Poole, 2001). The OA knee subjects were required to complete a global assessment question on two occasions, once at the conclusion of the intervention and again at the follow up period (see Appendix 12). The overall improvement in the status of the knee following the intervention was rated on a seven point scale with zero being rated very much improved and six rated very much worse.

3.13 Medications

Medication being taken for the OA knee was not restricted but subjects were encouraged to reduce their medication if they felt the exercise programme provided adequate pain relief. Subjects were questioned about their medication use at the conclusion of the intervention period.

3.14 The intervention

3.14.1 The stretching group

Subjects in the stretching group were instructed to stretch all the major muscle groups in the lower limb, quadriceps, and hamstrings, upper and lower calf and hip flexors. The stretches shown in the figures below were used to provide a balanced stretching programme as per other studies investigating OA of the knee joint (Borjesson et al., 1996; Deyle et al., 2005; Deyle et al., 2000; Fransen et al., 2001; Law, 2001; Peloquin et al., 1999; Rogind et al., 1998). Subjects' were given instruction in the stretching procedures once allocated to that group. These instructions were provided by a research assistant who was not aware of the project and the allocation of the subjects to each group. The stretches were taken to the point where the subject perceived a stretching sensation in the target muscle group. The stretch was held for 60 seconds and repeated three times on each muscle group and on each leg. The stretches were performed once a day for a minimum of five days of the week for a period of six weeks. The subjects in the stretch groups were supplied with written information with relevant pictures to ensure compliance (see Appendix 9). On two days of the week, subjects attended a supervised stretching session at the University. Preceding their stretching sessions, subjects undertook a warm-up routine consisting of light aerobic activity such as walking on a treadmill or cycling on a stationary bicycle for three minutes. A research assistant independent of the testing instructed the subjects in the stretching exercises, modifying these as required, to ensure that all subjects understood how to do the stretches and ensure compliance with the stretching programme. The remaining three stretching sessions were undertaken independently at the subject's homes. The subjects kept a diary of the number and frequency of these stretching sessions (see Appendix 9) and an attendance record was kept for the sessions at the AUT gymnasium. Following the completion of the stretching intervention, subjects in the stretching groups were advised to continue with their normal daily activities. There was no requirement for them to continue with the stretching programme but were informed they would need to attend a follow up assessment at the 12 week time point.

3.14.2 Specific stretches

1. The swing phase hamstring stretch (Bandy & Irion, 1994; Bandy et al., 1997; Bandy, Irion, & Briggler, 1998) (Figure 3.11a). In this stretch, the subjects placed the heel of the leg to be stretched on a low box or chair. The knee joint was in an extended position. The back was kept as straight as possible and the subject asked to bend forward at the hip joint until a stretching sensation was felt in the hamstring muscle. If subjects were not able to undertake this stretch an alternative stretch was provided. In the alternative stretch, the subjects lay supine on the floor (Figure 3.11b). Subjects were also provided with a skipping rope to allow easier application of the stretches to the muscle group being stretched. A skipping rope or towel was looped around the sole of the foot. The leg to be stretched was kept in knee extension. Using the rope, the subject elevated the leg until a stretch was felt in the hamstring muscle. By using the rope to elevate the leg the stretch it was thought a more passive stretch would be induced. The leg not being stretched was kept extended on the floor.

2. The gastrocnemius and soleus stretch in standing (Gajdosik, Vander Linden, McNair, Riggin et al., 2005) (Figure 3.12a). To stretch the gastrocnemius

muscle, subjects' placed their hands either against a wall or on the back of a chair. In the step-stand position, the back leg to be stretched was placed on the ground with the heel on the floor. The knee was kept in extension. The front leg was flexed at the knee. Subjects then leaned forward in this position until a stretch was felt in the upper calf region. To stretch the soleus muscle, subjects took up the same position, but with the heel still fixed on the ground, then flexed the knee joint until the stretch was felt in the lower part of the calf (Figure 3.12b).

3. The quadriceps stretch in standing (Figure 3.13a). Subjects stood with the support of a chair or bench. The leg to be stretched was held either with the hand of the same side or a small skipping rope looped over the front of the foot to allow the knee to be passively pulled into a flexed position. If subjects were not able to undertake this stretch an alternative stretch was provided (Deyle et al., 2005)(see Figure 3.13b). In the alternative stretch, the subjects lay prone and a small rope was looped around the front of the foot. The subject then pulled on the foot to flex the knee joint until a stretch was felt in the quadriceps region or the limit of knee flexion is achieved. The leg not being stretched lay flat on the floor.

4. Hip Flexors in kneeling (Kerrigan et al., 2003) (Figure 3.14). Subjects were instructed to kneel on one knee with the other leg flexed at the knee with the foot placed on the floor. A soft pad could be placed under the knee if this stretching position created any pain in the knee. Subjects then gently moved forward until a stretch was felt in the front of the hip. Subjects were instructed to keep their back straight during the exercise.

Figure 3.11a): The swing phase hamstring stretch.

Figure 3.11b): The alternative hamstring stretch.

Figure 3.12a): The gastrocnemius stretch.

Figure 3.12b): The soleus stretch.

Figure 3.13a): The quadriceps stretch in standing.

Figure 3.13 b): The quadriceps stretch lying prone.

Figure 3.14: The hip flexor stretch.

3.14.3 The control group

Subjects in the control groups did not stretch and were instructed to maintain normal activities of daily living. Those subjects in the OA knee control group were exposed to a placebo intervention. This was required to assess the effects of an improvement in outcome due simply to the interaction with the research assistants delivering the stretching programme and counteract any potential Hawthorne effects (Polgar & Thomas, 1988). The placebo intervention consisted of the application of a sub-therapeutic dose of Interferential therapy. An Interferential Current (IC) was a medium frequency current amplitude modulated at a low frequency for therapeutic purposes (Kitchen, 2002), and has been used in the treatment of individuals with OA of the knee joint (Adedoyin, Olaogun, & Fagbeja, 2002). A therapeutic dose normally provides pain relief and mild muscle stimulation. When this modality is applied to patients with musculoskeletal injuries they may perceive a mild tingling sensation. In a sub-therapeutic dose minimal, if any, tingling is perceived. At these "sessions" the machine was turned on but no current was delivered to the subjects. The research assistants delivering the placebo gave the subjects standard instructions as to the benefits of the interferential current with respect to pain relief and that no sensation was to be felt during the procedure. Should the subjects have felt any tingling sensations, or felt their knee pain was increasing, they were to let the assistant know and the treatment was terminated. The subjects received 10 minutes of the placebo intervention; two days a week for the six weeks of the intervention period. Attendance at these treatment sessions was recorded and no adverse reactions to the treatment were encountered.

3.15 Statistical analysis

Descriptive statistics were analysed to determine the appropriateness of utilising parametric analyses. Normality of the data were assessed via the Kolmorgorov-Smirnov test. A three factor (time x group x condition) ANOVA was utilised for this study. The 3 factors were time (pre, post intervention and follow up), which was the repeated measure, and group (experimental and control) and condition (OA and non OA). Post hoc pair-wise comparisons using the Bonferonni test were undertaken to examine specific differences across group and time. Following the initial data analysis where differences in some baseline variables were noted, an ANCOVA was utilised using the baseline variable as the covariate. The statistical analysis was undertaken using Statistical Package for Social Sciences Version 14.0 (Chicago, Illinois). The alpha level was 0.05. The results of Study 2 are presented on page 98.

Chapter 4

Results

Introduction

This chapter is divided into two sections. The first section provides a description of the subjects that participated in Study 1, followed by the results of the tests performed. The activity levels of the subjects assessed via the LLTQ and the WOMAC are also presented. The second section follows a similar sequence to above for Study 2 with the addition of the findings related to effects of the periodic stretching intervention on function and at the 12 week follow up.

4.1 Study 1

4.1.1. Subjects

Data from sixty two subjects were collected. There were twenty four males and thirty eight females males aged between 57 and 78 years (mean 68.3, SD: 5.1). Independent *t*-tests indicated no significant difference was found between groups for age, height or weight ($p>0.05$). There were sixty two subjects of which half had OA of the knee joint. Of the 31 subjects with OA, 13 subjects had a diagnosis made with Altman criteria (mean score 1.05, SD: 07) and 18 subjects had the diagnosis made with Kellgren Lawrence Criteria (mean score 2.03, SD: 1.6). All subjects completed the intervention however, following the analysis of the EMG data seven subject's (three OA and four non OA) data were discarded, as the EMG was greater than 1% of MVC. A total of 55 subjects' data were subsequently analysed with respect to knee extension range of motion, peak torque and stiffness. 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.

Group	Number	Age (yrs)	Height (cm)	Mass (kgs)
OA	28	67.5 (5.0)	168.5 (11.1)	80.8 (14.2)
Non OA	27	69.0 (5.2)	162.8 (7.7)	69.2 (12.2)
Overall	55	68.2 (5.5)	165.6 (9.8)	75.1 (14.2)

4.1.2 WOMAC and LLTQ

All subjects completed the functional questionnaires. Independent *t*- tests indicated that the subjects with OA were significantly different from the non OA subjects for the WOMAC total score ($p<0.05$), and the individual components of the WOMAC; pain ($p<0.05$), stiffness ($p<0.05$), and function ($p<0.05$). Similar results were evident for the LLTQ scores ($p<0.05$). The WOMAC and LLTQ scores are presented in Table 4.2.

Table 4.2: The WOMAC and LLTQ scores. Data are means and standard deviations. * indicates significant difference between groups.

Group	WOMAC Total	WOMAC Pain	WOMAC Stiffness	WOMAC Function	LLTQ (ADL)
OA	806.2 (548.7)*	160.6 (112.8)*	75.4 (54.2)*	571.71 (404.7)*	32.3 (6.0)*
Non OA	33.9 (72.8)	4.5 (13.5)	4.4 (11.1)	24.3 (53.6)	38.9 (1.8)

4. 2 Changes in range of motion, torque and stiffness

4.2.1 Knee extension range of motion

The torque angle curve for a typical OA knee subject pre and post intervention is displayed in Figure 4.1. It illustrates the key findings and shows that the subject increased their range of motion following the intervention, with less resistive force but with increased steepness of the curve in the final 10% of ROM.

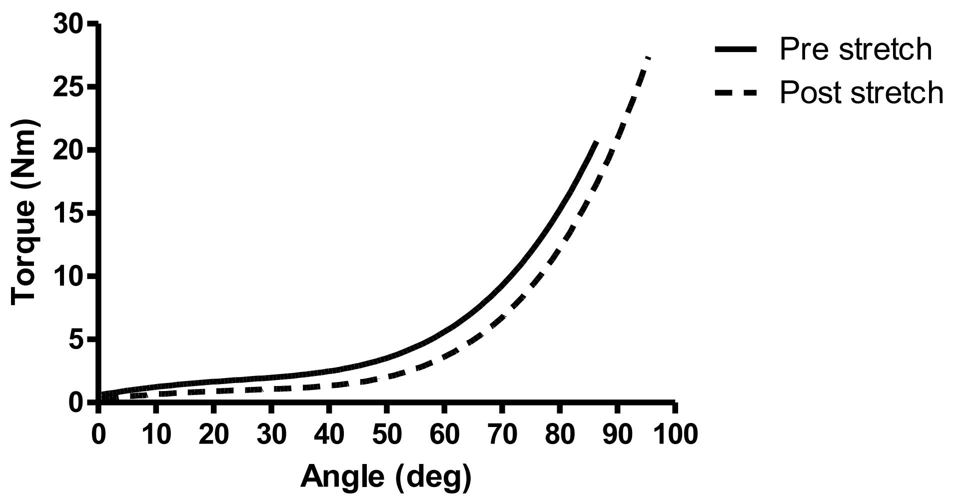


Figure 4.1: The torque-angle curve for a typical OA knee subject pre and post intervention.

Figure 4.2 displays peak knee extension for the OA group and the non OA group. There was a significant main effect for time ($p<0.05$).There was no interaction effect between groups across time ($p >0.05$). The OA group had a mean maximum knee extension of 75.6 (SD: 17.2) degrees before the intervention and this increased significantly to 80.5 (SD: 22.3) degrees after the intervention ($p<0.05$). For the non OA group the mean increased significantly from 77.5 (SD: 15.5) degrees to 81.9 (SD: 18.2) degrees ($p<0.05$).

With respect to the knee extension angle at 50% of the maximum torque level, there was a significant main effect for time ($p<0.05$). There was no interaction effect between groups across time ($p >0.05$). The mean knee extension range of movement recorded at 50% of the peak torque level pre intervention for the OA group was 60.3 (SD: 18.7) degrees and this increased significantly to 67.2 (SD 16.7) degrees post intervention ($p<0.05$). For the non OA group, it increased significantly from 60.1 (SD: 15.2) degrees to 65.8 (SD 16.0) degrees ($p<0.05$).

In regards to the knee extension range of movement recorded at maximum peak torque level pre intervention (points A-B in Figure 3.1), there was a significant main effect for time ($p<0.05$). There was no interaction between group and time ($p>0.05$). Pre intervention, the OA group had 75.6 degrees (SD: 17.2) and this increased significantly to 79.2 (SD 17.1) degrees at the same torque level post intervention ($p<0.05$). For the non OA group it increased significantly from 77.5 (SD: 15.5) degrees to 80.1 (SD 16.7) degrees post intervention ($p<0.05$).

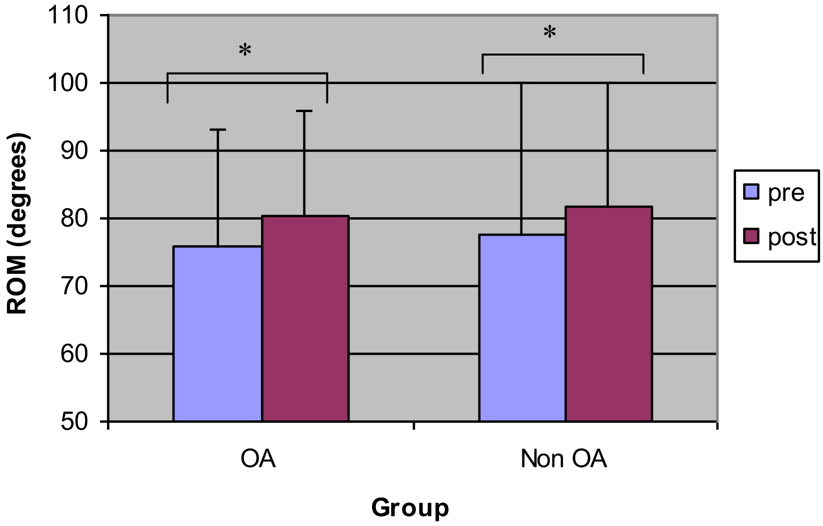


Figure 4.2: The knee extension range of motion for the OA group and non OA group before and after the intervention (* indicates $p<0.05$). Data are means and standard deviations.

4.2.2 Torque measurements

Figure 4.3 displays the peak torque during the passive knee extension test of the OA group and the non OA group. There was a significant main effect for time ($p<0.05$). There was no interaction effect between groups across time ($p >0.05$). The OA group had a mean of 18.1 (SD: 9.6) Nm before the intervention and this increased significantly to 22.5 (SD: 12.9) Nm after the intervention ($p<0.05$). For the non OA group the torque increased significantly from 21.0 (SD: 11.6) Nm to 22.0 (SD: 12.8) Nm ($p<0.05$).

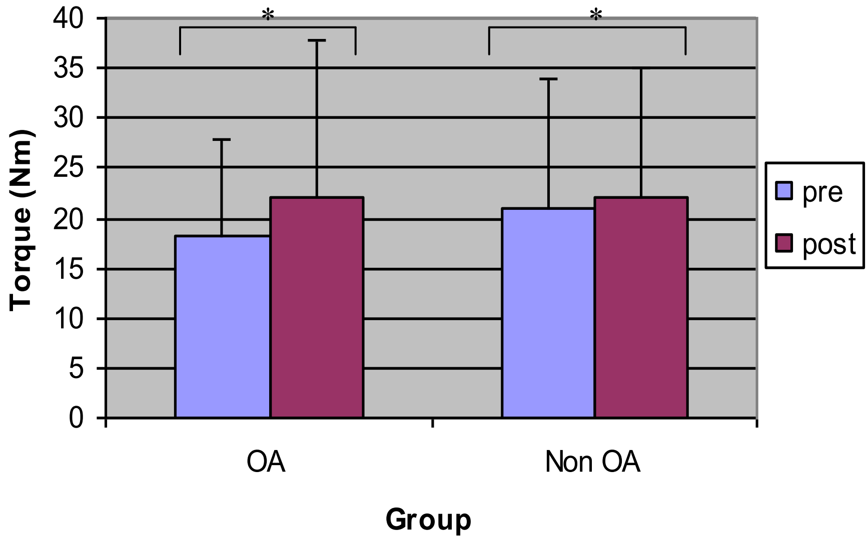


Figure 4.3: The peak torque for the OA group and non OA group before and after the intervention (* indicates $p<0.05$). Data are means and standard deviations.

4.2.3 Stiffness

Figure 4.4 displays the data for stiffness over the final 10% of knee extension range of motion for subjects in the OA group and the non OA groups at baseline and after the intervention. There was a significant main effect for time ($p<0.05$). There was a significant interaction effect ($p <0.05$) between groups across time. The OA group had a mean of 0.70 Nm/deg (SD: 0.35) before the intervention and this increased significantly to 0.89 Nm/deg (SD: 0.5) degrees after the intervention ($p<0.05$). The non OA group had a mean 0.78 Nm/deg (SD: 0.36) before the intervention and this increased significantly to 0.82 Nm/deg (SD: 0.42) after the intervention ($p<0.05$).

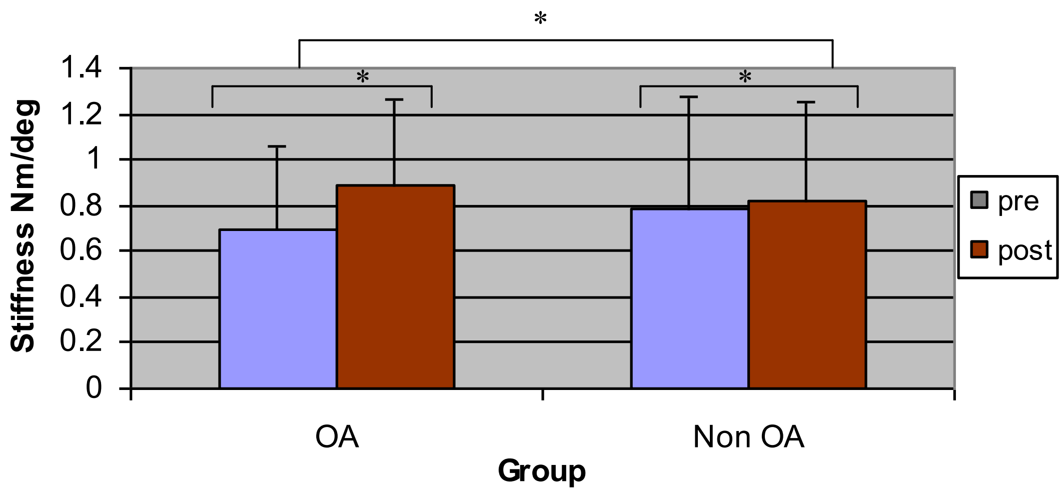


Figure 4.4: The stiffness in the final 10% of knee extension range of motion for the OA group and non OA group before and after the intervention (* indicates $p<0.05$). Data are means and standard deviations.

4.3 Study 2

4.3.1 Subjects

Forty three subjects were eligible for the study. However following the baseline measurements of age, height, mass, WOMAC and LLTQ data, one subject indicated that he was suffering an acute episode of low back pain. Therefore this subject was not eligible to continue through to the physical data collection and subsequently withdrew from the study. Three subjects had high BMI's (range 32-34) and it was difficult to secure the leg to the Kincom®. As a consequence of this issue, their terminal range of motion may not have been limited by the hamstring muscle and they were able to go further into the range than the other subjects. Following analysis of the baseline range of motion, peak torque and stiffness data, these subjects in the OA control group had values that were deemed as outliers (Grubbs test) so their data were removed from further analysis. Therefore data from thirty nine subjects were analysed. There were twenty two females and seventeen males aged between 60 and 78 years (mean 68.7, SD: 4.8). There were twenty subjects with OA of the knee joint and nineteen subjects without OA of the knee joint. Of the 20 subjects with OA knee, 9 subjects had a diagnosis made with Altman criteria (mean score 1.3, SD: 05) and 11 subjects had the diagnosis made with Kellgren Lawrence Criteria (mean score 3.0, SD: 0.9). All subjects in the control groups and the intervention groups completed the programme. Independent *t*-tests indicated no significant difference was found between groups for the variables of age, height, mass or body mass index ($p>0.05$). Descriptive characteristics of the subjects are presented in Table 4.3.

Table 4.3: The subjects age, height, mass and body mass index. Data are means and standard deviations.

Group	Number	Age (yrs)	Height (cm)	Mass (kgs)	BMI
OA stretch	13	69.0 (5.8)	166.9 (13.0)	81.9 (13.3)	29.4 (4.8)
OA control	7	67.4 (5.0)	168 (11.9)	82.3 (17.8)	28.7 (4.2)
Non OA Stretch	8	67.9 (4.0)	168.2 (9.2)	74.3 (19.3)	25.9 (4.9)
Non OA Control	11	69.6 (4.3)	163.3 (5.7)	74.8 (9.9)	27.9 (3.5)
Total	39	68.7 (4.8)	166.3 (10.2)	78.4 (14.6)	28.1 (4.4)

4.4 WOMAC

All subjects with OA of the knee joint completed the WOMAC questionnaires at the three time points. Both the total WOMAC score and the score for the three individual domains are presented below.

4.4.1 WOMAC total scores

There was no significant main effect for time ($p>0.05$). There was no significant interaction for time or group for the WOMAC total score ($p>0.05$). Subjects in the OA stretch group had a mean score of 686.6 (SD: 426.9) pre intervention, a score of 501 (SD: 306.7) post intervention, and a score of 525 (SD 311.9) at the follow up assessment. Subjects in the OA control group had a mean score of 819.6 (SD: 440.4) pre intervention, a score of 928.1 (SD: 635.8) post intervention, and a score of 857.1 (SD: 651.1) at the follow up assessment.

4.4.2 WOMAC pain scores

There was no significant main effect for time (p>0.05). There was no significant interaction for time or group for the WOMAC pain scores (p>0.05). Subjects in the OA stretch group had a mean score of 118.1 (SD: 95.4) pre intervention, a score of 76 (SD: 49.0) post intervention and a score of 118.7 (SD: 113.02) at the follow up assessment. Subjects in the OA control group had a mean score of 175.6 (SD: 94.0) pre intervention, a score of 169.8 (SD: 110.3) post intervention and a score of 159.1 (SD: 123.5) at the follow up assessment.

4.4.3 WOMAC stiffness scores

There was no significant main effect for time (p>0.05). There was no significant interaction for time or group for the WOMAC stiffness scores (p>0.05). Subjects in the OA stretch group had a mean score of 75.8 (SD: 41.6) pre intervention, a score of 63 (SD: 44.5) post intervention and a score of 62.3 (SD: 42.4) at the follow up assessment. Subjects in the OA control group had a mean score of 63.1 (SD: 54.1) pre intervention, a score of 74.4 (SD: 52.8) post intervention and a score of 64.6 (SD: 61.5) at the follow up assessment.

4.4.4 WOMAC function scores

There was no significant main effect for time (p>0.05). There was no significant interaction for time or group across for the WOMAC functional score (p>0.05). Subjects in the OA stretch group had a mean score of 484.25 (SD: 317.9) pre intervention, a score of 362.0 (SD: 232.3) post intervention and a score of 344.0 (SD: 250.2) at the follow up assessment.

Subjects in the OA control group had a mean score of 580.8 (SD: 302.9) pre intervention, a score of 638.8 (SD: 480.2) post intervention, and a score of 637.7 (SD: 478.1) at the follow up assessment.

4.5 The Lower Limb Task Questionnaire

All subjects with OA of the knee joint completed the LLTQ questionnaires. There was no significant main effect for time ($p>0.05$). There was no significant interaction for time or group ($p>0.05$). Subjects in the OA stretch group had a mean score of 30.9 (SD: 7.1) pre intervention, a score of 31.2 (SD: 6.1) post intervention and a score 30.7 (SD: 6.5) at the follow up assessment. Subjects in the OA control group had a mean score of 28.4 (SD: 7.0) pre intervention, a score of 25.6 (SD: 7.3) post intervention and a score of 27.6 (SD: 9.1) at the follow up assessment.

4.6 Programme compliance

Attendance at the supervised stretching and placebo treatment sessions was moderate in the two stretching groups and high in the OA control group. A mean of 6 (SD: 3.51) of the possible 12 supervised stretching sessions were attended by the OA stretch group (50% compliance). A mean of 7.1 (SD: 4.5) sessions were attended by the non OA stretching group (58% compliance). A mean of 10 (SD: 2.2) of the possible 12 placebo interferential sessions were attended by the OA control group (83% compliance). With respect to the home exercise sessions, an examination of the stretching groups diaries indicated higher levels of compliance. A mean of 29.5 (SD 1.4) of a possible 30 stretching sessions were undertaken at home by the OA stretch group (98.3% compliance). A mean of 28.8 (SD: 1.0) of a possible 30 sessions were undertaken by the non OA stretch group (96% compliance). The OA control group and the non OA control group were not required to follow a home exercise programme.

4.7 Medication use

Of those subjects in the study who had OA of the knee, only eight subjects (34%) were taking anti- inflammatory medication on a regular basis. There were three subjects in the OA stretch group (23%) taking anti- inflammatory medication for their knee and five subjects in the OA control group (50%). None of these subjects altered the amount of medication taken during either the stretching intervention or the placebo intervention.

4.8 Changes in range of motion, torque and stiffness

There was a significant main effect for time and group (stretch and control) with respect to the variables of peak knee extension range of motion, peak passive torque and stiffness in the final 10% of knee extension ROM ($p<0.05$). However there was no significant interaction for condition (OA and non OA) ($p>0.05$). A planned contrast was undertaken using the Bonferonni test to determine which group, at which time point had significantly changed (time 1 vs time 2, time 2 vs time 3, time 1 vs time 3). Because there was no interaction for condition, the data were combined to form a stretch and control group that were compared over time.

4.8.1 Knee extension range of motion.

The torque angle curve for a typical OA knee stretch group subject pre and post intervention is displayed in Figure 4.5. It illustrates the key findings and shows that the subject moved further into the range following the intervention, the curve moved upward to the left and the steepness of the curve also increased in the final 10% of knee extension ROM.

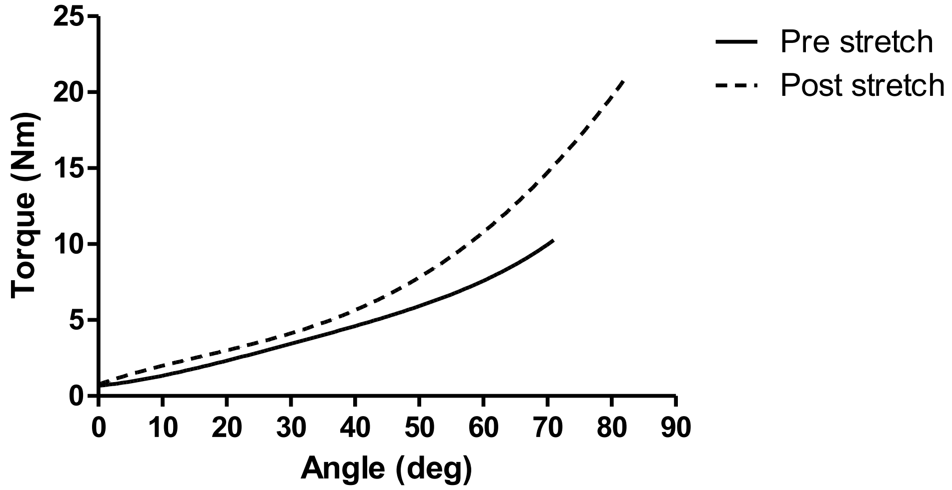


Figure 4.5: The torque-angle curve for a typical OA knee stretch group subject pre and post intervention.

With respect to peak knee extension range of motion, there was a significant main effect for time ($p<0.05$). There was a significant interaction for group and time ($p<0.05$). Figure 4.6 displays the mean peak knee extension range of movement for the stretch group and the control group at the three time points; pre intervention, post intervention and at the 12 week follow up assessment. The zero start position for the test movement was 80 degrees of knee flexion. Subjects in the stretch group had a mean of 68.9 (SD: 15.5) degrees knee extension pre intervention and this increased significantly to 76.7 (SD: 14.4) degrees post intervention ($p<0.05$). This corresponded to an 11.5 % change in range of motion. At the 12 week follow up assessment, the subjects had a mean of 72.5 (SD: 20.51) degrees. This difference was not significant when compared to the pre and post intervention assessment ($p>0.05$). Subjects in the control group were a mean 71.4 (SD: 10.3) degrees pre intervention, a mean of 69.3 (SD: 11.1) degrees post intervention and a mean of 69.4 (SD: 10.1) degrees at the 12 week follow up assessment. These differences were not significant ($p>0.05$).

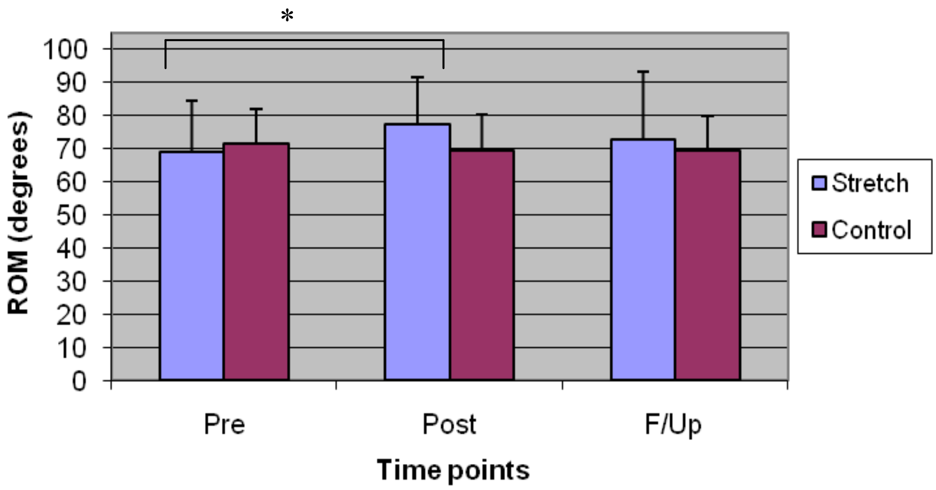


Figure 4.6: The peak knee extension range of motion for the stretch and control groups before and after the intervention and at the 12 week follow up (* indicates $p<0.05$). Data are means and standard deviations.

With respect to the knee extension angle at 50% of the maximum torque level, there was a significant main effect for time ($p<0.05$). There was no interaction effect between groups across time ($p >0.05$). The mean knee extension range of movement recorded at 50% of the peak torque level for the stretch group pre intervention was 55.9 (SD: 15.0) degrees and this decreased significantly to 50.8 (SD 12.3) degrees post intervention ($p<0.05$). The mean knee extension range of movement recorded at 50% of the peak torque level pre intervention for the control group was 60.2 (SD: 11.4) degrees and this decreased significantly to 57.1 (SD 11.0) degrees post intervention ($p<0.05$).

In regard to the knee extension range of movement recorded at maximum peak torque level pre intervention (points A-B in Figure 3.1), there was a significant main effect for time ($p<0.05$). There was no interaction effect for group and time ($p>0.05$). The stretch group had 68.9 (SD: 7.1) degrees knee extension range of motion pre intervention and this decreased significantly to 63.68 (SD 12.9) degrees at the same torque level post intervention ($p<0.05$). The mean maximal knee extension range of movement recorded at maximum peak torque level for the control group pre intervention was 71.4 (SD: 10.3) degrees and this decreased significantly to 69.3 (SD 11.1) degrees at the same torque level post intervention ($p<0.05$).

4.8.2 Torque measurements

With respect to peak passive torque, there was a significant main effect for time ($p<0.05$). There was a significant interaction ($p<0.05$) for time and group. Figure 4.7 displays the mean peak torque during the passive knee extension test of the stretch groups and the control groups. Subjects in the stretch groups generated a mean peak torque of 13.2 (SD: 7.7) Nm pre intervention and this increased significantly to 19.7 (SD: 9.5) Nm post intervention ($p<0.05$). This corresponds to a 48.5% increase in peak torque. At the 12 week follow up assessment, the subjects in the stretch group generated a mean peak torque of 20.2 (SD: 11.5) Nm. This difference was not significant when compared to the pre and post intervention assessment ($p>0.05$). The subjects in the control group generated a mean peak torque of 17.2 (SD: 6.3) Nm pre intervention, a mean of 16.6 (SD: 7.9) Nm following post intervention and a mean of 17.8 (SD: 7.4) Nm at the 12 week follow up time point. These differences were not significant ($p>0.05$).

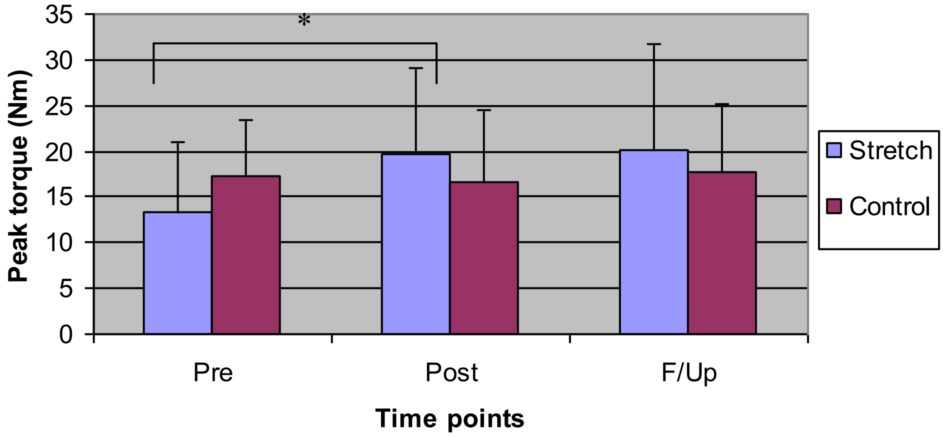


Figure 4.7: The peak torque for the stretch and control groups before and after the intervention and at the 12 week follow up (* indicates $p<0.05$). Data are means and standard deviations.

4.8.3 Stiffness

With respect to stiffness in the final 10 % of knee extension ROM, there was a significant main effect for time ($p<0.05$). There was a significant interaction for time and group ($p<0.05$). Figure 4.8 displays the mean data for stiffness (Nm/deg) for the stretch groups and control groups. Subjects in the stretch groups generated a mean stiffness of 0.62 (SD: 0.3) Nm/deg pre intervention and this increased significantly to 0.84 (SD: 0.3) Nm/deg post intervention ($p<0.05$). This corresponds to a 35.5% increase in stiffness. At the 12 week follow up time point, the subjects in the stretch group had a mean stiffness of 0.88 (SD: 11.5) Nm/deg. This increase was not significant when compared to the pre and post intervention assessment ($p>0.05$). The control group generated mean stiffness of 0.72 (SD: 0.2) Nm/deg pre intervention, a mean of 0.70 (SD: 0.2) Nm/deg following the intervention and a mean stiffness of 0.69 (SD: 0.2) Nm/deg at the 12 week follow up time point. These difference were not significant ($p>0.05$).

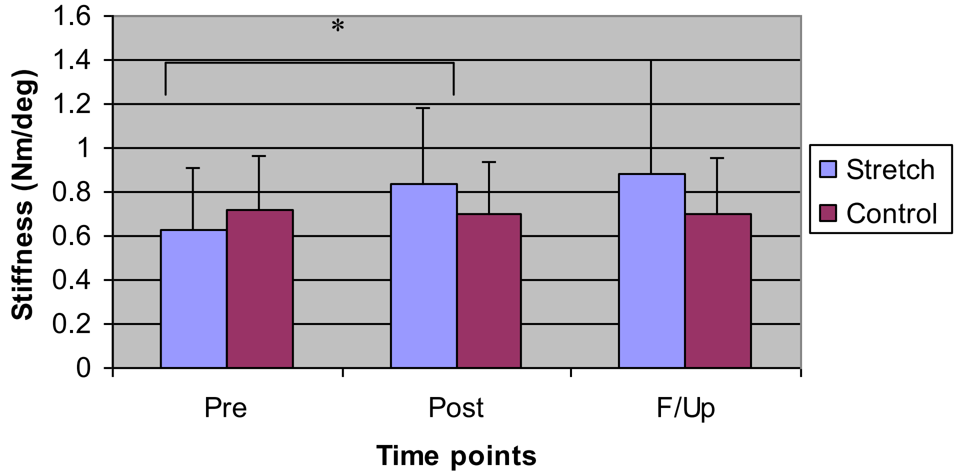


Figure 4.8: The stiffness in the final 10 % of extension range of motion for the stretch and control groups before and after the intervention and at the 12 week follow up (* indicates p<0.05). Data are means and standard deviations.

4.9 Aggregated Locomotor Function (ALF) Score

With respect to the Aggregated Locomotor Function (ALF) score, there was a significant main effect for time ($p<0.05$). There were no significant interactions for time by group or time by condition ($p>0.05$). Note that a reduction in time for the sum of the three activities indicates an improvement in function. Figure 4.9 displays the mean ALF score for the stretch groups and the control groups at the three time points; pre intervention, post intervention and at the 12 week follow up. Subjects in the stretch groups had a mean score of 23.1 (SD: 3.9) seconds pre intervention and this reduced significantly to 19.8 (SD: 5.4) seconds post intervention ($p<0.05$). This corresponded to a 20 % change in score. At the 12 week follow up time point, the subjects had a mean score of 20.9 (SD: 3.1) seconds. This difference was not significant when compared to the pre and post intervention score ($p>0.05$). Subjects in the control groups had a mean AFL score of 24.8 (SD: 3.1) seconds pre intervention and this reduced significantly to 22.3 (SD: 3.0) seconds post intervention ($p<0.05$). This corresponded to an 11 % change in score. At the 12 week follow up assessment, subjects had a mean ALF score of 23.2 (SD: 3.3) seconds. This difference was not significant when compared to the post intervention score (p>0.05).

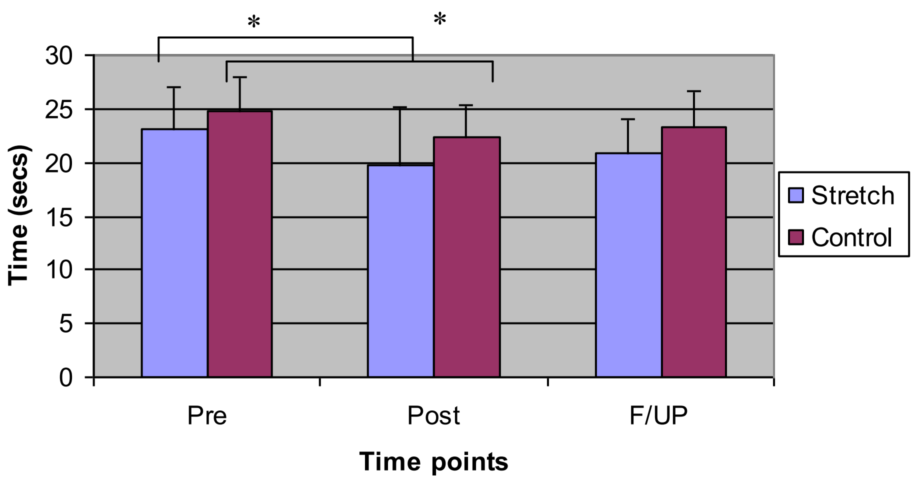


Figure 4.9: The ALF score for the stretch and control groups before and after the intervention and at the 12 week follow up (* indicates p<0.05). Data are means and standard deviations.

4.10 Gait characteristics

The main gait characteristics are displayed in Table 4.4. With respect to walking velocity, there was a significant main effect for time (p<0.05). There was no significant interaction for time by group or time by condition for stride length or step length (p>0.05). Table 4.4 displays the mean walking velocity for the stretch group and the control group at the three time points; pre intervention, post intervention and at the 12 week follow up. Subjects in the stretch group had a mean walking velocity of 1.84 (SD: 0.4) m/sec pre intervention and this improved significantly to 2.18 (SD: 0.4) m/sec post intervention (p<0.05). This corresponded to an 18.5 % change in walking velocity. At the 12 week follow up time point the subjects had a mean walking velocity of 2.06 (SD: 0.4) m/sec. This difference was not significant when compared to the post intervention time ($p>0.05$). Subjects in the control group had a mean walking velocity of 1.73 (SD: 0.3) m/sec at baseline and this improved significantly to 1.94 (SD: 0.4) m/sec after the intervention period ($p<0.05$). This corresponded to a 12.1 % change in walking velocity. At the 12 week follow up time point they had a mean walking velocity of 1.82 (SD: 0.3) m/sec. This difference was not significant when compared to the pre and post intervention time point ($p>0.05$).

Table 4.4: Gait characteristics of the stretch and control groups before and after intervention and at the 12 week follow up (* indicates p<0.05). Data are means and standard deviations.

	Walking Velocity (m/sec)			Stride Length (R) (m)			Stride Length (L) (m)			Step Length (R) (m)			Step Length (L) (m)		
Time Point	**Pre**	**Post**	**F/Up**	**Pre**	**Post**	**F/Up**	**Pre**	**Post**	**F/Up**	**Pre**	**Post**	**F/Up**	**Pre**	**Post**	**F/Up**
Stretch	1.84	2.18	2.06	1.40	1.45	1.33	1.41	1.43	1.37	0.70	0.73	0.67	0.68	0.70	0.67
(SD)	(0.4)	(0.4)*	(0.4)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Control	1.73	1.94	1.82	1.35	1.34	1.35	1.39	1.41	1.36	0.70	0.70	0.66	0.70	0.69	0.66
(SD)	(0.3)	(0.4)*	(0.3)	(0.2)	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)

Key: pre =pre intervention, post = post intervention, F/up = 12 week follow up, SD = Standard deviation

4.11 Patient global assessment of change

For the rating of the overall status of the condition since the last assessment, a reduction in score indicates an improvement in the condition. There was no significant main effect for time ($p>0.05$).There was no significant interaction for time or group ($p>0.05$). Subjects in the OA stretch group had a score of 3.3 (SD: 0.8) after the intervention and score of 3.0 (SD: 1.0) at the 12 week follow up assessment. Subjects in the OA control group had a score of 3.8 (SD: 0.7) after the intervention and a score of 3.8 (SD: 1.0) at the 12 week follow up assessment.

Chapter 5

Discussion

Introduction

This chapter presents the discussion relevant to Study 1, followed by the discussion relevant to Study 2. Thereafter, the limitations, summary and conclusions from the findings of both studies are provided. Areas for future research conclude the chapter.

5.1 Study 1 Analysis

The purpose of the first study was to examine the effects of an acute stretching hamstring intervention in subjects with OA of the knee and compare these with a group of subjects of a similar age without OA of the knee. As few other studies have examined the variables of torque and stiffness in association with range of motion in individuals with OA of the knee joint, this was also of interest.

The subjects for this study were recruited from the local community via a newspaper advertisement. Those with OA of the knee joint were similar in age to other studies that have investigated the effects of physiotherapy interventions in this population (Borjesson et al., 1996; McCarthy et al., 2004; Rogind et al., 1998).

The findings of this study have demonstrated an immediate increase in knee extension range of motion, in subjects with and without OA of the knee joint. Subjects in the OA group increased by 4.9° (6.5%), and subjects in the non OA group increased by 4.4° (5.6%). As there was no control group in the current study, it was not possible to calculate an effect size using the method described earlier. However, these results are consistent with other acute stretching interventions undertaken in uninjured young (De Pino et al., 2000; de Weijer et al., 2003; Ford & McCesney, 2007; Zakas, 2005) and elderly populations (Feland, Myer et al., 2001; Zakas et al., 2005; Zakas et al., 2006). With respect to the elderly populations, the magnitude of the increase in this study was similar to Feland Myer and Merrill (2001). These authors compared 1 x 30 second static stretching with a similar duration of proprioceptive neuromuscular facilitation (PNF) stretching to the hamstrings, and found a four degree increase in range of motion. In comparison, Zakas et al (2005) noted a greater increase of seven degrees in range of motion of hip flexion in a group of 20 elderly women who performed a 1 x 60 second stretch to all the major lower limb muscles including the hamstrings. In this study, a greater stretch duration of 3 x 60 seconds did not result in a greater increase in range of motion. Thus, it may be that three repetitions of the stretch are not required to achieve a significant increase in ROM. This may be useful in individuals with OA of the knee joint, as having to undertake fewer stretches may place less stress on the joint and therefore improve compliance with stretching programmes.

As acute stretching interventions are often used as part of a warm up procedure, Zakas et al (2006) compared the effects of a warm up routine (20 minutes walking and cycling), with static stretching and a combination of static stretching and warm up exercises to assess the effect on the hamstrings flexibility in 22 elderly women. Using the same stretching duration as the current study (3 x 60 seconds), a 6.4° increase in knee extension ROM was seen on the combined group and a 7° increase in the static stretch only group. No change in ROM was observed in the warm up only group. These results suggest that static stretching achieves a greater increase in joint ROM than a more dynamic exercise such as cycling or running and therefore supports the use of static stretching as part of the warm up routine, a finding similar to McNair and Stanley (1996) in younger subjects. This may be of value in the OA knee populations to ensure that exercises, such as strengthening are undertaken to utilize the full available range of motion, and therefore enhance joint function.

It was of interest that those subjects with OA of the knee joint achieved the same increase in range of motion as those without OA of the knee joint. A possible reason for this may be related to the level of impairment in the OA knee group. An evaluation of the WOMAC and the LLTQ scores (See Table 4.2) indicates that the subjects with OA knee were only moderately affected by the disease. Thus at this stage of the disease process, the soft tissues that resist changes in range of motion still appear to be adaptable. This is encouraging as exercise programmes that limit the progression of joint damage are part of the OARSI recommendations for the management of hip and knee OA (Zhang et al., 2008).

The changes in range of motion observed in the current study were accompanied by changes in peak torque and stiffness. An examination of the torque angle curves (See Figure 4.1) indicated that following the acute stretching intervention the curve had shifted to the right. The shift of the curve in this direction is consistent with other studies examining acute stretching protocols in young populations (Magnusson, Simonsen, Aagaard, & Kjaer, 1996; McHugh et al., 1999; Nordez et al., 2006). It indicates that following the stretching intervention, subjects were able to move into a greater range of motion with less resistance. This change was similar in the OA and the non OA groups at the baseline peak torque and at the 50% level. The mechanisms behind the torque angle relationship changes and the shift of the curve to the right following stretching are multifactorial and include viscous and structural changes. Viscous changes may be due to a redistribution of the more mobile constituents of the tissues, such as the polysaccharides and water (McNair et al., 2001), while the structural changes may be taking place in both the parallel and series elastic components of the muscle. They include uncrimping and slippage of collagen tissues (de Weijer et al., 2003; Magnusson, Simonsen, Per Aagaard et al., 1996; Stromberg & Wiederielm, 1969). Other temporary structural changes may include the breakage of bonds between actin and myosin filaments which have been shown to occur early in the range of motion (Proske & Morgan, 1999).

Apart from these temporary viscous and structural changes, stretch tolerance cannot be ruled out (Folpp et al., 2006; Halbertsma et al., 1999; Magnusson, Simonsen, Aagaard, Sorenson et al., 1996). Stretch tolerance is a term that describes the psycho-physiological response to stretching, that is, as the joint being stretched approaches the terminal range of motion, an increasing amount of discomfort is felt in the muscle tissue resisting that motion. Gajdosik et al (2004) commented that this phenomena is a subjective limitation of joint range and may not reflect the true mechanical end point of joint range of motion. Authors such as Halbertsma et al (1999) and Magnusson et al (1996) have suggested the increases in ROM observed following an acute stretching intervention are possible because the subject has adapted to pain and therefore is more tolerant of the stretching induced discomfort in the new range. It has been suggested that pain modulation via the nociceptive nerve endings in both muscles and joints may be responsible for this effect (Magnusson, Simonsen, Per Aagaard et al., 1996).

In the final 10% of movement, the slope of the curve became steeper indicating an increase in stiffness in the OA group only (See Figure 4.4). The mechanisms behind increased stiffness at this point are difficult to determine. While stretch tolerance may be responsible, a number of authors have demonstrated that the mechanical stiffness of the knee is larger in terminal extension and that this stiffness is generated by the posterior capsule and cruciate ligaments of the knee (Arms et al., 1984; Grood, Stowers, & Noyes, 1988; Grood et al., 1992). With arthritis, these structures have been shown to become less compliant and contribute to the typical capsular pattern of the knee causing reduced extension (Fritz, Delitto, Erhard, & Roman, 1998) and hence as the OA knee subjects moved into the new range following the stretching intervention, these less compliant tissues may have provided greater resistance to the movement. Alternatively, the observed increase in stiffness may reflect changes in the muscles per se. In this regard, perimysium in particular provides significant resistance to stretch at the end of range of motion (Herbert, 1988; Purslow, 1989). These thoughts should be seen as speculative at this time.

In summary, following an acute 3 x 60 second bout of hamstring muscle stretching, knee extension range of motion improved. Such immediate increases in ROM are important as acute stretching programmes are often used as a precursor to other activities. This is especially so in the case of individuals with OA of the knee joint as they are often encouraged to participate in other exercise regimes, such as strengthening programmes following a warm up procedure. The increase in the knee joint angle was accompanied by an increase in peak torque and a shift of the torque angle curve to the right. There was also a greater increase in stiffness towards the terminal range of knee extension ROM in the OA knee group. This increase in stiffness may be reflective of changes within the muscle and joint as an adaptation to the joint disease. Most importantly, having degenerative joint disease did not affect the subjects’ ability to demonstrate improvements in range of motion in the knee joint. These findings indicate that there are benefits of acute stretching in older individuals and those living with osteoarthritis of the knee joint, and provide evidence for developing longer term stretching programmes for this population such as that undertaken in Study 2.

5.2 Study 2 Analysis

The purpose of the second study was to examine the effects of a six week periodic lower limb stretching intervention in subjects with OA of the knee and compare these with a group of subjects of a similar age without OA of the knee. No other studies have examined the variables of torque and stiffness in association with range of motion in individuals with OA of the knee joint. A secondary aim of the study was to examine the effects of the stretching intervention on functional activities. A randomized controlled trial design was used for this study. A number of important methodological considerations were implemented. These were; blinding the allocation of the subjects to the relevant groups, blinding of the assessors to the group allocation, and blinding of the therapists who delivered the intervention. These measures were put in place in the current study, as the review of literature highlighted low levels of compliance in the areas of assessor blinding and subject blinding. A twelve week follow up assessment was also undertaken at the conclusion of the intervention to measure the lasting effects of these interventions.

In this study, those with OA of the knee joint were similar in age to other studies that have investigated the effects of physiotherapy interventions in this population (Borjesson et al., 1996; McCarthy et al., 2004; Rogind et al., 1998). Based on the WOMAC score, the levels of disability of the OA of the knee subjects could be gauged as moderate with mean scores ranging from 686 to 819 out of a possible 2400.

5.2.1 Analysis of the stretching intervention

The main findings of the study have demonstrated that OA and non OA groups were not significantly different across any of the measured variables. However, post intervention, those subjects allocated to the stretching groups were significantly different to the control groups with respect to the primary variables of knee extension range of motion, peak passive torque and stiffness. With respect to knee extension ROM, the stretch and control groups had a similar range at baseline, but the stretching groups improved significantly more following the six week stretching intervention. Subjects in the stretch groups had a 7.8° increase in knee extension (effect size 0.7), which equates to an 11.5 % increase in ROM, while the subjects in the control group did not change significantly. This effect size is greater than any of the other reviewed studies that investigated stretching in subjects with OA of the knee joint (0.3 in Borjesson et al (1996) and Peloquin et al (1999)). However, it was lesser in magnitude than two studies that investigated stretching in uninjured elderly populations (1.2 in Gajdosik et al (2005) and 2.6 in Girouard et al (1995)).

The total stretching duration (TSD) used in the current study (5400 seconds) was greater than some other studies in elderly populations (Raab et al., 1988), but less than others (Feland, Myrer et al., 2001). Raab et al (1988) noted an 11.4 degree increase in hip flexion with a TSD of 1500 seconds and Giroud and Hurley (1995) found a 10 degree increase in hip flexion with a TSD of 1800 seconds. Thus, in comparison to these studies a much greater volume was used to achieve a smaller change in ROM in the current study. In the one other study that used a 60 second stretch, Feland et al (2001) had subjects stretch for a total of 7200 seconds and observed an increase in hip flexion of 14.4 degrees. These results indicate that the optimal stretching duration may not yet be clear for elderly subjects, and that further work is required that focuses upon different prescriptions (sets and repetitions).

The increase in knee extension range of motion in the stretching groups was also accompanied by an increase in peak torque and stiffness in the final 10% of the range of motion. With respect to the increase in peak torque, the magnitude of this increase was high (48%). This was accompanied by a 35% increase in stiffness in the final 10% of knee extension ROM. These increases are reflected in changes in the torque-angle curve which moved further upward to the left (see Figure 4.5). This implies following the stretching intervention the subjects moved further into the range of motion, but this was accompanied with greater resistance to passive stretch. These changes are similar to those found by Gajdosik at al (2005) who demonstrated that following an eight week stretching programme to the calf muscles of elderly women with reduced ankle dorsiflexion, there was an increase in maximal dorsiflexion ROM and an associated increase in maximal torque and a shift of the torque angle curve to the left. The authors of this study felt this increase in maximal dorsiflexion and torque indicated that the stretching intervention had enhanced the muscles ability to withstand a maximal passive load.

The results of the current study were also consistent with other studies that have found increases in knee extension ROM associated with increases in peak passive torque in younger subjects (Chan, Hong, & Robinson, 2001; Gajdosik, 1991; Reid & McNair, 2004). An examination of the force angle curve in the study by Reid and McNair (2004) indicated that while the post intervention curve initially followed a similar path to the pre intervention curve, the post intervention curve was longer and steeper particularly in the final 10% of the new knee extension ROM. However, the curve did not move to the left or right but just continued further into the range, an observation also noted by Magnusson (1996). These findings would be in keeping with the concept of stretch tolerance as suggested by some authors, who have argued that this lack of change in the force curve was related to stretch tolerance and not physical changes within the muscle (Folpp et al., 2006; Magnusson, Simonsen, Aagaard, Sorenson et al., 1996). Reid and McNair suggested these increases in torque and stiffness may also have been associated with the increase in ROM, due to an increase in the number of sarcomeres added in series as a consequence of the stretching stimulus, a view also postulated by Gajdosik (1991). Stretching exercises undertaken in a terminal range of joint motion place considerable force on the muscle tendon unit. The increased stiffness following the stretching intervention observed in the current study may have occurred as a result of such structural changes or hypertrophy creating an increase in the cross sectional area of the muscles contractile and/or non contractile tissues. Increases in muscle stiffness and cross sectional area have been observed following strengthening exercises (Chleboun, Howell, Conaster, & Giesey, 1997; Klinge et al., 1997) but may not have been considered as a consequence of the stimulus to long term stretching interventions.

The increases in peak torque and stiffness associated with the increase in knee joint ROM could also be reflective of the methodology used in the current study. In the current study the torque angle curves were assessed from a fixed point (80° knee flexion start angle) before and after the intervention. Other studies have examined the torque angle curves throughout the full available range as determined by the subject (Gajdosik at al 2005). This difference in methodology may make direct comparison of the torque angle changes more difficult. Also, in a number of the other studies (Magnusson, 1998; Magnusson et al., 2000; Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996) that have examined viscoelastic properties of muscle with stretching interventions, the subjects have been taken to the terminal range of motion pre intervention and returned to that same position post intervention (the so called constant angle stretch protocol) (Magnusson et al., 1995; Magnusson, Simonsen, Aagaard, & Kjaer, 1996). In the current study the subjects were encouraged to allow the dynamometer to take them to their maximal tolerable limit pre intervention and then following the intervention, were again encouraged to let the dynamometer take them as far as tolerable, the so called variable angle stretch protocol (Magnusson, Simonsen, Per Aagaard et al., 1996). In studies that have used this methodology an increase in range of motion post intervention has been accompanied by an increase in peak torque (Magnusson, Simonsen, Per Aagaard et al., 1996) and stiffness in the final 10% of knee extension ROM (Chan et al., 2001; Reid & McNair, 2004). Using this variable angle methodology as used in the current study, it would be expected that the subject's peak torque and stiffness would increase in the new range of motion, indicating the subjects can tolerate higher forces within the new range.

Until recently, the ability to explicitly examine the changes taking place with the muscle fibres has not been possible in human subjects. Previously, evidence from studies involving animals and experimental protocols that involve immobilization of the muscle in a lengthened position has shown that increases in muscle fibre lengths do occur (Herbert & Balnave, 1993; Williams & Goldspink, 1973). Williams and Goldspink (1973) demonstrated that a muscle immobilised in a lengthened position had increased mass, and added sarcomeres in series and that this event occurred primarily at the distal end of the muscle fibres. Goldspink (1974) suggested that such changes were a local response to increased tension in the muscle. With the advent of diagnostic ultrasound the ability to examine the changes in the muscle tendon unit has become possible (Herbert et al., 2002;

Kawakami et al., 2008; Mahieu et al., 2007; Morse et al 2008) and therefore should provide further information on these changes in the future.

The improvements in range of motion in the current study were not maintained at the 12 - week follow up, however peak passive torque and stiffness in the final 10% of knee extension ROM were. With respect to the ROM loss, this is not surprising as subjects were instructed to return to their normal daily activities and discontinue the stretching exercises. The reduction in ROM is also consistent with other research investigating the effects of cessation of stretching. Willy, Kyle and Moore et al (2001) have demonstrated that a10 degree increase in knee extension range of motion following a six week stretching programme, was lost once the intervention was ceased for four weeks. The reasons why the peak torque and stiffness were maintained at the follow up are not clear. Whilst subjects were instructed not to continue stretching, diaries were only used in the intervention period to monitor the volume of stretching and therefore it is not possible to determine if the subjects did in fact continue to stretch. The subjects were also more active than subjects in other studies (Feland, Myrer et al., 2001; Gajdosik, Vander Linden, McNair, Williams et al., 2005) and therefore may have been able to maintain these variables through this activity. There is little research at this time as to the volume of stretching required to maintain ROM following the initial intervention period.

5.2.2 Analysis of functional changes

A secondary aim of the study was to investigate the effects of the stretching intervention on aspects of function. The Aggregated Locomotor Functional (ALF) score was used for this purpose. The results of the study indicate that there was an overall effect for time but no difference between the stretch and control group and no difference between those with OA and those without OA. These results provide evidence that stretching alone is not enough to induce improvements in these gait activities. Such activities might also be influenced by strength, balance and proprioception. It may be that these variables are more important when planning exercise interventions for those with OA of the knee joint.

As improvements were observed in the control groups, there may have been a learning effect over the three measurement points. In a number of the other gait and functional studies, subjects were asked to walk at a self moderated pace (Gok et al., 2002; McCarthy et al., 2004; McCarthy & Oldham, 2004), whereas in the current study the subjects were encouraged to undertake the tasks as quickly as possible. This may have led to a competitive element being present and furthermore a greater understanding of the task requirements by the second and third measurement points.

The lack of difference may have been because the subjects were recruited from the community rather than from hospital waiting lists, where subjects are often more disabled with the disease. The subjects with OA of the knee joint in the current study were not as disabled as subjects in other studies (Deyle et al., 2005; Deyle et al., 2000) who had WOMAC scores ranging from 1038-1389 out of a possible score of 2400. The subjects in the non OA group had to be 'fit and active'. This may have lead to the recruitment of a group of subjects who were in fact more active than other studies that have investigated stretching interventions in elderly where participants were required to be more sedentary (Feland, Myrer et al., 2001; Gajdosik, Vander Linden, McNair, Williams et al., 2005). Interestingly, the levels of medication use by the subjects in the current study was low, with only 34% of subjects taking non steroidal anti inflammatory drugs for the arthritic knee possibly indicating low levels of discomfort in the knee and hence the greater level of functioning.

An analysis of the global assessment of change indicated that subjects with OA knee rated the overall status of the knee with a score 3.3 (SD: 0.8) after the intervention and 3.0 (SD: 1.0) at the 12 week follow up assessment. This would indicate the status of the knee joint was unchanged following the stretching intervention. Equally these results indicate the knee joint may not have deteriorated over time. This is important as the OARSI guidelines for the management of OA of the hip or knee indicate that prevention of deterioration should be a key goal of treatment interventions (Zhang et al., 2008).

Direct comparison of these results with other studies that have used the ALF score is not entirely possible because of the modifications made in the current study to accommodate the Gait Mat®. However, as the ALF score is an aggregated score, some aspects are comparable. In the current study subjects in the stretch group had a 20% improvement in the total ALF score and the control group an 11% improvement. Larger improvements in the ALF score have been observed following exercise programmes by McCarthy et al (2004). A 30% improvement in the ALF scores was found in 214 subjects with OA knee who took part in lower limb muscle strengthening programmes either at home or in a class based exercise programme.

Perceived function was assessed with LLTQ questionnaire and the WOMAC. The results of the current study found that for the LLTQ there was no significant difference between the OA knee stretch and control groups across the measurement points, and less than two points change was observed at any of the measured time points. McNair et al (2007) have indicated that a Minimal Important Difference in activities of daily living (ADL) is two point two points.

The WOMAC total score for the OA stretch group in the current study did not reduce significantly following the intervention. The effect size for this variable was small (0.2). While a comparable effect size was not able to be calculated, in the study by Deyle et al (2005) a significant change of 45% in the WOMAC total score was observed after the eight week intervention period. However in this study, stretching was combined with manual therapy and strengthening exercises to the knee joint. It may be that this combination is more effective in altering the combination of pain, stiffness and function as measured by the WOMAC. Unfortunately, Deyle et al (2005) did not provide any measures of ROM to allow a more direct comparison with the current study.

5.2.3Analysis of gait characteristics

The use of the Gait Mat® allowed the collection of data related to the variables of gait velocity and step and stride length. The results of the study indicated that there was a main effect for time for gait velocity but no significant differences between the groups or condition. Subjects in the stretch group had a walking velocity of 1.84 (SD: 0.4) m/sec and this improved to 2.18 (SD: 0.4) m/sec following the intervention. Subjects in the control group had walking velocity of 1.74 (SD: 0.3) and improved to 1.94 (SD: 0.4) m/sec. When compared to other studies that have measured walking velocities in subjects with OA and those of elderly subjects without OA knee, subjects in the current study walked more quickly. In a study by Oberg (1993) subjects without OA aged 60 -70 who were encouraged to walk fast, had a gait velocity of 1.55 -1.63 m/sec. In the studies that have examined subjects with OA knee, walking velocities range from 0.55 m/sec (Al-Zahrani & Bakheit,

2002) up to 1.09 m/sec (Gok et al., 2002; Kaufman et al., 2001; Messier et al., 1992) have been observed. The subjects in the current study are nearly 0.5 -1.00 m/sec faster than the subjects in these studies. The possible reasons for this relate to the level of disability and fitness characteristics of the subjects in this cohort, as already mentioned.

With respect to the other gait variables of step and stride length, the results of the study indicate no significant differences for time group or condition. The values recorded in the study of approximately 1.35- 1.41 meters were similar to values recorded in other studies measuring these gait parameters (Messier et al (1992) 1.3 meters, and Al-Zahrani et al (2002) 1.27 meters) for subjects without pathology. Again the values in the current study were higher compared to those subjects with OA knee measured in other studies (Messier et al (1992) 1.2 meters and Al-Zahrani et al (2002) 0.75 meters).

5.2.4 Analysis of the compliance with the programmes

Compliance to the intervention in the study was fair in some areas and very good in others. The attendance rate for the subjects in the OA stretch and non OA stretch groups was less than the subjects in the OA control group who received the placebo (50% and 58% respectively versus 83%). One of the main reasons stated by the subjects for these variable levels of attendance was the requirement of many to still attend part time work duties. This reduced attendance may have had an impact on the results. However the decision to have a supervised programme was based upon previous research. McCarthy et al (2004) have demonstrated that when prescribing exercise programmes to individuals with OA of the knee joint, supervision in a clinic environment as an adjunct to the home programme alone is more effective. McCarthy et al showed that those subjects who received clinic supervision twice a week over an eight week period had a greater improvement in locomotor function and pain with walking when compared to those who undertook the exercises in an unsupervised way in their own homes.

The compliance with the home programme in the current study was better than the supervised programme. Subjects in the stretch OA group had a compliance rate of 98% and subjects in the non OA stretch group had a compliance rate of 96%. These rates are higher than other physiotherapy studies that have investigated home exercise compliance rates. Schneiders, Zusman and Singer (1998) investigated patient compliance in 100 subjects with acute low back pain. These researchers found that the use of written and illustrated instruction as well as verbal feedback generated compliance rates of over 77%. In the current study strategies that may have contributed to this higher level of compliance included the use of an instruction leaflet outlining the stretches and alternatives where appropriate (see Appendix 9), the use of a diary to record the frequency of home stretches and the verbal instruction given to all subjects in the stretching groups prior to commencing the programme and during the supervised session. Another reason for the high levels of compliance may be due to the recruitment methods. With subjects recruited from the local community they may have had an interest in helping improve the status of their OA knee. Campbell, Evans and Tucker et al (2001) have demonstrated that compliance to exercise programmes in patients with OA of the knee are improved where there was a perception that physiotherapy would help the condition, and where subjects have a positive attitude to exercise. This concept was not investigated in the current study but could be worthy of investigation in the future.

5.3 Limitations of Study 1 and Study 2

One of the main limitations of these two studies was that passive capsular restriction of knee joint per se was not measured before and after the stretching intervention. It was thought that the extensibility of the hamstrings might have been more affected by the loss of knee extension in these subjects and therefore a greater emphasis was placed on the measurement of the muscle properties rather than those of the knee joint capsule. The methodology used was chosen to maximize the stretch on the hamstring muscle and reduce the chance of the knee joint capsule contributing to the potential changes in knee extension range of motion. A future study could look at the acute and lasting effects on the capsule of the knee joint.

There are a number of methodological considerations for Study 1. Firstly, the duration of the rest phase between stretches was 60 seconds. Other acute studies have used shorter rest phases ranging from 10 seconds (de Weijer et al., 2003) to 30 seconds (Magnusson, Simonsen, Aagaard, & Kjaer, 1996). Having a longer rest period may have had an effect on the improvement in range of motion. Having a shorter rest period may allow less time for the tissue to return to pre stretch levels and induce a more cumulative response. Secondly, the methodology required taking the mean of the two peak knee extension tests before and after the intervention. Given that resetting the KinCom takes more than 60 seconds between test sequences, it is possible that what were actually being measured were the effects of the last test stretch and not the accumulative effect of the 3 x 60 seconds intervention. Thirdly, the subjects were stretched to 80% of their maximal pre intervention ROM. This was done to reduce the possibility of increased EMG activity when applying stretches to maximal ROM, however this type of stretch may have influenced the results and a greater increase in

ROM may have been achieved if the stretch was taken to this maximal range during the intervention. Studies by McNair et al (2001) have demonstrated though that stretching the joint to 80% of the maximal range still has a significant effect on range of motion and passive torque within the first 20 -30 seconds of the stretch procedure.

The determination of the maximal knee extension range of motion in both studies was reliant on the subject's perception of the stretch discomfort. This has been suggested to be a psycho-physiological response to stretching (Gajdosik et al., 2004) and may not reflect the true mechanical end point of joint range of motion. In the subjects with OA of the knee the pain in the knee joint itself may have impacted on the terminal range of motion. This pain levels within the knee joint at the start of testing and at the conclusion of the stretching procedure could be added in future studies to gain a clearer picture of this variable on the knee extension range of motion.

The recruitment of the subjects for this study came from the local population and not from medical specialists, hospital waiting list or registered health professionals. This may have introduced an element of bias in that the OA knee subjects may have had an interest in finding some way of improving their condition. Also as stated previously the level of disability in these subjects was moderate. At most, had these subjects been selected from a hospital waiting list or orthopaedic clinic they may have had a higher level of disability. The wording of the advertisement also indicated that the non OA subjects had to be 'fit and healthy'. This too may have affected the results as these subjects were functioning at a high level already and therefore to see a difference in their functional measures may have been less likely.

In Study 2, the random allocation of the subjects to the four groups was undertaken by staff independent of the project. Despite clear instruction about the allocation of the sealed envelopes to the subjects, a mistake was made in the group allocation that meant the groups were unevenly distributed. This may have had an effect on the ability to detect statistical change between the OA groups and the non OA groups.

The stretching intervention in Study 2 was delivered to all the major muscle groups in the lower limb, yet only the hamstring muscles were assessed for changes in ROM, peak passive torque and stiffness. Whilst argued initially that the hamstring muscle may have been more affected by a loss of knee extension ROM than other groups, the other groups were not explicitly measured to determine their contribution to the loss of ROM. Investigating the specific effects of stretching exercises to the other muscles passing over the knee joint could be the subject of further studies. Stretching to all the lower limb muscles was also instigated to try and achieve maximal improvements in function. As no significant change in the ALF score occurred it may have been even more difficult to detect a difference in function if this more extensive stretching programme had not been utilised.

The specific stretch to the quadriceps muscle used in Study 2 may have been focussed more on the bi-articular rectus femoris muscles and not the other mono-articular components (vastus lateralis, medialis and intermedius) and hence these may not have been maximally lengthened. Reducing the amount of hip extension may need to be introduced in future studies to ensure this occurs.

The review of literature was undertaken using the format of a systematic review. However it was not a true systematic review, as it is normal practice to have two or more reviewers assess the methodological quality of the selected studies. In this thesis, the primary researcher (DR) analysed the methodological quality of the studies and assigned a score. This may have introduced an element of bias; however where there was a question concerning the score, independent advice was sought.

5.4 Summary and conclusions

The purpose of these two studies was to investigate the effect of an acute and periodic hamstring-stretching intervention on knee extension range of motion, peak passive torque and stiffness in subjects with and without OA of the knee. This was seen as important as no other studies that have investigated these variables in subjects with OA of the knee joint. Those studies that have instigated stretching interventions on this population have done so in combination with other modalities and so prior to this study the effects of a stretching intervention alone were unknown.

The results of these two studies have demonstrated that those people with OA of the knee and those without, are capable of increases in knee extension range of motion, peak passive torque and stiffness in both an acute and periodic setting. A four to five degree increase was seen in the acute study and an eight degree increase in the periodic study. These results were consistent with other studies examining these parameters in younger and older subjects who did not have OA of the knee.

An important difference in the viscoelastic characteristics of the hamstring muscle were demonstrated depending on the type of setting. In the acute setting there was significant movement of the torque angle curve to the right indicating that the intervention had produced an increase in range of motion associated with less resistance in the tissues. In contrast, the periodic stretching intervention caused movement of the torque angle curve upwards and to the left, demonstrating that an increase in range of motion in these subject's tissues was associated with an increase in the tissues resistance. The reasons for these differences most likely reflect a combination of stretching, perceptual and tissue mechanisms.

The ability of the periodic stretching intervention to improve functional activities such as walking, transferring from sitting and stair climbing, was not demonstrated in the current study as improvements in function were found in both the stretch and the control groups. This lack of difference may have been due to the characteristics of the subjects recruited for the study who may not have been as disabled by the disease as other people suffering OA of the knee. Another possibility is that other types of exercise such as strengthening may need to accompany the stretching programs to see a greater improvement in function. This combination of exercises has been demonstrated to be effective in the OA knee populations by (Deyle et al., 2005) and (Deyle et al., 2000).

These two studies provide evidence that people with OA of the knee and those of a similar age without OA of the knee joint are still capable of significant changes in ROM with stretching interventions. As one of the key recommendations of the OARSI guidelines for the management of OA is to provide exercise programmes that maintain range of motion, and in doing so reduce the deterioration of the joint associated with the disease process (Zhang et al., 2008), the current findings are valuable.

5.5 Future Research

There are a number of other areas worthy of future research. Firstly, a future study that compared a specific stretching intervention to the hamstrings with specific knee joint mobilisation, with passive knee joint extension as the dependent variable, would be of interest. Secondly, as the subjects in the current study had only limited disability, a study that investigated the same variables in a sample that were more disabled would be of interest. Thirdly, with respect to stretching interventions in general, there has been little research undertaken on the optimal levels of stretching required to maintain range of motion once the initial improvements have been observed. This is of importance particularly in groups with chronic conditions such as OA, as the long term stretching may be helpful in preventing further loss of range of motion and function. Fourthly, whilst RCT's are the preferred methodology to investigate the effectiveness of various treatments, further insights into the effects of OA on individuals might be from qualitative methodologies. Endeavouring to gain an understanding of such matters as why subjects complied or not with the treatments, qualitative aspects of the subject's pain experiences, why so few subjects took medication and subject's motivation to be involved in the self management of their condition, would be of interest. Fifthly, given that the LLTQ is a relatively new lower limb functional questionnaire; further analysis of its psychometric properties compared to more commonly used OA measures such as the WOMAC would be of interest. Finally, a more explicit examination of these variables could be undertaken by gender. It is known that female subjects are more flexible than male subjects and therefore to apply the stretching intervention to females and males separately would be of interest. In the current study this was not undertaken as the primary aim was to investigate the effects of the stretching intervention on an osteoarthritic population and compare these results with other studies of similar age and gender balance.

Appendices

Appendix 1

Cochrane Musculoskeletal Injuries Group (CMSIG) Scoring System for Methodological Quality

The following aspects of internal and external validity were assessed using the criteria **A-L** listed below.

A) Was the assigned treatment adequately concealed prior to allocation?

2= method did not allow disclosure of assignment.

1= small but possible chance of disclosure of assignment or unclear

0= clearly no, quasi randomised or open list/tables

B) Were the outcomes of patients/participants who withdrew included in "intention to treat" analysis?

2= withdrawals well described and accounted for in analysis.

1= withdrawals described but no analysis possible.

0= Inadequate detail and no analysis.

C) Were outcome assessors blinded to treatment status?

2= effective action taken to blind assessors.

1= small or moderate chance of un blinding of assessors.

0= not mentioned or not possible

D) Were the treatment and control group comparable at entry?

2= if comparable Means, SD SE confidence intervals for each group expressed or confounding adjusted for in analysis.

1= confounding appears small.

0= statistically significant differences between groups present and no adjustments made or baseline data does not include all those who were randomised.

E) Were the subjects blind to assignment status after allocation?

2= effective action taken to blind subjects.

1= small or moderate chance of un-blinding of subjects.

0= not possible or not mentioned, or possible but not done.

F) Were treatment providers blind to assignment status?

2= effective action taken to blind treatment providers.

1= moderate or small chance of un-blinding of treatment providers.

0= not possible or not mentioned, or possible but not done.

G) Were care programmes other than trial options, identical?

2= care programmes clearly identical.

1= clear but trivial differences.

0= not mentioned but clear and important differences in the care programmes.

H) Were inclusion and exclusion criteria clearly defined?

2= clearly defined.

1= described but inadequately defined.

0= not defined or not possible to see how the sample was made up.

I) Was the intervention clearly defined?

2= clearly defined interventions applied with standard protocol.

1= clearly defined but application of protocol not standardised.

0= intervention or application of protocol not mentioned.

J) Were outcome measures clearly defined?

2= clearly defined with specific algorithm and method of data collection described.

1= algorithm defined but data collection poorly described.

0= no clearly defined algorithm and method of data collection unclear.

K) Were diagnostic tests used in outcome assessment clinically useful?

2= accuracy and precision are established for measures and are the best available at the time of the study.

1= accuracy and precision established at the time but not the best available.

0= accuracy and precision not established.

L) Was the duration of the surveillance active and clinically relevant?

2= surveillance active and timing of outcome measures judged optimal at time of review.

1= surveillance active and timing of outcome measures appropriate but not optimal at time of review.

0= not active or appropriate.

Appendix 2

MEMORANDUM

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

To:	Peter McNair
From:	**Madeline Banda** Executive Secretary, AUTEC
Date:	17 November 2006
Subject:	Ethics Application Number 06/189 **The effects of hamstring stretching on a range of motion and viscoelasticity in individuals with OA of the knee: Study One.**

Dear Peter

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 9 October 2006 and that as the Executive Secretary of AUTEC I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 11 December 2006.

Your ethics application is approved for a period of three years until 15 November 2009.

I advise that as part of the ethics approval process, you are required to submit to AUTEC the following:

- A brief annual progress report indicating compliance with the ethical approval given using form EA2, which is available online through *http://www.aut.ac.nz/research/ethics*, including when necessary a request for extension of the approval one month prior to its expiry on 15 November 2009;
- A brief report on the status of the project using form EA3, which is available online through *http://www.aut.ac.nz/research/ethics*. This report is to be submitted either when the approval expires on 15 November 2009 or on completion of the project, whichever comes sooner;

It is also a condition of approval that AUTEC is notified of any adverse events or if the research does not commence and that AUTEC approval is sought for any alteration to the research, including any alteration of or addition to the participant documents involved.

You are reminded that, as applicant, you are responsible for ensuring that any research undertaken under this approval is carried out within the parameters approved for your application. Any change to the research outside the parameters of this approval must be submitted to AUTEC for approval before that change is implemented.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all written and verbal correspondence with us. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at charles.grinter@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the Committee and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Madeline Banda
Executive Secretary
Auckland University of Technology Ethics Committee

Appendix 3

MEMORANDUM

To:	Peter McNair
From:	**Madeline Banda** Executive Secretary, AUTEC
Date:	17 November 2006
Subject:	Ethics Application Number 06/190 **The effects of lower limb stretching on range of motion and tissue viscoelasticity in individuals with OA of the knee: Study Two.**

Dear Peter

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 9 October 2006 and that as the Executive Secretary of the AUTEC I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 11 December 2006.

Your ethics application is approved for a period of three years until 15 November 2009.

I advise that as part of the ethics approval process, you are required to submit to AUTEC the following:

- A brief annual progress report indicating compliance with the ethical approval given using form EA2, which is available online through http://www.aut.ac.nz/research/ethics, including when necessary a request for extension of the approval one month prior to its expiry on 15 November 2009;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/research/ethics. This report is to be submitted either when the approval expires on 15 November 2009 or on completion of the project, whichever comes sooner;

It is also a condition of approval that AUTEC is notified of any adverse events or if the research does not commence and that AUTEC approval is sought for any alteration to the research, including any alteration of or addition to the participant documents involved.

You are reminded that, as applicant, you are responsible for ensuring that any research undertaken under this approval is carried out within the parameters approved for your application. Any change to the research outside the parameters of this approval must be submitted to AUTEC for approval before that change is implemented.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all written and verbal correspondence with us. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at charles.grinter@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the Committee and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Madeline Banda

Executive Secretary

Auckland University of Technology Ethics Committee

Appendix 4

Participant Information Sheet

Study 1

Date Information Sheet Produced: 25 October 2006

Project Title

The effects of hamstring stretching on range of motion and tissue viscoelasticity in individuals with OA of the knee.

An Invitation

You are invited to participate in a research study performed as part of the requirements for completion of a Doctor of Health Science thesis for Duncan Reid. Participation is completely voluntary and you may withdraw from the study at anytime without giving a reason or being disadvantaged.

What is the purpose of this research?

People with osteoarthritis (OA) frequently complain of pain and stiffness in the joints affected by this disease. The knee is a commonly affected joint. As a consequence of pain and stiffness, the knee joint can lose range of motion. Stretching, particularly to the hamstring muscles is one activity that may reduce this loss. Patients without OA also lose flexibility as they age. Therefore both of these groups of people may benefit from stretching exercises. While there is some research into the effects of stretching in elderly populations there are few studies that have investigated the effects of stretching in patients with OA of the knee. Therefore the aim of the study will be to investigate the flexibility characteristics of the hamstring muscles patients with osteoarthritis (OA) of the knee and compare these with subjects of a similar age without OA, in a single stretching session.

These results will be published in relevant scientific journals and also presented at national and internationals conferences.

How was I chosen for this invitation?

You were selected for this study by answering an advertisement in the local newspaper and advertisements placed around the AUT campus and the North Shore region. You may also have been part of the AUT or YMCA Never Too Old programme or belong to the Arthritis foundation.

The requirements for participating are as follows:

For the non OA knee group, men and women aged 60-75 years of age, who are living in the local community are eligible. You must be able to read, understand basic English and simple verbal commands.

For the OA knee group, men and women aged 60-75 years, who are living in the local community, with a history of OA in one or both knees are eligible. You must be able to read, understand basic English and simple verbal commands. If you are taking non-steroidal anti-inflammatory (NSAID) medication (e.g. Voltaren) you will be able to continue to use this medication.

In both types of participants you will need to fill out a short questionnaire that assesses your current level of health and to ensure that you will be able to participate in the testing. This form is called the Par-Q.

We will also have to check that you are not currently participating in physical therapy treatments for the OA knee condition nor have other conditions that would affect your ability to undertake the testing such as neurological conditions (such has a past stroke) or significant heart conditions.

What will happen in this research?

There will be four research assistants who will help you with the procedures listed below. These assistants are final year physiotherapy students. They will be working under the supervision of the principal researcher and will have been thoroughly trained in the use of the procedures and the testing.

The procedure will be in three parts.

Firstly, you will have the flexibility of your hamstring muscles (these are on the back of your thigh) tested on a machine called a Kin Com at the Physical Rehabilitation Research Centre at AUT. (see Figure 1 below) The test is painless and requires no activity from you. All it does is slowly straighten your lower leg until you feel some tightness in the back of your leg. The test position for this is sitting supported in the machine. When you have reached the position that creates a modest stretch in the hamstring muscle you push a button that stops the test sequence. This position of your end of range of motion is then recorded. At the same time, the electrical activity of your muscles will be recorded. This is called Electromyography (EMG). The reason for recording this information is that we want to ensure that your muscles are not creating the movement of the limb and that the Kin Com is passively moving the leg. Electrodes will be attached to your thigh muscles front and back. These electrodes are self-adhesive. The hair on your leg where the electrodes will be placed will need to be removed and this will be done with a disposable razor. Once on your skin, the electrodes, are not painful and do not in any way generate electrical impulses.

Secondly the Kincom will provide a hamstring stretch for you. The machine will take the knee joint to a position that is 80% of the range you achieved in the first part of test. You will be held in this position for 60 seconds and then have a 30 second rest. This process will be repeated two more times. At the conclusion of this process you will repeat the first test described in the previous paragraph.

Thirdly, at the conclusion of the Kincom testing you will be asked to perform a strong contraction of the thigh muscles. This will allow us to see what proportion of muscle activity was taking place during the test procedure.

Following these tests on the Kincom, we will ask you to fill in two questionnaires about your level of function.

The Questionnaires are the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Lower Limb Task Questionnaire (LLTQ)

The WOMAC asking you about pain, stiffness and physical activities you do in the day. There are a total of 24 questions, two questions relating to pain, two questions relating to stiffness and 17 questions relating to physical function. The questionnaire is self administered and takes approximately 5 to 10 minutes to complete.

The LLTQ involves 10 questions that relate to activities of daily living that require use of the lower limbs. Each question has a five-point scale and subjects rate the activity from no difficulty (4 points) to unable to do (0 points).

Figure 1 The set up in the KinCom Machine

What are the discomforts and risks?

During the Kincom procedure described above, the sensation you will feel is a stretch to the hamstrings. You are in complete control of the amount of discomfort you can tolerate. There is a cut out switch that turns off the test if at any stage you are not happy with the sensation or experience pain (see Figure 1). The only potential risk associated with the research is a mild muscle strain. The research assistants undertaking and supervising the study all hold current first aide certificates.

How will these discomforts and risks be alleviated?

Should you feel any pain or discomfort that occurs during or following the testing you will receive appropriate treatment from a physiotherapist or referral back to your doctor

What are the benefits?

Flexibility is an important component of general health. Flexibility can be lost with age and disease processes. Gaining a greater understanding of the effects of stretching on both elderly subjects and those with OA of the knee will help physiotherapists design the most appropriate stretching regimes to improve your health.

What compensation is available for injury or negligence?

Compensation is available through the Accident Compensation Corporation within its normal limitations.

How will my privacy be protected?

Once you have consented to participation in the project and we have you contact details, you will be entered into the research data base and referred to by number only. In that way whenever anything is published and reported from the research you will remain confidential. The data concerning the project is stored in locked cabinets at AUT or password protected computers. Only the principal researcher and the supervisor have access to this information.

What are the costs of participating in this research?

There is no cost other than your time. You will be provided with petrol vouchers to cover the cost of getting to and from the testing site. The testing procedure will take approximately 60 minutes.

What opportunity do I have to consider this invitation?

If you are interested in participating in the study the principal researcher will contact you to discuss the study and answer any further questions that may arise from reading this information sheet. You will have up to one week to decide if you wish to participate in the study.

How do I agree to participate in this research?

If you agree to participate you will need to sign a consent form on the day of the testing

Will I receive feedback on the results of this research?

You will be able to receive a written summary of the findings of the study on request to the principal researcher

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

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Dr Peter McNair, Physical Rehabilitation Research Centre Division of Rehabilitation and Occupation Studies AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7143 Email peter.mcnair @aut.ac.nz

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

Whom do I contact for further information about this research?

Researcher Contact Details:

Duncan Reid, Division of Rehabilitation and Occupation Studies, AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7806 Email duncan.reid @aut.ac.nz

Project Supervisor Contact Details:

Dr Peter McNair, Physical Rehabilitation Research Centre Division of Rehabilitation and Occupation Studies AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7143

Email peter.mcnair @aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 17th November 2006
Ethics approval number 06/189

Appendix 5

Participant Information Sheet

Study 2

Date Information Sheet Produced: 25 October 2006

Project Title

The effects of lower limb stretching on range of motion and tissue viscoelasticity in individuals with OA of the knee.

An Invitation

You are invited to participate in a research study performed as part of the requirements for completion of a Doctor of Health Science thesis for Duncan Reid. Participation is completely voluntary and you may withdraw from the study at anytime without giving a reason or being disadvantaged.

What is the purpose of this research?

People with osteoarthritis (OA) frequently complain of pain and stiffness in the joints affected by this disease. The knee is a commonly affected joint. As a consequence of pain and stiffness, the knee joint can lose range of motion. Stretching, particularly to the hamstring muscles is one activity that may reduce this loss. Patients without OA also lose flexibility as they age. Therefore both of these groups of people may benefit from stretching exercises. While there is some research into the effects of stretching in elderly populations there are few studies that have investigated the effects of stretching in patients with OA of the knee. Therefore the aim of the study will be to investigate the flexibility characteristics of the hamstring muscles patients with osteoarthritis (OA) of the knee and compare these with subjects of a similar age without OA, following a six week stretching programme.

These results will be published in relevant scientific journals and also presented at national and internationals conferences.

How was I chosen for this invitation?

You were selected for this study by answering an advertisement in the local newspaper and advertisements placed around the AUT campus and the North Shore region. You may also have been part of the AUT or YMCA Never Too Old programme or be a member of the Arthritis foundation. You may also have been selected as a consequence of participating in the previous acute stretching study run by the same researchers.

The requirements for participating are as follows:

For the non OA knee group men and women, aged 60-75 years, who are living in the local community, are eligible. You must be able to read, understand basic English and simple verbal commands.

For the OA knee group, men and women, aged 60-75 years, with a history of OA in one or both knees and who are living in the local community, are eligible. You must be able to read, understand basic English and simple verbal commands. If you are taking non-steroidal anti-inflammatory (NSAID) medication (e.g. Voltaren) you will be able to continue to use this medication.

In both types of participants you will need to fill out a short questionnaire that assesses your current level of health and to ensure that you will be able to participate in the testing. This form is called the Par-Q.

We will also have to check that you are not currently participating in physical therapy treatments for the OA knee condition nor have other conditions that would affect your ability to undertake the testing such as neurological conditions (such has a past stroke) or significant heart conditions.

What will happen in this research?

There will be four research assistants who will help you with the procedures listed below. These assistants are final year physiotherapy students. They will be working under the supervision of the principal researcher and will have been thoroughly trained in the use of the procedures and the testing.

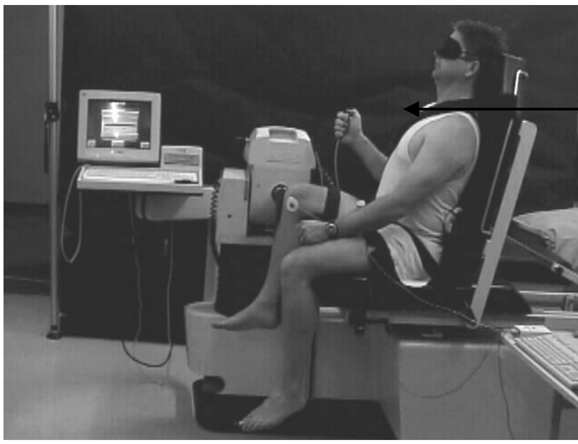
The procedure will be in three parts.

The following tests will be undertaken at three points: commencement of the study, 6 weeks thereafter, and then a further 6 weeks later.

Firstly, you will have the flexibility of your hamstring (muscles on the back of the thigh) tested on a machine called a Kin Com at the Physical Rehabilitation Research Centre at AUT (See figure 1). The test is painless and requires no activity from you. All it does is slowly straighten your lower leg until you feel some tightness in the back of your leg. The test position for this is sitting supported in the machine. When you have reached the position that creates a modest stretch in the hamstring muscle you push a button that stops the test sequence (see Figure 1). This position of your end of range of motion is then recorded. This will be repeated two further times to get an average of the three readings.

At the same time, the electrical activity of your muscles will be recorded. This is called Electromyography (EMG). The reason for recording this information is that we want to ensure that your muscles are not creating the movement of the limb and that the Kin Com is passively moving the leg. Electrodes will be attached to your thigh muscles front and back. These electrodes are self-adhesive. The hair on your leg where the electrodes will be placed will need to be removed and this will be done with a disposable razor. Once on your skin, the electrodes are not painful and do not in any way generate electrical impulses. At the conclusion of the Kincom testing you will be asked to perform a strong contraction of the thigh muscles. This will allow us to see what proportion of muscle activity was taking place during the test procedure.

Figure 1 The set up in the KinCom Machine



Cut out switch

Following these tests on the Kincom, we will ask you to fill in two questionnaires about your level of function and then undertake a series of functional tasks.

The Questionnaires are the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Lower Limb Task Questionnaire (LLTQ)

The WOMAC asking you about pain, stiffness and physical activities you do in the day. There are a total of 24 questions, two questions relating to pain, two questions relating to stiffness and 17 questions relating to physical function. The questionnaire is self administered and takes approximately 5 to 10 minutes to complete.

The LLTQ involves 10 questions that relate to activities of daily living that require use of the lower limbs. Each question has a five-point scale and subjects rate the activity from no difficulty (4 points) to unable to do (0 points).

The functional activity test is the Aggregated Locomotor Function test (ALF) This test comprises three components. You will be timed for the following activities

4. 8 metre walk. This requires you to walk as quickly as possible across a 10-metre space of floor. You will have three attempts at this task

5. Stair climb one flight of stairs or 7 steps. You will be asked to ascend and then descend seven steps as quickly as possible. You will have four attempts at this task

6. Chair sit and stand. You will be asked to walk a distance of 2 metres at their own pace to a chair sit down then immediately stand up and return to the starting position. You will have three attempts at this task.

Treatments

If you have osteoarthritis, then you could be assigned to one of two groups. Group 1 has an exercise program that will be undertaken 5 times per week for 6 weeks. Two of these sessions will be supervised at AUT, while the others will be undertaken at home. The exercises are predominantly stretching activities to the major muscles groups in the lower legs. Group 2 will receive an electrotherapy device that may help the arthritic knee joint. This treatment will be applied at AUT twice per week for six weeks.

If you do not have osteoarthritis, you will be assigned to one of two groups. Group 1 has an exercise program that will be undertaken 5 times per week for 6 weeks. Two of these sessions will be supervised at AUT, while the others will be undertaken at home. The exercises are predominantly stretching activities to the muscle groups in the lower legs. Group 2 will undertake normal daily activities.

Those in the stretching groups will also need to record the number and frequency of the stretching exercises you perform each day. A diary will be provided to you for these recordings. This will only take a few moments each day to fill out. These diaries will be collected from you at the end of the study.

What are the discomforts and risks?

During the Kincom procedure described above, the sensation you will feel is a stretch to the hamstrings. You are in complete control of the amount of discomfort you can tolerate. There is a cut out switch that turns off the test if at any stage you are not happy with the sensation or experience pain (see Figure 1). The only potential risk associated with the research is a mild muscle strain.

During the other functional tests there will be no discomfort and you will be closely monitored during the stair climbing and the sit to stand exercise to ensure you do not fall.

With the stretching programme there is a very low chance of injury as the stretches are generated by you. You will also be under supervision during the sessions at AUT. The most likely injury would be the development of muscle soreness following the stretches or a slight increase in joint pain in those subjects with OA knee.

How will these discomforts and risks be alleviated?

Should you feel any pain or discomfort that occurs during or following the testing you will receive appropriate treatment from a physiotherapist or referral back to your doctor

What are the benefits?

Flexibility is an important component of general health. Flexibility can be lost with age and disease processes. Gaining a greater understanding of the effects of stretching on both elderly subjects and those with OA of the knee will help physiotherapists design the most appropriate stretching regimes to improve your health.

What compensation is available for injury or negligence?

Compensation is available through the Accident Compensation Corporation within its normal limitations.

How will my privacy be protected?

Once you have consented to the project and we have you contact details, you will be entered into the research data base and referred to by number only. In that way whenever anything is published and reported from the research you will remain confidential. The data concerning the project is stored in locked cabinets at AUT or password protected computers. Only the principal researcher and the supervisor have access to this information

What are the costs of participating in this research?

There is no cost other than your time. You will be provided with petrol vouchers to cover the cost of each visit to AUT. The initial testing procedure and the follow ups after six and twelve weeks will take approximately 60 minutes.

What opportunity do I have to consider this invitation?

If you are interested in participating in the study the principal researcher will contact you to discuss the study and answer any further questions that may arise from reading this information sheet. You will have up to one week to decide if you wish to participate in the study.

How do I agree to participate in this research?

If you agree to participate you will need to sign a consent form on the day of the testing.

Will I receive feedback on the results of this research?

You will be able to receive a written summary of the findings of the study on request to the principal researcher.

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

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor,

Dr Peter McNair, Physical Rehabilitation Research Centre Division of Rehabilitation and Occupation Studies AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7143 Email peter.mcnair @aut.ac.nz

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

Whom do I contact for further information about this research?

Researcher Contact Details:

Duncan Reid, Division of Rehabilitation and Occupation Studies, AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7806 Email duncan.reid @aut.ac.nz

Project Supervisor Contact Details:

Dr Peter McNair, Physical Rehabilitation Research Centre Division of Rehabilitation and Occupation Studies AUT, Private Bag 92006 Auckland

Ph 09 921 9999 ext 7143 Email peter.mcnair @aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 17th November 2006 Ethics Approval Number 06/190,

Appendix 6

# Consent Form	AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project title: The effects of hamstring stretching on range of motion and tissue viscoelasticity in individuals with OA of the knee.

Project Supervisor: ***Dr Peter McNair***

Researcher: ***Duncan Reid***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26th October 2006.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or 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 am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○
- ○ I wish to be sent information on a subsequent stretching study of 6 weeks duration (please tick one): Yes○ No○

Participant's signature

....

Participant's name:

....

Participant's Contact Details (if appropriate):

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on 17th November 2006 AUTEC Reference number 06/189

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

Appendix 7

Consent Form	AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project title: The effects of lower limb stretching on range of motion and tissue viscoelasticity in individuals with OA of the knee.

Project Supervisor: Dr Peter McNair

Researcher: Duncan Reid

○ I have read and understood the information provided about this research project in the Information Sheet dated 25 October 2006.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw myself or 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 am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection

○ I agree to take part in this research.

○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature: ....……………………………………………………

Participant's name: ....……………………………………………………

Participant's Contact Details (if appropriate):

……………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on 17th November 2006 AUTEC Reference Number 06/190

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

Appendix 8

ARE YOU READY TO EXERCISE?

Physical activity is important for physical and mental health. Typically, all individuals are encouraged to participate in physical activity. There are, however, certain circumstances in which it is suggested a medical physician give you written permission to exercise. Please answer the following questions below honestly. It is important for me to know if you have any health conditions that can be affected by physical activity.

All information is confidential.

Please circle 'Yes' or 'No' for each question.

Yes No 1. Has a doctor ever told you that you have asthma?

Yes No 2. Has a doctor ever told you that you have diabetes?

Yes No 3. Has a doctor ever told you that you have a heart problem?

Yes No 4. Do you ever feel pains in your chest when engaging in physical activity?

Yes No 5. Do you currently take prescription drugs for blood pressure or a heart condition?

Yes No 6. Do you have a bone/joint problem that may be made worse by exercise?

Yes No 7. Do you ever get light-headed/dizzy while exercising? If so, explain

Yes No 8. Do you know of ANY other reason why you should not engage in physical activity?

If so, explain:

If you have answered 'yes' to any of the above you may need a written permission from a physician to allow you to participate in class. If it is determined necessary for you to obtain a physician's note, you will not be able to participate in class until I receive the note. Please inform me as soon as possible if any aspect of your health changes that would result in a change of answers on this form. I have read and understand this questionnaire and have answered all questions to the best of my knowledge.

Name (Print): Date:________

Signature:

Appendix 9

Stretching Programme

All stretches are to be held for **60 seconds** to a level of mild discomfort in the target muscle. Repeat each stretch **three times** on each area. We will provide supervision of the stretches during the sessions at AUT. You will need to do these at home on the days you do not come to AUT to continue the improvement.

1. The hamstring stretches (2 stretches required)

Standing stretch (See diagram a).

- Place the heel of the leg to be stretched on a low box or chair. Keep the knee as straight as possible.
- Keeping the back as straight as possible bend forward at the hips until a stretching sensation is felt in the hamstring region

Lying Stretch (See diagram b)

- Now lie on your back on the floor. Loop piece of rope or towel around the sole of the foot.
- Keeping the leg to be stretched as straight as possible lift the leg until a stretch is felt in the hamstring region. The leg not being stretched is kept as flat as possible on the floor.

a)

b)

2. The calf stretch (2 stretches required)

Upper calf (gastrocnemius muscle)(See diagram a).

- Place your hands either against a wall or on the back of a chair.
- Place the back leg to be stretched on the ground with the heel on the floor. Keep the knee straight. The front leg needs be bent at the knee.
- Lean forward until a stretch is felt in the upper calf region.

Lower calf (soleus muscle)(See diagram b).

- Take up the same position as above with the heel still fixed on the ground.
- Bend the knee until the stretch is felt in the lower leg.

Upper calf (a) Gastrocnemius

Lower Calf (b) Soleus

3. The quadriceps stretch.

- Stand with the support of a chair or bench.
- Hold your foot with your hand (See Diagram a) or loop a small rope or towel over the front of the foot (See diagram b).
- Pull your heel towards your buttock until a stretch is felt in the quadriceps region or the limit of knee flexion is achieved.

Alternative stretch (See diagram c)

- Lie on your tummy on the floor.
- Loop small rope or towel is looped around the front of the foot.
- Pull on the foot to flex the knee until a stretch is felt in the quadriceps region or the limit of knee flexion is achieved.
- The leg not being stretched lie flat on the floor.

a)

b)

c)

4) <u>Hip flexor stretch</u>

- Kneel on one knee. Place a cushion or soft pad under the knee so that it is not painful to kneel on.
- Place the non stretched leg in front as shown in the picture.
- Lunge forward until you feel the stretch in the upper thigh and groin region of the leg being stretched.

Diary of Stretches

Name ____

Please place a tick or cross in the box when you have completed the stretching session for each day. You need to stretch 5 days of each week.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1							
Calf							
Quads							
Hamstrings							
Hip flexors							
Week 2							
Calf							
Quads							
Hamstrings							
Hip flexors							
Week 3							
Calf							
Quads							
Hamstrings							
Hip flexors							
Week 4							
Calf							
Quads							
Hamstrings							
Hip flexors							
Week 5							
Calf							
Quads							
Hamstrings							
Hip flexors							
Week 6							
Calf							
Quads							
Hamstrings							
Hip flexors							

Appendix 10

Lower Limb Tasks Questionnaire: Activities of Daily Living Section

Patient: _______________ **Date:**_____________

INSTRUCTIONS

Please rate your ability to do the following activities in the **past 24 hours** by circling the number below the appropriate response.

If you did not have the opportunity to perform an activity in the **past 24 hours**, please make your *best estimate* on which response would be the most accurate.

Please also rate how important each task is to you in your daily life according to the following scale:

1. = Not important
2. = Mildly important
3. = Moderately important
4. = Very important

Please answer all questions.

	NO DIFFICULTY	MILD	MODERATE	SEVERE	UNABLE	IMPORTANCE
1. Walk for 10 minutes	4	3	2	1	0	1 2 3 4
2. Walk up or down 10 steps (1 flight)	4	3	2	1	0	1 2 3 4
3. Stand for 10 minutes	4	3	2	1	0	1 2 3 4
4. Stand for a typical work day	4	3	2	1	0	1 2 3 4
5. Get on and off a bus	4	3	2	1	0	1 2 3 4
6. Get up from a lounge chair	4	3	2	1	0	1 2 3 4
7. Push or pull a heavy trolley	4	3	2	1	0	1 2 3 4
8. Get in and out of a car	4	3	2	1	0	1 2 3 4
9. Get out of bed in the morning	4	3	2	1	0	1 2 3 4
10. Walk across a slope	4	3	2	1	0	1 2 3 4

TOTAL (/40) :___

Enquiries concerning this questionnaire: Peter J. McNair PhD, Health Rehabilitation Research Centre, Auckland University of Technology, Private Bag 92006, Auckland; New Zealand. email: peter.mcnair@aut.ac.nz Phone: 921-9999 Ext 7143

Appendix 11

WOMAC OSTEOARTHRITIS INDEX VERSION VA3.1

Instructions to Patients

In Section A, B, and C questions will be asked in the following format. You should give your answers by putting an "***x***" on the horizontal line.

Examples:

1. If you put your "***x***" at the left of the line as shown below, then you are indicating that you have **no** pain.

No Pain | Extreme Pain

2. If you put your "***x***" at the right end of the line as shown below, then you are indicating that you pain is **extreme**.

No Pain | Extreme Pain

3. Please note:
    a. That the further to the right you place your "***x***" the **more** pain you are experiencing.
    b. That the further to the left you place your "***x***" the **less** pain you are experiencing.
    c. **Please do not** place your **"*x*" past the end of the line.**

You will be asked to indicate on this type of scale the amount off pain, stiffness or disability you have experienced in the last 48 hours.

Complete the questionnaire with respect to you knee.
You should think about your knee when answering the questionnaire. Indicate the severity of your pain, stiffness and physical disability that you feel is caused by arthritis in your knee.

Section A
PAIN

Think about the pain you felt in you knee due to your arthritis during the <u>last 48 hours</u>.

(Please mark you answers with an "***x***".)

QUESTION: How much pain do you have?	Study Coordinator Use Only
1. Walking on a flat surface. No Pain |————————————| Extreme Pain	Pain1_______
2. Going up or down stairs. No Pain |————————————| Extreme Pain	Pain2_______
3. At night while in bed. No Pain |————————————| Extreme Pain	Pain3_______
4. Sitting or lying. No Pain |————————————| Extreme Pain	Pain4_______
5. Standing upright. No Pain |————————————| Extreme Pain	Pain5_______

Section B
STIFFNESS

Think about the stiffness (not pain) you felt in your knee due to arthritis during the <u>last 48 hours</u>.

Stiffness is a sensation of **restriction** or **slowness** in the ease with which you move your joints.

(Please mark your answers with an "***x***".)

	Study Coordinator Use Only
6. How **severe** is your stiffness **after first awakening** in the morning? No Stiffness |————————————| Extreme Stiffness	Stiff6_______
7. How severe is your stiffness after sitting, lying or resting **later in the day**? No Stiffness |————————————| Extreme Stiffness	Stiff7_______

Section C

DIFFICULTY PERFORMING DAILY ACTIVITIES

Think about the difficulty you had in doing the following daily physical activities due to arthritis in your knee during the last 48 hours. By this we mean **your ability to move around and to look after yourself.** (Please mark your answers with an "***x***".)

QUESTION: **What degree of difficulty do you have?**	Study Coordinator Use Only
8. Descending stairs. No Difficulty ├──────────┤ Extreme Difficulty	PFTN8_______
9. Ascending stairs. No Difficulty ├──────────┤ Extreme Difficulty	PFTN9_______
10. Rising from sitting. No Difficulty ├──────────┤ Extreme Difficulty	PFTN10______
11. Standing. No Difficulty ├──────────┤ Extreme Difficulty	PFTN11______
12. Bending to the floor. No Difficulty ├──────────┤ Extreme Difficulty	PFTN12______
13. Walking on a flat surface. No Difficulty ├──────────┤ Extreme Difficulty	PFTN13______

DIFFICULTY PERFORMING DAILY ACTIVITIES

Think about the difficulty you had in doing the following daily physical activities due to arthritis in your knee during the last 48 hours. By this we mean **your ability to move around and to look after yourself.** (Please mark your answers with an "***x***".)

QUESTION: **What degree of difficulty do you have?**	Study Coordinator Use Only
14. Getting in or out of a car, or getting on or off a bus. No Difficulty |———————————————| Extreme Difficulty	PFTN14______
15. Going shopping. No Difficulty |———————————————| Extreme Difficulty	PFTN15_______
16. Putting on your socks or stockings. No Difficulty |———————————————| Extreme Difficulty	PFTN16______
17. Rising from bed. No Difficulty |———————————————| Extreme Difficulty	PFTN17______
18. Taking off your socks or stockings. No Difficulty |———————————————| Extreme Difficulty	PFTN18______
19. lying in bed. No Difficulty |———————————————| Extreme Difficulty	PFTN19______

DIFFICULTY PERFORMING DAILY ACTIVITIES

Think about the difficulty you had in doing the following daily physical activities due to arthritis in your knee during the last 48 hours. By this we mean **your ability to move around and to look after yourself.** (Please mark your answers with an "***x***".)

QUESTION: **What degree of difficulty do you have?**		Study Coordinator Use Only
20. Getting in or out of the bath. No Difficulty	Extreme Difficulty	PFTN20______
21. Sitting. No Difficulty	Extreme Difficulty	PTFN21______
22. Getting on or off the toilet. No Difficulty	Extreme Difficulty	PTFN22______
23. Performing heavily domestic duties. No Difficulty	Extreme Difficulty	PTFN23______
24. Performing light domestic duties. No Difficulty	Extreme Difficulty	PTFN24__

Appendix 12

Global Assessment

Name: ___________ **Date:_____________**

<u>Overall Status Change:</u>

1. Since the last assessment point, my overall status now is:

Please circle one number below:

0 -	Very much improved	4 -	Minimally worse
1 -	Much improved	5 -	Much Worse
2 -	Minimally improved	6 -	Very much worse.
3 -	No Change		

Appendix 13

Research outputs from the thesis

Journal publications

Reid, D., & Larmer, P. (2007). The New Zealand Health Priorities: Where do New Zealand Private Practice Physiotherapists fit? *New Zealand Journal of Physiotherapy, 35*(2), 42-46.

Reid, D., & McNair, P. (2008). The effects of a 6 week stretching intervention on range of motion, torque and stiffness in people with OA of the knee. (Abstract) *New Zealand Journal of Physiotherapy, 36*(2), 91.

Conference Presentations

Reid, D., & McNair, P. (2007). *Passive force, angle and stiffness changes following an acute bout of hamstring stretching in people with OA of the knee.* Paper presented at the New Zealand Manipulative Physiotherapy Conference: Manual Therapy Down under- Performance of the lower quartile, Rotorua.

Reid, D., & McNair, P. (2008). *The effects of a 6 week stretching intervention on range of motion, torque and stiffness in people with osteoarthritis of the knee.* Paper presented at the New Zealand Society of Physiotherapists Conference: Physiotherapy keeps you moving, Dunedin.

Reid, D., & McNair, P. (2008,). *Strengthening and stretching interventions for the osteoarthritic (OA) knee.* Paper presented at the IFOMT 2008 Connecting "Science" to Quality of Life, Rotterdam June 8th -13th.

Reid, D., & McNair, P. (2008). *Effects of an acute stretching intervention on range of motion, force and stiffness in people with osteoarthritis of the knee.* Paper presented at the IFOMT 2008 Connecting "Science" to Quality of Life, Rotterdam June 8th -13th.

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