The effect of chiropractic manual therapy on the spine, hip and knee

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THE EFFECT OF CHIROPRACTIC MANUAL THERAPY ON THE SPINE, HIP AND KNEE.

A thesis submitted in partial fulfillment of the requirements of the award of the degree

Ph.D.

from

THE UNIVERSITY OF WOLLONGONG

by

HENRY P. POLLARD BSc, Grad Dip Chiropractic, Grad Dip App Sc, M Sport Sc

DEPARTMENT OF BIOMEDICAL SCIENCE
FACULTY OF HEALTH & BEHAVIOURAL SCIENCES
2000
Declaration

The work presented in this thesis is the original work of the author except as acknowledged in the text.

I, Henry Pollard hereby declare that I have not submitted any material as presented in this thesis either in whole or in part for a degree at this or any other institution.

Signed: Date:

[Signature]

Date: 7/00
Dedication

This thesis is dedicated to three very special people in my life.

To my mother Rosetta who worked so very hard for so long to enable me the opportunity to seek an education.

To my father Don for fostering an environment of encouragement and support.

To my wife Grace for providing unconditional support so that I could satisfy my educational needs.

You are all dear to my heart and I love you very much.
Acknowledgements
To my supervisor and mentor Dr Graham Ward I extend my greatest thanks. Your expert direction and knowledge has been critical to the successful completion of this thesis, and your engaging style of academia should be viewed as a template for others to emulate.

To the following chiropractors I extend my thanks for their support in various parts of the five studies:


I wish to thank the Australian Spinal Research Foundation for financially supporting two of the five studies. I also wish to thank the University of Wollongong for providing seeding money to begin this study.
Abstract

This thesis examined the effect of commonly used manual therapy protocols on the range of motion (ROM) of the hip joint. The first study compared two hip manual therapy treatments for increasing ROM at the hip and lumbar spine. 57 chronic back pain sufferers between 18 and 40 years voluntarily entered a randomised clinical trial with three groups of hip treatment ( manipulation, stretching and control). Only the manipulation group increased the hip ROM significantly when compared to control. Also, manipulation of the hip was associated with significantly less back pain than the other group when compared to the control. Neither experimental group was significantly different to the control for changing lumbar ROM. The second study investigated the effect of manual therapy treatment on chronic knee pain and hip ROM in 57 subjects (between 47 and 70 years) with knee osteoarthritis. The results showed that manual therapy significantly decreased the short term pain reported by subjects, but the treatment did not change the hip ROM. The third study compared the effectiveness of an upper cervical manipulation or a manipulation of the sacroiliac joint for increasing hip ROM in 52 healthy university students. The results demonstrated that the two manipulation treatments resulted in increased ROM at the hip, but only the cervical procedure significantly increased hip ROM. The fourth study used similar methodology to the third to compare the effect of a sub occipital stretching technique to a hamstring stretching technique in 60 healthy university students. I have demonstrated that the two stretching treatments both increased hip ROM but only the spinal group was significant. The fifth study found that a group of healthy students receiving manipulation to the L3/4 motion segment statistically increased short term quadriceps femoris muscle strength. Taken together, these results help to document for the first time the effect of several clinical protocols used by manual therapists to increase the ROM at the hip joint. I conclude that: manipulation of the hip should be considered in protocols trying to achieve increased hip ROM, and that treatment of the spine demonstrated an improvement in peripheral joint function of the hip.

Key words
Chiropractic, Physiotherapy, Osteopathy, Manipulation, Stretching, Hip, Lumbar, Knee, Neck, Pain, Osteoarthritis, RCT
# Table of contents

Title Page........................................................................................................... 1
Declaration........................................................................................................... 2
Dedication ........................................................................................................... 3
Acknowledgement ............................................................................................... 4
Abstract ............................................................................................................... 5
Table of contents ................................................................................................ 6
List of figures ....................................................................................................... 9
List of tables ....................................................................................................... 10
Glossary of abbreviations .................................................................................. 15
Chapter One ....................................................................................................... 16
  Introduction ...................................................................................................... 17
  Purpose of the study ......................................................................................... 21
  Significance of the study ................................................................................ 25
Chapter Two
  Review of the literature ................................................................................... 27
  Introduction ...................................................................................................... 27
  History of manual therapy .............................................................................. 31
  The Goals of Manual therapy ........................................................................ 34
  Stretching ........................................................................................................ 39
  Introduction ...................................................................................................... 39
  Who uses stretching ........................................................................................ 40
  Types of stretches ........................................................................................... 42
  The Static Stretch ............................................................................................ 42
  The Ballistic Stretch ........................................................................................ 43
  The Slow Stretch .............................................................................................. 43
  Proprioceptive Neuromuscular Facilitation (PNF)
  Stretches ......................................................................................................... 44
  Time in stretch ................................................................................................. 45
  The mechanism of increased ROM with stretches ........................................ 46
  EMG evidence for Mechanism of PNF (CRAC) stretching ............................. 55
  Importance of warmup .................................................................................... 58
  Flexibility Sex differences ............................................................................. 59
  Stretching to prevent injury .......................................................................... 61
  Effect of a number of treatments .................................................................... 66
  Summary stretching ........................................................................................ 72
  Mobilisation ..................................................................................................... 74
  Manipulation .................................................................................................... 79
  Indications And Contradictions For Manual Therapy ...................................... 83
  Indications for Stretching .............................................................................. 83
  Indications for Mobilisation .......................................................................... 84
  Indications for Manipulation ........................................................................ 86
  Contraindications for manual therapy ............................................................ 87
  Contraindications for Mobilisation & Stretching .......................................... 87
  Contraindications for Manipulation ............................................................... 87
List of figures

Figure 2.1     Classification of grades of movement.                     p76
Figure 2.2     Emotive analogy of manipulation and gunshot.             p77
Figure 2.3     Schematic of paraphysiological range
                 achieved with manipulation.                                   p82
Figure 2.4     Maitland's grading system.                               p89
Figure 2.5     Anatomy of the posterior thigh.                          p92
Figure 2.6     Normal lumbopelvic rhythm (LPR).                         p98
Figure 2.7     Flexion and extension phases of the LPR.                p100
Figure 2.8     Cantilever model of the spine                           p104
Figure 2.9     Intra-abdominal pressure                               p105
Figure 2.10    The thoracolumbar fascia (TLF)                           p107
Figure 2.11    The hydraulic amplifier                               p107
Figure 2.12    The arch model of the spine (Part 1)                    p108
Figure 2.13    The arch model of the spine (Part 2)                    p109

Figure 3.1     Surface markings for experimental protocol.             p149
Figure 3.2     Schematic of hip and lumbar angles for
                 experimental protocol.                                       p150
Figure 3.3     Diagram of SLR position of practitioner.                p152
Figure 3.4     Hip manipulative procedure part one.                   p154
Figure 3.5     Hip manipulative procedure part two.                   p155
Figure 3.6     Hip stretching procedure.                              p156

Figure 4.1     Diagramatic representation myofascial release
                 of patellofemoral joint.                                        p201
**List of tables**

**Table 1.1**  
Summary Of Comparison Of Stretching Methods  
*p64*

**Table 2.1**  
A comparison of results from studies of lumbar ROM from full extension to full flexion using roentgenographic analysis.  
*p112*

**Table 2.2**  
A comparison of reliable assessments of hip and lumbar range of motion.  
*p131*

**Table 3.1**  
Pre treatment SLR ROM differences between males and females in degrees (Paired t-test)  
*p159*

**Table 3.2**  
Pre treatment differences between males and females in hip standing ROM data (Paired t-test)  
*p159*

**Table 3.3**  
Pre treatment differences between males and females in lumbar standing ROM data  
*p159*

**Table 3.4**  
Pre treatment differences between males and females in McGill Pain Questionnaire data  
*p160*

**Table 3.5**  
Pre treatment differences between males and females in Dallas pain questionnaire data  
*p160*

**Table 3.6**  
Pre treatment differences between males and females in Oswestry pain score data  
*p160*
Table 3.7
Differences between average change in group mean (Post - pre) in the supine (SLR) ROM data (Paired t-test) p161

Table 3.8
Differences between average change in group mean (Post - pre mean) in the standing hip ROM data (Paired t-test) p162

Table 3.9
Differences in average group changes in TTT hip ROM scores (Analysis of variance). p162

Table 3.10
Differences between pre & post lumbar ROM data in the manipulation group (Paired t-test) p163

Table 3.11
Differences between pre & post McGill pain score data in the manipulation group (Paired t-test) p164

Table 3.12
Differences between pre & post McGill pain score data in the Placebo/control group (Paired t-test) p164

Table 3.13
Differences between pre & post McGill pain score data in the PNF group (Paired t-test) p164

Table 3.14
Pre treatment differences in McGill pain scores p165

Table 3.15
Differences in average group changes in McGill pain scores (Analysis of variance). p165

Table 3.16
Differences between pre & post Oswestry pain score data in the manipulation group (Paired t-test) p166
Table 3.17
Differences between pre & post Oswestry pain score data in the placebo control group (Paired t-test) p166

Table 3.18
Differences between pre & post Oswestry pain score data in the PNF group (Paired t-test) p166

Table 3.19
Pre treatment differences in Oswestry pain scores (Analysis of variance). p167

Table 3.20
Differences in average group Oswestry pain scores p167

Table 3.21
Differences between pre & post Dallas pain score data in the manipulation group (Paired t-test) p168

Table 3.22
Differences between pre & post McGill pain score data in the placebo/control group (Paired t-test) p168

Table 3.23
Differences between pre & post Dallas pain score data in the PNF group (Paired t-test) p168

Table 3.24
Pre treatment differences in average group Dallas pain scores (Analysis of variance). p169

Table 3.25
Differences in average group Dallas pain scores p169

Table 4.1
Group change in pain scores p203

Table 4.2
Group difference in pain scores before intervention p204
Table 4.3
Group difference in pain scores after intervention  p204

Table 4.4
Group post treatment scores to VAS questions  p206

Table 4.5
Group differences in pain scores before intervention.  p206

Table 4.6
Group differences in pain scores after intervention.  p207

Table 4.7
Group post treatment scores to VAS questions.  p208

Table 5.1
Post treatment differences in average group ROM  p223

Table 5.2
Post treatment differences in average group ROM  p223

Table 5.3
Group changes in ROM  p223

Table 5.4.
Pre test ANOVA reporting differences between the control, cervical and the sacroiliac groups in average range of motion measured in degrees  p224

Table 6.1.
Change in mean scores with standard error (in brackets) of angle of hip for groups (in degrees).  p241

Table 6.2.
Analysis of variance of average group data scores (post - pre treatment scores)  p241
Table 6.3.
Analysis of variance of before treatment ROM scores p242

Table 7.1.
Change in means and standard errors of angle of isometric strength test value at 180 degrees of hip extension and 90 degrees of knee flexion for groups (in kilograms). p261

Table 7.2.
One way analysis of variance of change in treatment scores p261

Table 7.3.
One way analysis of variance of difference in pre-test groups p262

Table 8.1.
Effects of immobilisation. p284
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK</td>
<td>Applied Kinesiology</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis Of Variance</td>
</tr>
<tr>
<td>ASIS</td>
<td>Anterior Superior Iliac Spine</td>
</tr>
<tr>
<td>ASRF</td>
<td>Australian Spinal Research Foundation</td>
</tr>
<tr>
<td>C</td>
<td>Cervical Vertebra</td>
</tr>
<tr>
<td>CC</td>
<td>Contractile Component</td>
</tr>
<tr>
<td>CNS</td>
<td>Central Nervous System</td>
</tr>
<tr>
<td>CR</td>
<td>Contract-Relax</td>
</tr>
<tr>
<td>CRAC</td>
<td>Contract-Relax-Antagonist-Contract</td>
</tr>
<tr>
<td>CT</td>
<td>Computerised Tomography</td>
</tr>
<tr>
<td>DF</td>
<td>Degrees Of Freedom</td>
</tr>
<tr>
<td>DOMS</td>
<td>Delayed Onset Muscular Soreness</td>
</tr>
<tr>
<td>DPQ</td>
<td>Dallas Pain Questionnaire</td>
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<tr>
<td>EMG</td>
<td>Electromyogram</td>
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<tr>
<td>FFD</td>
<td>Finger To Floor Distance</td>
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<tr>
<td>GTO</td>
<td>Golgi Tendon Organ</td>
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<tr>
<td>L</td>
<td>Lumbar Vertebra</td>
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<tr>
<td>LBP</td>
<td>Low Back Pain</td>
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<tr>
<td>LPR</td>
<td>Lumbopelvic Rhythm</td>
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<tr>
<td>MMPI</td>
<td>Minnesota Multiphasic Personality Inventory</td>
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<tr>
<td>MPQ</td>
<td>McGill Pain Questionnaire</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>NSW</td>
<td>New South Wales</td>
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<tr>
<td>OA</td>
<td>Osteoarthritis</td>
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<tr>
<td>OPQ</td>
<td>Oswestry Pain Questionnaire</td>
</tr>
<tr>
<td>PEC</td>
<td>Parallel Elastic Component</td>
</tr>
<tr>
<td>PLL</td>
<td>Posterior Longitudinal Ligament</td>
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<tr>
<td>PNF</td>
<td>Proprioceptive Neuromuscular Facilitation</td>
</tr>
<tr>
<td>PRYT</td>
<td>Pitch-Roll-Yaw-Tilt</td>
</tr>
<tr>
<td>PSIS</td>
<td>Posterior Superior Iliac Spine</td>
</tr>
<tr>
<td>ROM</td>
<td>Range Of Motion</td>
</tr>
<tr>
<td>SEC</td>
<td>Series Elastic Component</td>
</tr>
<tr>
<td>SIJ</td>
<td>Sacroiliac Joint</td>
</tr>
<tr>
<td>SLR</td>
<td>Straight Leg Raise</td>
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<tr>
<td>SOT</td>
<td>Sacro-Occipital Technique</td>
</tr>
<tr>
<td>SP</td>
<td>Spinous Process</td>
</tr>
<tr>
<td>SS</td>
<td>Static Stretch</td>
</tr>
<tr>
<td>STM</td>
<td>Soft Tissue Massage / Manipulation</td>
</tr>
<tr>
<td>T</td>
<td>Thoracic Vertebra</td>
</tr>
<tr>
<td>TLF</td>
<td>Thoracolumbar Fascia</td>
</tr>
<tr>
<td>TP</td>
<td>Transverse Process</td>
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<tr>
<td>TTT</td>
<td>Toe Touch Test</td>
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<tr>
<td>VAS</td>
<td>Visual Analog Scale</td>
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<tr>
<td>VO₂</td>
<td>Maximum Oxygen Consumption</td>
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</tbody>
</table>
Chapter One:

Introduction
Introduction

Treatment of hip joint conditions is most difficult and discouraging, probably because they are usually associated with and secondary to other body distortions, or are complications of unremitting pathological processes. The real challenge exists in the early detection of the distortional problems which may be the basic and underlying cause of the ultimate hip condition.

Reinert OC
Fundamentals of chiropractic techniques

Many procedures used by chiropractors and other manual therapists (medical, physiotherapy, osteopathy, movement, exercise therapists and exercise scientists) the world over are untested. I have attempted to reduce the number of these untested procedures by investigating under controlled conditions various manual therapy procedures used to improve hip function.

In dealing with these procedures I have selected procedures that are commonly used by a variety of manual therapists. I have chosen as the focus of this thesis procedures that involve manipulation (joint or myofascia) and stretching (Bandy & Irion 1994). These two approaches were chosen on the basis of their reported usage in the literature (stretching), or on the basis of the many claims made by the practitioners (manipulation) (Patterson 1993).

Mobilisation procedures have not been targeted for investigation on the basis that they have been shown to be inferior to manipulation when applied to spinal structures (Manga 1994, Meade et al 1990), or that they have been shown to be inferior to stretching when utilised on peripheral joints (Tanigawa 1971).

The selection of stretching as a therapy for investigation was also made on the frequency of its use by both practitioners and the public that they serve. It is a true universally applied therapy.
On the other hand, manipulation once the domain of mainly the chiropractor or the osteopath, is increasing in usage by other practitioners. Practitioners such as physiotherapists, medical practitioners, as well as an increasing number of lay practitioners with massage, Chinese and other backgrounds are utilising these procedures where legal jurisdictions allow it.

As will be outlined later in the review section, many procedures are currently being used by many therapists. Unfortunately, many procedures such as myofascial release techniques and manipulation of the hip currently in use have never been investigated under strictly controlled conditions.

What research that has been devoted to manual therapy has been directed primarily at spinal procedures. Specific procedures involving stretching have also been investigated at some of the peripheral joints. Whilst such investigations are appropriate and important, there remains a large void in quality research directed at the peripheral joints, especially by chiropractors. One explanation of this lack of research would be that chiropractors primarily concentrate on spinal conditions and not peripheral based conditions. However, many chiropractors do treat peripheral conditions, and these treatments can be directed to either the spinal structures, or the peripheral joints involved. Therefore, many treatments are being formulated to address peripheral based pain syndromes, but there appears to be little support of these actions through the use of procedures that have been tested with academic rigour. Thus we felt it was an important endeavour to investigate common procedures performed on a peripheral hip joint from the perspective of a chiropractor that specialises in the treatment of sporting or exercise related injuries.

The hip was selected as the target structure of this intervention on the basis of its integral relationship to the lumbar spine, pelvis, and knee. It was also chosen because its function, or lack thereof, has often been implicated in the changed function of its nearby joints. Thus it was the specific goal of these investigations to establish how the hip joint responded to several different procedures applied to it.
A second goal was conducted to address a very grey area of chiropractic literature, and one that was full of anecdotal evidence. I hoped to investigate the often made claims that the improvement of peripheral joints (especially the hip), could be accomplished by treatment of spinal structures. Such claims have been a part of manual therapy for many years. Based upon the extensive anecdotal evidence, we chose the hip region as the target of a treatment applied to the spine. By doing this, we have attempted to observe whether simple changes in function could result from treatment delivered to spinal structures. I reasoned that in the absence of solid basic research, if changes in range of motion or strength could not be effected following these spinal interventions, the likelihood of further findings of a more advanced nature would be unlikely.

Thus, this thesis consists of several research studies that have a common theme. That common theme was "chiropractic manual therapy and its effect on the hip joint". These research studies investigate and report upon a specific form of manual therapy as it relates to the hip joint either directly or indirectly.

As a result of these different approaches to the treatment of the hip, several studies were created to answer the questions posed. In order to best describe these results, I have arranged this thesis in the following manner.

The introduction is followed by a major review of the literature investigating the literature pertinent to manual therapy of the hip and the research that has been performed by the professions that provide these services. The review also presents information on the lumbopelvic rhythm and how hip function is thought to effect pelvic and lumbar function and how it should be assessed. The review also presents research on the measurement of range of motion and pain, as it pertains to the component parts of the lumbopelvic function.

It is from this point that the structure of the thesis changes. The data collected in the thesis pertains to five separate but intricately related studies. Each of these studies has been presented in a discrete chapter that presents the abstract, introduction, review, aims, hypotheses, method, statistics, results, discussion and conclusions sections associated
with each study. It was felt that a succinct discussion of each study would best describe the outcomes of each individual study.

After the reporting of the individual studies, a section discussing the general finding of this thesis, and its importance to the literature is presented in a general conclusion section. A discussion of research questions that have arisen from the results of the data and their implications for further investigation concludes the core of the thesis.

A general reference section follows the conclusion, which in turn is followed by the appendices. The appendices have been divided into three areas with the first appendix containing all the questionnaires used in the data collection of all the studies, the second appendix contains copies of peer reviewed publications that have arisen from the studies associated with this research, and the third appendix containing samples of the informed consent forms used by subjects.
Purpose of this study

Back pain treatment including manual therapy has received a great deal of investigation in the last 20 years. This is especially highlighted in the workers compensation literature where low back pain is considered to be the most important component of all costs related to injury (Shekelle et al 1995, Shekelle 1997). As a part of this research different forms of therapy have been tested (Etnyre & Lee 1987, Smith et al 1988, Vivian 1991, Puett & Griffin 1994, Shekelle et al 1995, Sihvonen 1997).

Many of the approaches commonly used by manual therapists have been studied in some detail. However, most of the research has involved treatment delivered directly to the spine, either as single interventions or as a series of interventions applied in a treatment protocol. Results of these studies therefore have been relevant to conditions of the back, but not to other regions of the body such as the peripheral joints.

The problem arises when techniques that have been shown to have some efficacy for the treatment of spinal conditions are applied to other structures that have not received the same research attention. Worse still, the situation that such techniques are applied to the peripheral joints utilising adapted spinal techniques have been shown to be efficacious at the spinal level but not to the periphery, but are performed on the basis of the perceived success of similar treatments delivered to other structures.

The fact remains that many of the procedures currently being used to treat peripheral joint problems are based upon a 'belief' or a 'philosophy' that manipulation or some other manual therapy will work on a specific joint despite the fact that it has never been tested on the specific target joint.

It is with this in mind that I have attempted to specifically investigate the effect of several treatment approaches designed to improve the function of the peripheral joint of the hip.

Thus, the major research question investigated during this study was: Do manual therapy protocols commonly used to treat hip dysfunction actually improve the range of motion (ROM) of the hip joint?
In order to answer this broad based question several aims were set and several smaller specifically targeted studies were conducted. Some of the general aims of the overall study were:

1. To document the different forms of manual therapy on the function of the hip.

2. To document some clinical protocols often used by manual therapists.

3. To establish normative data on clinical protocols commonly used to increase hip ROM.

Data gathered to provide answers to the above general question were used for the purposes of testing the following general hypotheses:

\[ H_1. \] That manual therapy applied to the hip will increase average range of motion of the hip ROM in flexion.

The first statement of the hypothesis is based on the analysis of ROM data in two experimental groups and one control group.

\[ H_2. \] That manual therapy applied to the neck will not increase the hip ROM in flexion.

The second statement of the hypothesis is based upon the analysis of ROM in two experimental and one control group.

\[ H_3. \] That manual therapy applied to the knee will not increase the hip ROM in flexion.

The third statement of the hypothesis is based upon the analysis of hip ROM in one experimental and one control group.

\[ H_4. \] That manual therapy applied to the sacroiliac joint will not increase the hip ROM in flexion.
The fourth statement of the hypothesis is based upon the analysis of hip ROM data in one experimental and one control group.

**Five targeted studies**

In order to achieve the outcomes set by the above, the thesis was broken into five separate studies. These studies each dealt with a different aspect of the general hypotheses.

The aim of the first study was to compare the effectiveness of two hip manual therapy treatments for increasing range of motion at the hip and lumbar spine. The hypotheses tested by this study include:

\[ H_{1.1} \] That a series of stretches applied to the hip will not increase the hip flexion ROM.

\[ H_{1.2} \] That a series of manipulations applied to the hip will not increase the hip flexion ROM.

\[ H_{1.3} \] That a series of manipulations applied to the hip joint will not decrease the chronic low back pain in subjects with chronic low back pain (LBP).

\[ H_{1.4} \] That a series of stretches applied to the hip joint will not decrease chronic low back pain in subjects with chronic LBP.

\[ H_{1.5} \] That a series of manipulations applied to the hip joint will not decrease the lumbar flexion ROM in subjects with chronic LBP.

\[ H_{1.6} \] That a series of stretches applied to the hip joint will not decrease the lumbar flexion ROM in subjects with chronic LBP.

The second study aimed to determine if a manual therapy treatment of the knee could alter the self reported pain (VAS) experienced by a group of knee osteoarthritis sufferers and if the treatment could alter the hip range of motion. The hypotheses tested by this study include:
H2.1 That a trial of myofascial mobilisation of the knee joint will not increase the hip flexion ROM in subjects with chronic knee pain.

H2.2 That a trial of myofascial mobilisation of the knee joint will not decrease the knee pain in subjects with chronic knee pain.

The third study aimed to compare the effectiveness of an upper cervical manipulation and a manipulation of the sacroiliac joint for increasing hip range of motion. The hypotheses tested by this study include:

H3.1 That a single manipulation of the upper cervical spine (C1) of the hip will not increase the hip flexion ROM.

H3.2 That a single manipulation of the sacroiliac joint will not increase the hip flexion ROM.

The fourth study aimed to compare the effectiveness of a spinal (sub occipital) stretching technique to a peripheral stretching technique for increasing hip flexion ROM.

H4.1 That a single stretch of the sub occipital muscles will not increase the hip flexion ROM.

The fifth study aimed to investigate if a manipulation to the L3/4 motion segment of healthy individuals would effect the strength of the homolateral quadriceps muscle tested post manipulation.

H5.1 That a single manipulation of the L3/4 will not increase the quadriceps muscle strength.
Significance of the study

Successful and speedy recovery from injury is important. In order for this to occur, appropriate diagnosis and treatment must be affected. Assuming that the appropriate diagnosis is made, the clinician is often left with a number of possible treatment options. This is as true for manual therapies as it is for the more conventional medical therapies.

In order to make an appropriate treatment selection, the practitioner must make an informed decision about the theoretical indications and contraindications of individual therapies determined by research, and then apply a selection process based upon them. Once selected, a therapy must be applied with the skill and empathy of an experienced practitioner in order to achieve peak results.

This study helps the clinician in the choice of the appropriate therapy for improving hip ROM (range of motion), and some forms of low back and knee pain. It is hoped that the results of this study assist the clinician to better select a therapy or to better know some of its limitations. Importantly, the results of this study help support the idea that manual therapy applied to spinal structures can have an effect on selected peripheral structures, and to this end I call for important further study on the implications of this work for various groups of pain sufferers.

Finally, this study begins to document the effect of various manual therapy techniques (joint and myofascial manipulation) on peripheral joints. Whilst some work on stretching has been done on the joints of the hip, knee, ankle and to a lesser extent the shoulder, it is hoped that this study into manipulation, and myofascial release mobilisations and stretching, will be followed by others. It is hoped that this study could be repeated at other peripheral joint sites so that all peripheral joints may be tested with the various manual therapy techniques so that a register of techniques and relative effectiveness may be constructed. Such a register of techniques would greatly aid the clinician in choosing the most appropriate and superior therapy for a given peripheral joint, so that the resultant treatment may occur in the quickest possible time with the least amount of side effect and cost. A requirement that is increasingly being demanded of the clinician by the paying and critical public.
Chapter Two:

Review Of The Literature
Review of the literature

Introduction

Manual therapy in some form or another has been used for thousands of years, in just about every civilisation known to man.

Over the last forty years, the use of such procedures has again gained much popularity, as seen in the rise of the chiropractic and osteopathic manual therapists (Unpublished figures from the NSW Chiropractic and Osteopathic Board of NSW, personal communication), often in spite of the institutional efforts to nullify such popularity (as reported by Simpson 1997a, Simpson 1997b, Simpson 1998).

Of these therapies, this study investigated the effects of two commonly used manual therapies, namely stretching and manipulation, on the peripheral hip joint.

A review of the literature revealed no such investigation had been undertaken to specifically investigate the effects of these two forms of therapy on the hip joint.

Past studies have centred around a retrospective investigation of treatment regimes (Shekelle et al 1995), although in recent studies a prospective trial design has been utilised more widely (Shekelle et al 1995, Meade et al 1996, Shekelle 1997).

The outcome of these studies, with respect to pain and range of motion (ROM), has been favourable for all of the procedures at one time or another (Etnyre & Lee 1987). This however depended upon the anatomical localisation, duration, intensity, quantity and combinations of treatments used within the treatment regimes.

Confusion has been an appropriate outcome of such an approach to published documentation. This I believe has been demonstrated by the continued factional rivalry of many of the professions that utilise these procedures (Blackman & Prip 1988, Patterson & Oyao 1993).

It was therefore an important goal to assess whether the effects of these procedures as applied to a single joint peripheral system, was similar to
the work done prior to this investigation, especially in reference to multiple joint spinal systems.

Over the past forty years there has been a great deal of interest into spinal manipulation (Shekelle 1997). This interest has demonstrated a perceived superiority of manipulation over other forms of manual therapy for low back pain. Also, it has been hypothesized that certain types of manipulation (or more correctly, approaches) to be superior to other forms (Plauger 1993).

The past studies have been conducted primarily to investigate the approach to treatment, rather than the effects of individual interventions in a controlled fashion (Meade et al 1996). Once the superiority had been attributed to a particular approach to manual therapy, claims about the efficacy of this approach to other areas of the musculoskeletal system naturally followed (Patterson & Oyao 1993). Such claims hamper the truth.

Claims to the contrary are also frequently made (Blackman & Prip 1988, Terrett 1995). Hence, an emotional factor has precipitated in the constant comparison of one treatment regime versus another.

Conversely, however, the same claims are often responsible for stimulating needed research into an area, of which the current studies were an example.

I felt a need to document the effects of these procedures as stand alone procedures at all levels of the musculoskeletal system, both central and peripheral. This action was taken to break away from the tradition of dogma often used by the various groups who deliver manual therapy.

Results need to be determined based upon the specific joint under consideration. Extrapolation of results based upon the effectiveness of some similar treatment protocol applied to complex multi segmental elements of the human locomotor system, such as the lumbar spine, are not adequate as this form of therapy gains in both popular, and scientific credibility.
A research consideration during one of the five studies conducted was an investigation of the lumbopelvic rhythm theory popularised by Cailliet (1981).

The mechanism of the lumbopelvic rhythm theory suggested that there was a relationship between hip and lumbar spine function, such that restriction of one could lead to dysfunction or pain of the other. Of particular note was the interpretation given to this untested theory used by many clinicians (Sihvonen 1997, Vleeming et al. 1997). It was a goal of this investigation therefore to observe whether change in hip function (ROM) would alter the function of the lumbar spine (ROM and/or pain).

Although the proposed mechanism has been discussed by many authors including; Schafer (1983), Kreigbaum & Bartels (1985), Janda (1978) and McKenzie (1981), no direct experimental evidence seems to exist.

Thus, in the clinical investigation, a group of symptomatic lower back pain (LBP) subjects had one of two manual therapy procedures or a placebo treatment applied to their hips, in order to determine any change in lumbar pain or function.

Both the effects of the manual therapy on the hips, and the involvement of the lumbopelvic rhythm have been assumed to be true and present. Yet there was no documented evidence to confirm or deny the theory.

This study was a clinical one, which attempted to effect parameters commonly seen, and for which relief is commonly sought in the patient population. Whilst a clinical study, I have attempted to scrutinise the untested clinical approach with the accepted scientific process required of modern clinical studies. These parameters include: hip range of motion, lumbar range of motion, knee and lumbar pain. The study therefore had the potential to change clinical protocols that were commonly used without question in this form of therapy. Therefore, the private practice protocols of chiropractic, physiotherapy and manual medicine may all be altered given a change in inclusion criterion for the practice of manual therapy.
Aside from the clinical implication, there was the consideration of the theoretical component of the lumbopelvic rhythm, which may redefine or support, a commonly held view of the clinical practitioner, about one aetiology of lower back pain being used over the other.

Chapter two discusses the different types of manual therapy and how they evolved. In the subsequent chapters, discussion about the commonly used manual therapies and their implications will be undertaken. It also includes a general discussion of pertinent historical and political features that have influenced the direction of development of manual therapy, followed by specific references to manipulation, mobilisation, and stretching. The discussions centre on the research relevant to the hip joint under investigation in this study. Following the literature review of the manual therapies, a further review of literature relevant to pain, pain assessment, and the functional characteristics of the hip joint and the lumbopelvic region will conclude this section.

The aims, hypotheses, methods, results, and discussion of the research including, recommendations for further research and the specific conclusions will be found in chapter three.
Manual Therapy

History of manual therapy
Through the ages the exact origin of manual therapy has been lost. Cyriax 1970 suggests that the practice of manual therapy has been conducted for centuries. According to De Giocomo (1978), these procedures have been practiced in one form or another since ancient Chinese times, where tissue manipulation is said to have been practiced around 2700 BC. He further suggests that the ancient Greeks (1500 BC.) gave instruction in manoeuvring the lower extremities in the treatment of lower back pain conditions. Apart from these early practitioners, no single origin has emerged. It is apparent that nearly every continent, and every culture has utilised its own form of therapy at one point or another. Evidence exists to suggest that the ancient Japanese, Indians, Early Babylonians, Syrians, Hindus, Tibetans, Polynesians, Indians of America (Sioux, Winnebago, Cree) and South America (Aztec, Toltec, Mayan, and Incas) have all utilised manual therapy. Further, the early Greeks (Hippocrates & Herodicus) and in particular, Galen (130-200), the “prince of Physicians” clearly advocated their use.

During the middle ages much of the acquired knowledge was lost to the barbarian knowledge. As the period known as the Renaissance dawned, the art of manual therapy again began to ascend, now commonly called bonesetting. This practice was often passed from father to son, mother to daughter, and was common practice in Europe, North America and Asia according to De Giocomo (1978).

Several other significant individuals have been noted. A lady referred to as Mrs. Mapp was Queen Victoria’s bonesetter, and her, as well as other successful practitioners inspired a surgeon of the day, Pagent, to write in the British Medical Journal (Jan 5, 1865) an article called; “Cases that bonesetters cure”.

By the end of the 19th Century, many of the concepts and clinical principles of modern day exponents had been established. It is likely that the early concepts of chiropractic and osteopathy came from this time.
The next significant individual would have to be the founder of the osteopathic profession. Andrew Taylor Still established this break away group in 1874 after splitting from his orthodox medical education. He believed that a displacement of one vertebra upon another compressed the relevant spinal artery resulting in a diminished blood flow to peripheral effector organs (Sandler 1987). He later suggested that pressure upon spinal nerves could also create injury.

Alleged to have been a disciple of Stills’, David Daniel Palmer split from his mentor and founded the Chiropractic profession after ‘adjusting’ the spine of his janitor who had a traumatically induced deafness early in his childhood. The deafness disappeared after the "adjustment". The term adjustment is still utilised today by chiropractors referring to a short amplitude high velocity thrust delivered in a specific direction. They (the chiropractors) contend that the adjustment is a more refined and skilful application of a manipulation, and as such prefer to utilise this word to describe the procedures that they perform. Therefore, an adjustment is a specific application of a manipulation.

For the next fifty years or so, great hardship was brought to bear upon the ‘lay manipulators’. It almost became a family battle as the prominent medical practitioners of the day (Cyriax, and Mennel), passed their conviction onto their sons, as did Palmer, whose son B.J. then fought for the chiropractors.

Meanwhile, other relevant developments in manual therapy continued to occur in 1965, and 1968 when Kabat, and Knott and Voss developed their respective systems of stretching known as Proprioceptive Neuromuscular Facilitation.

However, Cyriax, a practicing orthopaedic surgeon, continued to fuel the fire by referring to the new therapists as cults, bonesetters or lay manipulators, although their formal education had actually begun (Schiotz & Cyriax 1975, Cyriax 1970). His opinion mellowed later, especially toward the physiotherapy profession, who he hoped would take on the mantle of medical manipulation and institutionalise it.
Physiotherapists such as the Australian, Maitland, and the Englishman Grieve, and the New Zealander McKenzie, have all contributed significant protocols in dealing with manual therapy (Grieve 1978, Johnson & Chiarello 1997, Gillan et al 1998).

As the interest in the manual therapies grew, so did the rationale for their use, and the research that investigated their effects. In this respect, all of the professions have contributed to the scientific validation of the effectiveness of the procedures, as demonstrated by several authors such as: Calliet (1981), Cyriax (1977), Grieve (1986), and Waagen & Haldeman (1986).

However, although early research was scanty at best, the period from the 1960’s to the present, has seen a veritable explosion in quality and quantity of the research. This is especially true of spinal manipulative procedures, as their effectiveness in reducing pain and injury, has largely been established according to Haldeman (1992). However the same research best represents the division between orthodox, and heterodox medicine according to the findings of the in-depth report of the New Zealand government Commission of Inquiry into Chiropractic 'Chiropractic in New Zealand' (1979).

Some long held dogmas about treatment rationales have changed also. The once used bone out of place theory used to describe the processes underlying the spinal pathology and physiology has been replaced, by the osteopathic lesion (Fixation theory), and the updated version of the chiropractic subluxation complex.

Although once referred to as a bone out of place, the subluxation has been replaced by the revised subluxation complex (although the two are often used interchangeably). These are a complex of five components that may be present singularly or in some combinations, thereby incorporating a model to explain the joint dysfunction, especially at the level of the spine. Recent developments of the concept have further divided the concept of a subluxation into spinal and peripheral subluxation complexes, recognising the influence that adjacent structures of the body have on function. This shift is controversial in some sections of the chiropractic profession, but they do appear to be gaining credibility as chiropractors seek to regain lost scope of practice rights
(Personal observations). Change has occurred to incorporate recent developments in science and medicine into the science, art and philosophy of chiropractic.

The Chiropractic subluxation complex now incorporates the following five components:

1. Neuropathophysiological component.
2. Kinesiopathologic component.
4. Histopathologic component.
5. Biochemical component.

Therefore the type of therapy utilised in treatment is likely to be different, and probably multiple, as various components of the complex are addressed. Thus manual therapies may affect the complex directly, or by reflex action. For a full description and discussion of this subject, the reader is referred to the text by Schafer & Faye (1989).

Similar concepts have been adopted by the other groups within manual medicine, such as the medical manipulators of Europe (Lewit 1985), who call this form of therapy; Chirotherapie. In addition, the physiotherapy (Maitland 1977) and the osteopathic (Stoddard 1969) groups also utilise similar concepts, although the terminology is different.

**The Goals of Manual therapy**

The basic tenets on which the various forms of manual therapy are performed and universally accepted are twofold:

1. They increase ROM (Etnyre & Lee 1987, Yoder 1990)
2. They decrease pain. (Gitelman 1980, Full 1986)

Other claims are largely unproven to date, even though they often receive much attention in the lay press. The effects of the two forms of therapy here investigated; stretching, and manipulation, in achieving these and other effects have been documented, and will be discussed further in later chapters. With regard to stretching and mobilisation, much investigation both spinal and peripheral has been undertaken.
(Tanigawa 1971). However, Brunarski (1984) suggests that the great majority of the literature investigating the effects of manipulation have been conducted at the spinal level only. This bias probably reflects the application that they normally receive. What has not been documented are comparative studies between the different approaches on specific spinal joints or peripheral joints. Furthermore, the isolation of the effect of the procedures to one joint is a desirable aim, which hitherto has not been achieved in peripheral joint systems. Recent investigations are beginning to investigate some parameters of the single spinal joint effects of manipulation (Reggars & Pollard 1995, Carrick 1983).

Different theorems of the actual amount of ROM available to the different forms of therapy exist, and how the therapy actually effects this ROM (Cyriax 1970, Haldeman 1989).

The chiropractic model, based upon the hypothesis revised by Sandoz (1976), considers a joint to possess a finite amount of active movement, followed by another finite amount of passive movement, that may be achieved by mobilisation. Following this movement, there is said to be another plane of movement that is passive in nature, and is achieved only by the application of a specific adjustive or manipulative procedure. This paraphysiological space is the mainstay of manipulative procedures, although mobilisations may occasionally pass into it, especially after a manipulative procedure has already been performed. Entering this space is said to produce the crack sound often heard in manipulative procedures (Meal & Scott 1986). It appears that the audible release is associated with a rapid separation of the joint surfaces and cavitation within the intra-articular fluids as they rush in to collapse the gas bubble formed by the quick movement (Reggars & Pollard 1995, Reggars 1998, Reggars 1999). The maximum ROM thus achieved is bordered by the integrity of the anatomical limits of the ligamentous and muscular tissue. Exceeding this limit thus causes sprain, strain or dislocation (Sandoz 1976).

The medical/physiotherapy viewpoint, as demonstrated by Maitland (1979), and Grieve (1984), suggest a more structured system of gradation of passive movement, and the therapy used to effect it. In this viewpoint manipulation is considered to be an extension of the first four
grades of mobilisation, thus creating five categories of mobility. This is demonstrated in Figure 11.6 from page 127 of Grieve (1984).

This is not the case with the heterodox viewpoint. Here the emphasis is upon manipulation, or adjustment as it is referred to, as being a separate, and more powerful tool, in rehabilitation than mobilisation (Haldeman 1989). The opposite may be true of the orthodox approach (Grieve 1986).

As with the heterodox approach, the emphasis is on the palpation of abnormal or pathological movement, with the emphasis upon the particular phase of the pathology, rather than the pathology itself. Several authors with different philosophical backgrounds (Schafer & Faye 1989, Cyriax 1977, Grieve 1986), have suggested similar concepts.

Both mobilisation and manipulation procedures achieve the aim of increasing ROM according to Grieve (1986), but one procedure is under conscious control of the patient, whereas the manipulation, or adjustment is not.

Stretching in its basic form (static stretching) operates through the active and not the passive range (Haldeman 1980, 1989). With the active range of motion being that range of motion achieved by the action of one’s own muscles, which contrasts with a passive movement which any movement of the body effected by a force entirely outside the body (like a practitioner) (Dorlands Medical Dictionary 1994)

Some of stretching procedures have been modified to incorporate an end ROM passive stretch into their application. Some versions of the PNF stretches are an example, ballistic stretches, are another (Etnyre 1986).

The only diagnostic determination of these procedures is end feel, or joint play. Schafer & Faye (1989), suggest that this can only be determined by the very subjective art of palpation. Skilled practitioners from all the schools of manual therapy place a large emphasis of technique selection upon this ubiquitous art form.
At this juncture, it would not be inappropriate to suggest that different practitioners have different priorities in assessing and administering treatment. Many of the medical interventions are primarily pain treatments (Nachemson 1979), whereas many of the paramedical (chiropractic & physiotherapy) approaches are based primarily on the return to function (Schafer 1983, Brunarski 1984).

Thus, the assessment of this normal, and abnormal function is of great importance. Aside from the standard orthopaedic and neurological tests, postural, structural and palpatory analysis of varying intensity of degree is performed. Within the category of palpation, two hybrids exist. Motion and static palpation. As the name suggests, one evaluates mobility at a segmental or joint level in various directions of movement, whereas the other merely palpates the structures/tissues whilst in one position only. Thus, motion palpation is said to be able to, in addition to the information gathered by static palpation (tightness, spasm, heat, oedema etc), detect and document the state of the intrinsic motions of the feel of joint end feel or joint play, into particular directions. Thus, by relying on this form of palpation, a determination of joint restriction may be made. Although this hypothesis is appealing, and very commonly used, it still remains totally unfounded at this point.

Of interest, is that the heterodox forms of therapy, chiropractic and osteopathy, who were more likely to utilise manipulation in treatment, also placed a greater reliance on these motion palpation techniques for their diagnosis.

Particularly of interest is that the ability of these forms of therapy (manipulation based approach) seem to improve ROM and pain at a greater rate than do conventional methods when applied in a treatment regimen (electrophysical therapy, mobilisation etc) (Meade et al 1990).

Therefore this effect may be related to the ability of the examiners to locate the lesion to be treated, rather than the actual treatment itself. This, as many other areas within this literature requires much investigation. I believe this issue to exist as an extremely important factor in the field of manual therapy. Until some method is devised to determine the in-vivo tissue effect of the choice of therapy, and the
ability of the examiner to determine the appropriate choice of therapy, much difficulty will remain in validating these procedures.

As this investigation did not have the determination of local tissue effects on the tissues of the hip or other joints as a goal, this line of thought will be left, and a recommendation only for further research made. How exactly this maybe achieved without invasive procedures being performed on the human subject, is difficult to perceive. Some models may have to be tested on animal subjects in the first instance.

Therefore, the location of the joint, the end feel and the amount of pain are all factors in choosing an appropriate therapy.

The exact indications for the use of manual therapies are variable, and change according to the specific form of manual therapy chosen.

Collectively, the primary treatment aim of the manual therapies is to restore normal painless joint range, according to Grieve (1984). He further states that this is achieved by any one or combination of the following:

1. Relief of pain and muscle spasm.
2. Restoration of normal tissue-fluid exchange, soft tissue pliability and extensibility, and normal joint mobility.
3. Correction of muscle weakness or imbalance.
4. The stabilisation of unstable segments.
5. The restoration of adequate control of movement.
6. Relief from chronic postural or occupational stress.
7. Functional reablement of the patient.

Other authors (Lewit 1985, Haldeman 1989) also confirm these values. These aims differ in order and or importance from one individual to another. Thus, the variability of an individual may cause some of the variability in treatment approaches and effects.

A discussion of the literature relevant to the common forms of manual therapy will now follow.
Stretching

Introduction

Stretching techniques have been used by therapists for years and has recently been the subject of renewed interest in the scientific community (Hanten & Chander 1994, Osternig et al 1990, Etnyre & Lee 1987). It is now well established that the range of motion is actually changed by stretching (Etnyre & Lee 1987). Given this fact, one must choose which stretching procedure to use from the variety available. This is of relevance due to the superiority attributed to each variety at one time or another.

However, the more functional aspects of stretching are of considerable interest to those who may use them. Such persons would include various medical and paramedical therapists, and their patients. Others would include trainers, coaches, and athletes.

Factors such as; the amount of force required to achieve a stretch, what is an adequate stretch, how long to apply a stretch, and whether the procedure produces any injuries are of great relevance. To date these factors have not been entirely addressed, nor have the issues of over stretching, injury prevention, injury relief, relief of delayed onset of muscular soreness. However, they have been raised by several authors including: Ebbing & Clarkson (1989), Abraham (1990), and Safran et al (1989).
Who uses stretching

These are all issues of relevance to the practitioner employing these procedures, whether they are a therapist or not. In the case of this investigation, the term practitioner refers to a healthcare practitioner, although it is well known that stretching is used by a great proportion of the community including: athletes, trainers, exercise & sport science therapists, masseurs, patients etc).

For the purposes of this investigation, stretching may be considered a procedure applied by a second party (therapist) or the subject (self). The stretch would be applied to a specific target tissue, such as, muscle or ligament, to achieve an elongation of that tissue without any undue pain or discomfort. When such a procedure does in fact create pain, discomfort or tissue injury, it is hereafter referred to as overstretching. Stretching is used by many different people for different reasons. Many individuals will undertake a stretching program (yoga) as a part of a callisthenics routine to try and obtain better health, in much the same way as others use a daily exercise routine such as jogging, swimming, cycling or weight lifting.

Another group of enthusiasts who may utilise stretching in an extensive manner are the athletic community. This group performs stretches for a number of reasons. These reasons include; stretching as a part of a warmup routine, or to reduce the stiffness and tight musculature associated with the training individual (Alter 1996). Also, athletes may use stretching for the ergogenic potential they think that it possesses to improve performance. Recent evidence suggests that there may be some substance to these claims. In a study by Worrell et al (1994), the application of a stretching procedure (PNF & static) was able to increase peak torque measurements of hamstring function when measured eccentrically (60∞/sec, 120∞/sec) and concentrically (60∞/sec) in both men and women. They concluded that increased hamstring flexibility increased hamstring performance (Hatfield 1985). However, other athletes, such as gymnasts or other individuals may require stretching as an integral part of the training routine, necessary for basic flexibility requirements of their chosen sport.

Yet another group who frequently utilise stretching procedures and are the focus of this study, are the healthcare practitioners. Practitioners
such as chiropractors and physiotherapists frequently use stretching as a modality of treatment. Their use is largely restricted to the removal or reduction of contracted muscles and joints, but may also encompass muscle re-education according to Knott & Voss (1968). These practitioners often prescribe the exercises as a home treatment program, to enable an injury to receive ongoing restorative forces whilst undergoing repair. If the amount of stretching received by the patient may be considered the dose of the treatment, one may consider the home program as an increase in dosage. The dose response characteristics of stretching are of importance and have not been investigated other than utilising the training studies. Their use is not restricted to these individuals. However, because coaches, trainers, teachers and other therapists would probably utilise some form of stretching within their program it is conceivable therefore, that a wide cross section of the community may be using the procedures collectively known as stretching. This cross section of individuals is not homogeneous in nature. Individuals with great knowledge and experience in anatomical structure complement those who are devoid of such information, and include the health care practitioner, to the novice school athlete. However, as many beneficial claims have been made of stretching (Hatfield 1985, Anderson & Burke 1991) as comparisons and counterclaims from opposed researchers (Buroker & Schwane 1989, Etnyre & Lee 1987). The matter of experience with these procedures and the skill of their application is of importance. One may naturally expect a very different level of skill between these individuals, and standardisation of the forces and their direction of application would be impossible to gauge. It is unfortunate that this factor has not received more attention from the scientific community.

It has been suggested by Stanish (1982) that a passive increase in ROM may be with or without pain and injury, depending upon the procedure chosen, and how it is applied. I feel that the injury associated with this form of manual therapy is probably related more to the injudicious application by novices, rather than the expert application by healthcare practitioners.

When considering the issue of stretching, one may read of more than one variety of stretching carried on by many practitioners. Initially one may classify the broad term of stretching into those stretches that are
either (A) static or (B) dynamic in nature. The classification of static stretching may further be broken down to that of; static, and proprioceptive neuromuscular facilitation (hereafter known as PNF). Of the PNF type, the contract-relax (CR) and contract-relax-antagonist-contract (CRAC) are the main varieties used.

According to Tanigawa (1971) the dynamic stretch group, may include mobilisation (although mobilisation is not strictly a stretching procedure), and therefore is not listed as such by Hartley-O’Brien (1980). It could fall into the category of passive, slow stretches however. Thus we may state, that stretching by definition elongates the tissue of a joint to which it is applied. Therefore, the soft tissues surrounding a joint and controlling the actions of the joint may be considered as limiting factors when trying to increase the mobility of a joint (Hartley-O’Brien 1980). The soft tissue include the nerve, connective tissue joint capsule, and capsular and extra-capsular muscles and ligaments. The stretching procedure, by definition, will affect all these tissues. It is unknown whether stretches affect certain tissues in preference to others, although recent studies suggest that a new stretch can bias a stretch toward the stretching of the neural tissue, although it is not stated how it does this specifically (Johnson & Chiarello 1997). Moore & Hutton (1980) stated that the advantages of using the static stretches and the proprioceptive neuromuscular stretches were explained by the classical Sherringtonian views (Sherrington 1906, 1908) regarding the stretch reflex and reciprocal innervation.

It is now accepted by Etnyre & Lee (1987) in their review of the stretching literature, that some forms of stretching seem superior to others. There are four different types of stretches that are explained within the literature (Etnyre et al 1986, Osternig et al 1990). Although others have been discussed over the years, they appear as variations or combinations of the four principle forms of stretching.

Types of stretches
The Static Stretch
Firstly, there is the static stretch. This stretch is performed by slowly and passively stretching the muscle to which it is being applied. This is done by increasing the range of motion (hereafter referred to as ROM) until a resistance is felt, the stretch is then maintained in that position.
for a period of approximately twenty to thirty seconds. It is then released, usually for a repeat performance ranging from two to five repetitions (Williford et al 1986, Wallin et al 1985, Moller et al 1985a, Moller 1985b).

The Ballistic Stretch
The second type of stretch is the one of two dynamic stretches considered here, the ballistic stretch. Moore & Hutton (1980) state that this form of stretching involves the muscle being accelerated through its full range of motion by the subject themselves or by the second party, which forces the stretch of the muscle, by the momentum of the swinging body segment.

A further consideration according to Kottke (1966) in the choice of stretching and other techniques, is that the attachments between collagen fibres show high resistance to suddenly applied tension, but demonstrate a creep or prolonged tension. This factor would suggest the application of sudden stretching movements to be less than ideal.

Thus the ballistic stretching methods and procedures seem recently to have fallen into disfavour due to their potential for injury. Etnyre & Lee (1987) suggest that even though such dynamic speed and mobility are desired qualities in the sporting arena, there are no indications, at this point, that suggest this form of stretch may achieve this aim any better than the static forms, or just plain active warm-up exercise. Based on 15 years of clinical experience treating sporting injuries, I feel that ballistic stretches should be considered an advanced exercise that is given for action specific tasks in sport or rehabilitation in those individuals already proficient in static and PNF stretches.

The Slow Stretch
Moore & Hutton (1980) describe a second albeit more gentle type of dynamic stretch called the slow stretch. These stretches are slow purposeful movements as those conducted in some forms of ballet dancing routines and exercises such as tai-chi. They involve the participant actively moving through all available active range of motion often accentuating the end range of motion in a fashion that is specific to the sport of the action being performed (Moore & Hutton 1980).
Proprioceptive Neuromuscular Facilitation (PNF) Stretches
The fourth and fifth types of stretching are commonly referred to as PNF stretches after Knott & Voss (1968) and Kabat (1965). This type of stretching is divided into two basic PNF varieties. The first variety of PNF is called the contract-relax (CR) form, and is a combination of the static stretch followed by an isometric contraction of the already stretched (agonist) muscle. With this type of stretching, the muscle is then relaxed after a contraction time of no greater than 10 seconds (Cornelius & Hinson 1980, Lucas & Koslow 1984), and the procedure is repeated once or twice.

Hardy (1985) describes that in this procedure, the muscle is taken through a ROM until a resistance is felt (as was the case in the static stretch). This is followed by an isometric contraction that lasts from 3-10 seconds at the end point of the ROM. After which, a new end point is found and the procedure repeated. Also, Moore & Hutton (1980) report that the contracted muscle maybe reflexly inhibited by overcoming the golgi tendon organ and muscle spindle activity, which may promote a lasting and prolonged discharge thereby increasing the ROM through a decreased level of resting of muscle length, utilising the reciprocal innervation first postulated by Sherrington in 1906.

Animal studies reported by Laporte & Lloyd (1952) have shown that the golgi tendon organ (1b fibre) operates to disynaptically inhibit the alpha motor neuron of the same muscle and disfacilitate stretch via the primary afferent nerve, as later reported by Moore & Hutton (1980), Etnyre & Lee (1987). It is further recognised that the action of the group 2-4 afferent nerve fibres may result in an abrupt decrease in the muscle force generated according to Moore & Hutton (1980). All these mechanisms implying a decrease in contractility of the muscle being stretched.

The second type of PNF stretching is the contract-relax-antagonist-contract (CRAC) form. This particular form of stretching utilises the components of the contract-relax (CR) form and hence the static stretches, with the addition of an antagonist muscle contracting concentrically in the place of, or following the agonist relaxation.
There appear to be commonly occurring variants of the same procedure in the literature (Tanigawa 1972, Godges et al 1989). These variants are divided into two groups, those that are performed at the end of ROM, and those that are performed at a point in the mid range of joint movement. These mid ROM procedures often involve several groups of muscles rather than a single target muscle. It is therefore likely that due to this variation in the application of stretching, there is likely to be an even larger variation in the effects, especially if the previously mentioned variables in the force, direction and time are also included. These variants usually occur in the form of treatment regimens dealing with motor learning, and rehabilitation, as typified by Knott & Voss (1968).

Hartley-O’Brien (1980) rightly suggests that the PNF stretches actually incorporate passive static stretches into the first part of the procedure. This would not be true of a mid ROM procedure utilised by investigators such as Knott & Voss (1968), and Godges et al (1989). However, it would be so for the end ROM procedures used by other investigators such as (Hardy & Jones 1986, Hanten & Chandler 1994).

**Time in stretch**

Another factor for consideration, is the actual time spent in the stretch, or the contraction of muscles themselves. It has been estimated by Hardy & Jones (1986), Wallin et al (1985), Sady et al (1981), that a ballistic stretch be performed actively and then passively for up to one minute, and that a static stretch should be held for a period of twenty to thirty seconds. In contrast, the PNF stretches require a stretch period of three to ten seconds, according to protocols set by several research groups (Tanigawa 1972, Moore & Hutton 1980, Moller et al 1985a, Hardy 1985, Wallin et al 1985). Thus the dosage used during the intervention is quite different, and according to Etnyre & Lee (1987), this particular problem occurs frequently within the literature. Once standardisation has been achieved, several researchers including Sady et al (1972), Tanigawa (1972), Medieros et al (1977), Cornelius & Hinson (1980), have shown that the PNF methods are superior to both the static, and the ballistic forms. Several research groups (Holt et al 1970, Cornelius & Hinson 1980, , Moore & Hutton 1980, Holt & Smith 1983), have shown that the PNF (CRAC) method was superior to the PNF (CR) method.
Another factor frequently not controlled for, is that of the amount of force used in the application of the stretch. Again, only a few attempts seem to have been made to standardise this effect, examples of which are those projects conducted by Medieros et al (1977) and Godges et al (1989).

It is intuitive that the application of a larger force is more likely to create a greater change in ROM. However, the extra force may be at a cost. Tissue disruption resulting in frequent pain and discomfort has been reported by many authors including Kulund (1983), and Jacobs et al (1986). Based on the above, patients and sports persons appear to have been the most exposed individuals receiving extra force during treatment. This has probably occurred because the force delivered during treatment was made to simulate that of a sporting activity.

The mechanism of increased ROM with stretches
According to Etnyre & Abraham (1986), stretching has only really one proven effect sustained thus far in the literature; it increases ROM. Therefore, the proposed mechanism of action of the stretches is of great interest to the authors because little in the way of evidence of the advantages of stretching has been proven.

According to Moore & Hutton (1980), the prolonged static stretch allows the muscle spindle stretch response to subside. This effect is due to a less intensely responding group of 1a afferent fibres when a stretch mechanism is static rather than dynamic in nature (Hortobagyi et al 1985). However, according to Etnyre & Abraham (1986) this is followed by a low level of autogenic facilitation to the antagonist muscle group, causing the muscle to contract thereby creating an adverse inhibition of muscle activity according to the classical Sherringtonian views. Although despite support by Etnyre & Abraham (1986), Hortobagyi et al (1985) did not consider the effect to be proven a decade earlier. Recent work by Etnyre & Abraham (1988) , and Spring et al (1991) suggests that the static stretch is said to overcome the influence of the myotatic stretch reflex produced by the muscle spindles. Thus the stretch produced in the post isometric phase also influences the golgi tendon organs, creating an inhibitory influence. Authors such as Etnyre & Lee (1987), Tanigawa (1971) usually cite these effects by the
golgi tendons as the reason for the decrease in facilitation of the muscle being stretched. Williford et al (1986) also suggests that apart from the neurogenic mechanisms operating, there are proposed mechanical changes to the tissues that include the deformation of non contractile tissue located within connective tissue (loss of ligamentous crimping due to creep induced by prolonged loading of tissues).

Recent electromyographic (EMG) studies of stretching procedures suggest that CRAC stretching produces up to 110% more electromyographic activity than CR or static stretching, and increases ROM by up to 13% (Osternig et al 1990). The same study also found that some endurance trained athletes have 58-113% more hamstring activity than do either the sprint athlete or sedentary controls.

Hortobagyi et al (1985) also suggests that stretching affects the intrinsic muscle mechanical behaviour. Sarpega (1982) further proposes that low intensity stretching, as that found in static stretching, may affect the connective tissues within muscle and ligament by inducing increased range of motion secondary to creep induced changes. According to Gould (1973) the “end feel” associated with passive stretching is derived from the strength of the connective tissues and not the contractile components themselves, a view supported by Etnyre & Abraham (1986) and Osternig et al (1986). Kottke et al (1965) previously posed a view that connective tissue demonstrates a property of progressive shortening when not opposed by a stretching force. Therefore, the changes have been attributed to the changes in length of the collagen fibres themselves, according to Avery (1936), and the metabolic response by the fibroblasts (Robbins et al 1981). This contracture is a slow process, commonly requiring weeks to occur. Therefore, the amount of connective tissue in and around the joint, may seriously affect the joint mobility if the joint/muscle is injured, or immobilised for a period. Thus, the characteristic movement restrictions of joint following trauma, known as capsular patterns, may be in part represented by the above mentioned changes in the connective tissue component, along with other changes such as fluid aggregation in and around the capsule of the joint (Cyriax 1982).
If connective tissue can be lengthened via stretching, and other manual therapy procedures, an indication for the use of these procedures in the reduction of joint immobility and injury therefore potentially exists.

Given the proposed effect on connective tissue, other factors, controlled or not, may therefore affect the stretch via the connective tissue. According to Williford (1986), and Laban (1961), tissue temperature can greatly affect the tissue extensibility. At the lower temperatures, the elastic properties of connective tissues prevail, however, at higher temperatures (as in exercising states, and fever) viscous properties prevail. Therefore, according to Viidik (1971), and Warren (1985), at the higher temperatures greater elongation of the tissue occurs. A recent study by Cornwall (1994) showed that peak force and rate of force development decreased, while time to peak force development increased following exposure to cold. It is further suggested by Viidik (1971) and Warren (1985), that repeated stretching of connective tissue will act toward a steady state, which implies an optimum length over which further stretching may be of no value or may actually have a negative physiological effect. This could be a major factor in the aetiology of injury attributed to stretching, and other manual therapies, and commonly referred to as over-stretching (Reid 1988). A state that is also associated with a decreased power output (Tacker et al 1991). This mechanism could potentially explain some of the negative side effects of a manual therapy. It may simply be a question of dosage, or application of technique, two areas that have received no, or little attention from scientific investigators.

According to Spring et al (1991), ballistic stretching is performed to rapidly exceed the muscle spindle and golgi tendon organ ability, to react to a force applied and hence increase the ROM. Rahlmann (1987) suggests this procedure may break down any small soft tissue fixations or adhesions that may have accrued due to some inflammatory response such as trauma. Adhesions in the joint space have been postulated for some time to be a source of restriction, and are responsible for a decrease in mobility often present within joints. This problem is termed adhesive capsulitis, and is a commonly occurring clinical entity, according to Rahlmann (1987), in those people suffering muscle or joint pain. It is the authors opinion, that this mechanism may be occurring at a subclinical level. This may be directly relieved by various manual
therapy procedures, by breaking the adhesions, and thus improving pain response and ROM in these subclinical states. Depending on the location, and size of the restrictions, more forceful, and specific procedures may theoretically demonstrate superior results. I would hypothesise that the manipulative procedures would be superior in achieving these results when compared to the mobilisation techniques. The theory of one sub-group of causes of low back pain remains unchallenged to date, with the exception of anatomical dissection work conducted on meniscoids at the spinal level (Jones et al 1989), reported by Shekelle (1994). This hypothesis proposed that meniscal folds (referred to as meniscoids), could be responsible for joint locking. Further, the hypothesis suggested that the meniscoids were amenable to manipulative treatment (Jones et al 1989).

This factor, of joint or myofascial adhesions, if present may contribute to a decrease in ROM according to Cailliet (1988). However, Wallin (1985) warns that as muscle is rapidly stretched with these dynamic techniques, the intrafusal muscle spindles could be activated, reflexly causing a protective muscle contraction of activated muscle. Therefore creating the exact state that the stretch was attempting to reduce in the first instance. It has been proposed by Wallin (1985) and others, that this could be a source of injury experienced whilst receiving these dynamic techniques.

I propose that a similar mechanism based on overstretching primarily accounts for most adverse reactions associated with manipulative thrusts. Such changes are recognised to be the most common form of adverse reaction to manipulative therapy (Terrett & Klenyhans 1992).

With respect to muscle contraction, Armstrong (1984) has postulated that the group 2-4 nerve fibres are responsible for delayed onset muscle soreness exhibited after unaccustomed exercise. Other authors such as Friden et al (1981), and Newham et al (1983), have connected the specific type of muscle pain known as DOMS to eccentric contraction of muscle. Due to the common innervation of the effects, an avenue exists for dual activation, should the stretches be performed in a manner that may overload the eccentric contractile capacity inherent in a given muscle. Should this overload be due to muscles that are forcefully lengthened, microtrauma to the muscle may result causing that type of
pain associated with eccentric contraction. It is hypothesised that this form of injury and pain is a possible form of discomfort associated with over stretching and vigorous mobilisation and manipulation, especially if the subject is not relaxed. It is hoped that this interesting concept receives further attention from the scientific community.

Whether the common mode of perception of these two states forms the basis of claims made by some investigators, remains a mystery. An example of one such claimant was Hatfield (1985), who seems to have made claims without little research foundation. He has claimed that stretching can reduce the effects of DOMS soreness. Given that such soreness is the product of overstretching of the musculotendinous junction, it remains a mystery how further stretching of the damaged tissue could resolve such pain, other than to provide a counter-irritant for a pain gate effect to reduce the perception of pain (Melzac 1983).

It is primarily the lay literature that perpetuates such fantasy. To date, there have been at least two discussions of the topic by High et al (1989), and Buroker & Schawne (1989), that suggests there is no relationship between delayed onset muscular soreness (DOMS) and stretching.

The relationship tested by these investigators was whether stretching was able to decrease the pain and disability associated with DOMS. From a clinical point of view, stretching could perhaps improve the state of the subacute or chronic sufferer, as adhesion (scar formation) and contraction are a normal consequence of injury. This however, was not the intention of the original claimant (Hatfield 1985). It is of further interest, that such an intervention was largely redundant, as Friden et al (1986) suggest the pain associated with DOMS is self limiting, in so far as it usually resolves within 5-7 days.

Cornelius & Hinson (1980), suggest that a maximum voluntary contraction elicited before a flexibility manoeuvre does influence the ability of a muscle to extend, specifically to increase the ROM. The mechanism proposed by these researchers implicates the inhibition of the relax stretch of muscle by the golgi tendon organ, and supports work by Holt et al (1970) and Tanigawa (1972). These investigators also suggest that the golgi tendon organs are sensitive to changes to both
stretch and contracture. In addition, they also suggest that inhibition occurs at the anterior horn cells by central mechanisms.

The exact mechanism of the increase in ROM created by stretching procedures has been postulated, but has not been proven by any research to date. It is suggested that part or all of the following may contribute to the mechanism of action:

a) the (CR) procedure could produce a lasting inhibition of the stretch muscle via the golgi tendon organs and the 1b fibres. This is a manifestation of the tendon reflex, which functions to mediate the tension building up in the musculotendinous complex. It is intuitive that increasing the stretch of the muscle, firstly by passive stretch, and secondly by the contraction of the muscle, serves to increase the tension within the muscle.

b) that activation of a pain mechanism could occur via the large fibre input arising from the contraction phase. The pain gate mechanism first proposed by Melzac & Wall (1965), was a theory about the perception and organisation of pain impulses arising from the peripheral pain receptors, to their central transmission for perception. Briefly, it states that pain perception is governed by the summation of all sensory impulses. Pain, plus other tactile and mechanoreceptive information are processed. Melzac & Wall (1965) also stated that impulses mediated through large neuronal fibres, that were faster conducting fibres, had a positive or facilitatory effect on the substantia gelatinosa in the spinal cord. Also, this facilitatory effect on the substantia gelatinosa had an inhibitory effect on the interneurones that transmit the pain to higher centres. This centre is the first in a chain processing centres within the central nervous system, and has its own ability to decrease pain perception. This is done by the liberation of opiate like substances from the cellular network located in this region of the cord, and this centre has been theorised to have a profound analgesic effect via this mechanism, therefore decreasing the pain perceived (Melzac 1983).

However, the small neuronal fibres which were slower conducting, served to inhibit the substantia gelatinosa, therefore inhibiting the
inhibitory effect of this area, or in addition facilitating the overall pain perceived.

The relevance of this mechanism becomes undeniable when it is known that the joint and muscle mechanoreceptors travel by large fibre input to the cord, as discussed by Astrand & Rodahl (1988). Therefore, the action of the muscle spindle (1a fibre) and the golgi tendon organ (1b fibre) have an inhibitory effect on the pain perception, which is mediated by the smaller c fibres from free nerve endings, Astrand & Rodahl (1988).

This pain inhibition may also be modified by higher centres according to Kirkaldy-Willis (1983). Such input occurs from descending central nervous system feedback systems of the reticular formation, the thalamus, and the cortex of the brain.

c) Enoka (1988) expands upon early work by Hough (1902), by presenting a classic three component model representing the mechanical characteristics of muscle contraction. In the model, the series elastic component could be used to explain the effect of stretching on the non contractile and the contractile elements within a muscle. It is suggested that stretching of the series elastic component occurs during muscle contraction and during the performance of stretching. The model suggested by Enoka actually comprises three components. These are the contractile component (CC), and the elastic component, which is further compartmentalised into the series elastic and parallel elastic components, the contractile component of the muscle (CC), and the elastic component of the muscle. The parallel elastic component (PEC) represents the elasticity present when the muscle is stretched when unstimulated, and the series elastic component (SEC) represents the elasticity available when the muscle is contracted, and is much less extensible than the PEC. It is therefore possible to explain small increases in ROM via such a mechanism.

d) that there may be some increase in supraspinal inhibition of that stretching muscle motor neuron during the active phase of the movement into the new extended range.
Kirkaldy-Willis (1983) reports that central modulation of pain occurs via decreased cortical activity, therefore decreasing the perception of pain. As mentioned previously, the reticular formation, via the reticulospinal tract, exerts an inhibitory effect on the pain gate by processing and summatating various interneuronal activity sources including, but not limited to:

i. Distracting attention away from pain
ii. concentrating on other activities
iii. utilising emotional states or hypnosis
iv. others

According to Astrand & Rodahl (1988), these effects are mediated via higher centres of the brain affecting the resting tonus of the musculature via action of the long loop gamma efferents of the extra pyramidal system, affecting the tonus of the musculature mediated by the reticulospinal, vestibulospinal and cerebello-olivo-spinal tracts of the spinal cord (groups of neurones within the spinal cord that conduct like information from the muscle to the central nervous system or vice versa). Moore & Hutton (1980) suggest, that the comparative action of the cerebellum in alpha/gamma co-activation is integral to this function. Astrand & Rodahl (1988) further suggest that the co-activation occurs with the exception of very fast movements, where it is likely that only alpha motor neurones are active (Berne & Levy 1990).

The other type of PNF stretch commonly encountered in the literature is the contract-relax-antagonist-contract (CRAC) form. This procedure is similar to that of the (CR) procedure but with addition of a concentric contraction of the antagonist muscle following the relaxation of the antagonist. It too has many variations. In addition to the previously discussed mechanism of action of the (CR) stretch, the reciprocal innervation specific to the (CRAC) form of stretching may also be demonstrated (Sherrington 1906, Etnyre & Lee 1987, Enoka 1988).

The reciprocal innervation proposed firstly by Sherrington in 1906, was later applied by several other researchers including; Knott & Voss (1968), Moore & Hutton (1980), Etnyre & Abraham (1986), Osternig et al (1987) and others, to explain the mechanism of the PNF CRAC stretches. Simply stated, it calls for relaxation of the agonist muscle
when the antagonist is activated. However, in opposition to this viewpoint under conditions of very strong voluntary contractions, a certain amount of co-activation of agonist and antagonist can be expected according to Person (1953). This is especially when the task requires precision or is being applied by a novice, which implies some form of motor learning effect. Osternig et al (1987), who found significant increases in ROM following PNF stretching, proposed co-activation of agonist and antagonist muscles to explain the electromyographic (EMG) activity in the antagonist or stretched muscle, when none or little should be present.

Although the most impressive gains in ROM have been attributed to this form of stretching (Etnyre et al 1986, Etnyre & Lee 1987), there has been much debate by researchers such as Hartley-O’Brien (1980), Cornelius & Hinson (1980), and Lucas & Koslow (1984), about the proposed mechanism, because conflicting evidence has been presented.

Firstly, let us examine the evidence proposed by Hartley-O’Brien 1980, and Lucas and Koslow (1984). They found the differences between the stretching groups and the non stretching groups to be non significant. However, if these studies had have been properly controlled or designed, results may differ. In the Lucas and Koslow experiment, no control groups were used. In the other study, by Hartley-O’Brien, the actual amount of time spent performing the stretch was not controlled adequately, although an attempt was made. The active stretch component of the modified PNF procedures was not equal to that of the static stretch component, although the overall amount of stretching time (active + passive) was equal.

By contrast, several other well performed studies have been compared in a recent review paper by Etnyre & Lee (1987). They conclude in their paper that well controlled studies demonstrate PNF stretches were superior to static stretches.

The debate about the mechanisms, and ultimately the effectiveness of the PNF stretches continues to be fueled by evidence of researchers who have found no significant differences between stretches. PNF procedures incorporate in their initial portion of their execution, a static stretch. Because of this fact, it could easily be surmised, that no benefits
were attributable to the PNF varieties, as they were merely an extension of static procedures. This is especially so, when some researchers were reporting significant differences between the two types. Further weak evidence by Osternig et al (1987), demonstrated some positive effects of PNF over static varieties, but did nothing more than perpetuate the negative reporting about the efficacy of the PNF stretches, because the proposed action of the PNF stretches was not supported by the findings of Osternig and his co-workers.

Earlier, Moore & Hutton (1980), explained the phenomenon as the enhancement of the myotatic stretch reflex following a brief static contraction. The electromyograph findings showed that the magnitude of activity during the (CRAC) stretching procedure was greater that the (CR) procedure which was in turn greater than the static stretches. This also added to the disquiet amongst researchers regarding this topic, because there was no direct relationship between EMG and ROM, but Sady et al (1980) explained the differences more as a measure of poor design and control.

These results were confusing and unexpected. The theory proposed to explain the action of PNF procedures, calls for reciprocal innervation of the antagonist muscle, when the antagonist is contracting. Although researchers such as Osternig et al 1987 did in fact report superiority of the PNF procedures in ROM gains, these gains were associated with an increase, and not a decrease, in the activity of the antagonist muscle group. The evidence was therefore very contradictory.

EMG evidence for Mechanism of PNF (CRAC) stretching
The fact that the increase in the EMG activity resulted in increased length seemed to counter the whole basis for the use of the PNF stretching procedure. However, a glimpse of understanding began to emerge when Etnyre & Abraham (1988), noted that all previous EMG studies in this area utilised surface electromyography and not indwelling or needle electromyography. Etnyre & Abraham (1986) postulated that it was in the realm of possibility that the increase in EMG activity was in fact due to spurious information, or interference. This idea was further strengthened by knowledge that surface electrodes are often influenced by attenuation, propagation in the tissue and cross talk from adjacent muscles as explained by Etnyre & Lee (1987). They therefore
used indwelling as well as surface electrodes to investigate this phenomenon more closely. The results showed activity in the surface electrode, and no activity in the indwelling electrodes. Other forms of PNF stretching techniques were also used for comparison, and they, with the surface and indwelling electrodes, indicated that the source of the EMG activity was not of the same origin as that measured by the surface electrodes. It was therefore concluded by Etnyre and Abraham (1988), that the mechanism proposed for the CRAC PNF method did include reciprocal innervation, and was in fact valid.

Furthermore, in those studies that standardised the time in contraction, and number of interventions, the CRAC technique was found to be superior. In their review paper, Etnyre & Lee (1987) expanded upon this view to state that the dosage variables given during the interventions should be standardised, so that a direct comparison could be appropriately made, and that in studies that dosage was standardised, the PNF CRAC variant demonstrated superiority. Therefore, the evidence presented thus far would indicate that the PNF CRAC variety of stretching to be superior to the other forms, and that the likely mechanism for its action involves reciprocal innervation.

I was unable to locate case control studies testing the effectiveness of slow stretching protocols in a literature search of the Medline, CINHAL and MANTIS databases.

Variation from these stretches do occur. The primary source of this variation is the performance of the four variants at some point before the end of physiological ROM, as mentioned in the procedures utilised by Tanigawa (1972) and Godges et al (1989), although this appears to be occurring less in the literature recently (authors observations).

Another variation is the use of stretches that stretch some combination of muscles acting over a number of joints in oblique planes. An example of these stretches would be those used by Knott & Voss (1968). These could also fall within the mid ROM procedures mentioned above, as variants of the end ROM procedures. Although the stretches utilised by Knott & Voss (1968) were for clinical use, consideration must be given to standardising the stretching processes in order to adequately research their true potential. Comparing different procedures, as in
other areas of manual therapy, gives only an indication of the superiority but not its true worth. Removing all the available confounding variables takes the comparison into the realm of true comparison, where the superiority may be determined. Factors learnt from these comparisons may then be applied to improve the efficacy of performance, and selection criteria. Attainment of goals in the most appropriate fashion may relate to the speed of recovery in the clinical setting, and result in a cost saving to the benefactor.

The question of the desired outcome being affected by the performance of the stretch is an important issue. Standardisation of the stretching procedure is essential to not only compare with other studies, but also to allow comparisons within the study. Now let us consider the example of the hamstring muscle group, as it formed the basis of this investigation. The tension on the hamstring muscles may be affected by a number of factors. These factors include the function around two joints, and also its multiple attachments (Pansky 1979). If pelvic rotation, later involving the reduction of the lumbar lordosis, and knee position is not considered, much variation in function, and ultimately results could be effected. This is a major factor in the examination of the relevant literature on the subject of stretching.
Assessment of flexibility: Importance of warmup

The state of the muscle when stretched may also influence the results of any procedures applied to the muscle. The physiological state of the muscle may affect function (Astrand & Rodahl 1988). The anatomical state of the muscle and joint that it spans may also directly effect the function according to Calliet (1981). Also, the general level of heat within the body, and that of the local heat within the muscle may also influence the movement applications. It is known that heating the body and the muscle mass may allow better function (Lamb 1984), and that cooling the muscle decreases performance (Cornwall 1994). Safran (1989) discusses the effect of changes in ROM following the use of a warm-up routine, and no warm-up. Such effects of heating could be the basis of tissue injury also. Should the extra extensibility of the tissue be exceeded during the stretch, over stretching could result from passing the elastic phase of the tissues into a plastic phase, where unwanted deformation of tissue could result.

Also, Atha & Wheatley (1976) suggest that diurnal variations in flexibility should be eliminated by re-testing at the same time of the day.

Further, restriction of movement is often a desirable feature. Any person who has suffered from an unstable joint injury or broken bone, would readily attest to this.
Flexibility: Sex differences

It is a commonly held view in the athletic and general community that females possess greater flexibility than males. However, this does not seem to carry over to the gender response to stretching. Etnyre & Lee (1987), found that females possessed greater absolute ROM compared with their male counterparts, but the response to stretching was the same in both sexes.

One could postulate that male and female work practices probably still differ greatly on average, even though the balance is changing. It remains that on average males still seem to perform more manual labour than females, and on the average, females tend to perform more secretarial or office duties. Such an observation would be reinforced upon walking into the majority of office blocks or building sites. It is however, an opinion based more on theory than fact.

If these activities were significantly different, they could be responsible for the changes noted in the initial values of ROM. I would therefore suggest the differences to be based upon lifestyle, work practices and possibly anthropometrical considerations, rather than any inherent physiological difference.

To quantify the implication of this point, it has been suggested by several authors (Weber 1949, Holland 1968, Ekstrand et al 1981), that long term heavy labour and habitual work postures that operate through restricted ranges of motion may lead to adaptive shortening of muscle and connective tissue. Further, it has been claimed by Janda (1967), and Lewit (1988), that muscles that function primarily as postural ones are prone to shortening, and that those muscles involved with dynamic physical work are subject to weakening. Thus, the prolonged physical work done by the males could account for the findings of decreased ROM with respect to females. Obviously, various physical activities, of which sport is included, could be placed into this category. Sport is still largely dominated by males in most countries, and this may also be an explanation for the discrepancy in the figures quoted in that study. Sampling errors could also cause result fluctuations. In a study by Ekstrand & Gillquist (1982), it was shown that soccer players possess tighter muscles than did a group of non playing controls. Thus the amount and type of sport, or activity or work may again be implicated.
According to Moore & Hutton (1980), comparisons of subjects that already possess a great deal of flexibility with subjects not possessing the same degree of flexibility could be dangerous due to the possible existence of ceiling effects that may not allow a fair comparison. Thus, there may be a point of optimum flexibility where any further attempts at increasing ROM is met with resistance or worst still injury, as theorised by Viidik (1978). Osternig et al (1987) and others including, Abraham (1977), Armstrong (1984), Friden et al (1986), and Newham (1988) have suggested that it is not unusual to feel residual muscle soreness and possibly strain after the inappropriate or unaccustomed activity, of which, the application, or more appropriately, the incorrect application of stretching could be an example. Although no explanation of the statement is given with regard to the context of the word stretching, Safran et al (1989) suggested that improper stretching will lead to injury. Others such as Stanish (1984) have even postulated that stretching to be a waste of time or possibly detrimental to a physical performance. Kulund in (1983) suggested that a syndrome may be created from over stretching that is characterised after the activity by further muscle tightness and possibly injury. The mechanism of which may be pondered but not stated as fact. Of further interest is the thought that the very result of over stretching is the state that prompted the use of a stretching protocol in the first place, because some subjects actually decreased their ROM when over stretching had occurred. One could hypothesise that over stretching could be a result of any one or combination of the following:

1. Too great a force during the stretch application (Anderson & Burke 1991),
2. Too long an application time (Friewald et al 1998),
3. Too high a frequency of stretching (Friewald et al 1998),
4. Too great a speed of application (Garrett 1990),

A stretch incorporating too great a speed of application, which may or may not accompany too great a force, may be considered with interest. Such a form of abuse is highly possible in the ballistic form of stretching and therefore may be a great source of injury, as some investigators such as Stanish (1984), and Etnyre & Lee (1987) have suggested. Another possible mode of injury may be explored through
the application of a stretch for too long a time period. Rahlmann (1987) has suggested that such stretching may have a destabilising effect on the joint due to the greater mobility available in one direction without the due support of the antagonist muscle to secure the movement and protect the joint capsule and ligaments. This is merely speculation at this point, as such parameters have not been investigated with respect to stretching procedures.

**Stretching to prevent injury**

It is also common, that a stretching program is only one component of a therapeutic or training program, and that due to the wide number of activities and therefore variables, isolation of the variable of stretching alone is difficult. An example, would be the injury associated with sport. Let us consider the runners and triathletes as examples.

It is noted by McQuade (1986), and Jacobs & Berson (1986), that many different variables lead to injury, and these may range from, too long a period of training, too high a frequency of training, a sudden increase in training volume or intensity, incorrect technique, and many others. Therefore any one combination of the above could cause problems.

Altered hip anatomy, either genetically, post operative, or post injury, may also alter the ROM available, by an alteration of the normal biomechanics. This could only be described as an inherent risk in performing the procedure, especially if the problem is not known to the practitioner or the patient (Stanish 1984). In addition, the head of the femur, how it aligns itself in the acetabulum of the innominate (pelvic) bones, and the integrity of the ligaments that fix it in that position are also all important, as Reid (1970) points out with athletes. Further, any factor interfering with the flexion in the lumbar spine, lumbosacral articulation and the sacroiliac joints, would also be likely to effect the total ROM into flexion, as postulated by Calliet (1995), in his theory of the lumbopelvic rhythm.

In the studies reported on stretching thus far, there has been no mention of pain, discomfort or injury resulting from the application of stretches by suitably qualified practitioners. A discrepancy may exist between experienced professionals, and those where novices perform the stretches without supervision, rather than the stretching procedures
itself causing the injuries. It is very likely that the type of stretch application by inexperienced practitioners could cause problems. Without proper instruction in application, one could reasonably expect a certain amount of error. After all, stretching the muscle is indeed an acquired skill, and requires time to master. As such, it has been stated by Ekstrand (1982) and Moller (1985), that it is easy to teach, and after time gives good results.

Hartley-O'Brien (1980) has suggested that there are two ways to achieve an increase in ROM due to stretching. Stated simply, one may increase the strength of contraction of the agonist, resulting in an increased acceleration and ROM (if it is available). Or one may increase the overall ROM by increasing the length of the antagonist, by decreasing the resistance of the soft tissues. It has been suggested also by Hartley-O'Brien (1980) that the increase in the strength that will activate the increase in ROM maybe achieved by various muscle loading activities as well as reflex facilitatory techniques. This theory has helped advance the active versus passive flexibility schools of thought. Etnyre & Lee (1987), suggested that there is in fact no significant difference between two forms of stretching, while the other groups to which Hartley-O'Brien subscribes, suggest that the training of active flexibility is superior, as this most closely approximates that found in human activity (Hartley-O'Brien 1980, Hardy & Jones 1982).

It is possible that active flexibility is merely an extension of the baseline passive flexibility already present, and that the training of the active form of flexibility may only proceed when an adequate level of both strength and flexibility already exist at the static level, and then only with caution. It has been theorised by Hardy & Jones (1986), that the greater the ROM, that is the gained ROM, the greater the progression of a contraction of the muscle through it, especially through the now larger mid range of the total ROM. Such a contraction could allow a greater speed of contraction which in turn would generate greater power, which according to Hardy & Jones (1986) would hopefully produce a more efficient muscle contraction. This could be a mechanism by which performance increases may occur, and this in fact has been suggested by Zebas & Rivera (1985) and others previously, such as Cureton (1942) and Dintiman (1961).
It is apparent that there are several forms of stretching used and several theories for their effectiveness. However, the effects of these procedures are of interest to any practitioner working closely with joint injury and/or immobility. How long these effects persist, and whether they require repetition in order to achieve the desired results has only recently been investigated. Various studies have been undertaken to investigate these queries, including: Tanigawa (1972), Medieros (1975), Cornelius & Hinson (1980), Hartley-O'Brien (1980), Sady et al (1981), Henricson et al (1983), Wiktorsson-Moller (1983), Hardy (1985), Hortobagyi (1985), Moller (1985), Wallin (1985), Etnyre & Abraham (1986), Hardy & Jones (1986), Williford (1986), Etnyre & Lee (1987). All have demonstrated an increase in ROM for the particular stretching protocol chosen, whilst some have shown one particular form to be superior to the other.

I refer the reader to table 1.1 for a complete summary of the studies investigating the trainable effects of stretching, as modified from table 1 appearing in Etnyre & Lee (1987).
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^aTotal Range of Motion. ^bPre-Post Gain. ^cReach Gain. ^dNo difference between CR & CRAC.
Many of the above mentioned studies possess design problems in relation to the standardisation of time, force and controls. What is significant, is that all demonstrate increases in ROM when stretching is used, and those that are well controlled demonstrate the superiority of the PNF (CRAC) method. Further study by Wiktorsson-Moller (1983) has shown that stretching is superior to warm-up and massage for ROM increases, and that static stretches are no more effective than biofeedback, according to McGlynn et al (1979).

Also, Tanigawa (1971) demonstrated that PNF stretching was superior to passive mobilisation, in achieving increases in ROM of the hip joint. This is the only study that has investigated two manual therapies in such a fashion. I have been unable to find any evidence of research into manipulation of the hip, and comparisons of such manipulation with other forms of manual therapy. These other forms of manual therapy will be discussed in the following chapters of this review.

Effect of a number of treatments
In 1982, Ekstrand suggested that the duration of a single effect of stretching lasted at least 90 minutes, and Moller (1985), suggested that this effect could last throughout a training session, and even for the next 24 hours. Wallin (1985) then hypothesised that one training session per week was sufficient to maintain any gains derived from the previous effort and that a stretching frequency of three to five times per week, was sufficient to increase the effect. In this particular study, there was a variable stretch time used. The time spent in the relax phase of a PNF CR stretch was 10-25 seconds in total, and 35-40 seconds in the contraction phase. There were 14 training sessions of this nature over a one month period. Training began with a standardised warm-up and the total training time was equal. It seems that the total stretch time probably was not standardised, although this was not specifically stated. Evaluation took place on day 14 and day 30. Given that the effect of stretching lasts a minimum of 90 minutes and possibly 1-7 days as stated by Moller (1985) and Wallin (1985), could this serve to do anything other than increase ROM? McGlynn et al (1979), have promoted the benefits of a stretching program for other than ROM increases. Based on my 15 years of practical experience utilising several froms of manual therapy, stretching does appear to possess the ability to enhance
performance. As a practicing professional dealing with many different patient populations (geriatric, paediatric, sport and others) it has been my experience, that a significant improvement in mechanical function is possible with the use of appropriately applied stretching programs. How much of this effect is due to placebo, I cannot rightfully tell.

Emotion often enters the debate when improvement of performance is discussed. This seems to be especially so, when stretching or other forms of manual therapy are included in the subject matter. It has been my experience, that improvements are generally found in response to stretching procedures, although, some patients have responded with considerable improvement. I feel these improvements to be due to the reduction or removal of resistance to movement. I especially consider joint movement to be important, and a discussion of techniques specific to achieving specific increases in joint movement are undertaken in the following chapters. Resistance to effective joint ROM could come in the form of simple mechanical problems, such as muscle spasm or intra articular joint restriction secondary to meniscoid or adhesive capsulitis, or more complex anomalies. Joints may not be restricted in all planes of movement, but if movement is restored to that of optimum, full function and alleviation of any symptomatology may be expected. This topic is discussed in greater depth in a review by Rahlmann (1987).

Therefore, the statements made by many investigators about improvement in performance should be more a statement about the return to optimum performance. It is my opinion, that the normal loading patterns of the musculoskeletal system by people, is sufficient to create the above mentioned changes in function. As these changes in function generally exist only as functional changes, and not as pain syndromes, people are generally not greatly inspired to act on the functional changes, as they are in the minor painful ones.

Medical and paramedical practitioners could conduct a great number of medical case histories on patients presenting with pain or dysfunction. It would be a feature of many of these histories to demonstrate dysfunction prior to any manifestation of pain. It is unfortunate, that most people are motivated to respond to pain and not loss of function. The reason for which is probably threefold:

1. There may be inability to perceive changes in function
(especially in chronic states).
2. The excellent functional adaptation of the body.
3. The number of practitioners able to detect the changes present.

Therefore, function may decrease long before:
1. It is perceived
2. Pain or gross dysfunction results
3. It is acted upon.

Consider (as a speculative concept) the individual who exists in a state of less than optimal function. He/she trains in this state, and therefore performance is measured whilst in this state. Enter the practitioner who appropriately assesses the situation, and surmises a decrease in function, say restricted hamstrings. A manual therapy procedure is introduced to remedy the situation. The athlete returns to full function, and when tested in maximal performance, an improvement is noted. The improvement of performance may really only be a symptom of the original returning function.

It has been suggested for some time now, that stretching and manipulation is beneficial in the prevention of injuries, although the exact mechanism for this benefit is never clearly stated (Hatfield 1985, Patterson 1989). Claims have been made that stretching may be used in the treatment of injuries (Boyling & Palastanga 1994). This is nothing new, as athletes, trainers, coaches and various medical and paramedical groups have been doing this for some time (Shellock & Prentice 1985, Safran et al 1989, Jensen et al 1989). The proposed mechanism of action has always been vague, and totally unsubstantiated by the literature of this time, and thus mistrust about the effects have grown (Anderson & Burke 1991, Smith 1994, Gleim & McHugh 1997).

It has been further suggested by Janda (1976) that heavy, prolonged or unaccustomed use of a muscle may cause the muscle to contract. As a result of this contracture, muscle function may be less than optimal. Therefore, the performance of the individual may also be less than optimal. Stretching could be employed to remedy the contracted state of the musculature, therefore increasing the ROM. A performance increase would be expected with the removal of the contracture.
Thus, an individual who is already in a state of contracture may be performing below the expected optimum level. If a series of stretches are applied, an increase in performance could be reasonably expected. The important factor here is the state of the muscle prior to stretching. It would be my suggestion that a muscle, joint or myofascia, that is not in a state of contracture may not derive any true benefit from stretching or other manual therapies. With regard to the alleviation of injury, it has been stated by Foreman & Croft (1988) that muscle spasm or contracture is a common result of and cause of injury, but there has been no validation of this statement. A contracted muscle may not possess the ability to elongate far enough or at a rate that is fast enough to adapt to the loads placed upon it. Such limitation would ultimately lead to the strain injury so common in sport today (particularly the explosive power sports and activities such as sprinting) (Renstrom & Peterson 1980). However, the long term submaximal efforts such as distance running, may also have a similar mechanism operate, which in turn may produce only small derangement in the muscle integrity, causing the common overuse syndromes so noted by Stanish (1982), (1984). Therefore, should the aetiology of injury include muscle and/or joint contracture, then stretching procedures would likely have a beneficial effect in their resolution.

The question of performance enhancement is also a difficult debate. I have discovered only two examples in the literature of a definite performance enhancement arising solely from the application of a stretch.

Godges et al (1989) studied two types of stretching. One type was an end ROM static procedure, and the other was a mid ROM PNF procedure plus soft tissue mobilisation (massage / STM). On day one of the testing, a maximum oxygen consumption (VO₂ max) test utilising a graded treadmill protocol was performed. Seven days subsequent to that, submaximal oxygen consumption measures using treadmill exercises at 40, 60 and 80% of the subject’s VO₂ max, were performed. The subjects spent 4 minutes at each of these intensities in order to reach steady state. This was then followed by a 10 minute rest in the supine position. After the rest period, assessment of hip flexion and extension ROM followed. The first group (the static stretch condition) then
reviewed their stretches and were again given assessment of ROM. A repeat of the three submaximal exercises protocols was followed. All the subjects then rested for seven days. On the third test day, the same procedure as that of the second day was followed, with the exception of the second stretch condition (PNF + STM) which replaced the first group (static stretch). This ended the protocol. The procedure resulted in an increased efficiency of running at 60% VO2 max in the case of the PNF + STM, and an increase at 40, 60 and 80% VO2 Max following a single bout of graded stretch. However, the study was flawed in several ways. Firstly, the sample size was limited to n=7 males, and the subjects demonstrate a moderate degree of variability leading to the possibility of greater error and therefore the requirement for greater subjects to attain the same significance levels (or a loss of statistical power leading to a type II statistical error). Limitation of the study in the form of exclusions was discussed. All subjects were male, therefore the investigator could not eliminate the possibility of any gender effect, especially when earlier, one was implied by Hartley-O’Brien (1980), even though that study seemed flawed for the same reason. Unfortunately, a mid ROM PNF procedure was compared to an end ROM static procedure. The study was further contaminated by the use of a massage procedure applied with the PNF procedure, which compromised the treatment effect, as it could not be isolated to just stretching. The reason for this is unknown as nothing was stated as to why it was included.

Bearing this in mind, the study by Godges et al (1989) would seem to have interesting implications for distance athletes who operate at extreme efficiencies during their events. As pain is such a subjective sensation, and a problem that appears to be associated with over stretching the tissue, the abundance of pain may be considered with caution. Pain is not only uncomfortable, but is especially inconvenient if your livelihood, chosen profession of sport depends upon physical performance. Any mechanism by which such people can minimise such problems, will surely be looked upon favourably.

A decrease in pain may be achieved through stretching via a pain gate mechanism mentioned earlier (page 44). The action of the group 3 and 4 nerve fibres arising from the mechanoreceptors and nociceptors may actually help counter some of the pain felt.
In the study by Worrell et al (1994), nineteen university students without knee, hip or hamstring pain, but with decreased knee extension ROM were tested with an isokinetic strength device in the eccentric and concentric modes of hamstring contraction, before and after the application of a stretch. This procedure was then repeated with a second form of stretching.

They found that significant increases in peak torque occurred in the eccentric modes at \(60^{\circ}/\text{sec}\) and \(120^{\circ}/\text{sec}\), and in the concentric mode at \(60^{\circ}/\text{sec}\). They concluded that increasing hamstring flexibility was an effective method for increasing hamstring performance at selective isokinetic conditions in the open kinetic chain. They recommended further study into these effects in the closed chain application that more closely approximated actual performance.

It is my opinion, the possibility of increased performance due to stretching is due to this pain gating effect, along with the “freeing” of joint movement created by increased ROM (Rahlmann 1987). Suppose the restricted ROM about a joint acts as a form of splint to restrict the joint movement (which is one of the functions of reactive muscle spasm). As discussed earlier, joint function may be imperceptibly restricted, which may form the basis of a training induced decrease in performance. However, the same may ultimately lead to injury following an acute injury to a joint. Therefore, the joint, or more specifically, the muscles about a joint, will spasm. According to deVries (1966), Bourdillon (1982), Calliet (1995), this spasm can be very severe, and approximate the function of a splint.

Clinically the splinting reaction of muscles and joints often seen following injury, would create pain to the individual should the splinted joint be exercised through a ROM that exceeds its available ROM, albeit a decreased one. It is likely that the individual would not continue to exercise the muscle through full and painful ROM. If movement was pursued, it is likely that such movement would cause improper biomechanical movement patterns due to the avoidance of pain. I theorise that a procedure similar to those used here to decrease the muscle spasm may decrease the pain and return function. This scenario is one that is often discussed by manual therapists of all persuasions.
(Anderson & Burke 1991, Smith 1994). This could be perceived by the recipient as an increase in performance, if the original pain was chronic and not acute in nature. This would be especially so for sub-clinical (joint restriction without the presence of pain) syndromes that are commonly treated by manual therapists.

**Summary: stretching**

It is known that stretching definitely increases the ROM, and of the four types of stretch available, the PNF (CRAC) form is superior (Etnyre & Lee 1987). It is likely that there is a difference between skilled and unskilled practitioners, which may further be extended to those who have no knowledge of the functional anatomy.

An example of the unskilled practitioner may be the average individual, coach, athlete or novice practitioner. The implication of the difference between the two is a learning effect.

It is proposed that this learning effect, or lack of it may be the source of pain, discomfort and injury associated with stretching, and commonly referred to as over-stretching. It has been suggested by Etnyre & Lee (1987) that the time, frequency, and force of application of stretching are variables that need to be standardised by the practitioner. Stretching is not limited to the muscle. Its effects pull upon the muscle, ligament and other connective tissue about the joint that the stretch is applied to. These tissues (especially the connective tissue) are affected by many factors. Factors such as blood flow, anatomical integrity, history of injury and heat and the load of physical activity are all relevant (Smith 1994, Garrett 1996, Talbot & Morgan 1998).

Therefore, their effects should be considered when the outcome of stretching is being examined. An obvious example is that of heat/blood flow. It is known that warm-up effects the extensibility of joints (Lamb 1984). The heat generated effects the connective tissue component according to Spring et al (1991), and the blood flow especially effects the muscle component due to its increased vascularity. Together, according to Williford et al (1985), these warm-up effects may have a significant effect on stretch (Barclay et al 1995).
Finally, Moller (1985) states the effects of a stretch are said to last from 90 minutes to 7 days depending on the source of the reaction. The proposed study will incorporate an examination of the hamstring function about the hip joint. Therefore, a brief discussion of the anatomical structure and function of the hip and the muscles that span it, is warranted and will follow later in this chapter.
Mobilisation
A form of manual therapy that has been used for a time undisclosed, and a form of therapy used by all the manual therapy professions today. Much interest has returned in this form of therapy by way of the frequent comparisons made with other manual therapies such as stretching and manipulation (Tanigawa 1971, Breen 1977, Relman 1979, Phillips 1983, Meade et al 1990). Traditionally the mainstay of the physiotherapist (Gould 1990), it is by no means used exclusively by this group, or exclusively excluded from the practice of other manual therapists such as chiropractors (Schafer & Faye 1989) and osteopaths (Stoddard 1969).

Most modern day physiotherapists also utilise electrophysical therapeutics, exercises and manipulative procedures (Blackman & Prip 1988), just as many chiropractors and osteopaths might (Stoddard 1969, Haldeman 1992).

Mobilisation is a passive procedure by oneself, or by a second person (practitioner), usually applied by hand, to move the joint to which it is applied through all available active plus passive ROM (Grieve 1988).

Passive movement ROM is that gained in excess of active movement, and is usually applied by the practitioner to specifically increase joint ROM (Maitland 1977). The passive range of motion is greater than that achieved by active range of motion, but is less than that achieved by manipulation. Therefore, it does not enter that ROM that was referred to by Sandoz (1969) as the paraphysiological range, a ROM that is achieved by the manipulation or the adjustment (Haldeman 1992). Although Sandoz further states that a mobilisation may be taken into the paraphysiological range after an adjustment has occurred.

A major difference between mobilisation and manipulation, a difference that mobilisation shares with active ROM exercises, and most stretching procedures, is that they are under the control of the recipient. This factor has been frequently raised as being an important, but often emotive factor in the choice or preference of treatment approach by some authors, such as Rogoff & Licht (1980) and Blackman & Prip (1988). Unlike manipulation, especially when specific (adjustment), mobilisation does not require the same level of skill to execute. For this
and other reasons, such as fewer contraindications, and greater safety, it is often taught to the patient, in an attempt to increase the dosage of the treatment, over the treatment time. Because mobilisation is under the control of the operator, the danger associated with this procedure is minimal in appropriately selected individuals, and is therefore ideal for home use. This does not occur in the manipulative procedures, as such procedures may be associated with a small, but significant danger according to Klenyhans (1980), and Maurice-Williams (1981) (see page 91).

Mobilisation is primarily used to increase joint ROM (Maitland 1977), and decrease pain (Van Hoesen 1986). Unlike both stretching, and the manipulative procedures, unsubstantiated claims of treatment benefits does not seem to occur in the literature.

From a personal viewpoint, we have heard and read many claims about the efficacy of stretching and manipulation. The same cannot be said of the mobilisation techniques. This is merely an observation of the current practice of manual therapy, and one that will be supported or refuted with time. Examples and examination of the claims made by stretching and manipulative protagonists will be examined in the relevant chapters.

Further, perusal of any text covering these procedures, will quickly demonstrate the wide scope that mobilisation has as a treatment protocol for the human body. Every synovial articulation of the body may be mobilised, and usually is when post traumatic treatment of scar tissue is sought (Maitland 1977, Grieve 1986, 1988, Gould 1990, Yoder 1991).

Universal approval of mobilisation, as a procedure that increases ROM and decreases pain after injury, is evident from the wide acceptance it shares from all schools of therapy (Lewit 1985, Linde et al 1986).

Some schools appear to favour this approach to others, or more appropriately, disfavour the general application of other approaches such as manipulation (Blackman & Prip 1988). Such points of view are undergoing great change, as manipulative procedures gain wider acceptance (Meade et al 1990, Gould 1990, Manga 1994), almost at the expense of the mobilisation procedures.
Mobilisation procedures have been graded by Maitland (1977) in a response to control such things as treatment protocols, indications and execution. The method has been widely adopted by practitioners and as such may almost be considered as a standard.

Maitland's gradation method also includes manipulation. Thus, it is a complete system of reference for manual therapy conducted in the passive ROM. Because of the link forged by this system, some authors such as Maurice-Williams (1981) and Maitland (1977), have used both manipulation and mobilisation interchangeably.

Strict criteria exist for the various grades of mobilisation, and why, how and when they should be used (Grieve 1986a). I believe that the difference in the indication for use of the manual therapies as set by this protocol, probably exemplifies the differences in approach and philosophy of the various schools of thought within manual medicine. The system used by Giles & Singer (1997) based upon Maitland (1986) grades movement and treatment as follows:

![Diagram of grades of movement](image)

A diagrammatic representation of grades of joint movement in relation to the available range in a normal joint (A), and a joint with pathological movement restriction (B).

Figure 2.1 A diagrammatic representation of grades of movement. Modified from Edmondson & Elvey (1997); p377:
Whilst this paradigm is evolving, specific and well controlled investigations are required to determine the superiority of one procedure over another, at all articulations on which they are used. Statements such as;

"Manipulation has very little indication in the treatment of painful involvement of the hip, nor is passive mobilisation useful. Active mobilisation is always better".....

as used by Rogoff & Licht (1980, p107), and diagrams such as that appearing on page 5 of Blackman & Prip (1988) (a diagram likening a manipulation with a gunshot) are based upon little or no scientific rationale or evidence, are emotive and in my opinion have no place in the literature.

![Scheme to symbolize the difference between effects of low velocity passive movement and the high velocity thrust](image)

**Figure 2.2** Emotive analogy of manipulation and gunshot. (Modified from Blackman & Prip 1988, p5)

The use of mobilisation techniques is so common, that their use is almost taken for granted. Studies about their efficacy in increasing ROM, and decreasing pain are numerous: Kaltenbourn (1985), Cibulka et al (1986), Linde et al (1986), Smith et al (1988), and Engle & Canner
(1989). However, studies that compare mobilisation to stretching, and/or manipulation are not as common.

Tanigawa (1971) conducted a study that compared a PNF stretch to a mobilisation procedure. The study applied the procedures to the hip joint and assessed which of the two procedures was superior in increasing ROM of the hip. The result suggest that the PNF procedure was significantly better than the mobilisation procedure.

I have not been able to find any comparative studies of mobilisation and manipulation of the large peripheral joints. Smaller peripheral joints (metacarpophalangeal joint) have been investigated by several authors (Roston & Haines 1947, Sandoz 1976, Meal & Scott 1986). These studies will be discussed in detail in the following chapter. Studies on the differences of these two procedures have been conducted on the spine, especially the lumbar spine. These studies have been usually poorly controlled, and primarily aim to elicit differences between treatment approaches (that is a number of therapies used together). Thus, attempting to demonstrate the superiority of one approach to treatment, cannot be compared with studies aiming to compare individual interventions.

As mentioned previously, the great majority of these investigations are not controlled to the extent of a direct comparison between the two treatments directed at one joint. Thus, we feel there is a need to investigate these effects especially to one joint. I have chosen the hip, as these procedures are often applied to this single peripheral joint, and thus comparisons would be of value to the practicing clinician.

Studies that attempt to compare combined treatment approaches of one profession against the combined treatment approach of another do nothing to address the questions of superiority or appropriateness of one specific treatment over another for different spinal or peripheral joints. Examples of such studies include: Torstrensen et al (1997), van Tulder et al (1997), and Skargren et al (1998).
Manipulation
As with the other manual therapies, manipulative procedures have also been used for many years by various practitioners (De Giocomo 1978). These range from bonesetters, to medical practitioners to modern day chiropractors, physiotherapists and other exercise experts.

This form of therapy, of which mobilisation is often incorrectly included, has had many healing properties associated with it, rightly or wrongly. It is unfortunate that the best part of the last 30-50 years has been taken up with emotional and political in-fighting of its use, namely from the chiropractic and medical professions. It is heartening to note that some middle ground is being found more recently, with the resultant advances in research and patient care.

As this is not a forum for discussion of history or politics, we will not mention this factor any further, other than to say that the time and money spent on factional in-fighting, and the numerous government inquiries (New Zealand Commission of Inquiry 1979, Manga 1994) could have been better spent on sponsoring much needed well controlled research.

Manipulation is defined by Brunarski (1984), as a skilled passive movement to a joint either within or beyond its ROM. Many studies on spinal manipulation have now been conducted, and have been reported by Brunarski (1984), Haldeman (1992), Anderson et al (1992), and Shekelle et al (1995), in excellent reviews of literature regarding the clinical efficacy of spinal manipulative therapy.

However, as we have previously stated there are few studies that have studied the effect of manipulation upon one joint only, and the changes, if any, following the intervention. One recent study of a single cervical spine facet joint manipulation assessed cervical spine mobility following a single joint manipulation. This study by Carrick (1983) demonstrating good improvements in pain and range of motion in the neck and arm pain sufferers participating in the study. A later comparative study by Cassidy et al (1992) also demonstrated superiority to the manipulative approach.
An example of the type of study being conducted in the past may be highlighted by one performed by Wansel et al (1989), where the palpatory finding (subjective observation of joint immobility) of the subject was noted and then manipulated into a specific direction. Pre and post intervention measurements were taken, and comments were made about the validity of the manipulative approach, compared with that of a sham, placebo or another form of therapy control. Such studies are a useful indicator for further indepth study that is more objective and prospective in nature, however, on their own they do not further the scientific credibility of manipulation outside of the professions already accepting of the virtues of manipulation.

Comparisons between mobilisation and manipulation have primarily been conducted in this fashion in the past. Examples of these studies include the work of Potter (1977), Jayson et al (1981), McNight & DeBoer (1988), and Briggs & Boone (1988).

Although examples of treatment protocols are being investigated, the actual effect(s) of the manipulative procedure(s) upon the joint being manipulated is still largely theorised.

It is understandable that difficulty in assessing pre and post interventional effects on single spinal joint may be encountered. Thus, it should be with some priority, that the effect of treatment protocols be sought from single peripheral joints, as proposed in this investigation.

The only controlled investigation of manipulation of a single peripheral joint is that of the proximal interphalangeal joint of the finger. There have been several investigations relating to this particular joint (Unsworth et al 1971, Sandoz 1976, Meal & Scott 1986). These have been undertaken to ascertain what constitutes the cracking sound often accompanying manipulation, and whether this phenomenon is intra or extra-articular in nature.

The cracking sound that accompanies a manipulation is essentially what separates a manipulation from a mobilisation in the eyes of many practitioners and patients.
The cracking sound heard occurs at a point where there is a rapid
decrease in joint surface tension, which is accompanied by an increase in
the space between the two opposing surfaces of the joint. The
implications of the investigation in “cracking” was not totally realised
by Roston & Haines (1947), until Sandoz (1976) investigated the
phenomenon further. Sandoz reviewed the original work of Roston &
Haines, with the emphasis on joint ROM improvement. Here it was
found that the mobilisation prior to the joint cavitation, or crack, was
not as effective in separating the joint surfaces as was a manipulation
which did.

Although this investigation involved the non physiological long axis
traction movement, and did not specifically investigate the
improvements in a physiological ROM, such as flexion or extension, a
definitive pre and post difference occurred following the two
approaches to manual therapy. An implicit assumption of these studies,
and others concerning the various manipulative procedures, is that,
separation of joint surfaces not disrupting anatomical integrity is most
likely to improve ROM. This may not be so. Sliding movements may
best approximate this goal. These are but a few questions that arise
from these particular studies.

The most significant aspect of the work of Sandoz is the concept of
paraphysiological range. Sandoz proposed a theorem to explain the
movement of the joint, and where the effects of manual therapy are
likely to affect the joint (see diagram at the end of the next paragraph).

In the diagram, there are three barriers to motion. The first is the
passive barrier, which coincides with the end of active ROM, and the
start of passive ROM. Following this barrier, is the second barrier,
which represents the end of the physiological passive ROM. This also
represents the greatest gain from the mobilisation procedures (unless
following the manipulation), and the start of the paraphysiological
range. The paraphysiological range is that range achieved following a
manipulation, or a mobilisation following a manipulation. It is bounded
by the third barrier, which represents the end of anatomical integrity.
Should this barrier be surpassed, physical damage to joint and soft tissue
will result. Thus, it is theorised that an extra ROM may be achieved by
entering the paraphysiological range, with a manipulative procedure.
This is in accord with the dogma of chiropractic, and recent studies of spinal manipulative therapy (Vernon 1982, Howe et al 1983).

The majority of the studies investigating the effects on spinal levels demonstrate successful reduction of pain and improvement in ROM. Unfortunately, this positive effect, albeit a tentative one, has then been attributed as a panacea to all levels of the spine and peripheral joints (Schafer & Faye 1989).

The comparison of a DIP joint and a spinal apophyseal joint is a tenuous one at best. The similarity of total joint surface may be all that is common to the two joints. The muscular and ligamentous supports acting on the finger are not comparable to that of the spinal joint, let alone that of a large peripheral weight bearing joint, such as the hip. Thus, the extrapolation of the effect of manipulation on a small spinal joint to that of a large peripheral joint may be intuitive but dangerous. How the difference in joint surface area, and muscular and ligamentous
support affects the function of the joint may only be speculative at this point.

As mentioned earlier, Tanigawa (1971) investigated the effect of a stretching procedure and a mobilisation, to the hip. The results indicated that the stretch was superior. Spinal studies have demonstrated the superiority of manipulation over mobilisation. What then of the comparison of a stretch and a manipulation? To my knowledge, this comparison has not been conducted in peripheral joints, and has only been attempted on the spinal level as a part of a combination of procedures, or approach (Meade et al 1990, Anderson et al 1992, Skekelle et al 1993).

Thus, we saw it as an important matter, to investigate the effect of the procedures, in a controlled comparative fashion, on a one joint system. The hip was selected so that a commonly used protocols used to treat the hip joint could be investigated. From the results of previous studies that follow, it is also recommended that a similar approach be taken for all peripheral joints.

**Indications And Contradictions For Manual Therapy**
The indications and contraindications of use for the manual therapies is included in many texts advocating their use. Thus, a complication of indications and contraindications from Cyriax & Russell (1977), Grieve (1986), Gould (1990), Yoder (1990), and O’Neil & Esposito (1991) will be utilised for the two manual therapies being reviewed.

**Indications for Stretching**
The indication for the use of stretching procedures are similar to those of mobilisation, and are probably exactly so in the majority of cases, as the procedures are closely related. Their use is advocated for the alleviation of tight soft tissue structures and pain caused by them, and this is especially so of the chronic condition (Edmondston & Elvey 1997).
Indications for Mobilisation

Indications for the use of this particular form of manual therapy are numerous (Giles & Singer 1997, Vleeming et al 1997). As a general rule, any non-pathological symptoms that are aggravated by movement, and relieved by rest, are usually amenable to mobilisation therapy. In addition, another important consideration in this and other forms of manual therapy, is that of referred pain and discomfort (Avillar et al 1997).

Pain emanating from a structure distant to the complained source of pain exists as a potential problem in the diagnosis, and thereafter treatment (Dvorak & Dvorak 1984). It is essential that the therapist, independent of training or philosophy, be able to determine the source of the pain and/or dysfunction.

For example, when considering indications for treatment of the hip, whatever the form, local disease states should be considered. An appropriate history of the patient pain and injury should be taken during the consultation, and thorough orthopaedic, neurological and radiological examination be conducted, if appropriate.

Commonly, referred pain from the spine, especially from the thoracolumbar nerve roots traveling along the 12th Thoracic, and 1st Lumbar dermatomes, is encountered as pseudo hip pain (Haldeman 1992). The possibility exists for this to be a direct referral via nerve root encroachment, or by reflex action due to changes in local sensory input acting reflexly on the alpha motor neurones at the same level of the spinal cord (Vernon 1988).

Pain may be referred from lumbosacral structures to the posterolateral aspect of the hip, and from the sacroiliac joints to the posterior aspect of the sacrum and gluteal mass, and anteriorly to the groin region (Boyling & Palastanga 1994).

Other factors to consider, include those that may be grouped into mechanical causes. Such factors as: foot pronation, valgus or varus deformity or change of the ankle, knee or hip, may all biomechanically effect the function of the hip, and should therefore be considered in the selection of treatment to the hip (Oatis 1990).
Cailliet’s (1995) proposed action of the lumbopelvic (lumbosacropelvic) rhythm also exists as a potential biomechanical factor to consider. This particular factor will receive further detailed discussion later in this chapter.

Pelvic girdle lesions should also be considered as a potential source of changed biomechanical function, as ultimately all the forces transmitted through the sacrum of the pelvis will pass through the hips according to Kapandji (1975). Thus, dysfunction resulting in the commonly noted pelvic asymmetry (Schafer 1983), is likely to load the hip asymmetrically. Leg length differences therefore have a great potential to load the hips asymmetrically, whether they are functionally, or structurally shortened.

Indications for the use of local mobilisation may be given by the findings of history, observation and examination, of which the following are the likely examples (Bernard & Kirkaldy-Willis 1987, Lowdermilk et al 1999, Rosomoff & Rosomoff 1999):

1. Joint irritation or moderate pain on joint movement
2. Pain from particular postures
3. Pain distal to the site, especially if spinal
4. Cough, sneeze but not valsalva manoeuvre positive
5. Poor sleeping
6. Pain constant for some time
7. Postural spasm
8. On testing, the pain is sufficient to evoke facial distortion or vocalisation
9. Spinal movement producing distal pain
10. Pain and/or paraesthesia increases after testing movements
11. Spasm of muscles spanning joint in lesion. A manifestation of the arthrokinetic reflex (Kirkaldy-Willis 1983)
12. Periosteal pain points on palpation (Lewit 1985)
13. Reproduction of distal pain following pressure or stretch of active trigger point within muscles (Travell & Simons 1983).

As with all treatment, the dosage is vitally important. Due to a lack of clinical trials of matters regarding manual therapy, a procedure beginning with gentle mobilisations, progressing to more vigorous one
is recommended by Maitland (1986). According to Grieve (1986a,b), who advocates the Maitland approach, the more vigorous mobilisation is indicated by the presence of a static pain, not aggravated by any neurological testing, with little or no distal referred pain, and finally, not aggravated by movement. This view clearly does not highlight the knowledge that somatic structures are capable of and often refer pain (Kellgren 1938, Dvorak & Dvorak 1990).

Essentially the choice of therapy is often made by noting the degree of the symptomatology, and the degree to which they, the patients are aggravated by movement. Aside from the more specific mobilisations, a more general approach may be undertaken.

Regional mobilisation is often given to those joint segments of the body that demonstrate general degenerative changes, perhaps with local symptoms. These techniques are also used when generalised myofascial or ligamentous thickening has occurred, or when specific techniques are not tolerated by the patient. Thus, they are often used as preparatory procedures by some manual therapists. They may or may not include various other manual therapies such as stretching according to Grieve 1986b. Herein lies a reason why, little research has been specially targeted to the treatment of mobilisation. This curiosity has also been noted by other researchers such as Etnyre & Lee (1987), Brunarski (1984) and Anderson et al (1992). Due to this combined approach, stretching has often been given the same indications as mobilisation and are referred to interchangeably in the literature. Recent texts address this obvious shortcoming (Haldeman 1992, Brukner & Khan 1993).

**Indications for Manipulation**

Manipulation has been attributed a more restrictive group of treatment indications due to the nature of the forces that it utilises during its execution. According to the conservative approaches of Maitland (1986) and Grieve (1986b), manipulation is indicated only as a progression from an inadequate mobilisation that has reached a grade 4 level and improvement has not occurred. Further indication for these procedures is given as the absence of any articular signs upon examination, and a diffuse non specific ache. Although, not when there is the presence of an old site of pathology. Other indications include: the requirement of breaking of myofascial and joint adhesions,
stretching joint capsules and muscles, and the reduction of intra-articular displacement and bony subluxation (Rahlman 1987). The maintenance of joint ROM and to decrease pain are probably the most frequently encountered indications (Maitland 1986, Grieve 1986, Rahlman 1987, Haldeman 1992).

Contraindications for manual therapy
There are many reasons why manual therapies should not be performed on a particular individual. Any one or combination of these may cause further injury and pain, therefore the practice of such manual therapies should not be undertaken in their presence. As mentioned in the previous section, the stretching and mobilisation procedures are often used in conjunction with each other, and would therefore share the contraindications to their use. However, if one was to utilise the stretching procedures, caution should be taken when applying the procedure to muscle that have a tendency to elongate and weaken, according to Grieve (1986a). Also, the application of stretches to areas involving reactive muscle splinting to an acutely injured joint is specifically contraindicated.

Contraindications for Mobilisation & Stretching
When considering contraindications to mobilisation therapy, the following factors need to be considered:

1. Neoplastic disease
2. Neurological involvement
3. Signs and symptoms of spinal cord involvement
4. Inflammatory arthritis in the active phase
5. Active infections
6. Bone and muscle disease

Contraindications for Manipulation
When considering the contraindications to performing manipulative procedures, the following factors should be considered:

1. Osseous anomalies and deformity
2. Neoplastic disease of muscle or other soft tissue
3. Inflammatory arthritis
4. Central nervous system involvement (in spinal procedures)
5. Positive kernig’s and l’hermitte’s signs
6. Active infective processes  
7. Neurological involvement  
8. Advanced diabetes  
9. Vascular abnormalities (abdominal aortic aneurism)  
10. Anticoagulant therapy (warfarin)  
11. Uncontrolled hypertension  
12. Severe degenerative joint disease  
13. Congenital generalised hypermobility (Ehlers-Danlos syndrome)  
14. Undiagnosed pain  
15. Acquired joint hypermobility or biomechanical instability  
16. Splinting spasm  
17. Rubbery or absent end feel on palpation  
18. Pregnancy, especially if there is threat of miscarriage  
19. Psychological disturbance.

Many schools of thought, of which Maitland (1986) and Grieve (1986a) are included, advocate a grading system in treatment classification and execution, when considering passive movement treatments.

It should seem to most observers, that the approach undertaken by Maitland, is the most refined approach and classification system utilised in the classification of joint function abnormalities. Other authors such as Grieve (1986b) and Gould (1990) agree.

In this system, joint abnormalities and their effects may be classified into five categories.

1. Pain on movement of the joint, and this pain limits movement.
2. Pain and tissue resistance are responsible for joint limitation of movement.
3. Resistance, with little pain, which is due to tissue contracture.
4. Full ROM which is tempered by a catching sensation at some point within it.
5. Complete loss of joint integrity (fracture, dislocation) usually determined by radiological studies.
With this system, as common in manual therapy, it is the abnormal movement that forms the indication for treatment, not the pathology at the time and place of treatment (although they are obviously considered).

Thus the approach by Maitland (1986) attempts to further classify the movement delivered by the treatment, and a system for progression from one level to the next. It is therefore hierarchical in nature. Movement is graded from 1-5, with the first four stages representing mobilisation, and the fifth representing manipulation. This is demonstrated overleaf from Figure 11.6 from page 127 of Grieve (1986a).

Figure 2.4 Schematic representation of Maitland's grading system. Adapted from Grieve 1986a, p127

In the diagram the movements associated with the start and end of available physiological passive ROM are small. The middle portions of this movement are larger. This system is a graded one, thus, there are shades of uncertainty associated with each level. These overlapping
areas are expected, and are assigned a positive or negative to the grade indicating their status.

Although this approach is highly structured, it does suffer from an orientation towards the use of mobilisation. In the manipulative schools, grades of manipulation are often discussed but classification systems such as that adopted by Maitland have not been published. These grades are based upon the attainment of the joint click discussed previously.

Thus, it is considered by chiropractic (Meal & Scott 1986, Schafer & Faye 1989), osteopathic (Stoddard 1969), and medical viewpoints (Cyriax & Russell 1977), that attaining this joint click is the desired aim for manipulation, and this is the criteria for which success in the use of manipulation may be attributed. At the very least, many chiropractors and osteopaths feel less satisfied if they do not hear a crack (Sandoz 1969, Mireau et al 1988).

I suggest that the grading of manipulations may be achieved on this basis. Therefore the manipulation may also achieve various stages of success as does the mobilisation. Therefore the bias towards mobilisation and manipulation may be changed to accept the differing philosophy of its users. I, and others within the chiropractic profession often grade the successfulness of the manipulation by the type of release and sound achieved during the adjustment (Unpublished Macquarie University, Department of Chiropractic Skills V Lecture Notes). Therefore breaking the success into categories of no audible release, minor, good or excellent release. This approach is effective in my opinion, although highly subjective. A criticism equally applicable to the Maitland (1986) approach.

Whether the emphasis is placed upon mobilisation or the manipulation, the interpretation is of the greatest importance, as both are subjective in nature. It is important to have some criteria to base the treatment upon. Examination of all the joints of the body, and their treatment approaches, could demonstrate which approach should have superiority, and therefore which bias is appropriate, if at all. The possibility exists that spinal and peripheral joints act differently, and that all joint systems may require their own approach. Recent evidence such as the Meade
(1990) study and the Manga report (1994) suggests that the manipulative approach to the spinal joints may be superior. This conclusion is a tentative one, as is the opposing view for the peripheral joints (Blackman & Prip 1988).

The peripheral joints have been subjected to far less specific scrutiny than that of the spine, especially within the last ten years. This, and other related studies will help to investigate these controversial areas.

**Function anatomy of the lumbopelvic region**

**Functional significance of the hamstring muscle group to the low back**

The hamstring group of muscles is located on the posterior aspect of the thigh, and is made up of three muscles: biceps femoris (long head), semimembranosus and semitendinosus. As a group, they originate from the ischial tuberosity of the ischium of the pelvis. They insert in various positions in the region of the knee. The biceps femoris inserts into the postero-lateral condyle of the tibia, and the head of the fibula. The semimembranosus inserts on the postero-medial tibial condyle, and the semitendinosus, has a very long and rounded tendon insertion into the antero-medial aspect of the tibial shaft, along with the sartorius and gracilis according to Pansky (1979). They generally function to extend the thigh and flex the leg. They are biarticular in nature, and their efficiency depends upon the position of the knee (Pansky 1979). Locking the knee enhances the extensor action of the hip (Pansky 1979). A position that will be utilised in this study.
Figure 2.5 Anatomy of the posterior thigh. (Modified from Stanton & Purdum 1989)

However, Kapandji (1975) states that the short head of the biceps only acts on the knee to flex it. It is a more efficient flexor of the knee, especially in the second half of the flexion, where the long head relaxes (Panksy 1979).

Secondary actions of the hamstring are also important in their function. The biceps femoris laterally rotates the knee, and the long head laterally rotates the hip (Wheatley & Jahnke 1987). The semimembranosus and the semitendinosus both act to medially rotate the knee and the hip (Wheatley & Jahnke 1987). Furthermore, when the femur is fixed, the hamstrings act to posteriorly tilt the pelvis (reverse the action) in the sagittal plane (Norkin & Levangie 1983). When such a contraction does
in fact take place, the entire muscle contracts regardless of whether the upper or lower joint is moved (Basmajian & De Luca 1983). This posterior rotation of the pelvis implies some interaction between the posterior thigh muscle function, and the function of the lower back. The relationship between the hamstrings and the lower back will now be discussed.

The role of the hamstrings in LBP

One of the first messages taught to me at undergraduate school was to check the role of the hamstrings in any patient presenting with LBP. The implication of this teaching was that based on the untested hypothesis of Cailliet (1995) an interpretation could be made that suggested that tight hamstrings were etiological in the incidence of LBP, at least in part. As they were deemed to be part of a mechanical cause of mechanical "non-specific" LBP, they should also be part of the solution. Whilst some disagree with this position (Gajdosik et al 1994), other agree with it (McClure et al 1997).

In contrast to the above, the stance of Kippers (1984) can be supported by the work of Li et al (1996) who found no relationship between hamstring length and lumbar spine posture despite a change in hip range of motion as measured by both the TTT and SLR methods. Li et al (1996) also found that stretching the hamstrings did not effect the lumbar posture or the flexion range of motion in an asymptomatic population. Kaigle et al (1998) tested a small number of subjects (n=7) using surface EMG and found that during the flexion relaxation period, noted by Kippers & Parker (1984), that the segmental motion increased. However, an earlier study by Haas & Nyiendo (1992) found no relationship between LBP and coupled range of motion. Yet another study by Shirado et al (1995) demonstrated that sufferers of low back pain did not demonstrate the same period of flexion relaxation noted by Kippers, and suggested that there was a time lag between trunk and hip movement that was greater in sufferers of LBP. The increase in the time was said to be associated with an increased eccentric muscle contraction activity, a type of muscular contraction frequently associated with a specific type of pain (Bourgeois et al 1999). Despite the findings of these unrelated papers, Pope et al (1985) concluded from their study that LBP status was not correlated to lumbar flexion range

However, the opposing view that hamstring tightness does contribute to LBP can also be made strongly. McClure et al (1997) has found tight hamstrings to be correlated strongly with LBP using an SLR & AKE tests. Stokes & Abery (1980) in an important original contribution conclude that the hamstrings can restrict hip flexion range of motion in a group of LBP sufferers, a view supported by Gajdosik et al (1994), and Esola et al (1996). The implications of these findings perhaps are best summarised by Roach & Miles (1991) who stated that any loss of hip joint ROM is abnormal and should be treated and, Revel (1995) who suggested that those treating LBP should attempt to increase hip and lumbar mobility as a standard approach to care.

Support for this view can be gained from the work of Mellin (1990) who concluded that LBP was associated with a decrease in hip flexion range of motion, a view supported by Ellison et al (1990). An analysis of hip and lumbar movement by Porter & Wilkinson (1997) demonstrated a decrease in hip flexion range of motion and overall (total lumbopelvic) flexion was noted in low back sufferers. In contrast to Porter & Wilkinson (1997), Esola et al (1996) found that total flexion range of motion to be the same in LBP and non-LBP sufferers. The study by Esola and co-workers (1996) also suggested that quantitative data on the ROM may not present the whole story that was occurring in the functional aspects of any limitation to sagittal plane movement when the measurement was performed in the standing position. They performed a qualitative analysis of movement and demonstrated that in those persons with LBP, despite a similar overall range of motion, that the pattern of motion was different to the non-LBP sufferers. They suggested that the LBP sufferers moved later than did the normals and concluded that LBP sufferers should be taught to move more efficiently to incorporate an earlier movement of the hips in their forward bending motion. Magnusson et al (1997) noted whilst using the TTT that "tight" (hamstrings) were particularly tight during the mid range of the hamstrings, and that this range was inversely proportional to the overall range achieved.
The mid range of motion of movement noted by Esola et al (1996) consisted of a combination of hip and lumbar movement. Tight hamstrings would therefore reduce the load to the lumbar spine in such cases.

The extra tightness noted in those with LBP has supported a view that LBP sufferers compensate for their injury by tightening their hamstrings such that the hamstring tightness is actually protective of the back (Burgess-Limerick et al 1995). Burgess-Limerick et al (1995) have demonstrated that tight hamstrings enhance their strength. They suggest that the tightness coupled with the co-activation of the hamstrings and the quadriceps (Greenfield 1993) could increase the moment at the hip thereby increasing the possible load carriage potential (a desirable trait for those with lower back injury). Thus, Burgess-Limerick et al (1995) propose that tight hamstrings are an effect of injury rather than a cause.

These points of view contrast with the findings of a study by Jonhagon et al (1994) in a group of subjects with hamstring injury who suggest that those with such injury are tighter (have a decreased range of motion), have a large eccentric torque capability at all ranges, and who have a decreased concentric peak torque at low joint angles.

Taken together one could propose that an initial injury to the back may result in a stiffening of the lumbopelvic mechanism allowing a compensation for greater load carriage in the compromised anatomy. However, with the large eccentric torques being generated by the extensor muscles, a potential for eccentric muscle damage could result from further unaccustomed activity. An activity that would appear to an observer as a concentric flexion activity of the lumbopelvic region with a synergistic eccentric muscle activity of the extensor groups. Should a further insult be directed at the back in this fashion as is typical of the region (Vivian 1991) LBP could result, illustrating one of the most common presentations of acute low back pain (personal clinical experience).

**EMG**

The EMG has been in use in biomedical research for many years. As a result it is a well accepted tool for investigation of muscular activity
associated with movement. As the topic of this research is the lumbopelvic region of the body and is primarily concerned with movement analysis, the use of EMG has been proposed and attempted (Sihvonen 1997, Kaigle et al 1998).

Sihvonen (1997) has demonstrated a relaxation phenomenon of hamstrings in forward bending in much the same fashion as Kippers & Parker (1984) had earlier demonstrated in the lumbar spine. Kaigle et al (1998) noted a flexion relaxation of the lumbar erector musculature and correlated it to an increase of segmental vertebral motion. It had been suggested that the increase in mobility associated with the relaxation of muscle would increase loading to the non-contractile structures of the posterior spine possibly leading to hyper mobility and increased pain (Gracovetsky et al 1989, Dolan et al 1994, Adams 1995, Knolmayer et al 1997), and that the effect could be increased by a loss of hip flexion range of motion (Gajdosik et al 1990, Goeken & Hof 1991, Van Wingerden et al 1995).

Whilst Sihvonen (1997) demonstrated a relaxation of musculature in forward bending, Sihvonen et al (1997) demonstrated apparently conflicting results when presenting surface EMG evidence that suggested that there was activity in both LBP sufferers and non LBP normals in 86% of all cases. By contrast, Shirado et al (1995) have demonstrated that flexion relaxation was not demonstrated in a group of LBP sufferers when compared to normals. Despite the fact that Wolh et al (1997) suggested that intratester reliability in EMG studies was good and should therefore be used in research, Magnusson et al (1995) reported that EMG was not a good measure of function when outcome measures included a change in resistance of muscle due to the stretching of target muscles. A view supported by Wiemann & Hahn (1997) when they concluded that stretching based protocols changed the EMG output. Magnusson et al (1998) took this investigation of muscle further by suggesting that static and cyclic stretching was a good method of increasing joint range of motion by increasing the tolerance of the joint whilst leaving the viscoelastic properties unchanged.

The idea that material properties of tissues are effected by treatment has also received attention by other investigators. Klinge et al (1997) in an isometric strength training study concluded that the material properties
of muscle were unaffected by flexibility exercises, thereby supporting the later view of Magnusson et al (1998).

The earlier view of Magnusson et al (1996) formed whilst investigating the change in EMG associated with PNF stretching states that at a constant angle the viscoelastic properties of muscle were unchanged, however, with a variable angle stretching altered the stretch perception. These perceptual changes noted by Magnusson et al indirectly support the view by Halbertsma & Goeken (1994) that stretching improves tolerance to stretch, but not the actual length of muscle when measured with either the SLR or the TTT method. A view that would not be supported by the majority of studies designed to investigate the effect of therapy on hip range of motion (Etnyre & Lee 1987, Pollard & Ward 1998).

So despite the fact that EMG is often used to measure quantitative aspects of lumbopelvic function, several researchers have concluded that it is best used to investigate the qualitative aspects of such functioning (Esola et al 1996, Mayhew et al 1983). This point can be demonstrated in the findings of early work by Mayhew et al (1983) when testing subjects with the SLR method of assessment that on page 1769: "subjects could consciously alter the EMG pattern and output of the abdominals and the hamstrings", thereby corrupting the results obtained for quantitative analysis purposes.

Therefore, as the five studies investigated in this thesis investigated the quantitative aspects of manual therapy, the EMG assessment was not the most appropriate form of assessment, and was not used. Future studies investigating the qualitative aspects of the component parts of the range of motion could consider the use of EMG as a part of the protocol. If such a protocol was to be utilised, very careful attention need be given to the effect of movement elicited by the manual therapies on the EMG response and the type of EMG used.

**Lumbopelvic rhythm**

The lower back is related to the muscles of the posterior thigh by the action of the lumbar-pelvic rhythm (LPR) (Cailliet 1981). The lumbar pelvic (or lumbopelvic) rhythm has been described by several other
authors including, Janda (1981), and Troup et al (1968), to specify the amount of anterior and posterior tilting, in which there is a coordinated action with the pelvic lumbar spine and hips, during the total flexion and extension movement of the trunk (Stokes & Abery 1980). Although Cailliet is probably best associated with the term LPR, the use of the idea is in no way exclusive. According to Cailliet, and other authors such as Paquet et al (1994), Stokes & Abery (1980), in certain circumstances of forward flexion of the spine, there may be an inadequate amount of flexion to flex to the point of toe touching. Thus, the remainder of this movement must occur by anterior pelvic tilting, incorporating the movement of the hips into flexion. This series of events are sequential, and make up the LPR described by Cailliet (1981). It is further suggested by Cailliet and Norkin & Levangie, that restricted motion of the lumbar spine or the hip will disrupt the normal function of that rhythm, and result in limited overall ROM in flexion. What therefore would result if the requirement for rapid flexion exceed the capability to produce it? I would suggest, from a practical viewpoint, as Cailliet and others have from a theoretical viewpoint, that injury could result. Passive tension in the hamstrings may prevent normal anterior tilting of the pelvis (Adams & Dolan 1995, Dolan et al 1994, Gracovetsky et al 1989, Macintosh & Bogduk 1987) thereby placing a greater strain on the posterior elements of the lumbar spine, which serve to restrict flexion of the lumbar spines (Norkin & Levangie 1983).

**Figure 2.6 Normal lumbopelvic rhythm (LPR).**
Adapted from Scafer (1983), p393
Therefore, a greater potential for injury to the lumbar spine exists if the hamstring group of muscles exist in a restricted fashion. This observation of tight hamstrings and flexible lumbars has been made by several authors. Stokes and Abery (1980) demonstrated that persons with a small range of hip flexion ROM demonstrated the largest range of lumbar curvature when measured in the sitting position. They concluded their study by recommending that hamstring extensibility be monitored in sedentary sitting working populations. Biering-Sorensen (1984) in a prospective study of middle aged adults demonstrated that hypermobility of the lumbar spine was associated with an increased risk of lower back pain. He also stated that good endurance of lumbar musculature decreases the risk. In a more recent paper by Lindsay & co-workers (1993) who assessed elite cross country skiers, the authors suggested that any restriction of sacroiliac joint mobility is a risk factor for LBP. This statement is important in the light of the fact that only the flexors of the hip and trunk (iliopsoas and rectus femoris) actually span the sacroiliac joint (Pansky 1983). Therefore it maybe argued that a loss of hip flexion ROM may decrease the ROM through which the sacroiliac joint normally articulates, thereby increasing the load to the lumbosacral spine, as the implied by Lindsay & co-workers (1993).

Several studies of clinical theory of LBP and limited hip joint mobility have been undertaken. These studies demonstrate that a decrease in hip mobility is often the only difference between a LBP population and normal controls (Magora 1975, Fairbank et al 1984, Mayer et al 1984, Mellin 1986a,b).

Normal ROM of the hip at different ages is discussed below. Hip ROM in the newborn is significantly different to the adult. The neonate possesses a significant hip flexion contracture of approximately 28° (Forero et al 1989). This contracture is associated with increased rotation, especially external rotation. The rotation is greater with hip flexion (Greene & Heckman 1994), and the increased rotation noted in the neonate could be due to the hip contracture and the fact that development was incomplete (Haas et al 1973, Waugh et al 1983).

The increase in hip rotation, and the hip flexion contracture resolves within the first year of life (Phelps et al 1985). By the end of the second
year, internal and external rotation of the hip are equal (Staholi et al 1985).

Top, normal extension from flexion. First phase of return is primarily pelvic, with lumbar lordosis returning only near the neutral position. Bottom, if the pelvis fails to rotate posteriorly during extension because of weak hip extensors (rarely painful) or hyperactive lumbar extensors (often painful), the lumbar spine will develop a hyperlordosis near 60° that places severe stress upon the lumbosacral joint. In approaching the neutral position, this stress is often reacted to by a flattening (spasm) of the lumbar curve, exhibiting an antalgic stiff spine.

Adapted from Scafer (1983), p394

**Figure 2.7 Flexion and extension phases of the LPR.**

ROM is generally greater in children than in adults (Greene & Heckman 1994). Surprisingly, adults demonstrate very little decline in hip motion with advancing age. In a study of 1683 adults, Roach & Miles (1991) found minimal change in hip ROM up to the age of 74 years. They concluded that any substantial loss of ROM and joint mobility was abnormal, and not attributable to aging (Boone & Azen 1979, Roaas & Andersson 1982).

Hip measurement is best performed in the supine position with the pelvis strapped to minimise rotation or tilt (Greene & Heckman 1994).
However, many clinicians do not measure hip extension, and prefer to focus on the presence of hip contracture.

By the very same mechanism, injudicious application of stretching or other mobilisation routines, especially the ballistic variety, may stress the lower back too greatly into flexion, causing strain injury at the level of the lower back. In particular, probably at the level of the lumbosacral insertions of the spinal erectors which is commonly occurring in lower back injury. (Kirkaldy-Willis 1983) It has been suggested by, Chicoine (1987), Chibulka et al (1982), that the hamstrings via a restriction of the mechanism theorised by Dolan et al (1994), are a primary cause of lower back strain experienced in such a large number of the population. As the lumbosacral insertions of the erector spinae muscles may be considered to be a long lever system, with the fulcrum existing at the flexion and extension occurring at the lumbosacral level (Kreigbaum & Bartels 1985), one should consider the application of a great deal of weight, far from the fulcrum point as a very good way to heavily load the lever point at the insertion point of the musculature. Thus the weight of the upper body and head may act in this fashion (Kreigbaum & Bartels 1985) thereby loading the spine. Should the relative body positions change such that the amount of weight bearing borne by the lumbosacral insertions change, the amount of strain on the lower back may also proportionately change. A summary of the mechanisms used to stabilise the lumbopelvic region will occur in the next section.

The excessive lumbar flexion movement hypothesised to be caused by decreased hip flexion would load the lumbosacral region too greatly causing strain injury during quick movements, or microtrauma during smaller repetitive movements. This tenuous link between hamstring tightness (decreased hip flexion) and the lower back has been observed by several authors. For example, Barash and co-workers (1970) have commented on the implications of tight hamstrings in a population of persons with spondylolysthesis. Another study by Fisk and Baigent (1981) associated the LBP of Scheuermann's disease (an osteochondritis of the vertebral endplates) to be associated with tight hamstrings and decreased flexion of the hips and thoracolumbar spine. Further evidence of the widespread belief by the medical community of the importance of the hamstrings in the generation of low back pain can be illustrated by
the surgical procedure that is sometimes performed by orthopaedic surgeons to cut spastic hamstrings to reduce low back pain in select groups of low back pain sufferers (Angles et al 1997).

In addition to these findings, it has been well documented that flexion plus rotation movements are particularly successful at dangerously loading the spine asymmetrically (Farfan et al 1970). Other authors (Gracovetsky & Farfan 1986, Gracovetsky et al 1985) have also suggested unilateral loading to be associated with disc and other tissue pathology in the lower back region (Hadjipavlou et al 1998, Hadjipavlou et al 1999). I feel that it is likely that this form of loading could be a unilateral manifestation of an inappropriate lumbopelvic rhythm. The even greater forces generated by the unilateral loading would be even more likely to cause injury to the lumbosacral spine. I feel that this interesting concept should receive further study.

The straight leg raise (SLR) can be used to measure length and passive compliance of the hamstring muscle (Gajdosik 1991). In another study by Gajdosik and co-workers (1993), four tests for assessing hamstring length were undertaken. The findings suggest that these commonly used assessment measures of hamstring length actually involved indirect measurement of the homolateral hip flexion angle (valid when the knee was held in full extension). Gajdosik (1991) demonstrated that the passive tension in the hamstring was not related to EMG and that there was a significantly decreased difference between the initial and final length of those who demonstrated short hamstrings. He concluded that this resulted in a significant decrease in the ability to passively respond to short hamstrings. However, Sullivan & co-workers (1992) conclude their study by suggesting that anterior pelvic tilt is a more important factor in hamstring stretching than is the muscle flexibility, and should therefore be controlled in any measurement such as SLR by strapping the pelvis to the treatment couch.

In order to assess the lumbar aspect of the proposed lumbopelvic interaction, a measure of trunk flexion was required. Kippers & Parker (1987) as an extension of Kippers masters qualifying thesis (1981) developed a reliable method for assessing hip and trunk flexion ROM, but not vertebral flexion. This method has also been used by several other investigators including the group lead by Gajdosik (1990), (1993).
Interestingly, the reliability of the overall extensibility of the hip and trunk as measured by this method was not affected by limb length, abdominal girth, amount of subcutaneous fat or the degree of musculoskeletal development (Kippers 1981). This finding is in contrast to other methods of assessing lumbar and hip flexibility that suggest there are differences between different subject populations (Cornbleet & Woolsey 1996, Webright et al 1997).

Osternig et al (1990) demonstrated that habitual endurance or high intensity (sprint) activity was significantly different to no sport control in terms of initial hip flexion ROM. In addition, Hopkins & Hooper (1992) using sit and reach and modified sit and reach assessments of flexibility suggested that anthropometric variables of limb and trunk length were factors affecting performance outcomes of the sit and reach test. In another study on hamstring tightness, Gajdosik & Lusin (1983) concluded that high test retest reliability will be achieved only from strict body stabilisation and placement, the use of a well defined end point of ROM and an accurate placement of recording instruments. The standardisation of these factors was therefore included into this study, and may be read in the chapter on methodology.

Lumbopelvic rhythm theory is untested at the present time. Recent studies have tried to associate specific components of the proposed mechanism. Bohannon et al (1985) suggested that despite the widespread use of the straight leg raise (SLR) test, little was known about the relative contributions of the pelvic and femoral motions that achieved a passive SLR often used to assess hip flexion ROM. Their results show that increases in SLR by passive stretching did so by increasing both the pelvic and hip angles.

With this in mind, we felt it necessary to begin to evaluate the proposed lumbopelvic mechanism. I proposed and completed an investigation observing any changes in pain levels and ROM that took place in subjects suffering LBP who were subjected to treatments designed to increase the ROM of the hips. In order to observe any manifestations of the proposed relationship between the lumbar spine and the hip, we measured the ROM of the hips and lumbar spine before
and after treatment. The chapter on methodology will outline clearly the steps taken to achieve this.

Stabilisation mechanisms of the lumbopelvic region
The cantilever model of the spine

The role of the muscular support system of the spine is paramount to the transmission of large loads from the spine to the legs (Norris 1995). When considering the human spine devoid of musculature Panjabi et al (1989) have demonstrated that a load of only 2-2.5 kgs could buckle the fresh cadaveric human spine. This effect can be demonstrated when considering a model(s) that assumes that the centre of mass of the upper body lies at the sternal level (Norkin & Levangie 1995). Farfan (1988) summated all these and other effects to be mentioned shortly to conclude that when such effects were combined, the net effect of the loading on the spine could be represented by a cantilever system that was comparable to balancing a weight of 35 kgs on the end of a 14 inch flexible rod (Farfan 1988).

\[ \text{Tension of spinal extensors} \]

\[ \text{Weight of head, neck and arm} \]

\[ \text{Weight of object lifted} \]

\[ \text{Weight of trunk} \]

\[ \text{Reaction force exceeds failure load of lumbar discs} \]

**Figure. 2.8 Cantilever model of the spine**

Adapted from Norris (1995)

Such an effect is magnified when lifting (Norris 1995). In order to calculate or otherwise estimate the loads falling on the lumbosacral region, several mechanisms have been proposed to attenuate the force. Based on these mechanisms, several authors have provided various

In the cantilever model the spine may be viewed as a cantilever pivoting on the hip. The weight of the trunk and any object lifted forms a load which is retarded by the action of the back and hip musculature. Importantly, many authors have calculated that without the supporting action of the musculature, the forces calculated using this model would be sufficient to create disc rupture (Morris et al 1961). Therefore a number of mechanisms have been postulated to reduce the stress to the lumbar spine.

**Intra-abdominal pressure mechanism**

The intra-abdominal pressure mechanism is that pressure acting within abdomen acting against the diaphragm, the pelvic floor and the abdominals (especially the transversus abdominis) (Troup 1979). By making the trunk into a more solid cylinder, axial compression loads are dissipated through a greater area and tissue mass thereby reducing the load imparted to the lumbosacral region (Twomey & Taylor 1987).

![Intra-abdominal pressure mechanism. Pressure within the abdomen acting against the pelvis and diaphragm provides an additional extensor moment to the spine (after Troup, 1979)]

**Figure 2.9**  
Intra-abdominal pressure.  
Adapted from Troup (1979)
The concept of increased load bearing capacity due to an increase in intra-abdominal pressure is not new. Despite the still sometimes controversial concept, it also is a source of decreased spinal compression (Aspden 1987). This effect is explained by the knowledge that the abdominal content exerts a force on all structures in all directions of the abdominal cavity. If the glottis remains closed after inspiration, and the pelvic floor remains rigid, there is a resultant upward force that tends to extend the spine, thereby opposing flexion (Norris 1995, Bartelink 1957, Morris et al 1961).

As this mechanism can cause a reduction in sagittal plane flexibility, its effect should be considered in any methodology that involves the thoraco-abdominal mechanism by the closure of the glottis (holding the breath).

**The posterior ligamentous system**
The interspinous and supraspinous ligaments, the zygapophyseal joint capsules and the thoracolumbar fascia together provide passive support to the lumbar spine totaling approximately 24%-55% of the imposed flexion load stress (Adams et al 1980). When the spine is flexed, the posterior ligaments are stretched becoming taut and stiff. The increased stiffness enhances the support of the lumbar spine. In a similar fashion, the collagen fibres in the muscle and supporting connective tissue also becomes stiffer through increased tension also leading to increased support of the lumbo-sacral region (Kirby et al 1989, Hukins et al 1990). Thus, the power created by the hip extensors during a contraction can act to tension these structures to increase the stiffness and the load carrying capacity at the time when loads are increased during lifting.

**Thoracolumbar fascia mechanism**
The thoracolumbar fascia mechanism has both a passive role through the action of the connective tissue, and an active role primarily through the action of the transversus abdominis. The two roles are manifest through the action of the lateral raphe of the thoracolumbar fascia (see diagram below).
The thoracolumbar fascia (TLF) mechanism. The transversus abdominis through its attachment to the lateral raphe pulls onto the TLF. The angulation of the deep and superficial layers of the TLF creates a net force tending to approximate the vertebrae.

Figure 2.10 The thoracolumbar fascia Adapted from Norris (1995)

The hydraulic amplifier
The hydraulic amplifier refers to the build up of fascial tension in the fascia encapsulating the erector spinae. As the erector spinae contract, there is a build up of tension in the fascia as the expansion of the erectors is resisted (Oliver & Middleditch 1991). It is this build up of tension that has a primary anti-flexion effect to support the lumbar spine during flexion loading (Macintosh et al 1987). See diagram below.

Figure 2.11 The hydraulic amplifier. Adapted from Oliver & Middleditch (1991)
The arch model of the spine

An alternative representation of the spine is one which uses an arch model rather than a lever system (Aspden 1987, 1989). In this model the ends of the arch are provided by the sacrum caudally, and a combination of bodyweight, musculature and ligamentous forces proximally. The difference between the two models lies in the fact that the lever is extrinsically supported, whereas the arch is intrinsically supported (Norris 1995). Any load placed on the convex side of the arch structure (i.e., muscle contraction) will create an internal thrust line which runs straight through the arch abutments (in this model represented by the vertebral bodies). For this model to remain stable, the thrust line must stay within the arch ring, and the deeper within the arch ring this occurs, the greater the inherent stability with the lift (Aspden 1989). Whilst this model can fully express the action of the contractile and non-contractile mechanisms to reduce forces, this model has been criticised for seriously underestimating the excessive compressive loads generated on the spine (Adams 1989).

Figure 2.12 The arch model of the spine (Part 1).
Adapted from Aspden 1987
Arch abutment

Arch model of the spine. A load positioned on the convex surface of an arch creates an internal thrust line. For the arch to remain stable, the thrust line must stay within the depth of the arch ring (Aspden, 1989)

Figure 2.13 The arch model of the spine (Part 2). Adapted from Aspden 1987

Trunk muscle action
Richardson et al (1990) have proposed that the co-contraction of all muscle acting on the spine could greatly reduce the instability resulting from lifting, thereby supporting the spine during heavy loading.

Spinal extensor muscles
The spinal muscles may be classified into broad superficial muscles (the erector spinae) which travel the length of the spine, and the deep segmental muscles (multifidus, interspinales and intertrasversarii) (Oliver & Middleditch 1991).

The deeper muscles lying close to the centre of rotation of the vertebrae have a shorter lever arm than the superficial muscles, but because they are close to the spine, any change in their length results in small changes to the angular position of the spine. The shorter length of the intersegmental muscles give them a faster reaction time, creating a smoother and more efficient control system (Panjabi et al 1989). As a result of these functions, the intersegmental muscles are often referred to as proprioceptive muscles acting to fine tune spinal movement (Aspden 1992). In contrast, the larger superficial muscles located further away from the centre of rotation of the spine act to create gross sagittal plane movements (Panjabi et al 1989).

In addition, the line of action of multifidus muscles can be viewed as being comprised of small horizontal and larger vertical components, enabling a posterior rotation motion of the vertebra to directly oppose
the forward rotation of the vertebra occurring during trunk flexion (Macintosh & Bogduk 1986). The net effect of these muscles is to increase the lordosis of the spine, an action shown to occur through the entire flexion range of motion (Valencia & Munro 1985). The superficial muscles can also be resolved to act in a similar fashion to support the action of the deeper muscles (Macintosh & Bogduk 1987).

**Summary: Stabilisation mechanisms of the lumbopelvic region**

Whilst the precise action of these mechanisms is still unresolved, the importance of the active mechanisms is increasingly recognised (Norris 1995). It appears logical that the co-ordinated action of all these mechanisms is essential for total lumbar spine stability, and that tightness in some or all of the structures is likely to stabilise a spine that has become unstable secondary to acute or chronic injury (McClure et al 1997).
Review lumbopelvic measurement systems

Lumbar ROM in the Sagittal Plane
Several of the studies used in this research have required the use of a sagittal plane (flexion) ROM assessment. Total sagittal plane ROM of the low back region has been referred to as the lumbopelvic rhythm (Cailliet 1995). This rhythm describes the co-ordinated action of the thoracolumbar, lumbar, pelvic and hip ranges of motion. This motion is usually described in terms of flexion / extension ROM, but it can also relate to coronal and lateral planes as well (Cailliet 1995). For the purpose of this research, we have focused on the sagittal plane ROM. An indepth review of this ROM will now follow.

Manual therapists frequently treat conditions of the lumbar spine (Shekelle et al 1995). Injury to this region causes more presentations to manual therapists than any other injured body part (Shekelle et al 1995). As such, many treatment protocols have been developed to treat the resulting dysfunction.

As a part of the assessment that many manual therapists make on these injuries, assessment of various joint ranges of motion usually accompany any requisite neurological, orthopedic, radiological or other testing.

Many of the tests employed by the practitioners are performed to provide a diagnosis of a tissue in lesion, that is, the tissue change that is causing the patients presenting symptoms.

Once the practitioner has determined the tissue in lesion by those testing and interview techniques, the information must be formulated into a clinical or diagnostic statement. It is here that the practitioner determines whether the tissue has simply been dramatically overloaded, or that other nearby joints have contributed to the loading of the injured body part to ultimately cause tissue damage pain.

In the case of low back pain, many authors suggest that dysfunction of the lumbopelvic rhythm as being a cause (Cailliet 1995). They imply that changes in joint range of motion away from the ideal has the ability
to impact negatively on lumbar spine range of motion. These implications are particularly true of the sagittal plane ROM.

Therefore, accurate measurement protocols are required for evaluation of dysfunction before, during and after any treatment protocol. In order to appropriately discuss the implications of the LPR, we will now discuss the component contribution to this overall ROM.

**Lumbar spine**

Several authors have investigated the ROM of intersegmental (vertebral) ROM in the lumbar spine (Tunz 1953, Allbrook 1957, Clayson et al 1962, Froning & Frohman 1968, Pearcy et al 1984, Panjabi et al 1989, Hayes et al 1989, Dvorak et al 1991). Table 1.3 below presents the results of several relevant studies on lumbar segmental ROM. From this table we can observe that ROM of the upper lumbar segments is the smallest, and that this ROM progressively increases to L4-5 segment where it is maximal. These findings appear to be universal. However, the ROM at the lumbo-sacral region is said to increase in 2/3 of studies, and a slight decrease is noted in the rest.

Table 2.1: A comparison of results from studies of lumbar ROM from full extension to full flexion using roentgenographic analysis.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>Subject No.</th>
<th>L1-2</th>
<th>L2-3</th>
<th>L3-4</th>
<th>L4-5</th>
<th>L5(6)-S1*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanz, 1953</td>
<td>14</td>
<td>5.6</td>
<td>7.6</td>
<td>8.6</td>
<td>12.2</td>
<td>8.2</td>
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<tr>
<td>Allbrook, 1957</td>
<td>20</td>
<td>6.0</td>
<td>8.0</td>
<td>13.0</td>
<td>19.0</td>
<td>18.0</td>
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<tr>
<td>Clayson et al, 1962</td>
<td>26</td>
<td>12.6</td>
<td>15.8</td>
<td>15.9</td>
<td>17.7</td>
<td>18.7</td>
</tr>
<tr>
<td>Froning and Frohman, 1968</td>
<td>30</td>
<td>9.0</td>
<td>11.0</td>
<td>13.0</td>
<td>16.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Pearcy et al, 1984</td>
<td>11</td>
<td>13.0</td>
<td>14.0</td>
<td>13.0</td>
<td>16.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Panjabi et al, 1989</td>
<td>10</td>
<td>10.1</td>
<td>10.8</td>
<td>11.2</td>
<td>14.5</td>
<td>17.8</td>
</tr>
<tr>
<td>Hayes et al, 1989</td>
<td>59</td>
<td>7.0</td>
<td>9.0</td>
<td>10.0</td>
<td>13.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Dvorak et al, 1991</td>
<td>41</td>
<td>11.9</td>
<td>14.5</td>
<td>15.3</td>
<td>18.2</td>
<td>17.0</td>
</tr>
</tbody>
</table>

*This category also includes the anomalous L6-S1 articulation as well as the normal L5-S1 motion segment.
Most of the figures presented are comparable except for two studies by Clayson et al (1962) and Dvorak et al (1991) which had larger ranges of motion. The Clayson study had design problems that included the use of a single gender (a problem known to occur because of the gender differences in range of motion, and the generalisation of the conclusions) (Hartley-O'Brien 1980), and the use of a non-standard examination procedure. By contrast to all the studies mentioned above, the study by Dvorak et al (1991) was the only study of the group that assessed passive ROM. All other studies assessed active ROM. Thus, the possibility exists that the different assessment methods were actually measuring different variables. In defence of this approach, Dvorak et al suggest that individuals suffering lower back pain only flex to the extent of their pain and, as such, the true full ROM is not determined.

Further clinical observation will need to determine the validity of these approaches by a comparative study format. However, other research has demonstrated that low back pain sufferers have decreased sagittal plane ROM compared with non low back pain sufferers. (Troup et al 1968, Burton et al 1989, Ensink et al 1996). Thus, Dvorak and coworkers argue that an active test is not a true indication of clinical function, and that a passive test of ROM should be performed to determine joint ROM.

The study by Pearcy et al (1984) demonstrated the overall ROM can remain the same despite short comings in ROM with segments of the region. They found that when extension of the lumbosacral region was decreased, it was made up by increased general lumbar flexion and vice versa. Thus, they concluded that the overall lumbar flexion ROM remained constant despite segmental changes within the ROM. Despite this finding, no correlation was found between the lumbar lordosis and the degree of flexion or extension at the lumbosacral level.

Diurnal variation in lumbar ROM
Tyrell and coworkers (1985) have shown that placing loads on the shoulders produced a non-linear height decrease with weight increase. It is thought that fluid is expressed from the nucleus pulposis and the annulus fibrosis under sustained compressive loads (Nordin & Frankel 1989).

Tyrell and coworkers also noted that 54% of the height lost in the disc occurs in the first hour, and 83% occurs within the first 3 hours. Krag et al (1985) noted a 50% loss in 2 hours and a 90% loss in 8 hours. Thus, the loss in height (amount of fluid expressed from the disc) is dependent on both the size of the compressive loading and the length of application of that loading.

Conversely, when intervertebral discs are unloaded, they are thought to imbibe fluid back into the disc via microscopic pores located in the end plates of the vertebral bodies (Burton et al 1989).

A large study of 1217 subjects ranging in age from 5 - 90 years of age demonstrated a 1% increase in height after one night of sleep (De Puky 1935). Other researchers have also demonstrated similar changes in different age groups, with similar tests (De Puky 1935, Twomey 1982, Wing et al 1992). Thus, if weight could be removed from the spine, a greater increase in height could be expected. To highlight this proposition, height increases of up to 7 cm have been recorded by astronauts in microgravity environments (Brown 1977, Thorton & Moore 1987).

Wing et al (1992) has noted that 40% of the increase in height occurs in the lumbar spine, and that approximately 2 mm of height increase at each inter vertebral level can be expected overnight. These results have been confirmed by a radiographic study (Thery et al 1987).

Several authors have proposed the idea that the loss of stiffness in joint ligament secondary to the loss of disc height and increased ligamentous slack is a potential cause of an increase in ROM (Ensink et al 1996, Wing et al 1992, Adams et al 1987).
Adams et al (1987) have confirmed the increase in ROM with results that have demonstrated a 5° increase in vertebral flexion by late afternoon in a patient group. Ensink et al (1996) using similar methodology demonstrated an increase in ROM from morning to late afternoon.

Whether decreased flexibility in the morning is due to taut intersegmental ligaments created by the overnight expansion of the disc or whether tight soft tissues are causative is indeterminate.

Whilst there is no data demonstrating a specific relationship between injury and loss of flexibility in this fashion, there is a dearth of indirect evidence that suggests injury rates are greater in the presence of inflexibility (Yamamoto 1993).

**Electrical activity in the lumbar spinal extensors during lumbar flexion**

Several authors have demonstrated electrical silence in lumbar erectors during trunk flexion (Floyd & Silver 1955, Kippers & Parker 1984). These researchers have demonstrated electric silence in the lumbar muscles at a point approximately 2/3 into full lumbar flexion in the standing position. Past this point they observed electrical silence. This silence indicates that approximately 90% of flexion ROM of the spine has occurred, range of motion that is passively limited by the posterior ligamentous system (which consists of the thoracolumbar fascia, the supraspinous, interspinous and posterior longitudinal ligament, the ligamentum flavum and the zygapophyseal joint capsules).

Kippers and Parker (1984) have established a reliable method for assessing lumbar and hip flexion ROM, and it is this methodology that has been used in the standing (toe touch test) assessment of hip flexion range of motion in this research. It involves the assessment of flexion by a modified toe touch test referred to as the finger to floor distance. An in-depth analysis of the standing and supine measures of hip flexion ROM follow shortly.
The sacroiliac joint contribution to sagittal plane flexibility of the lumbopelvic rhythm

Egund and co-workers first quantified sacroiliac joint (SIJ) movement in three dimensions using a radiological process described as stereophotogrammetry. This process consisted of the radiological imaging of radio-opaque markers implanted into the SIJ, the ilia and the sacrum (Egund et al, 1978). They demonstrated a maximum of 2° rotation in the sagittal plane about the axis of the second sacral tubercle in 4 patients with SIJ disorders. Another group of researchers have since examined 25 patients using the above method (Sturesson et al, 1989). In this second study exposures were taken in several positions including: supine, standing, and sitting with straight knees. When moving from sitting to standing the innomates rotated posteriorly in all but one SIJ, and the rotation was equal on both sides. The mean sagittal plane rotation was 1° and ranged from 0° to 1.8°. The movement from the supine position to the sitting position caused an average 1.4° rotation that ranged from 0.4° to 2° degrees.

Another researcher (Weisl, 1955) earlier recorded 6° of rotation, but his method was found to contain an error of about 3° when compared with the error of the two previous studies that were 0.1° and 0.2° respectively.

An important consideration of the above studies is the fact that all subjects possessed some form of injury to the SIJ (which was unstated). This contrasts with that of an uninjured normal population. In addressing this limitation of their research Sturesson et al (1989) claimed that if there were patients that were hyper or hypo mobile, the standard deviation of the mean scores would be greater than that noted. This was not found to be so. They also concluded that the pain noted by the subjects in these studies was due to hyper mobility, and the possibility exists that the SIJ ROM of normal subjects may be less than that noted by them. Therefore, it is now accepted that the SIJs do move, but their contribution to sagittal plane ROM is minimal.

The structure and function of the SIJ

The sacroiliac joint is second only to the knee in size. The SIJ has been shown to display increased roughness of its surfaces with increasing age
over 35 years. By contrast, female SIJ do not demonstrate such changes even with advancing age (Brooke 1924, Stewart 1984).

Vleeming and coworkers have shown the presence of complementary ridges and depressions on the joint surfaces (Vleeming et al 1990) and these features are less defined in the female SIJ. They also conclude along with other investigators that female sacroiliac joints are smaller and flatter (Solonen 1957, Vleeming et al 1990).

Brunner et al using similar methodology to Egund et al (1978) found that with SIJ samples with the musculature stripped away that there was 58% less posterior rotation of the movement around the sacrum in men compared with women (Brunner et al 1991). They also noted similar rotations to Egund's group (Brunner et al 1991).

Several reasons have been cited for the sex differences in the literature. Firstly the centre of gravity of occurs in approximately the same plane in females compared with the more ventral location of the centre of gravity in males (Tischauer et al 1973, Bellamy et al 1983). This implies a greater torque on the SIJ due to its greater distance away from the centre of gravity. This greater torque would correspond to greater joint loading. Therefore, the irregular joint surfaces first noted by Egund may be an adaptation to this joint loading (Vleeming et al 1990).

By contrast the female pelvis requires greater ROM for the purpose of accommodating pregnancy and birth. Thus any such requirement would require the greatest mobility, hence the flatter ridgeless SIJ surfaces.

The sacroiliac joint also displays a relatively large number of very thick ligaments according to Miller et al (1987). These ligaments are likely to help transmit loads via a constant tensioning of the joint (rather than compression), which is a feature of the lumbar spine (van Riel et al 1995). This tensioning effect of the sacroiliac joint ligaments manifests in both the sitting and the standing postures, and help to transmit loads through the pelvis (Snijders 1995).
A brief description of hip anatomy

Hip ROM
The hip is a major contributor to the LPR (Cailliet 1984). The extent of
hip ROM depends upon whether the hip is loaded actively or passively,
and it is also greatly affected by the action of the knee through the
action of the bi-articular muscles of the hip and the knee (Vleeming et al
1995).

Hip ROM in flexion is limited when the knee is extended due to the
tension developed in the hamstring muscles (Gajdosik et al 1993). To
illustrate this point, passive hip flexion ROM of the hip is 90° with the
knee extension and 120° - 135° with the knee flexed (Norkin & White
1985, Roach & Miles 1991). By contrast, active ROM of the hip with
the knee is only 110° - 120° (Roach & Miles 1991).

With this information it becomes a matter of importance to standardise
any measurement of hip flexion by keeping the knee, the cervical spine
and the ankle in a similar position for all tests, and either active or
passive in effort.

Active contraction of the hip flexors to attain maximum ROM activates
the psoas major muscle. The iliopsoas remains active throughout the
entire range of motion in an active movement of the hip such as that
which occurs when actively kicking a football (Dorge et al 1999). This
muscle originates on the anterior aspects of the transverse processes of
all the lumbar vertebrae and joins with the iliacus from the iliac fossa
(Kendall et al 1993). They have a common insertion into the lesser
trochanter of the femur (Kendall et al 1993). Contraction of these
muscles increases lumbar lordosis and restricts post pelvic rotation and
thus active straight leg raising (SLR). This apparent contradiction in the
action of the psoas as a flexor or as an extensor is related to the task
specific nature of motion due to the relative contributions of the muscle
to the competing demands of stability and mobility of the lumbar spine,
pelvis and hip in various positions (1995). In addition, active hip flexion
with simultaneous knee flexion considerably shortens the rectus femoris
which increases the likelihood of active insufficiency (Norkin &
Levangie 1992) further reducing the SLR.
Joint Congruency of the hip

Williams & Warwick (1985) have described that when the hip joint was lightly loaded the femoral head did not contact the superior aspect of the acetabulum.

Norkin and Levangie have proposed that full congruence of hip joint surfaces can only take place when loaded with a weight of at least half the body weight, which usually occurs in unilateral weight bearing (Norkin & Levangie 1992).

With this in mind joint congruency may be different in the standing and recumbent positions. Therefore joint flexion and subsequent ligamentous laxity may be different in these positions contributing to a difference in sagittal plane flexibility. However, it is likely that the differences noted would be easily overcome by the greater joint torques exerted by the action of the two joint muscles (hamstrings) and the degree of active effort employed during the effort.

The thoracolumbar fascia (TLF)

The thoracolumbar (TLF) consists of 3 layers described as an anterior, middle and posterior layer. The posterior layer consists of 2 laminae one superficially with caudomedial fibre direction and a deeper lamina with fibres arranged in a caudolateral direction (Bogduk & Macintosh 1984).

This structure arranges muscular sections in a series of overlapping triangles, with triangular apices lying in the lateral raphe and the base lying in the midline. Thus, any lateral tension placed on the apex of any triangle is transmitted to the midline along the border of the triangles and thence connected to longitudinal tension and the spinous processes. This force supports extension by increasing the lumbar torque, and consequently may restrict flexion ROM in the lumbar spine.

The effect of the TLF is transmitted to the SIJ from the deep fibres which are connected to the sacrotuberous ligaments and thence to the long posterior sacroiliac ligaments (Vleeming et al 1995). Tension in the TLF could therefore generate forces perpendicular to the SIJ that
would stabilise the joint, likely decreasing the joint ROM (Vleeming et al 1995).

From the distal perspective, the long head of the bicep tendon is continuous with the distal part of the sacrotuberous ligament and the posterior ischial tuberosity and inserts in the lateral aspect of the fibula head, the tibial condyle, and the deep fascia on the lateral side of the leg (Vleeming et al 1995). Tension in the TLF may therefore be transmitted by connective tissue from the TLF to the sacrotuberous ligament and thence to the biceps femoris to the knee via the hamstring muscle. Therefore, the possibly exists that the combined actions of these muscles could actively restrict hip joint ROM.

Vleeming et al (1995) have provided evidence that this functional explanation has merit by demonstrating that traction to the biceps tendon could result in displacement of the deep lamina up to the lumbosacral level.

From the proximal perspective the aponeurosis of the transverse abdominus is continuous with the middle portion of the TLF (Bogduk & Macintosh 1984, McGill & Norman 1988). These fibres are then continuous with the lateral raphe and thence the internal oblique (Vleeming et al 1995, Macintosh et al 1987).

Several researchers have thus claimed that rotating the abdominals can cause tension the TLF (Bogduk & Macintosh 1984). Although this proposal has been supported by some researchers (McGill & Norman 1988) another anatomical study has revealed such a small muscular interconnection to be insignificant in the production of tension in the TLF (Gracovetsky et al 1977).

By contrast, the latissimus dorsi and the gluteus maximus have greater attachment to the TLF and therefore carry a far greater potential to pretension the TLF (Macintosh & Bogduk 1987, McGill & Norman 1988).

In support of this contention, Vleeming and coworkers (1995) have demonstrated that traction of the latissimus dorsi to cause between 2 and 10 cm of upward displacement of the TLF. Vleemming et al also
demonstrated the action of the gluteus maximus activated the opposite (contralateral) superficial lamina. Vleeming et al suggested that this action was due to the effect on the posterior layer of the TLF. In support of this observation, Hutton and Adams (1982) have found electromyographic activity of the latissimus dorsi and the lumbar spine musculature to be in phase during lifting. However, evidence that this co-activation during lifting does not occur was provided by other researchers (Anderson et al 1977, Gracovetsky & Farfan 1986).

In addition, Gracovetsky et al suggested that tension may be increased in these muscles by the traction of non contractile tissue by the swelling effect of blood occupying the fixed space of the muscle compartment of the erector spinae which in turn tractions the deep layer of the TLF thereby acting on the hip and lumbar range of motion (Gracovetsky et al 1985).

The contribution of weight bearing of the static supporting elements of the lumbo-pelvic region should be considered during tension development of structures (and ultimately the flexibility) of the region as the activity of these structures can be up to 20% different dependent on whether the lower limb is in a closed or open kinematic chain (Mayer et al 1984).

Movement and hip flexion range of motion
Many studies have utilised various forms of assessment for the determination of hip flexion range of motion (ROM) (Tanigawa 1970, Etnyre & Lee 1987, Mayer et al 1984). Of all the common assessments, the straight leg raise (SLR) and the toe touch test (TTT) are the most common. However, assessing the suitability of these assessments is difficult because of the non-standardised nature of the studies in which they have been used. Great variability exists in the form of several variables including: injury status; test-retest reliability; randomisation and other sampling errors, the averaging of results, variations within methods and subject anthropometry.

The effect of these variables are usually assumed (or ignored) to relate to the action of pure hip range of motion (ROM). The following will
discuss the reliability of the two common methods of assessing hip flexion range of motion (ROM).

Moran and co-workers claimed that the TTT or "finger to floor distance" (FFD) was an unreliable measure in the adolescent population because of the variability of measurements (Moran et al 1979). Other results studied have confirmed these measures (Frost et al 1982, Merritt et al 1986, Kippers & Parkers 1987). Despite these claims, reliability co-efficients for the toe touching method range from 0.86 to 0.98 in both children and adults (Scott & French 1950, Broer 1958, Harvey & Scott 1967, Mathews et al 1957, Bruxton 1957, Mathews et al 1959). Based on these earlier studies we considered the finger to floor method of assessing hip flexion to be reliable. For example, in the finger to floor method, its main difference to the straight leg raise (SLR) method, is that the finger to floor distance (FFD) method is performed in the erect weight bearing position. This position brings with it another set of issues that could potentially alter the accuracy of the measurement. Standing measurements would need to assume a good degree of balance. Any problems with balance or postural sway could effect movement. These factors are known to be associated with age or disease, so these factors may mean that the finger to floor distance (FFD) method assesses general functioning more than the straight leg raise (SLR) method (Mellin et al 1991).

Another important difference between the two methods is the degree of active effort involved. The finger to floor distance (FFD) is an active movement that may be influenced by the patient while the SLR seems a lot less movement oriented due to its passive tension and pelvic stabilisation.

Keeley's group have suggested that poor effort and malingering may contribute to the movement obtained, thereby, influencing significance of any results obtained (Keeley et al 1986).

Other differences may be attributed to a group of factors related to anthropometrics of the subjects. Forward bending may be limited by a large abdominal girth, extreme body shapes, those with relatively short lower limbs, and those with long upper limbs and trunk (Broer & Galles 1958). The problem of using these subjects with long upper limbs
and or extreme flexibility can be overcome by performing finger to floor distance (FFD) measures with the subject standing on a box (Gaovin et al 1990, Hyyfianen et al 1991).

The finger to floor method of assessing hip flexion range of motion was used in the methodology that compared both measures in the first study of this thesis because we wished to compare the open (SLR) and closed (FFD) kinematic chain as Mayer et al (1984) has previously suggested the measurements cannot be taken as statistically similar. Further to this aim we attempted to demonstrate any such differences in a population of low back pain sufferers. The straight leg method of measuring hip flexion so predominant in the literature was used in all of the five studies of this thesis to assess and compare the validity of the past literature’s accuracy and to validate the observations that the finger to floor activity was more useful in measuring the effects of lower back pain.

**Mechanics of the Straight Leg Raise**

The straight leg raise (SLR) has been used as a test of both orthopaedic and neurological functioning (Hoppenfeld 1977). The interpretation of a limited straight leg raise can range from tight hamstrings to tight neuromeningeal structures and include many other orthopaedic conditions of the lumbopelvic region (Butler 1991). It is also used to assess hip flexion range of motion (Urbam 1986).

The SLR is a movement that may be performed in either an active or passive fashion. The movement when performed passively (practitioner assisted) and with knee straight is thought to involve the following sequence of events. When the leg is first lifted, a pure relaxation of the hips occurs until tension in the hamstring group limits further rotation. At this point there is said to occur a posterior pelvic rotation and the lumbar flexion (Kendall et al 1993). This sequence of events is similar to that said to occur with the lumbo-pelvic rhythm (Cailliet 1984). An important difference between the standing toe touch test (TTT) and the straight leg raise (SLR) is that in the standing position, an anterior tilt of the pelvis occurs thereby increasing the extensor movement on the lumbosacral spine.
Bohannon et al using cinematography has demonstrated a two part movement with passive straight leg raise (SLR) that consists of true hip flexion and posterior rotation of the pelvis (Bohannon et al 1985). Ellis and Stowe have reported that hip flexion in the range 70° to 130° occurs prior to pelvic rotation (Ellis & Stowe 1982). Another researcher has cast doubt on these figures by reporting that the start of pelvic rotation does not commence until the leg has reached 90° of rotation (Fisk 1979).

Opposing these viewpoints are studies that report pelvic rotation beginning at 44° (Hseik et al 1983), 9° (Bohannon et al 1985), 8° (Bohannon et al 1985). Thus, the point where posterior rotation begins the passive straight leg raise (SLR) is intermediate at this time. These findings help draw a conclusion that the amount of pelvic rotation posteriorly could provide an explanation for the differences in the standing and supine measures of hip flexion range of motion, as a greater degree of hip flexion range of motion is assessed by the SLR method.

As it is universally accepted that pelvic rotation does occur in the supine measure of hip flexion range of motion it is also now accepted that this extraneous movement should be controlled when measuring hip flexion range of movement. Attempts to minimise this movement have met with mixed success. Despite a reasonable assumption that fixing the opposite leg to a table would control the pelvic rotation, Bohannon et al determined that despite their effort 1/4 to 1/3 of the flexion mobility came from pelvic movement (Bohannon et al 1985). Another study by Elia et al has demonstrated that active contraction by the subject to stop pelvic movement was ineffective; however, physical therapists with training in pelvic stabilisation procedures were able to control this movement (Elia et al 1996). Despite this finding they concluded that no individual was able to eliminate the pelvic rotation (Elia et al 1996). Mayer et al (1984) feel that mobility testing of the hip should have the contra lateral hip held in hyper extension, with the contra lateral thigh off the couch. It would be interesting to test this form of assessment in a further study, because the above studies demonstrate that pelvic rotation cannot be eliminated by strapping the contralateral thigh to the table. It also shows that unwanted rotation cannot be stopped by active control of the subject, therapist control, or in the presence of slack
hamstrings. I conclude that it is presently not possible to completely eliminate pelvic rotation from hip flexion range of motion assessments. Attempts to minimise these pelvic movements usually involve the pelvis being strapped to the table to limit rotation (Gajdosik et al 1993). Thus, it is a limitation of the measurement system, that some pelvic rotation will occur with the hip flexion assessment. Importantly, effort to minimise and standardise this degree of pelvic movement should be undertaken by the investigators. A goal that was satisfied by all investigations performed in this thesis.

Cameron et al (1994) have noted that the degree of contralateral flexion results in a greater degree of straight leg rotation with respect to the horizontal plane, but not the pelvic plane. Thus a contralateral limb held in flexion would result in a greater SLR reading than one held in extension.

Now, assuming that the straight leg rotation reflects the true hip flexion range of motion with reference to the pelvic plane, the above illustrates that the straight leg rotation is affected more by pelvic movement than it is by pure hip joint muscles. To support this contention, Elia et al (1996) have found a pelvic contribution of between $\frac{1}{4}$ and $\frac{1}{5}$ of hip flexion movement, and Bohannon et al (1985) with the pelvic contribution being between $\frac{1}{3}$ and $\frac{1}{4}$ of the whole range of motion.
The Toe Touch Test (TTT)
The lumbopelvic rhythm describes an open chain co-ordinated flexion movement of the lumbars, the pelvis, the hip and the hamstring muscles to produce an overall range of motion that is greater than the sum of the parts (Cailliet 1988). Davis et al (1965) and White and Panjabi (1990) have suggested that the first 60° of flexion originates in the lumbar spine, and is followed by about 25° of anterior pelvic rotation and full hip rotation. These movements are reversed when rising from full flexion to full extension (Cailliet 1988).

Kippers and Parker (1987) demonstrated a significant correlation between toe touch test (TTT) (measured with subject standing on a box) and hip flexion, but not the TTT and vertebral flexion.

They believed that finger to floor distance is not a measure of intrinsic (bony shape or ligament tension), but rather a measure of hamstring extensibility. As the hip can achieve a greater range of motion with the knee bent (hamstrings relaxed), than with the knee straight (hamstrings taut), it is likely that hamstring tension limits hip flexion range of motion more than intrinsic factors when measured by the finger to floor distance.

The toe touch test involves the hamstrings being fixed due to the closed kinetic chain being formed when standing. As forward bending is attempted the pelvis rotates anteriorly and begins to tension the hamstring group. The act of tensioning the hamstrings together with the effect of the forward rotation placed on the lumbosacral spine secondary to the large extensor torque placed on the spine places a posterior torque on the pelvis to actually limit rotation motion. As the pelvic rotation reaches its limit later in the motion the hamstrings pull tight and retard forward flexion at the hip.

As the above movement is an active one, great contraction must occur in the hamstring group to oppose body weight. This further reduces the potential anterior pelvic rotation as active contraction of the hamstrings would posteriorly rotate the pelvis due to its point of insertion (Pansky 1981). In support of this contention, James and Parker (1989) have demonstrated significant increases in passive straight leg rotation when
compared with active straight leg rotation in the same elderly subjects. Findings by Cameron et al (1994) also support that work.

Myoelectric Activity during the straight leg raise
Nortan and Sahrmann (1981) have found no significant myoelectrical activity in the hamstring during a passive straight leg rotation. Goehnen and Hof (1991) also tested myoelectric activity in hamstrings, and noted that relatively no activity was noted at the point where passive tension was felt. By then placing significant over pressure on the hamstrings, they were still unable to register significant myoelectrical activity in the hamstrings. The only point where significant activity was noted was at the end range of motion, which implied a neuromuscular protective pattern at end range of motion rather than an active control of the muscle.

In opposition to this view is some indirect evidence provided by Markos (1979). Markos demonstrated an increase in hip range of motion following the application of PNF stretching. The mechanism of this form of stretching involves the relaxation of muscle groups (hamstrings in this case), and the passive stretch of non contractile components of the musculo-ligamentous system (Osternig et al 1987, 1990). Therefore they act to decrease both the active (and to a lesser extent) the positive tension in the muscles, thereby decreasing the resistance to movement, and increasing hip flexion range of motion (Osternig et al 1987, 1990). Whilst this indirect evidence suggests a place for hamstring activity during the SLR, the majority of the studies discount it.

Myoelectric Activity in the Toe Touch Test (TTT)
In order for the body to maintain balance in the standing position, activity of the postural anti-gravity muscles must be expected. This is particularly true in light of conclusions drawn by Oddson and Thorstonsson (1986). They concluded that such activity was dependent upon the size of the base of support, the vertical location of the centre of mass, and the height from the ground of the centre of mass.

The toe touch test requires a forward flexion of the trunk which is controlled by eccentric contraction of the spinal erectors and hip
extensors. The eccentric contraction continues to a point $\frac{2}{3}$ through the range of motion whereupon they become electrically silent. This silence continues to full range of motion where load is supposed to be borne by non contractile elements (Kippers and Parker 1984). Beside the work of Kippers and Parker, Paquet et al (1994) have also demonstrated early hamstring activity prior to the acquisition of full range of motion.

This active contraction of the hamstrings has the effect to overcome the large flexion movement that must be present on forward bending (Paquet et al 1994). According to Paquet et al (1994) the hamstrings are active throughout the full range of motion, and increase in activity toward the end of movement in order to brake the movement at the hip. Thus, it would appear that the hamstrings are active whilst the trunk is flexing. It is possible that a slow stretch shortening cycle was begun by a quick extension of the fixed lumbar spine prior to the complete relaxation at the end point of flexion range of movement. This would likely increase the output of the concentrically acting hamstrings / gluteals / spinal erectors. So the time taken before contraction should be shown so that sequencing effects may be noted (although Paquet's group did not state this).

Sihvonen (1997) determined that flexion control of the lumbar / hip region is taken from the hamstrings at near end range of motion (97% of the full movement). Hereafter, it is assumed that pelvic control factors take over.

A potential confounding variable in many of the studies that use surface electromyography is that of crosstalk. As it is known that some neuromuscular activity can be lost or clouded by interrupted signal coming from overlying or surrounding tissue, the use of indwelling electrodes could solve this dilemma (Basmajian & Deluca 1983), but surface EMG would be suitable if determination of general activity of the region were the goal, that is, a quantitative analysis.

To conclude, Mayer and co workers (1984) demonstrated that standing flexion is limited by the hamstring group (when the knees are straight), and that this form of assessment is 20% less than that achieved by using a straight leg raise (SLR) movement.

128
I thus conclude that these two movements (SLR & TTT) of hip flexion are different, result in different measurements, and probably measure different things. The use of these two movements interchangeably is not recommended. The singular use of either method is consistent with the literature and deemed by it to be appropriate if the position of the assessment is standardised and the pelvis is strapped to the couch to prevent excessive pelvic movement in the straight leg raise method.

Assessment Procedures
The appropriate and reliable assessment of the effect of manual therapy treatment on the hip joint is an important underlying goal of this thesis. In order to substantiate the effect of treatment on the function of the hip a reliable measure of assessment must be selected. To this end, the following discussion reviews the acceptable methods of assessment of the hip and pelvis as used by clinicians and scientists alike.

During the recent past, many tests of hip and pelvic movement have been suggested to measure the sagittal plane movement (Goeken & Hof 1993, Kippers & Parker 1987, Cameron et al 1994, Gajdosik et al 1993). These tests range from a most traditional form of hip flexion assessment such as the straight leg raise method (SLR) as recently used by McHugh et al (1998), to another form of assessment such as the instrumental SLR as used by Goeken & Hof (1993). The SLR form of testing is the traditional form of assessment used in the clinical assessment of orthopedic and neurological functioning of the lumbar spine. However, the SLR also acts as a direct measure of sagittal plane flexion range of motion at the hip and hamstring muscle length (Refshauge & Gass 1995).

Despite the frequency of its use, the SLR is open to interpretation (Cameron et al 1994). The interpretation involves the potential for error if it is not performed in strict style incorporating several key controlling factors. Methods that are commonly used to minimise the error associated with the use of the test include: the fixation of the pelvis (Sullivan et al 1992), the removal of cervical movement (Cameron et al 1994), the removal of excessive knee mobility or its standardisation at one joint angle (Nemeth et al 1983), the removal of movement at the ankle (Nigg et al 1995), the use of spine or prone
assessments (Thurston 1982), and the determination of a reproducible end point of range of motion (Cameron et al 1994). All the above measures have been shown to effect the absolute movement obtained with the SLR and hence its outcome. For these reasons, any measure of hip flexion utilising the SLR method should control these extraneous variables (Cameron et al 1994), a procedure followed in this thesis (Pollard & Ward 1998).

Whilst the use of the standardised and controlled form of the SLR is considered to be a reliable measure of hip flexion range of motion (Cameron et al 1994, Matyas & Bach 1985), it remains a reliable measure of PASSIVE hip flexion range of motion. Despite this fact, some authors have suggested that the SLR would be more valid if performed as an ACTIVE rather than passive procedure (Gajdosik et al 1985, Cameron & Bohannon 1993).

It can be demonstrated from the literature that the use of the active SLR in the assessment of hip flexion ROM can be favoured by some (Gajdosik et al 1985, Cameron & Bohannon 1993). Those authors that prefer the active form to the passive form rationalise that the real world validity of the test is greater should the test be performed actively. Yet another group of authors contend that the knee angle should be fixed at the start and the knee should be extended whilst the hip is flexed so that the true function of the two joint hamstring muscle group may be determined (Cameron & Bohannon 1993, Gajdosik et al 1993). This test has come to be known as the active knee extension test (Cameron & Bohannon 1993, Gajdosik et al 1993). It is important to conclude that as the passive SLR variants have demonstrated reliability (Matyas & Bach 1985), the same has been demonstrated of the variations that utilise an active SLR approach (Cameron & Bohannon 1993, Gajdosik et al 1993).

One can conclude from this disparate approach to the assessment of hip flexion range of motion that both the active and the passive forms of the test are acceptable in the literature.

To add to the variety of potential testing methods describe above a prone assessment of hip flexion range of motion has also been described
(Thurston 1982). It too has demonstrated reliability in testing (Staheli 1977).

The astute observer would note that all the assessments mentioned to date have been measures taken in the non-weight bearing non-upright position. To further add to the potential variety of available testing, advocates of a more functional assessment highlight the point that any assessment should be upright to assess the body in a position that best approximates its normal (pragmatic) use (Porter & Wilkinson 1997). Some researchers have thus advocated another group of assessments that are based on hip flexion being achieved by a toe touching method in the upright position (Stokes & Abery 1980, Kippers & Parker 1987, Porter & Wilkinson 1997). Many other approaches to the assessment of hip flexion range of motion have also been proposed and a summary of these methods can be found in table 2.2.

### Table 2.2 Comparison of reliable assessment methods of hip and lumbar range of motion

<table>
<thead>
<tr>
<th>Type of reliable assessment</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Motion analysis</td>
<td>Porter &amp; Wilkinson 1997</td>
</tr>
<tr>
<td>Simple geometry</td>
<td>Kippers &amp; Parker 1987</td>
</tr>
<tr>
<td>Simple goniometry</td>
<td>Osternig et al 1987</td>
</tr>
<tr>
<td>Xray</td>
<td>Stokes et al 1987</td>
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<tr>
<td>MRI</td>
<td>Harvey et al 1998</td>
</tr>
<tr>
<td>Sit &amp; Reach</td>
<td>Brier &amp; Nyfield 1995</td>
</tr>
<tr>
<td>Video analysis</td>
<td>Tully &amp; Stillman 1997</td>
</tr>
<tr>
<td>Sitting Slump test</td>
<td>Johnson &amp; Chiarello 1997</td>
</tr>
<tr>
<td>Chair based</td>
<td>Jones et al 1998</td>
</tr>
</tbody>
</table>

However, considering all the available methods of assessment at the disposal of the researcher, the majority of the literature supports the use of either the SLR method (Hellsing 1988), or the toe touch test method (TTT) (Kippers & Parker 1987). The SLR method has been repeatedly shown to be a reliable assessment (Cameron & Bohannon 1993, Goeken
& Hof 1994, Li et al 1996). The TTT method was also considered to be a reliable method (Halbertsma & Goeken 1994, Li et al 1996, Magnusson et al 1997). However, a recent report by Tully & Stillman (1997) using a video analysis system based on the TTT protocols used by several researchers (Halbertsma & Goeken 1994, Li et al 1996, Magnusson et al 1997) has suggested that the TTT method of assessment was an unreliable indicator of both hip and lumbar vertebral mobility. An earlier paper by Merritt et al (1986) also suggested poor reproducibility for the technique. These two investigations clearly present evidence in opposition to that usually presented to support the use of the TTT (Halbertsma & Goeken 1994, Li et al 1996, Magnusson et al 1997). Despite these findings the TTT method continues to be used (Magnusson et al 1997) despite not appearing in the literature since the publication of the Tully & Stillman (1997) paper. By contrast, there have been several papers on related topics utilising the SLR method or one of its variants (McClure et al 1997, Cibulka et al 1998, McHugh et al 1998, Pollard & Ward 1997, Pollard & Ward 1998). Until such a time that the Tully & Stillman findings have been replicated it would appear that either method of assessment can be used. However, in making the decision to use one method over another, it was important to consider the use to which such testing would be put. Given the variety of assessments available to the researcher, one should consider the population of subjects being tested (clinical or experimental), and the literature into which any results may be published.

Assuming that any method selected should be reliable, the validity of the assessment to the research and the target group reading the results should receive consideration. As it was the goal of this research to be conducted under clinical conditions, reporting upon the results of clinical procedures utilising assessments commonly performed by clinicians (Giles & Singer 1997) using an assessment widely used in other similar studies (Clark et al 1999), the passive SLR method of hip flexion range of motion was chosen ahead of the TTT method for this project. However, when the assessment of lumbar range of motion was required for one of the studies, another reliable method was included because of the additional requirement to assess the lumbar range of motion. The TTT method was chosen for the first study on the basis that it could provide the required lumbar data, but could also provide data, for comparison purposes, on the hip. Despite this selection, a
recent paper published after the completion of the study investigating lumbar relationships to hip function suggests that whilst using several measurement devices (TTT motion analysis, lumbar extension testing, and liquid inclinometers) that all assessment produced different results for the same group of subjects (Shirley et al 1994). These findings follow an earlier study by Haas & Nyiendo (1992) into LBP sufferers that suggested no correlation between LBP and lumbar ROM.

To reiterate, the passive SLR is taught in many institutions all over the world to all manual therapists (unlike the TTT) (personal communication). It is widely used as both a scientific and a medico-legal assessment procedure and is both valid and reliable (Matyas & Bach 1985). Whilst other assessments could be used, they do not share with the SLR method the same desirable attributes of use despite the fact that they may also be valid and reliable. To close this section, of the discussion one can visit the findings of a paper by Cameron et al (1994) who concluded that all variants of the SLR are reliable and different. Whether one considers an active or passive, pelvis fixed or not, hip extended or not, there is a need for consistency of method between studies when performing and interpreting the SLR (or TTT) test data. Given the consistency of reporting of clinical studies lies primarily with the SLR methods, its selection as the most appropriate method for the hip flexion assessment used in this thesis can be supported by the author. Importantly, the assessment was used consistently throughout all studies in this thesis. A consistency that allows discussion between the studies and the literature in a fashion consistent with that recommended by Cameron et al (1994).

The central theme of this thesis was to test the effect of several different treatment protocols commonly used by clinicians to increase hip flexion range of motion. A secondary theme of the thesis was to test if a treatment of the neck, sacroiliac or knee could alter function of the hip, or if a treatment of the hip could alter function of the lumbar spine. Thus, it became necessary to assess the knee and lumbar spine as well as the hip. These assessments were objective movement based and subjective pain questionnaire based.

Subjective assessments were chosen for the knee because pilot testing of range of motion data revealed there to be no difference in gross range
of motion despite improvements in subjective pain levels. This differed from the anecdotal evidence and several published papers that treatment of the hip could improve back function (Porter & Wilkinson 1997, Mellin 1986). As such, the TTT of hip and lumbar flexion was chosen on the basis that both measurements could be obtained reliably at the same time. However, as mentioned in the previous section, this assessment was an active measure of hip and lumbar function (Magnusson et al 1997), which compares to the passive nature of the SLR (Pollard & Ward 1997).

Sandoz (1977) states that passive range of motion should be greater than the active range of motion as confirmed in orthopedic texts. The TTT and the SLR are different types of measures. Because of this difference, the results could be expected to be different based on whether an active or passive SLR test was performed (Cameron & Bohannon 1993). The tests all measure different effects. In addition to the variables of ankle position, neck position, pelvic fixation, knee position and contraction status, the TTT is a closed chain assessment compared with the open chain assessment that is the SLR. These tests can also affect the stability of the joints under investigation due to the differing amount of muscle joint reaction force and muscular contraction that was occurring. Thus, the closed chain TTT with its greater reliance on active muscle contraction / control would reasonably be expected to demonstrate less range of motion than a passive end range connective tissue limited procedure such as the SLR.
Measurement of Lower Back Pain

Pain is a unique phenomenon that all humans share at one time or another (Bowman 1994). Pain has the power at times to be incredibly debilitating and usually derives evasive action very quickly. This is especially so of lower back pain (Heliovaara 1989, Lebouf-Yde & Lawitson 1995).

Severe lower back pain is one of the worst forms of pain one can experience, especially if it is of a severe and chronic nature (Kirkaldy-Willis 1983). I have personally treated many sufferers that would gladly swap their lower back pain for the pain they had experienced through natural childbirth, or other serious pain producing events or conditions (personal patient communication).

The realisation that the pain is not only severe, but also is aggravated by many or possibly all common and simple activities. The pain usually elevates the importance of the issue in those suffering it. This is an area of investigation with great relevance in assessing sufferers of lower back pain according to Leboeuf et al (1989).

Thus it is of great importance when evaluating the lower back pain patient, to evaluate many areas related to the site of the actual pain, as well as that of the painful site. According to Kirkaldy-Willis (1983), and Guckian (1987), factors such as the intensity, depth, type, frequency, aggravating and relieving factors, associated symptoms, referral pain to distal or proximal structures, are commonly sought in the consultation and examination of any person suffering from such pain.

The ability to rate pain intensity, in objective terms is a desirable objective according to Murrin et al (1985). In addition, Leboeuf et al (1989) suggest it is desirable to note the activities that once could be performed, but can no longer be tolerated due to other limitation of the pain.

The above mentioned features of lower back pain may be determined within the normal practitioner-patient interview, however, it is harder to determine via other methods. According to Rollman (1983), Murrin & Rosen (1985) and Reading (1989), there are a wide variety of pain
measures available to the clinician and researcher, some direct, and some indirect. Examples are: thresholds, tolerances, categorical judgments, magnitude estimates, signal detection theory indices, visual analogue scales, multi dimensional scaling, cross-modality matching, scaled verbal descriptors, functional measurement, the McGill and other checklists, non-verbal pain expressions, cortical evoked potentials, autonomic indices, withdrawal reflexes and behavioural correlates such as activity levels or drug intake.

These tests are as diverse as they are detailed. Some involve measurement and others do not. In the field of medicine and particularly lower back pain investigations, functional assessment, pain drawings, visual analogue scales and pain questionnaires are commonplace (Kirkaldy-Willis 1983, Leboeuf et al 1989).

Functional assessments are performed on a daily basis by manual therapists of all persuasion, and represent an attempt to document available mobility at the onset of the pain.

Rating scales of one form or another are the most common reported measure in clinical pain research according to Gracely (1989). These vary according to the nature and number of the anchor points supplied, that is the numbers, words or the presentation of visual analogue lines.

A visual analogue scale (VAS) is a line (usually 10cm) which is taken to represent a continuum such as pain. It may also be associated with a statement. According to Huskisson (1983), these instruments are an easy, sensitive and reproducible expression of pain intensity which is especially true of the clinical trial.

The visual analogue scale (VAS) has been found to be highly accurate when reporting pain intensity according to Huskissen (1983). These pain scales have also been used to estimate the level of disability of the sufferer, thereby giving the evaluator some insight into the subject's functionality. The Oswestry scale is an example of such a scale. According to Fairbank et al (1980), this scale has been designed to examine the effect of the lower back pain (of a chronic nature usually) on ten areas of psychological and instrumental functioning. Because of the categorical measurement system that it employs, it may be
considered to be inflexible. Also, some reviewers such as Leboeuf et al (1989) feel that it does not relate to areas of function commonly affected by the lower back pain, such as the effect on work and leisure. Factors that may be very motivating, or a source of great anguish preclude usage of this questionnaire. Reading (1989) suggests the visual analogue scale and the verbal rating scale may not adequately reflect the complexity of the pain experience, which also includes strong emotional and behavioural components. This quality may be considered as a very important omission of sensitivity of the instrument in some pain populations, but it may serve well the needs of very controlled minor pain profiles such as the one proposed in this investigation.

The sensitivity associated with this form of evaluation so noted by Scott & Huskisson (1976), may serve the investigators in documenting small but significant changes. Others such as Gracely (1980) do not agree.

A questionnaire is employed according to Gracely (1983) to: standardise the response, and relate factors regarding interpretation, order, bias, and appropriateness to the situation or location, psychological involvement and organic content of pain, should all be considered in assessing the appropriateness of a particular questionnaire. In many applications such as research and screening procedures, the questionnaire is an ideal way to document information quickly and score and compare it. As a result, many different forms of questionnaire have been structured to be used in these and other arenas.

There are many individual pain questionnaires available from a variety of sources. However, over the last few decades, there are some that received more support than others from the scientific community, especially with regard to the area of lower back pain. These questionnaires may range from complete psychological tests, such as the Minnesota Multiphasic Personality Inventory (MMPI) (McCreary 1995), to simple pain atlas drawings (Rankine et al 1998).

These questionnaires are subjective measures of the type and severity of discomfort encountered by the patient. These measures are verbal descriptions of the pain felt by the patient/subjects. Such descriptions have always played a major role in diagnosis and treatment of injury. The description given by the patient/subject, is an indication or report
of an experience, and the clinician (or researcher) must accept the
description given by the patient. This must occur with the knowledge
that the response reported by the patient may be masked by language
(Melzac 1975), compensation claims (Block et al 1980), and other
factors (Kremer et al 1983). This is especially so of the chronic pain
sufferer.

In 1971, Melzac & Torgerson conducted an extensive study of the
descriptors of pain chosen by patients. The list of descriptors has since
evolved into the McGill pain questionnaire, and other questionnaires
like it (Melzac 1983). Examples of other questionnaires would be the
Middlesex, Oswestry and Dallas pain questionnaires.

Beside the functional component of pain, Melzac suggests the emotional
state of the patient may affect, and be affected by the pain. It is for this
reason that many tests incorporate assessment of any psychogenic
component of pain present. Tests such as the Minnesota Multiphasic
Personality Inventory (MMPI) are designed to test for severe
psychopathology according to Graham (1977). Psychologically
disturbed sufferers have been known to describe their pain more
severely than non-pain suffering normals according to Leavitt &
Garron (1980), therefore this would be of interest to the clinician
dispensing treatment for organic musculoskeletal pain. However, the
use of the MMPI in subjects with minor distress and who are
psychologically healthy has been questioned by Leboeuf et al (1989), as
subjects have been reported by Leavitt & Garron (1980), to object to
the emphasis on severe psychopathology and the implications that it may
carry for them.

An in depth review of the use of the MMPI in subjects suffering lower
back pain has been undertaken by Love & Peck (1987) and Graham
(1977), and the reader is referred to these reviews for analysis of its
use. The use of the MMPI in this investigation will not be instigated, as
the subject population will be experiencing minor pain whilst
participating in this investigation. Therefore, as suggested by Leavitt &
Garron (1980), the use of a sensitive test of personality disorder may be
too acute for the purposes of this investigation.
Another commonly used self assessment instrument, is the Middlesex Hospital Questionnaire (MHQ) (Pietri-Taleb et al (1995). This less commonly used questionnaire is a somewhat shorter version of psychological investigation, that measures milder aspects of psychological dysfunction. Further, the reliability of this questionnaire has been established in psychiatric and general medical patient populations, according to Crown & Crisp (1966), Crisp & Priest (1971). Due to reliance on psychological dysfunction, and lack of support in the research literature on lower back pain, this questionnaire will not be utilised in this investigation.

Like the MMPI questionnaire (McCreary 1995), the Oswestry Lower Back Pain Disability Questionnaire (Fairbank et al 1980) is also used amongst clinicians and researchers alike. This questionnaire allows a percentage of the level of function in the subject according to Fairbank et al (1980). These researchers found this questionnaire to have a high reliability and consistency in chronic pain patients.

Another type of measurement questionnaire is the Dallas Pain Questionnaire (DPQ) (Haas et al 1995) which was developed to assess the amount of chronic spinal pain a patient was suffering, and how it related to four aspects of the patients life. It incorporates a visual analogue scale, and has also been widely used in experimental and clinical situations. Lawlis et al (1989), further found the questionnaire to be internally consistent and externally reliable.

Due to the universal acceptance of the McGill Pain Questionnaire (MPQ), this questionnaire was utilised in the investigation.

The Dallas Pain and Oswestry Disability Questionnaires were also used to observe the consistency of any change of pain and disability during the course of the treatment protocol.

Thus, we attempted to show if the pain reported by subjects (before and after a treatment protocol) was consistently measured by three commonly used questionnaires. In addition, we aimed to determine if the changes noted by the questionnaires were all consistent, as Hass and Nyiendo (1992) has reported a good correlation between the use of the McGill pain questionnaire and the Oswestry Disability Questionnaire.
Chapter Three:

Study One

Change in range of motion of the hip and lumbar spine after hip manual therapy in a group of lower back pain sufferers
Abstract

Objectives
To compare the effectiveness of two hip manual therapy treatments for increasing flexion range of motion at the hip and lumbar spine.

Design & Setting
Randomised control trial in a private practice of chiropractic setting

Method
A reliable hand held dynamometer was used to determine the end point of range of motion in a straight leg raise and a toe touch test with photographic documentation was used to determine the end point of range of motion (ROM) before and after the application of a treatment. A goniometer and protractor respectively were used to assess the angles derived before and after the application of the treatments. Three groups of subjects were treated: hip manipulation, hip stretching and a placebo / control group. Range of motion of the hip and lumbar spine in flexion were used as the independent variables.

Sample
57 chronic LBP sufferers between the ages of 18 and 40 years.

Results
The two treatment groups increased their range of motion with respect to the control group. However, only the manipulation group increase the range of motion significantly when compared to the control group. Manipulation of the hip was associated with significantly less lower back pain than the other group when compared to the placebo group.

Conclusion
Manipulation of the hip significantly increased hip range of motion, but not lumbar range of motion. The change was associated with a significant decrease in lower back pain.

Key Words
Chiropractic, Manipulation, Stretching, Hip, Lumbar, Pain.
Hypotheses

H₁.₁ That a series of stretches applied to the hip will not increase the hip flexion ROM.

H₁.₂ That a series of manipulations applied to the hip will not increase the hip flexion ROM.

H₁.₃ That a series of manipulations applied to the hip joint will not decrease the chronic low back pain in subjects with chronic low back pain (LBP).

H₁.₄ That a series of stretches applied to the hip joint will not decrease chronic low back pain in subjects with chronic LBP.

H₁.₅ That a series of manipulations applied to the hip joint will not decrease the lumbar flexion ROM in subjects with chronic LBP.

H₁.₆ That a series of stretches applied to the hip joint will not decrease the lumbar flexion ROM in subjects with chronic LBP.
Aims

1. To determine which treatment protocol, of the two being studied, is the superior form of therapy for improving hip flexion ROM.

2. To determine if any of the treatment procedures being tested, is the superior form of therapy for achieving a change in lower back pain.

3. To determine if any of the treatment procedures decrease lower back pain.

4. To observe if a change in lumbar flexion range of motion results from an improvement in hip flexion ROM.
Introduction

Manual therapy for lower back pain (LBP) is considered by many to be a most appropriate intervention for mechanical LBP (Meade 1999, Shekelle 1994). Many authors have suggested that hip function directly influences the function of the lower back, and that any breakdown of the normal relationship (lumbopelvic rhythm) between these two areas may lead to LBP (Porter & Wilkinson 1997, Mellin 1986, Gajdosik et al 1990, Goeken & Hof 1988).

Specifically, it has been said that a decrease in normal hip function may predispose the lower back to pain, and that remedying such limitations may lead to an improvement in those precursors of lower back pain (Norkin & Levangie 1995, Barash et al 1970, Fisk & Baigent 1981).

Whilst investigating this lumbopelvic relationship, many studies have utilised various forms of assessment for the determination of hip flexion range of motion (ROM) (Etnyre & Lee 1987, Kippers & Parker 1981, Gajdosik 1990, 1993). Of all the common assessments, the straight leg raise (SLR) and the toe touch test (TTT) are common. However, assessing the suitability of these assessments is difficult because of the non-standardised nature of the studies in which they have been used. Great variability exists in the form of several variables including: injury status; test-retest reliability; randomisation and other sampling errors, the averaging of results, variations within methods and subject anthropometry. Importantly, some authors have suggested that the two assessment protocols (SLR and TTT) have different sensitivities, measure different outcomes, and should not be used interchangeably (Mayer et al 1984).

In order to investigate any potential differences in these assessment outcomes, we attempted to compare for the first time the effect of two manual therapy treatments to a placebo / control group of randomly assigned lower back pain sufferers. The goal of this study was to note the effect of these treatments on the flexion range of motion at the hip and lumbar spine when measured in the standing (TTT) and supine positions (SLR). A secondary goal was to determine if any of the treatments being tested could improve the self reported pain status of the subjects within the group.
Materials And Methods
All male and female subjects were required to give written consent prior to participation in this experiment, after having been fully informed of the procedures. They were informed that they may withdraw from the study at any time without prejudice.

Subjects were recruited via an advertisement in the print media which called for volunteers to participate in this observation trial. All subjects were volunteers who were randomly assigned to one of three groups by drawing a number from a hat.

The study was granted approval by the Human Ethics Board of The University of Wollongong prior to any experimentation.

Back pain
Lower back pain was defined as that pain occurring in the rectangle bordered by the thoracolumbar level of the spine, the lumbosacral level of the spine and the lateral margins of the body, as viewed from the posterior aspect. All subjects were diagnosed as having non-specific chronic low back pain after a criteria by Haldeman (1977).

In an attempt to control the many variables that may confound the controlled variable of treatment type, the study excluded certain variables, and included certain others. It is important to exclude the following conditions from non-specific mechanical low back pain (Jenner & Barry 1992). A list of inclusions and exclusions appears below.

Exclusions
1. Antalgic posture
2. Severe / acute lower back pain
3. History of motor vehicle accident, or other serious fall or accident in the last one month.
4. Less than 18 years of age.
5. Greater than 40 years of age
6. Abdominal pain
7. Neurological signs and symptoms (muscle wasting, nerve root signs)
8. Straight leg raise of less than 30°
9. Pregnancy
10. Previous recent spinal surgery (less than 2 years)
11. Bowel or bladder dysfunction

Inclusions
1. Subjects with a history of mild to moderate lower back pain.

Protocol

Subjects
All subjects possessed chronic (greater than 3 months) non-specific mechanical low back pain as outlined in the inclusion/exclusion criteria. Non-specific mechanical low back pain was utilised as it represented a large proportion of low back pain sufferers (Beaumont & Paice 1992). This group of sufferers have also been difficult to diagnose and treat (Heliovaara 1998), with often poor outcomes (Llyod & Troup 1983). This difficulty in diagnosis has occurred despite advances in imaging technology (Margo 1994). This group of conditions also represent that group which frequently visit a manual therapist for treatment (Meade et al 1995).

All subjects were randomly allocated into one of three groups, after appropriate selection criteria had been met. Each group had at least 16 subjects (see results tables for exact numbers). There was one group of each of the following treatments:

- a. Manipulation,
- b. PNF stretch
- c. Placebo / Control Ultrasound.

All subjects possessed lower back pain.

Observing changes in the lumbo-pelvis
In order to observe the associated movements of the lumbo-pelvis, it was necessary to utilise a reproducible method of determining lumbar and hip flexion range of motion. This procedure was to be applied before and after the treatment interventions. Therefore, any change in ROM due to the treatment could be reliably determined. A method used by Kippers (1981) was utilised in this study, as it has been demonstrated
to have internal consistency, and be able to demonstrate external changes in the lumbar and hip flexion ROM.

**Marking Procedure**

In this method, the subjects were marked anatomically with coloured ink and reflective markers placed over the site of the ink at the levels of:

1. the spinous process of the first thoracic vertebra
2. the posterior superior iliac spine (PSIS) of the pelvis
3. the anterior superior iliac spine (ASIS)
4. the greater trochanter of the hip
5. the lateral intercondylar space of the (R) knee

Subjects were clothed in bathing costumes to allow for easier placements of markers, and also to allow unhindered movement and recording.

**Questionnaires**

**Screening questionnaire**

Prior to all measurements, the subjects all completed a (1) screening questionnaire to determine the suitability for inclusion into the study. This questionnaire is found in appendix A.

All subjects after acceptance into the study were randomly allocated into one of three treatment groups: manipulation, PNF stretching, and placebo / control ultrasound. Thereafter the subjects had their body weight measured and recorded.

For those subjects included into this investigation, a further questionnaire was administered. One dealing with the (2) inclusion and exclusion criteria, and the other one (3) a pain questionnaire. These questionnaires are found in appendix A.

**Pain Questionnaires**

The questionnaires determined the pain status of the subject. The McGill Pain, Oswestry Disability and Dallas Pain Questionnaires were chosen on the basis of their frequency, reliability and common use in the literature. The questionnaires were required to be completed prior to any measurement, and five minutes following the conclusion of the investigation. Thus, a pre-, post- intervention measure of pain was
recorded. Observation and a comparison of the difference between the three questionnaires was then undertaken.

Experimental Measurement

Warmup

A warmup period of 5 minutes on the cycle ergometer was performed before each experimental condition to standardise the activity level of the subjects and the extensibility of the soft tissues. It was important to standardise the activity level of the subjects so that prior activity (or inactivity) did not impact upon the flexibility measurements taken during the study (Atha & Wheatley 1976). The ergometer was set at zero exercise load and the revolutions (cadence 50 rpm) kept constant throughout the warmup period.

Assessment of Range of Motion

Method One (1)
The subjects were all required to stand on a box of known height (30cm), where they were asked to flex forward whilst holding a weight of 5 kilograms (2.5kg in each hand).

The subjects had two (2) photographs taken in each of the following positions, before and after the experimental condition:

1. The erect position (reference position), in which the upper limbs were held slightly anterior to the pendant position to allow observation of all surface markings (including reflective tape folded so that it may be viewed from the lateral aspect)
Figure 3.1  Surface markings for experimental protocol.  
(Modified from Kippers 1981, p33)

2  The position of maximum forward flexion of the trunk, with the knees fully extended.
Figure 3.2  Schematic of hip and lumbar angles for experimental protocol.
(Modified from Kippers 1981, p29)

These positions served as the reference from which the maximum forward flexion could be determined. The long axis of the femur acted as the reference line so that rotational movements of the pelvis could be incorporated into the measurements of the angles of the hip and trunk.

The long axis of the femur was represented by a line joining the middle of the lateral intercondylar space, and a point 3cm superior to the most lateral projection of the femur, representing the level of the centre of the hip joint.

The plane of the hip was represented by a line joining the hip centre to a 1cm reflective marker, applied over the spinous process of the first thoracic vertebra, and a line joining the ASIS and the PSIS (both indicated by the reflective markers).
The lateral point of the shoulder (acromial marker) has been commonly used as the proximal marker (Okada 1970). This method was not utilised in this study as Kippers (1981) found it to be an unreliable source due to the movement available at the shoulder independent of the trunk. The developed photographs were then ruled as indicated in the previous diagrams, thus forming angles as previously outlined. These angles were then measured with a protractor and recorded. This procedure was based on the Kappers (1981) study, who found the procedure to be reliable.

The hip ROM data obtained was determined whilst in the standing position, and compared to the value achieved by the straight leg raising method in the supine position. No feedback from the subject was available for the practitioner to compare or modulate the force applied (see diagram 3.2).

Method Two (2)
Another method of hip flexion ROM assessment was also performed. This was done so that comparison of results achieved in the standing position may be made against the previous literature predominantly determined in the supine position. I have noted that hip flexion ROM is frequently determined by the straight leg raising method. This form of assessment is especially prevalent in the stretching literature and the literature reporting upon lower back pain. The addition of this measure has allowed a comparison between the results of the three treatments in both assessment methods of the hip (standing and supine).
Therefore, calibration of one system to the other may be made via common measurements, allowing a comparison of literature using both measurement systems. The straight leg raise was also used as a measurement and diagnostic tool in assessing the severity of lumbar spine dysfunction particularly that of discal origin. This test is used commonly in orthopaedic and neurological settings according to Hoppenfeld (1976, 1977), and for the reasons set out in the study, was used in this investigation.

**Determination of End Point of Range of Motion**

A hand held dynamometer (Nicholas Manual Muscle Tester, Model 01160, Lafayette Instruments) was used to determine the force used, and to provide a definition for the end point of ROM. This dynamometer was chosen because it had been demonstrated to have comparable reliability to both manual and isokinetic strength testing devices and is reliable in the range of 0.2-250kg, a range used in this investigation. Marino et al (1982) when investigating the potential use of this device concluded that the instrument was reliable, reproducible, and convenient to use as a clinical tool.

The end point of measurement in the pre and post tests were determined by the second examiner using the hand held force transducer. The
passive end point goniometer reading (end point of ROM) was defined as that point reached by an application of 5% of the subject’s body weight.

Much thought was given to bodyweight as a factor in measurement. After many trials prior to the start of the experimentation, it was found that 10% of bodyweight was too excessive for many people. A force using 10% of bodyweight often exceeded the pain free end of SLR ROM. It was imperative to standardize the amount of force used in the SLR test. Obviously, the greater the force used by the tester in the SLR, the greater the ROM that would be achieved. In addition, we deemed it inappropriate to use a fixed force (say 10kg), as such an absolute force would be minor to a large strong person but the same force would be too great for a less strong person. Thus, in an attempt to standardize the force of application, an arbitrary value of 5% of bodyweight was chosen.

The end point used in this study was defined as that ROM achieved when a force of 5% of body weight was applied perpendicularly in the sagittal plane, at the level of the calcaneus, on the unshod foot. Prior to the assessment of the ROM, the pelvis was strapped to the examination table at the level of the anterior superior iliac spine (ASIS) of the pelvis, in order to minimize any rotation of the pelvis. The importance of eliminating pelvic rotation in SLR measurements has been demonstrated by Gajdosik and coworkers (1990, 1993). Emphasis was placed on keeping the knee in the fully extended position at all times.

Once the appropriate position had been achieved, an examiner determined the joint angle using an electrogoniometer. The determination of the hip angle using the goniometer has been determined to be reliable by a study performed by Hsieh et al (1995).

**Experimental Groups**

**Group One: Manipulation**
The subjects were strapped to the examination table in the supine position at the level of the anterior superior iliac spine (ASIS). In this condition the subject had each hip manipulated in a manner similar to that utilised by O'Neil & Esposito (1991), to incorporate immobilisation of the pelvis, and full flexion of the hip. In this procedure (see diagram
3.3) the investigator first removed all available joint slack into flexion, internal rotation, and adduction, to determine the end point of ROM, and then applied a short amplitude high velocity thrust along the long axis of the femur. This procedure was then repeated twice within a period of 5 seconds.

Figure 3.4 Hip manipulative procedure part one.

A second manipulation was performed by comfortably rotating the leg inwards (internally), and then pulling on the leg in a long axis direction with a short amplitude high velocity thrust in a manner also described
by O'Neil & Esposito (1991). The pelvis was again strapped to the treatment table. This procedure was also repeated twice. The treatments were all administered by the same practitioner, at the same time of day on three consecutive days.

Figure 3.5   Hip manipulative procedure part two.

**Group Two: PNF (CRAC) stretching**
The subjects were strapped to the examination table in the supine position at the level of the ASIS. The investigator raised the leg in the same fashion as the straight leg raise until a comfortable non-painful end feel was felt by the subjects. This point represented the clinical end point of ROM used in this study, and the point at which the subject comfortably contracted the agonist muscle group, which, in this case was the hamstring group of muscles. Following a contraction period of 6 seconds, the subject was asked to relax the agonists and then contract the antagonists (the quadriceps) for a further 4 seconds. This procedure was repeated twice for a total stretch time of 30 seconds (see diagram 3.4).
Figure 3.6  Hip stretching procedure.

Group Three: Placebo Treatment (Detuned ultrasound)
Subjects in this group all received 5 minutes of detuned ultrasound and palpation to the greater trochanter of the femur. It was hoped that this placebo condition helped control any improvement attributed to a hands-on effect or the participation in this research study.

The results of the comparisons of the average change in ROM and the pain responses appear later in the chapter.

Standardisation of the time within each intervention was not possible due to the different forms of therapy employed. The manipulation method was by definition a high velocity thrust and therefore it was not possible to standardise the time (or force) in its application when compared with the other two experimental conditions and specifically the PNF stretching condition. As this study investigated the effects of two commonly used treatment protocols, the use of the protocols as they would be used in the clinical situation was a requirement of the study. It was hoped that the use of an experienced practitioner who performed all treatments would control to some degree the amount of force, and its variability in application. It should be recognised that manipulative procedures are applied only to overcome the restriction present in the
joint to which it is applied. As no two joints are the same, neither therefore can be the force used in the procedure.

**Statistical methods**

Results and descriptive statistics (ie. means and standard errors of the mean) of the three groups studied, (a) manipulation, (b) stretch and (c) placebo/control are presented. Descriptive and inferential statistics (student t tests and one way ANOVA's) were used to describe the differences within the groups and between the groups, and these results are also presented.

Statistical advice was given by Dr Ken Russell of the Department of Applied Statistics of the University of Wollongong. The data was entered into a Power Macintosh 7200/90 computer utilising a database software package (Microsoft Office 98), and then loaded into Minitab v8.2 for statistical analysis. Graphics were scanned on the Agfa Snapscan and imported into Adobe Photoshop 3.0 graphics package.
Results

Subjects
As previously suggested, subjects were recruited via an advertisement and asked to participate in this observational clinical trial. The final number of randomly assigned subjects participating were consistent across all ROM measures. The numbers were 19, 16 and 18 for the manipulation, stretch and placebo groups respectively. These numbers were smaller than for the pain questionnaires by a factor of 1 or 2 subjects due to the errors incurred with the taking and processing of the photography. If either the pre or the post data was lost due to this process the results were not included in the study.

The pain questionnaires had less incorrect completion rates, but this varied depending on the questionnaire type. The number of successful completions of the McGill Pain Questionnaire and the Oswestry Disability Questionnaire were the same. These numbers were 21 in the manipulation group, 17 in the stretch group, and 19 in the placebo / control group. The Dallas Pain Questionnaire had one less successful completion rate in the placebo group and therefore results for that individual were not included. The unequal group numbers were due to the incomplete or unsuccessful completion of some of the questionnaires by the subjects. If the questionnaires were inappropriately completed, they were excluded from analysis.

Body Mass
Body mass measures were taken for the purpose of determining a standardised percentage of body mass to be used in determining the resistance applied for the end point determination of the ROM measures. The manipulation group demonstrated an average body mass of 75.4 kilograms, the stretch group 74.8 kilograms and the placebo group 69.2 kilograms. The average body mass of subjects within each of the three groups was not significantly different to each other.

Age
The average age of the subjects in the manipulation group was 29.2 years compared with 25.4 in the stretch group and 29.2 in the placebo / control group.
Pre treatment scores
The sex distribution could have possibly acted as a confounding variable due to the often quoted superiority of female flexibility. Thus, it was important to demonstrate the pre treatment values for both the males and the females. Table 3.1 outlines the differences between these two groups.

Table 3.1: Pre treatment SLR ROM differences between males and females in degrees (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDe</th>
<th>SE</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>53.3</td>
<td>13.8</td>
<td>2.2</td>
<td>-0.58</td>
<td>0.57</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>55.6</td>
<td>14.7</td>
<td>3.9</td>
<td>-0.58</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Table 3.2: Pre treatment differences between males and females in hip standing (TTT) ROM data in degrees (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>60.9</td>
<td>14.6</td>
<td>2.3</td>
<td>-0.39</td>
<td>0.70</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>62.0</td>
<td>10.3</td>
<td>2.7</td>
<td>-0.39</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Table 3.3: Pre treatment differences between males and females in lumbar standing (TTT) ROM data in degrees (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>53.6</td>
<td>11.8</td>
<td>1.8</td>
<td>0.38</td>
<td>0.71</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>54.9</td>
<td>11.9</td>
<td>3.2</td>
<td>0.38</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Table 3.4: Pre treatment differences between males and females in McGill Pain Questionnaire data (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>17.6</td>
<td>3.6</td>
<td>0.6</td>
<td>-0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>17.6</td>
<td>3.9</td>
<td>1.0</td>
<td>0.93</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table 3.5: Pre treatment differences between males and females in Dallas pain questionnaire data (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>18.0</td>
<td>15.5</td>
<td>2.5</td>
<td>1.85</td>
<td>0.08</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>24.1</td>
<td>13.3</td>
<td>3.3</td>
<td>0.08</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Table 3.6: Pre treatment differences between males and females in Oswestry pain score data (Paired t-test)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>40</td>
<td>6.1</td>
<td>5.8</td>
<td>0.9</td>
<td>1.53</td>
<td>0.15</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>7.5</td>
<td>3.7</td>
<td>0.9</td>
<td>1.53</td>
<td>0.15</td>
</tr>
</tbody>
</table>

The above summary tables are presented to demonstrate the lack of significant difference between the male and female groups prior to treatment in of any of the variables measured (ie. hip SLR, hip TTT, lumbar ROM, McGill Pain Questionnaire, Oswestry Disability Score, or the Dallas Pain Questionnaire).
Duration of pain
The pain findings of the subjects are summarised below. In the case of the manipulation group, the average duration of pain was 6.6 years. In the case of the stretch group the average was 7.7 years and the placebo group had an average of 8.2 years. These findings indicate that there are similar levels of chronicity in the subject population in each of the groups used in this study.

(1) Range of motion assessments
(a) Supine measurement of hip ROM (SLR)
These results present the findings of the hip ROM measured in the supine position (SLR). The results of this assessment (table 3.7) show an improvement of hip ROM in the manipulation group (4.8°), and in the stretch group (4.4°). The placebo group however decreased their ROM by (2.2°). The results showed a p=0.002 and p=0.01 for the manipulation and stretch groups respectively, indicating a significant change within the groups due to the treatment applied. The difference between groups was less evident, with a significant difference noted only between the manipulation and placebo groups (p =0.05).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo / control</td>
<td>16</td>
<td>-2.2</td>
<td>10.4</td>
<td>2.6</td>
<td>2.79</td>
<td>0.014</td>
</tr>
<tr>
<td>PNF</td>
<td>16</td>
<td>4.4</td>
<td>9.8</td>
<td>2.4</td>
<td>3.60</td>
<td>0.002</td>
</tr>
<tr>
<td>Manipulation (SLR)</td>
<td>19</td>
<td>4.8</td>
<td>8.0</td>
<td>1.8</td>
<td>2.79</td>
<td>0.014</td>
</tr>
</tbody>
</table>

The difference between the manipulation and the stretch group (p= 0.949), and the stretch and the placebo (p=0.54) groups was insignificant.
(b) Standing measurement of hip ROM (TTT)
The effect of the treatments on hip ROM (table 3.8) was measured in the standing position. The change in the ROM was of a similar magnitude to that found in the supine measures, although the manipulation group was slightly greater. The manipulation showed an improvement of 3.7° while the stretch group improved 3.4°. The placebo group improved only fractionally by 0.4°.

Table 3.8: Differences between average change in group mean (Post -pre mean) in the standing hip ROM data (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo / control</td>
<td>16</td>
<td>1.7</td>
<td>5.7</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNF</td>
<td>16</td>
<td>3.4</td>
<td>10.8</td>
<td>2.7</td>
<td>0.62</td>
<td>0.54</td>
</tr>
<tr>
<td>Manipulation (SLR)</td>
<td>16</td>
<td>5.7</td>
<td>7.5</td>
<td>1.9</td>
<td>2.13</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 3.9 Differences in average group changes in TTT hip ROM scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>40.1</td>
<td>2</td>
<td>20.1</td>
<td>0.26^</td>
</tr>
<tr>
<td>Error</td>
<td>3650.9</td>
<td>48</td>
<td>76.1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3691.0</td>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

These results gave a p value of 0.04 for the manipulation group, p= 0.12 for the stretch group and p= 0.15 for the placebo group. Therefore, only the manipulation group achieved a significant difference within the group due to treatment. While the difference between the manipulation and the stretch and the manipulation and the placebo groups were, p= 0.914 and p= 0.10 respectively, the difference between the stretch and the placebo groups was p= 0.59. There was no significant differences found between any of the groups.
(c) Standing measurement of lumbar ROM (TTT)
In this assessment (table 3.10), the treatment groups marginally increased their lumbar flexion ROM. The manipulation group increased by 0.7°, the stretch group by 1.1°, and the placebo group decreased by 2.8°.

Table 3.10: Differences between pre & post lumbar ROM data in the manipulation group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>19</td>
<td>53.0</td>
<td>9.1</td>
<td>2.1</td>
<td>0.33</td>
<td>0.74</td>
</tr>
<tr>
<td>Post</td>
<td>19</td>
<td>53.7</td>
<td>8.9</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These results produced p values of 0.74, 0.62 and 0.33 for the three groups respectively. No treatment effect was demonstrated within any of the three groups. While the difference between the groups was also non-significant. There was no difference between the manipulation and the stretch group (p= 0.84), and no difference between the manipulation and the placebo group (p= 0.27). No difference was also noted between the stretch and the placebo groups (p= 0.51).

(2) Pain Scores
(i) McGill Pain Questionnaire
All groups demonstrated an improvement in pain as measured by the McGill questionnaire (tables 3.11-3.15). The placebo group improved 0.4 of a point and the stretch and manipulation groups improved 0.8 and 0.9 pain units respectively. However, none of the changes were significant at the p=0.05 level. There was no difference measured between the manipulation group with either of the stretching (p= 0.62) or placebo groups (p= 0.13). The stretching group also could not demonstrate a difference to the placebo group (p= 0.53). There was no difference between groups prior to intervention (p>0.05).
### Table 3.11: Differences between pre & post McGill pain score data in the manipulation group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>21</td>
<td>17.2</td>
<td>4.1</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>21</td>
<td>16.2</td>
<td>3.7</td>
<td>0.8</td>
<td>1.17</td>
<td>0.26</td>
</tr>
</tbody>
</table>

### Table 3.12: Differences between pre & post McGill pain score data in the Placebo/control group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>19</td>
<td>18.2</td>
<td>3.0</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>19</td>
<td>17.8</td>
<td>3.4</td>
<td>0.8</td>
<td>0.48</td>
<td>0.64</td>
</tr>
</tbody>
</table>

### Table 3.13: Differences between pre & post McGill pain score data in the PNF group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>17</td>
<td>17.5</td>
<td>3.6</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>17</td>
<td>16.8</td>
<td>4.1</td>
<td>1.0</td>
<td>0.77</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Table 3.14: Pre treatment differences in McGill pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>10.6</td>
<td>2</td>
<td>5.3</td>
<td>0.40^</td>
</tr>
<tr>
<td>Error</td>
<td>710.6</td>
<td>54</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>721.2</td>
<td>56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

Table 3.15: Differences in average group changes in McGill pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>3.50</td>
<td>2</td>
<td>1.75</td>
<td>0.46^</td>
</tr>
<tr>
<td>Error</td>
<td>204.43</td>
<td>54</td>
<td>3.79</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>207.93</td>
<td>56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

(ii) Oswestry Disability Questionnaire

This questionnaire endeavours to quantify the disability that is associated with lower back pain. The score on the placebo / control group actually marginally worsened during the trial (0.05 units), whereas the manipulation and the stretch groups each improved 2.8 and 0.06 units respectively (see table 3.16). Of these changes, only the manipulation group achieved significance at the p< 0.05 level (p= 0.033). The other groups achieved p= 0.95 and p=0.96 for the stretch and the placebo / control groups respectively. The change demonstrated within the manipulation group was also significantly different to the placebo group (p= 0.024). The change in the manipulation group was also significantly different to the stretch group (p=0.03). The stretch group was not significantly different to the placebo group for this measure (p= 0.85), and there was no significant differences between groups prior to intervention (p>0.05).
Table 3.16: Differences between pre & post Oswestry pain score data in the manipulation group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>21</td>
<td>7.9</td>
<td>6.7</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>21</td>
<td>5.1</td>
<td>3.8</td>
<td>0.8</td>
<td>3.34</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Table 3.17: Differences between pre & post Oswestry pain score data in the placebo control group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>19</td>
<td>6.2</td>
<td>3.6</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>19</td>
<td>6.2</td>
<td>4.3</td>
<td>1.0</td>
<td>0.05</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Table 3.18: Differences between pre & post Oswestry pain score data in the PNF group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>16</td>
<td>4.6</td>
<td>4.3</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>16</td>
<td>4.5</td>
<td>3.7</td>
<td>0.9</td>
<td>0.06</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Table 3.19: Pre treatment differences in Oswestry pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>99.5</td>
<td>2</td>
<td>49.8</td>
<td>1.86^</td>
</tr>
<tr>
<td>Error</td>
<td>1421.0</td>
<td>53</td>
<td>26.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1520.6</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

Table 3.20: Differences in average group Oswestry pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>100.2</td>
<td>2</td>
<td>50.1</td>
<td>3.73*</td>
</tr>
<tr>
<td>Error</td>
<td>711.7</td>
<td>53</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>811.9</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05

(iii) Dallas Pain Questionnaire

The final measure consisted of the Dallas Pain Questionnaire (see tables 3.21-3.25). This questionnaire also measured the pain that the subject was suffering at the time of the questionnaire completion. The changes noted in the scores were of a larger magnitude than that noted for the McGill Pain Questionnaire. The manipulation group improved by 8.6 points compared with 3.3 for the stretch and 3.0 for the placebo / control groups.

Of the three groups tested, only the changes noted in the manipulation group were significantly different to pre treatment levels (p<0.05). Despite the significance of this change, the magnitude of the change within the group was not large enough to be significantly different to the changes occurring in the other two groups (p>0.05) (see table 3.25). The manipulation demonstrated a p= 0.085 compared with the values of 0.3 and 0.3 for the stretch and placebo groups respectively.
### Table 3.21: Differences between pre & post Dallas pain score data in the manipulation group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>21</td>
<td>24.0</td>
<td>17.5</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>21</td>
<td>15.4</td>
<td>12.5</td>
<td>2.7</td>
<td>3.16</td>
<td>0.005</td>
</tr>
</tbody>
</table>

### Table 3.22: Differences between pre & post McGill pain score data in the placebo/control group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>18</td>
<td>17.6</td>
<td>11.2</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>18</td>
<td>14.6</td>
<td>12.2</td>
<td>2.9</td>
<td>1.04</td>
<td>0.31</td>
</tr>
</tbody>
</table>

### Table 3.23: Differences between pre & post Dallas pain score data in the PNF group (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>17</td>
<td>17.3</td>
<td>15.1</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>17</td>
<td>14.0</td>
<td>13.4</td>
<td>3.2</td>
<td>1.01</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Table 3.24: Pre treatment differences in average group Dallas pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>576</td>
<td>2</td>
<td>288</td>
<td>1.28^</td>
</tr>
<tr>
<td>Error</td>
<td>11945</td>
<td>53</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12521</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

Table 3.25: Differences in average group Dallas pain scores (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>394.4</td>
<td>2</td>
<td>197.2</td>
<td>2.31^</td>
</tr>
<tr>
<td>Error</td>
<td>4520.5</td>
<td>53</td>
<td>85.3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4914.9</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^p>0.05
Discussion

Experimental evidence does not currently exist to support the claims of clinical effectiveness for manipulation of the hips, or if such treatment can beneficially effect the status of pain in lower back pain sufferers. Thus, the purpose of this study was to test the effects of two commonly used manual therapy treatments of the hip upon lower back pain. It was also the purpose of this study to investigate the effects of these treatments on hip function, as a comparative study of this nature had not been previously performed.

Manual therapy has been used for many years to alleviate back pain (De Giocomo 1978). Over the past twenty (20) years there has been a growing interest in the value of this form of treatment for the escalating problem of back pain in Western societies.

This study examined the effects of two types of treatments on lower back pain when compared to a non treatment placebo / control. The two treatment groups represented different approaches to the examination of lower back pain. The two approaches may be considered to be representative of a manipulative approach (commonly used by chiropractors) and a non manipulative approach (commonly used by other manual therapists). In the past there has been a clear distinction between the operating protocols of different professions as one clearly utilised one approach over another. However, it has become apparent to us that the line dividing the various professions involved in the delivery of manual therapy is rapidly blurring.

The idea that a peripheral joint or structure can adversely affect a central structure is not new. Many authors from the fields of chiropractic, physiotherapy, osteopathy and medicine have suggested various untested hypotheses to explain some long held clinical views. Thus, it was a purpose of this study to observe, if a population of lower back pain sufferers was effected by a treatment that was applied to a distal structure.

Rene Cailliet (1995), a renown medical orthopaedist has championed a theory called “Lumbopelvic rhythm”. The idea that hip dysfunction impacts upon the function of the lower back is not a new one. It is
interesting to note that the term lumbopelvic rhythm is probably a misnomer as the word rhythm implies a structure that oscillates or vibrates at a frequency. It would better be described as a synergistic or coupled lumbosacral movement. The term rhythm is also used to describe the synergistic action of the scapula and the humerus in movements of the shoulder, especially abduction. Therefore, the same criticism may be levelled at the term scapulohumeral rhythm for the same reason.

The lumbopelvic rhythm is a dynamic concept of integrated and synergistic movement of the hip, pelvis and lumbar spine (Cailliet 1995). It was possible that the term rhythm originated from the progression of one movement, say flexion, into another movement, say extension to continue this example. Flexion movement would therefore progress from thoracolumbar flexion to lumbar, lumbosacral, sacroiliac and finally hip flexion and then reverse sequentially to complete the extension phase of the movement to return from the flexed position.

However, immobility of the hip, and in particular loss of hamstring length, can have an impact on the function of the lower back (Stokes & Abery 1980, Idola & Yoshida 1991, Esola et al 1996). Recent evidence supports the use of the concept that hip dysfunction (immobility) can be associated with low back dysfunction and pain (McClure et al 1997). Whereas other evidence presents an opposing view (Hellsing 1988).

Thus the hip flexion available could influence the overall flexion movement of the whole lumbopelvic apparatus. The implication of the theory is that a reduced ROM of the hip would require a compensatory change in ROM from the lumbosacral spine. Thus, theory would predict that when the hip function decreased, the lumbosacral ROM would change resulting in altered lumbosacral function that could in turn lead to pain due to the increase stretch, strain and loading (Shirado et al 1995, Wingerden et al 1995). Consequently, an assumption is made that those suffering lower back pain could have both decreased ROM of the hip and possibly increased ROM of the lumbosacral spine.

Thus, the theory would predict that by increasing the ROM of the restricted hips, the ROM of the lumbosacral spine would normalise and lessen. The findings of this study could not support this implication of
the theory, however, the findings did trend in the appropriate fashion. That is, that the placebo / control group showed no change of increased lumbosacral ROM, whereas the treatment groups decreased the lumbosacral ROM albeit non significantly.

Therefore, the “theory” suggested in the presence of a reduced hip flexion ROM, would suggest a compensatory increase in movement that would occur in order to maintain the same overall flexibility. It was in this light of these proposed changes that the study was attempted, and for which the following results are discussed.

In order to increase the range of motion of the hip, manual therapy was utilised. As previously alluded to, two different procedures were utilised in a comparative fashion to determine any superiority of procedure for achieving an increase hip ROM. The comparison of a manipulative procedure, and non-manipulative stretching procedure in this way has not previously been investigated.

**Choice of treatment protocol**
The protocols that were chosen for the treatment groups were chosen on the following basis:

1. They are commonly used treatment interventions (O'Neil & Esposito 1992).
2. They are taught by chiropractic & physiotherapy institutions as such.
3. They are representative of the broader category of manipulation and stretching / mobilisation.
4. They are well practiced by the practitioners participating in the study.

**Time**
The choice of time for the stretch protocol was determined from recommendations made by Etnyre & Lee (1987) in their review paper on stretching. The time used in this study is also commonly used in the clinic by the participating practitioners. The placebo time in treatment was selected as an arbitrary figure that would constitute a reasonable treatment time, but not be long enough to obscure follow up participation. The treatments and the assessments were all performed at the same time of day over three consecutive days to minimise any
diurnal variation that may occur in the measurement of flexibility, in accord with the suggestion from Atha & Wheatley (1976).

The warm-up period
Early studies utilising flexibility measures did not sufficiently prepare the subjects for their participation within the study. As flexibility is the dependent variable to be measured, any change to the variable of flexibility due to any reason other than the effects of the experimental protocol (in this case a treatment) would represent a false change, and therefore would increase the error associated with the experiment possibly corrupting any results that it achieved.

A warm-up was considered necessary due to the dependent flexibility measures that were to be used. As ROM has been shown to be effected by tissue heat (Wiktorsson-Moller 1981, Wiktorsson-Moller et al 1983), it was important that tissue heat and the resultant tissue extensibility was standardised. Thus it was deemed necessary to warm-up subjects, for a fixed period at a fixed output consistent with other protocols (Golden & Dudley 1992). It was deemed satisfactory to simply standardise the warm-up quantitatively rather than qualitatively due to the nature of the comparisons being made. In this study subjects were being compared with themselves for changes in the dependent variable, thus it was satisfactory to set a universal warm-up. However, if individual subjects were to be compared with other individuals, subjects would have to warm-up on the basis of their fitness level. If future studies were to investigate individual differences to treatment, a more stringent measure of power output and heat production would be required.

Age
The average age of the subjects in the manipulation group was 29.2 years compared with 25.4 in the stretch group and 29.2 in the placebo / control group.

It was important to control for age as closely as possible as joint structure and function would be expected to change with advancing age, and these results demonstrate all individuals to be in a similar age range. Whilst the average age of the participants in the stretch group was less than that of the other two groups, the changes were not significantly different at the p=0.05 level.
Sex distribution
Due to the random allocation of subjects and the relatively small numbers of subjects within each group responding to the advertisement, the group sex distributions were different. No attempt was made to control for this variable in this study because we randomly assigned all groups. In the manipulation group, 66.67% of the subjects were male, 93.75% in the stretching group were male while the control group showed 57.89% male. The implications of these sex distributions are explained later in the text.

Mechanism
The manipulation group demonstrated superior improvements in all measures that were taken with the exception of the lumbar range of motion values and the McGill pain questionnaire outcomes. The stretching group also demonstrated significant improvement to hip ROM and some pain findings. Although it is compelling to suggest that the stretching treatment affected the hip which in turn affected the function of the lumbosacral spine, the possibility existed that the application of the treatment also affected the lumbar spine directly. This exists as a limitation of the study, and the investigators cannot visualise any way of completely controlling for this factor. In an attempt to minimise any contamination the following steps were taken:

1. An experienced practitioner was used to minimise the force of application and improve the specificity of the application.
2. The pelvis was strapped to the examination table at the level of the ASIS.
3. Other joint movement at the knee was not permitted during the treatment application and the assessment.

Range of motion
Hip flexion ROM in the supine / SLR position
The responses of both treatment groups on hip ROM demonstrated a significant (p<0.05) increase in hip flexion ROM following treatment. The manipulation group increased 4.8° and the stretch group increased 4.4° whilst the control group decreased their average ROM by 2.2°.
These results are consistent with the results of previous studies investigating manual therapy treatment protocols on the hip. Ford & Mongeau (1993) and Etnyre & Lee (1987) have demonstrated that stretching increased active and passive hip flexion ROM. I have been unable to reveal any published investigation of manipulative procedures applied to the hip in an extensive search of the literature, therefore the results of this study set the direction for further investigation.

Tanigawa (1971) has demonstrated that stretching (PNF) was superior to mobilisation, and Wiktorsson-Moller et al (1983) further demonstrated that stretching was superior to massage or a warm-up procedure. Although this is the first attempt we know of to quantify the changes associated with manipulation of the hip joint, the results are completely consistent with the results of previous studies of spinal manipulation (Shekelle et al 1994). The change noted in the manipulation group was found to be significantly different from the control group (see tables 3.7 and 3.8). The stretch group was unable to demonstrate such a significant change in the supine SLR measure, but the trend was in the same direction. It is likely that the smaller number of subjects within the stretching group and the larger standard error associated with this group data impacted upon the significance of the findings. The need to utilise actual lower back pain sufferers presenting to a practitioner for treatment who met the stringent inclusion criteria curtailed some participation. Unfortunately, the number of subjects that volunteered for the study was lower than anticipated and contributed to the standard error. It is my opinion that a larger multi-centre trial would have reduced this error and enhance the results considerably. Of course, this was not possible as we did not have access to such a facility.

In a recently published study, Hanten & Chandler (1994) reported upon a treatment comparison of a PNF (CR) procedure, and a myofascial release leg pull treatment. Their results demonstrated superiority to the stretching procedure. Both procedures were able to increase ROM at the hip, but the PNF treatment did so more effectively. They argued that the myofascial release technique did not greatly differ from a traditional static stretch, which had already been shown to be inferior to PNF based stretches (Etnyre & Lee 1987). After careful consideration of their methodology, we feel that the method of myofascial release employed was a very passive treatment that approximated the effectiveness of a
mobilisation technique, already known to be inferior to a PNF stretching technique.

I feel that should the myofascial treatment have incorporated short amplitude high velocity thrusts at the “restrictions” noted in the movement plane, and not a oscillatory slow movement, then a superior result for the myofascial release group could have been achieved. It may be stated that the manipulation group utilised in this study was analogous to the type of myofascial stretch noted in the study by Hanten & Chandler (1994). As no direct comparison has been made of a mobilisation based myofascial release, and a manipulative one, this remains a mute point. It appears from the content of the paper that the previous approaches by some manual therapists supporting the use of overly gentle mobilisation procedures and the unqualified criticism of manipulation based high velocity treatments may be moving forward into the new treatment protocols known as myofascial mobilisation techniques Blackman & Prip 1985, Anonymous 1990, Assenderft et al 1991). To highlight the point we present a quote from the above paper to emphasise the very conservative approach to the myofascial release technique employed in the study of Hanten & Chandler (1994) on p 139:

“......any slack was taken up with gentle traction. The leg and hip were then gently externally rotated until a tightness was felt.....the investigator then internally rotated the leg......and waited for a release before continuing.....adducting a few degrees at any point of tightness and then waiting for a release. Whenever tightness was encountered, the protocol of reversing a few degrees and waiting for a release before proceeding was observed...”

Unfortunately, the conclusion to this paper was global in the disqualification of the myofascial procedures ability to achieve superior results when compared to the accepted stretching procedures. These results cast doubt on this conclusion, and we recommend a comparative study of a manipulative based myofascial stretch and mobilisation based myofascial stretch to resolve this debate.
Standing measure of Hip Flexion (TTT)
The results of the hip flexion (TTT) ROM were taken in the standing position. The method of assessing the lumbopelvic rhythm required an upright assessment performed in the standing and fully flexed positions. The method chosen was first utilised by Kippers (1981), and later used by Gajdosik 1991.

The stretching literature is almost exclusively represented by measurements of hip flexibility made in the supine position (Etnyre & Lee 1987). Whilst this was acceptable for investigations of stretching, a direct comparison of these results of changes in lower back pain to this literature was not possible unless there was a calibrating measurement performed. For this reason we investigated the effects of these treatments in both the standing and the supine positions. To my knowledge, direct experimental evidence does not exist to support the claims of clinical effectiveness for flexibility increases of the hip joint after manual therapy.

The results of this study demonstrate that stretching in the SLR position improves ROM, but not in the TTT position, and that manipulation improved ROM in both the SLR and TTT positions. Some consideration needs to be given to the implication of the difference (see tables 3.7-3.8).

Given that the human adopts a bipedal stance and motion base, the significance of the manipulation group being able to affect the ROM in the erect position in this functional way would suggest that it is the superior form of therapy to achieve functional improvements in ROM. Also, one may conclude from these results demonstrating differences in ROM dependent upon the position that the assessment is performed, that investigating manual therapy procedures in the supine position may in fact result in different measurements of ROM should they be conducted in the erect functional position. I therefore call for a re-examination of pertinent studies of stretching and mobilisation to discuss these new findings under controlled conditions where studies are matched for active or passive, upright / supine / prone positions, or closed / open kinetic chains, in direct response to research (including this thesis) that has suggested that measurement of any differences are based on the make up of the assessment position, and any comparison of the literature needs to account for this variability to be valid (Cameron et al 1994).
Another factor in the selection of the assessment procedures was the target tissue location. The extensor muscles acting at the hip joint are postural antigravity muscles (Pansky 1981). For example, a test utilising these muscles in a position that more greatly approximates their normal role such as standing may alter their effect on the variable of ROM that was being measured. This test also fixated the distal end of the muscle (closed kinematic chain), whereas the proximal end of the muscle was fixated in the supine measure of ROM (open kinematic chain).

The closed chain exercise is one which is performed in functional postures where some form of weight bearing was possible (Kisner & Colby 1996). This form of exercise loads the contractile and the non-contractile tissues around a joint leading to better joint stability. In addition to an increase in relative muscle strength, power and endurance, they improve the stability, balance and co-ordination and can be initiated into a rehabilitation program earlier than the open chain exercise (Tippett 1992).

The open chain exercise has been traditionally used when manual and mechanical resistance was required. These exercises generally cause less muscle contraction and cause considerable external resistance which prohibits and restrains movement (Greenfield 1993, Kelsey & Tyson 1994).

Such a difference in the leverage properties may alter the contractile properties of the muscle being tested, and ultimately the ROM that is able to be achieved. The fact that some of the hip extensors are biarticular in nature highlights the need to investigate how fixation of the joints occurs in this assessment and to what extent does it control the nature of the contracture performed. It is possible that combinations of movement of both the knee and the hip would alter the results. Joint movement combinations that result in the greatest increase in ROM has been investigated by Kabat (1951), and Knott & Voss (1952) in the early work on PNF patterning and later, and more specifically by Tanigawa (1972). The mid ROM procedures utilised in the work of Knott and Voss (1951) were formulated into treatment protocols based upon the PNF stretches used by those investigators. The results demonstrated in this study show increases in hip ROM as measured in
the (end ROM) straight leg raising position, which was consistent with previous stretching literature of Tanigawa (1972).

The results achieved with the TTT demonstrated a slightly smaller significant change in hip flexion ROM than the supine form of assessment discussed above. In the TTT assessment, the manipulation group improved ROM by 3.7° and the stretching group increased by only 3.4°. Due to the smaller number of subjects and the smaller change and larger standard error in the stretch group no significant difference was noted in that group. However, the manipulation group demonstrated a significant change due to treatment, but was not able to demonstrate a large enough change to be significantly different from the other groups (see table 3.9). Thus, only the manipulation group was able to demonstrate significant changes when measured in the weight bearing position.

It is important to consider the error associated with measurement in biological research. Error with the test-retest reliability can sometimes present as a significant finding in research, and should be considered in any discussion of results (Dijkstra et al 1994). When considering the procedures that were used to measure the joint angles used in this study, Hseih et al (1983) has demonstrated a test-retest reliability of 0.94. Gajdosik et al (1985) has shown a test-retest reliability for anterior pelvic tilt to be 0.92. Whereas Madson et al (1999) has shown a sagittal plane mobility test-retest reliability for the lumbar spine to be between 0.67 and 0.94, and 0.90 for flexion and 0.86 for extension movements.

Despite a significant statistical change, an error of measurement of approximately 3.0-3.6 degrees exists for the procedure (Hseih et al 1983). Therefore, the change whilst technically significant can be explained by variation associated with the measurement technique.

It is intuitive that the weight bearing position would load the hip joints greater than in the supine position. One could also expect greater muscular activity from the postural antigravity muscles. With that in mind, the manipulation group was able to improve hip extensibility in a greater way than the stretching group or the placebo / control group.
This new finding outlines that the two measurement approaches (TTT and SLR) actually produce results that are different when measured in the two positions. As the present literature on stretching was determined almost exclusively with supine measurements, conclusions reached about the efficacy of one procedure over another may need to be reassessed based upon the method of assessment. Consequently, the stretching literature should be reviewed to take account of this finding. This is especially so of the ballistic stretching methods which are frequently performed in the weight bearing position unlike the other forms of stretching, and whose reputation for effectiveness has suffered in recent comparisons because of the lack of clear advantage to its use whilst being associated with increased risk of injury (Moore & Hutton 1980, Smith et al 1993). The assessment in the weight bearing position may be said to be more functional, and as such be more suited to the dynamic functional activity that is ballistic stretching.

Whether the added extensibility measured is manifest as a ligamentous change, or the freeing of joint motion due to the breaking of intra-articular joint adhesions (Bogduk & Engel 1984), or an effect mediated by the stretching of muscular tissue (Rahlman 1987), or a reflex relaxation of manipulated shortened muscle is indeterminate at this time (Hayek et al 1993, Hayek et al 1995). However, given that the response to manipulative treatment is usually fairly quick (between one and four weeks for many simple biomechanical conditions), (Haldeman et al 1993), and that it increases ROM (Etnyre & Lee 1987, Yoder 1990) and decreases pain (Gitelman 1980, Full 1986), we would propose that the underlying mechanism probably involves the breaking of intra-articular joint adhesions. The location of the fibroadipose adhesions of the joint surfaces are proposed to be secondary to micro traumatic fracture and labral tearing and fissuring causing micro fragmentation (Bogduk & Engel 1984). Although the lesions could be secondary in importance to extra-articular causes because of the increased leverage acting on the joint (Bogduk & Engel 1984).

Adhesions are known to form during periods of immobilisation (Bland 1987). Even though studies on immobilisation have dealt largely with absolute forms of immobilisation, it is known that the longer or more complete the immobilisation, the greater the attendant joint restriction due to adhesion formation. Other structural changes in connective and
muscular tissue are also known to occur (Woo & Buckwater 1987). However, it is unknown whether they are also a feature of the partial or incomplete immobilisation associated with joint fixation referred to by manual therapists, and whether the improvements noted with the manual therapies investigated in this study feature changes in these tissues.

It is my opinion that due to the short term nature of the treatments it is unlikely that these factors would dominate over the faster response of breaking adhesions to restore lost ROM.

Only a well controlled histological study (probably an animal model) could evaluate these changes in-vivo. It is my opinion that at some future point, a well controlled study that artificially immobilised a joint, and then introduced a treatment to mobilise the created immobilisation will be required to adequately address this issue. Furthermore, if the scope of the study was large enough, it could investigate in a comparative fashion the effects of different treatment procedures on joint structures. I feel that this is the only avenue available to definitively determine such joint changes.

**Lumbar ROM**

It has been hypothesised by Calliet (1995) in particular and by others such as Gajdosik et al (1992) that lower back pain sufferers would have a decreased hip range of motion and an increased lumbar ROM, but no relationship has been found between low back pain and lumbar intervertebral movement (Mellin 1988, Haas et al 1992). However, part of this effect could be explained by the variability associated with the assessment of the lumbar range of motion (Shirley et al 1994). They further postulated or implied that these shortcomings would unduly load the lumbosacral spine causing a strain of the lower back muscles and ligaments causing pain. The common hypothesis of this study was that a treatment that increases the hip ROM should demonstrate the lumbar ROM to decrease its ROM in compensation, thereby, allowing lesser strain and pain of the lower back region. Therefore, it is inferred by Cailliet and stated by McClure et al (1997), Snijders et al (1993), Gajdosik et al (1990), Vleeming et al (1989) and Goekan (1988), that an increase in hip ROM should produce a decrease of lumbar ROM. These results did not confirm this, although a non-significant trend to that effect seemed to occur. Thus far, it has been noted that manipulation
increases ROM of the hip more than stretching, which in turn increases more than the placebo / control. Therefore, the reverse would be expected for the lumbar ROM findings. That is, that the ROM would decrease, taking the strain from the lower back and hip.

There was a non significant trend for the placebo / control group to increase their average ROM which was greater than the increase in the stretching group. Both placebo / control and stretching increased more than the manipulation group which in fact demonstrated a decreased ROM as the "hypothesis" had predicted. However, none of these findings were significant at the p = 0.05 level.

These findings are consistent with Gajdosik et al (1992) who found that when comparing normal males with tight hamstrings (decreased hip ROM) and those with normal hip ROM, that there was no significant difference between the lumbar ROM of both groups, although they did note a significant change in hip ROM and pelvic rotation.

The important difference between these two studies is that the study undertaken by Gajdosik and coworkers studied normal students whereas this study utilised chronic lower back pain sufferers. Also, in the study of Gajdosik and co-workers there was no intervention in terms of a treatment. It is likely (although unknown) that in order for a problem to manifest in the patient in the form of pain, a threshold may have to be reached. This parameter of decreasing mobility of the hips and or increased mobility of the lumbars may be required before pain will manifest. Therefore, as Gajdosik et al (1992) did not investigate lower back pain sufferers, the conclusions drawn from their study must be limited when applied to a population of lower back pain sufferers. The results of this present study confirm the findings of Gajdosik et al, by disagreeing with the idea of Cailliet that ROM of the back must decrease in the presence of hip ROM restriction.

These findings do not support the "lumbopelvic rhythm theory' as improvement in pain followed treatment, but no change in range of motion of the lumbar spine was noted. The trend noted appears to be sufficient enough in the short time during this experiment to warrant further investigation looking at acute and chronic lower back pain sufferers over a longer treatment period.
Range of motion data
This observational study did not attempt to test if increased ROM was present in persons with lower back pain, but it did attempt to demonstrate if changing the ROM of the hip would lead to an improvement of lower back pain, and if the change could be measured. To this end we have demonstrated an improvement in lower back pain following an improvement in hip ROM as measured by three different pain and disability questionnaires. Although often discussed clinically, we feel that this is the first time that experimental evidence has been documented in a clinical study.

This important finding has implications for the delivery of therapy to lower back pain sufferers. It suggests that practitioners dealing with chronic LBP sufferers should consider improving hip function as a part of their treatment, as it may decrease the pain suffered by their patients. This in itself would be a very valuable addition because patients with pain are much more difficult to treat than those subjects who do not have lower back pain. This finding suggests that at the very least there may be a component of hip dysfunction in the aetiology of the lower back pain sufferer.

This finding calls into question the practice of a spine only approach to the treatment of lower back pain. It would appear, although not conclusively at the present, that spinal function can be altered by a hip treatment that increases hip range of motion. The increased mobility of the hip allowed greater flexibility in flexion of the hip joint which in turn allowed a greater short term sagittal plane range of motion as consistent with Porter & Wilkinson (1997). Such a greater range of motion would likely produce a decreased resistance to movement (Magnussen et al 1997), allowing the subject to decrease the resultant eccentric contraction of the lumbar spine musculature, with less resultant eccentric loading. A reduced eccentric loading of muscle and connective tissue would likely result in a decrease of tissue damage and pain under mechanically stressful conditions (Ernst 1998). Further study of this diverse or combined approach to the treatment of lower back pain.
Pain questionnaires
In this study, we chose to test pain responses before and after treatment by utilising three commonly used lower back pain measurement devices. The chosen devices were the (1) McGill Pain Questionnaire, (2) the Oswestry Disability Questionnaire and (3) the Dallas Pain Questionnaire. These questionnaires are looked upon as industry standards and are used regularly in treatment clinics and written biomedical research.

The patients for this study were chosen on the basis that they were "real" lower back pain (LBP) suffering individuals who represented the type of condition commonly occurring in the private practice of a manual therapist and in this case, a chiropractor. This criterion was chosen to increase the validity of the study and any findings that may have been demonstrated. However, when such a group was chosen, one must expect that individual pain profiles and histories could vary greatly giving problems with the ability to standardise subjects. This probably for that reason, existed as a limitation of the study. A concerted effort was made however on the part of the investigator to control for variables such as location of pain, quality of pain, severity and chronicity of pain. It was for these reasons that all subjects participating in this study had to have: (a) back pain located within a certain area, (b) be of a certain duration and intensity, and (c) not be complicated by non-mechanical conditions such as neural compression secondary to disc prolapse or organic disease. I refer the reader to the methods section for a specific explanation of the inclusion and exclusion criteria relating to subject selection.

An important factor in the comparison of subjects in pain is the chronicity of their pain (Kirkaldy-Willis 1983). Chronic pain is a category of description that is based on the duration of pain. The exact location when an acute or sub acute pain becomes a chronic one is dependent upon the source of the definition. Most authors would suggest constant pain in excess of several months as chronic pain. The WorkCover Authority of NSW Australia (1992) utilises a category of greater than six, twelve or twenty four months (taken from their records of workman's compensation claims as chronic pain). The WorkCover Authority have noted that once a worker has been off work for the period of six months or longer due to LBP they are very
unlikely to return to full active duty. If the patients are off work for one or two years or longer it is normal for these patients to never work again. This point highlights the incapacity created by chronic lower back pain. Any comparison between acute and chronic sufferers is unwarranted as they respond differently to treatment and should not be compared. Short term pain sufferers are likely to respond in a much superior fashion to that of the chronic sufferer.

In this study, the manipulation, stretch and placebo / control groups had an average duration of pain of 6.6, 7.7 and 8.2 years respectively, with no subject suffering pain for a period of less than one year. From these findings, it is reasonable to suggest that the subjects were all chronic sufferers, and that there was no significant difference (p<0.05) between any of the groups at the start of treatment.

Within each of the groups studied, the duration of pain ranged from between 1 year to a maximum of 20 years. It was important to note that no individual within the study was receiving workers compensation benefits due to incapacity. It has been stated by Vivian (1990) that the chronic sufferer on compensation may have reasons other than physical capacity as a cause of their pain. Chronic pain sufferers are said to frequently have a psychogenic component to the pain and are therefore recommended to utilise the services of a psychologist or psychiatrist during the treatment of their pain (Mayer & Polatin 1992). Therefore we argue that the groups were fairly homogeneous given the conditions and limitations of the study and that any comparisons of pain findings were reasonable and valid.

**Pain Scores**

Nyiendo (1990) commented that in a clinical population one should expect a large range of scores. This was in fact what was observed in this study. This being the case, Love (1989) has suggested that when dealing with a large range of scores, the McGill Pain Questionnaire (MPQ) was an excellent questionnaire for the assessment of LBP as it had the ability to ascertain the complete range of pain scores from mild to severe.
McGill Pain Questionnaire (MPQ)
The results of the McGill Pain Questionnaire (MPQ) revealed a decrease in pain in all groups. These average group decreases were 0.9, 0.8 and 0.4 points in the manipulation, stretch and placebo / control groups respectively. However, no significant improvement of LBP was noted in any of the groups. This is a curious result when compared to the changes noted in all the other perturbations of this study. The fact that significance was unable to be reached in this perturbation was related more to the statistical power (small subject numbers and large standard error) as well as the actual dimensions of the change. However, the manipulation group in the standing or weight bearing position demonstrated a greater change than that of the stretch or placebo / control groups. The changes (improvement) in the manipulation group was homogeneous across the different perturbations whether standing or supine in all the tests except the MPQ. It is likely that the MPQ was not a sensitive enough instrument to detect the small changes occurring in the short term nature of this study. It is likely that the changes noted in this study may require a longer period of time to manifest.
Oswestry Disability Questionnaire (ODQ)

The Oswestry Disability Questionnaire (ODQ) according to Fairbank et al (1980) measures the functional disability associated with LBP sufferers. A goal of manual therapy is to improve the functional ability of the patient as well as trying to reduce the pain, and this questionnaire allowed the measurement of this change. Consequently any measure of lower back pain should consider the disability associated with the presence of the back pain or its improvement if it is improved by an intervention. The use of this questionnaire can not suggest whether or not improvement was being made in measures other than pain, or activities limited by pain as it was beyond the scope of the questionnaire. It was also likely that a greater time was required for a change to manifest in the activities of daily living. A premise supported by the lack of findings in the MPQ. The use of this measure therefore may be viewed as being a complementary subjective measure of the effect of pain on daily living and an adjunct to the objective range of motion findings.

In this study of the Oswestry Questionnaire, the placebo / control group increased their lower back pain (0.5 units) whereas the stretching group demonstrated a marginal improvement (1.1 units), while the manipulation group demonstrated a significant change of 2.8 units. The change in the manipulation group was large enough to be significantly different at the p= 0.024 from the placebo / control group. It was also significantly different to the stretching group (p= 0.03).

Triano & Schultz (1987) when measuring EMG responses of lumbar musculature demonstrated that those who scored highly on the ODQ (that is, a high disability rating) had increased lumbar muscle activity when compared with those that did not. This suggests that the muscle activity itself could be causing some of the pain. The research of Travell and Simonds (1983) highlights muscle spasm as a cause of pain. If we accept that muscle spasm can cause LBP as suggested by Dvorak & Dvorak (1984), and Cyriax (1970), then a decrease in back pain may be associated with a decrease in the disability associated with LBP. These findings were consistent with these findings which suggested that lower back pain decreased as a result of the treatment intervention, along with a functional limitation caused by that back pain as measured by the ODQ.
Hass & Nyiendo (1992) suggested that the MPQ and the ODQ when taken together are a good predictor of LBP, and that they can discriminate between different types of pain. Co et al (1993) added to this by suggesting that the disability index used on its own bears a weak relationship to pain, therefore, they are not interchangeable, and they make different assessments of the LBP. On the basis of my clinical experience and the results of this study we concur with the statements of Co and coworkers (1993) regarding the use of the disability questionnaire. However, we would be cautious about predicting the significance of LBP due to its multi-factorial nature. I feel that a functional assessment in the form of orthopaedic, neurological, radiographic and other testing is imperative to understanding the individual nature of lower back pain. I would agree that these questionnaires should be used to group LBP sufferers within nominal ranges for use in research or in the clinic where comparison is made within a single subject or between average changes in subject groups, and not between individual subjects. The same may be said of the Dallas Pain Questionnaire (DPQ), which we will discuss next.

**Dallas Pain Questionnaire (DPQ)**

Lawlis (1989) demonstrated that the DPQ was both reliable and consistent. The use of this questionnaire was included to observe if consistency was demonstrated with the use of all questionnaires, and particularly between the McGill & Dallas pain questionnaires. The results of the (DPQ) demonstrated larger percentage changes than the other questionnaires but demonstrated a significant improvement in pain in the manipulation group (p= 0.05). The changes were 8.6, 3.3 and 3.0 pain units respectively for the manipulation, stretch and placebo / control groups. The manipulation group demonstrated a much larger change than the other two groups and produced a p value that was significant at the p= 0.05 level compared with the other two groups which were insignificant at the p=0.05 level.

To illustrate this change in light of the result in the MPQ, a Newman-Keuls Post Hoc test of significance was performed to test the significance of the resultant changes in the means of each of the groups. The test demonstrated that the manipulation group had a mean that was significantly different to the placebo / control group. It was
also significantly different to the stretching group. Thus, the change noted by this questionnaire was a significant one, and its result contrasts with that of the MPQ result.

Lawlis (1989) suggested that the DPQ measures aspects of psychological or emotional functioning along with the issues associated with pain. Thus, he concluded that chronic LBP sufferers may score higher than other sufferers for those reasons. Gronbald et al (1990) suggested that if scores for one questionnaire were much higher than others that are used, then the scores could potentially be more significant in any comparative study due to an increased statistical power. I believed that this effect was operating in this study for the DPQ results. It should be reiterated that the results of this questionnaire are completely consistent with the trend occurring in all measurements undertaken in this study except the MPQ.

It is also possible that a male / female biasing error was partly responsible for this unexpected finding. However, analysis of the pre-treatment groups demonstrated that there was no significant difference between the sexes, but the difference within this group (DPQ) was the closest of all the measures taken to the 0.05 significance level. However, it too was not significantly different.

**Male / Female Differences**

Although it was the intent of the investigators to match the groups for an equal ratio of males and females, this situation did not arise due to a clerical error in the second advertisement that called for subjects. Instead of stating males and females, only males were called for which skewed the sample toward a much greater number of males in both the treatment groups. The exact percentages of males were 66.7, 93.7 and 57.9 for the manipulation, stretch and placebo / control groups respectively.

These ratios could have been a confounding variable on the basis that female ROM is thought to be greater than that of males according to Hartley-O'Brien (1980), and as such, a possible ceiling effect may have been present limiting the type or amount of change occurring in the female group. It was therefore important to demonstrate if there were any differences between the groups of males and females prior to the
application of any treatment. If, for example, there was a gender
difference noted and the female group were unable to increase their
ROM due to a ceiling effect, any possible improvement due to treatment
would not be demonstrated in the change of the ROM. The effect of the
treatment would therefore be wrongly validated. It is interesting to note
that the subject with the single greatest ROM in this study was a female
dancer in the manipulation group. Her improvement was greater than
the average of any of the groups and although her case was singular, it
helped dispel the idea of Hartley-O'Brien (1980) that suggested a ceiling
effect in particularly flexible females.

Although the difference between males and females was still
insignificant at p= 0.08, the DPQ was the closest measure by far to
approach significance. This possibly suggests that the male / female
distribution may have influenced the results of that questionnaire. The
only definitive way to assess this possible effect is to control this
variable of sex bias in any further study of this topic. The results
indicate that there was no significant difference at the p = 0.05 level in
any of the groups under investigation (hip SLR, hip TTT, lumbar,
MPQ, ODQ and DPQ) due to the male / female ratios present in the
groups.

**Type of assessment**

It is possible that the dynamic nature of the treatment and possibly its
effects can not be measured adequately by a static measurement such as
the SLR or the Kippers (1981) method of lumbar spine ROM analysis.
It may be necessary to expand upon the Kippers method by assessing a
more dynamic feature such as fatigueability or isokinetic power / torque
profiles before and after the application of the treatment protocol.
Whilst such testing is commonplace in the sport sciences literature,
testing of this nature is uncommon in the stretching and manipulation
literature and is only beginning to appear.

In a recent study by Worrell et al (1994), isokinetic torque values were
measured before and after a protocol of stretching. They found
significant improvements in peak torque values in both the eccentric and
concentric modes of muscle contraction.
Given the superior performance of the manipulation group compared with the stretching group, one could only hypothesise the changes that are possible with the isokinetic strength testing devices. I therefore recommend a study utilising the methodology of Worrell and co-workers to investigate the change in isokinetic performance associated with a manipulative trial.
Recommendations: Study One

Further study of the lumbopelvic rhythm theory and related manipulative procedures incorporating the use of the following:

1. Reproduce the study utilising an electromyographic analysis of lumbar, hip and muscle function associated with increasing ROM.

2. Reproduce the study using a more homogeneous population with larger group sizes matched for body type, age, sex, activity and occupation.

3. Utilise a longer treatment time to allow potential effects to materialise and better approximate a clinical treatment regimen.

4. Standardisation of work output and temperature during warm-up procedure by the use of constant output cycle and thermistors.

5. Investigate other peripheral joint responses to manipulation.

6. Re-examine previous stretching literature of the hip that incorporates measures of the lumbar spine utilising the upright method of hip range of motion assessment.

7. Analyse other parameters such as isokinetic power/torque profiles and fatigueability of muscles spanning the treated joints and muscles.

8. Compare pain and non-pain groups to determine baseline values of lower back and hip range of motion for both groups.

9. Conduct a long term prospective trial of pain free subjects in high risk occupations and monitor their incidence of lower back pain and hip range of motion. To determine any statistical relationship between the two parameters.
10. Investigate the possibility that a reverse lumbopelvic effect also exists. A study of the hypothesis that sacroiliac or lumbosacral mobility may change hip range of motion.
Conclusion

This study was the first of its type to attempt to document experimental evidence of static lumbopelvic function in low back pain sufferers (Cailliet 1995). The specific conclusions of this study are now outlined.

1. Manipulation of the hips significantly increases hip ROM in lower back pain sufferers when measured in the SLR and TTT positions. Whilst significant statistically, these changes were probably within the range of assessment error.

2. PNF CRAC stretching of the hip in flexion significantly increases hip ROM when measured in the supine position (when measured in the straight leg raising position).

3. Manipulation of the hips significantly decreases lower back pain as measured by the Dallas Pain Questionnaires, and the Oswestry Disability questionnaire, but not the McGill Pain Questionnaire.

4. PNF CRAC stretching of the hips did not significantly reduce lower back pain as measured by the three pain questionnaires employed in this study.

5. Manipulation of the hips was superior to PNF CRAC stretching of the hips for increasing hip flexion ROM.

6. Manipulation of the hips is superior to PNF CRAC stretching of the hips for decreasing lower back pain in lower back pain sufferers as measured by the Oswestry Disability Questionnaire and the Dallas Pain Questionnaire.
Chapter Four:

Study Two

The short term effects of manual therapy on arthritic knee pain as measured by a visual analogue scale
Abstract

Objectives
To determine if a manual therapy treatment of the knee could alter the self reported pain (VAS) experienced by a group of knee osteoarthritis sufferers and if the treatment could alter the hip range of motion.

Design
Randomised control trial

Setting
Private practice of chiropractic

Method
A reliable hand held dynamometer was used to determine the end point of range of motion (ROM) before and after the application of a treatment utilising goniometer assessments of the hip angles before and after treatment. Two groups of subjects were treated: knee manual therapy and a sham / placebo. Range of motion of the hip in flexion and subjective pain scores were used as the independent variables.

Sample
57 randomly chosen respondents to a print media advertising campaign between the ages of 47 and 70 years.

Results
The manual therapy treatment significantly decreased the pain reported by sufferers of OA of the knee, but the treatment did not change the hip flexion range of motion.

Conclusion
That manual therapy of the knee significantly reduced the short term pain suffered by subjects with osteoarthritic knee pain.

Key Words
Chiropractic, Manipulation, Hip, Knee, Pain, Osteoarthritis.
Introduction

Osteoarthritis (OA) is one of the most prevalent articular disorders affecting humankind (Felson 1988). OA is a disorder associated with changes in joint cartilage and subchondral bone. One of the early signs is loss of joint cartilage, which ultimately progresses to a loss of joint space as noted on radiographs (Shinmei 1990). Other bony changes include bone eburnation, osteophyte formation, and the formation of subchondral cysts and fractures (Yochum & Rowe 1987). The presence of osteophytes on the lateral joint margins is often the first abject plain film radiographic sign of the disorder (Yochum & Rowe 1987). Soft tissue changes include: loss of strength in the quadriceps, loss of range of motion in the sagittal plane, and soft tissue contracture to name a few (Scott et al 1993).

OA manifests in the major weight bearing joints and other intensively used joints of the axial and peripheral skeleton. Changes also manifest because of joint injury (Goldberg et al 1992), and OA is often the sequelae to previous accumulated stresses in the ligamentous, cartilaginous or other internal joint structures. Such changes are known to produce increased articular stress (Goldberg et al 1992) which is thought to lead to the OA process.

The most prevalent sites of OA are the spine, hip and knee (Altman et al 1986). In many cases no specific cause of symptoms can be determined (Altman et al 1986).

There is evidence of osteoarthritic change in 35% of the knees of men by the age of 30 years. This figure becomes nearly universal by the seventh decade of life (Lawrence et al 1966). The prevalence of OA does not appear to be affected by geographical area, ethnicity or climate. Furthermore, it is higher in men prior to the age of 45 years, and higher in women after 45 years. It is also noted that the women appear to manifest the severe form of the affliction more commonly than do the men (Felson 1988).

Many problems with the knee in the elderly involve OA. OA in the knee is a major cause of pain and disability in the senior population (McAlinton 1992). In order to treat this large and growing number of sufferers, various treatment approaches outside the use of drugs are
utilised. There appears to be no universal way to significantly modify the course of the disorder or to resolve it. Current approaches centre on a two fold approach of symptom reduction and improving function (Dieppe 1993).

Pain management appears to be a large part of most therapy. Analgesic and anti-inflammatory drugs are widely used with mixed results, despite known effects of long term usage, and doubts about their efficacy (Dieppe 1992). Adding to this list of chemical interventions in recent times has been the use of steroidal preparations such as cortisone. Whilst all these forms of therapy may help to deal with the symptoms of the disorder, the disorder is often viewed as a problem of biomechanical function that requires, at least in part, a biomechanical solution.

Thus, many sufferers visiting practitioners that provide therapy do so in the hope that they will improve their function. To address the concerns of lost function, and the ability to successfully ambulate, several forms of physical therapy have been advocated. These interventions include: general body exercise programs, quadricep exercises, the use of modalities (ultrasound and interferential), cryotherapy, range of motion exercises, flexibility exercises, endurance exercises, orthotic inserts, joint mobilisations and patient education (Lynch & Caughey 1995, Swezey 1974). Suffice to say that these approaches may be summed up by saying that most OA sufferers utilise pain medication and some exercise to manage their arthritis.

Other forms of management for OA include the various surgical procedures. The surgical option is one of last resort, and one that is both expensive and potentially harmful if selected for inappropriate candidates. It would appear that there is little to offer the OA suffer between medication and exercise at one end of the spectrum, and surgery at the other end of the spectrum for the management of their OA.

Therefore, there is a need for a simple and inexpensive treatment protocol to fill the void between medication, exercise and surgery. Interventions that empower the sufferer with an inexpensive therapy are particularly attractive to such patients. It is with this goal that I conducted this study. Specifically, it was the aim of this investigation to
determine if a new form of manual therapy could reduce the knee pain suffered by patients with a predetermined level of mild to moderate chronic osteoarthritis.
Materials And Methods

All subjects were volunteers who had responded to an advertisement. All subjects were required to give written informed consent prior to participation in the study. This study had sought and received approval from the Macquarie University and the University of Wollongong Human Ethics Committees prior to experimentation.

Participation

Participants between the ages of 45 and 70 years were recruited by paper advertisement for this research study. Participants were chosen on the basis that they suffered the following:

1. Mild to moderate knee pain (determined by a score of between 10-30 on the present pain intensity scale of the McGill Pain Questionnaire),
2. Knee crepitus
3. Restricted range of motion and/or joint deformity
4. A prior medical diagnosis of osteoarthritis in their knee(s) as per Forman et al (1983).

All potential participants underwent a screening procedure consisting of a physical examination to define the condition known as osteoarthritis of the knee. Subjects were then randomly assigned to either an experimental or a placebo / control group by drawing a number from a sealed container.

The experimental protocol was performed so that participants were not aware to which group they were assigned. The treatment regime consisted of 3 treatments per week for 2 consecutive weeks, with a follow-up assessment after the last treatment.

Following the initial assessment, subjects were randomly allocated to either a placebo / control group or an experimental group. A mobilisation procedure was performed on the symptomatic knee of the subject in the experimental group, while the control group received a placebo procedure in the form of a palmar contact to the knee, without the application of force, followed by electrotherapy (interferential) set to zero. The control subjects were told that the procedure was a micro
current application that they should not be able to feel. They were also informed that one treatment may be more effective than another.

Immediately following the 2 week trial of treatment, the changes in knee pain and hip ROM were again assessed in the same manner as the pre experimentation protocol using a protocol with a test-retest reliability of 0.94 (Hsieh et al 1983). The hip range of motion was determined in the same fashion as that outlined utilising the goniometer in experiment one. Subjects in the placebo / control group had the procedures explained to them and were offered the treatment program. All but one accepted.

Myofascial mobilisation procedure
A non-invasive myofascial mobilisation procedure was used on subjects in the experimental group. This mobilisation procedure directed a small oscillatory and specific force into the patellofemoral joint in the direction of restriction to movement noted during palpatory examination. The aim of this procedure was to gently mobilise any restriction to normal movement within the limits of patient tolerance. Patients were able to cease participation at any point during the application of the procedure or at any time during the experimentation.

![Diagram of myofascial release](image)

Figure 4.1 Diagramatic representation myofascial release of patellofemoral joint.
Modified from Reid (1992) page 363.
The first part of the procedure given to the subjects in this study were under voluntary control. As such, the subjects were able to cease participation in the manual therapy at any time they felt the need. This is an important first step in determining the limit to which force is used in the application of the manual therapy. It provides direct feedback to the practitioner about the degree of stiffness, limitation and pain present in the afflicted knee. The second part of the procedure utilises a manual therapy procedure that is not under the voluntary control of the patient. The second part applied a traction over the joint (tibio-femoral joint) in a manner designed to distract the knee and mobilise the joint in a near full extension position. Done correctly, this procedure is completely painless. However, this procedure requires intact ligamentous and cartilaginous structures to operate successfully. It also requires practice by the practitioner to acquire the necessary skills to perform the procedure.

**Questionnaire**

After completion of the study, subjects were given a questionnaire for feedback on their response to treatment. Debriefing was performed after all the results had been collected and the results tabulated.
Results
The 11 post treatment questions posed to the subjects after their involvement in the study utilised a visual analogue scale (VAS). This scale was used in a manner suggested by prior researchers (Ogon et al 1996). There were 11 short questions that required a response of between 0 and 10. The minimum or zero point response on the VAS represented the response: No effect (Questions 2, 10), No improvement (Questions 3, 4, 8), Not painful (Question 5), None (Question 1), Not effective (Question 6, 11), and No change (Questions 7, 9).

The 10 or maximum response on the VAS represented the following responses: Unbearable (Questions 1,5), Very effective (Questions 2, 6, 11), Excellent improvement (Questions 3,4,8), Much better (Questions 7,9), and Strongly disagree (Question 10).

The effect of manual therapy treatment
The results suggest that the treatment group rated their pain significantly less (p<0.05) after treatment (1.9) compared to the placebo group (3.0). The results prior to the treatment demonstrate no significant difference (P>0.05). As it was a requirement that the participants had mild to moderate knee pain (as determined by a score of between 10 and 30 on the McGill Pain Questionnaire (MPQ)) prior to involvement in the study, it was hoped that the VAS was a sensitive enough tool to use for such purposes. The changes after the treatment, between the groups was small but significantly different.

Table 4.1: Pre & post hip ROM scores in the control group in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>17</td>
<td>62.0</td>
<td>5.7</td>
<td>1.4</td>
<td>0.73</td>
<td>0.87</td>
</tr>
<tr>
<td>Post</td>
<td>17</td>
<td>62.3</td>
<td>5.8</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2: Pre & post hip ROM scores in the treatment group in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>26</td>
<td>60.5</td>
<td>3.3</td>
<td>0.6</td>
<td>0.21</td>
<td>0.84</td>
</tr>
<tr>
<td>Post</td>
<td>26</td>
<td>61.3</td>
<td>3.5</td>
<td>0.7</td>
<td>0.21</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Table 4.3: Differences between pre & post hip ROM score in the control and treatment groups in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>17</td>
<td>0.3</td>
<td>2.2</td>
<td>0.5</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>26</td>
<td>0.8</td>
<td>2.4</td>
<td>0.7</td>
<td>0.48</td>
<td>0.43</td>
</tr>
</tbody>
</table>

The above tables demonstrate that there was no significant differences in the means of the subjects straight leg raise before and after treatment in either the control group or the treatment group (P>0.05). A further assessment of the difference between groups revealed no significant difference between groups (p>0.05). I conclude that a treatment delivered to the knee does not produce any statistical or biological difference to the motion of the ipsilateral hip joint.

When the subjects were asked if the treatment helped them (question 2) the treatment group indicated a positive response (a score of 7.0) compared with the placebo group (a score of 4.1). The response between these groups was significant at the p<0.05 level. Subjects were also asked if the pain inside the knee had improved (Question 3). The response indicated that the treatment group was significantly different to the placebo / control group (a score of 6.6) compared with a score of 3.5) in the placebo / control group. The treatment group indicated that the pain inside the knee was rated as improved when compared with that of the placebo / control group.
Functional questions were also asked of the subjects. The subjects were asked if a general improvement in the knee mobility was noted since the treatment had begun (Question 4). The responses indicate an improvement in the treatment group (6.3) that was significantly greater than the placebo / control group (3.9).

When asked if the clicking and grinding sensations (crepitus) in the knee had changed since the start of the study involvement (Question 8), the treatment group (6.0) indicated a significant improvement when compared with the placebo / control group (3.3). The treatment group (6.5) also indicated a significantly improved ability to perform general activities (Question 7) when compared to the placebo group (6.0).

Authors have suggested that knee function has a major bearing on the function of the hip (Paul 1966). I asked all the subjects to comment on whether their hip movement had been improved by the knee treatment. The results indicated no perceived improvement in hip mobility by the treatment group (2.8) or the placebo / control group (2.5). These values were not significantly different to each other.

Following these questions I asked several other questions with regard to the type of treatment that the subject received. I asked in question 5 if the treatment was painful to receive. The subject responses indicated little discomfort with the treatment, and the results were similar (p>0.05) for both the treatment group (0.6 arbitrary pain units) and the placebo / control group (0.3 arbitrary pain units).

The use of manual therapy is sometimes perceived to be an aggressive and painful treatment to receive, especially in the older patient. These results clearly indicate that the treatment was in fact close to painless, and caused little or no discomfort to the patients. These findings are important in light of the fact the age of the patients ranged between 45 and 78 years old.

Question 6 of the post treatment VAS questionnaire asked subjects if they could compare the short term effect of their treatment to other drug based treatments that they had received. These included analgesics and anti-inflammatory medication. The results demonstrated a
significant feeling of effectiveness for the treatment group (7.4) when compared to the placebo / control group (4.2).

Question 10 of the post treatment VAS questionnaire asked the subjects if the treatment that they received should be included into the management protocol of their arthritic knee pain. The results suggested a significant difference between groups. The treatment group (1.8) felt strongly that the treatment that they had received should be included in the management of arthritis, but the placebo / control group (4.1) were somewhat equivocal. The equivocal result is appropriate in my opinion for a group of subjects receiving detuned interferential as a placebo treatment.

Finally, the subjects were asked to rate the treatment they received in terms of effectiveness. Again, the treatment group (7.76) rated the treatment as effective when compared to the equivocal result of the placebo / control group (4.65).

Table 4.4: Group change in pain scores

<table>
<thead>
<tr>
<th>VAS</th>
<th>Pretest</th>
<th>Posttest</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo Group</td>
<td>3.5 (2.5)</td>
<td>3.1 (1.9)</td>
<td>0.602</td>
</tr>
<tr>
<td>n=17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Group</td>
<td>3.9 (1.8)</td>
<td>1.9 (1.6)</td>
<td>0.004*</td>
</tr>
<tr>
<td>n=26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05

Table 4.5: Group difference in pain scores before intervention

<table>
<thead>
<tr>
<th>VAS</th>
<th>Pretest Placebo</th>
<th>Pretest Treatment</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference between groups before treatment</td>
<td>3.5 (2.5)</td>
<td>3.3 (1.8)</td>
<td>0.771</td>
</tr>
</tbody>
</table>
Table 4.6: Group difference in pain scores after intervention

<table>
<thead>
<tr>
<th>VAS</th>
<th>Pretest Placebo</th>
<th>Pretest Treatment</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference between groups after treatment</td>
<td>3.1 (1.9)</td>
<td>1.9 (1.6)</td>
<td>0.042*</td>
</tr>
</tbody>
</table>

* p<0.05
<table>
<thead>
<tr>
<th>Visual Analogue Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4.7: Group post treatment scores to VAS questions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Placebo mean (SD) (n=17)</th>
<th>Treatment mean (SD) (n=26)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How would you rate your pain?</td>
<td>3.1 (1.9)</td>
<td>1.9 (1.6)</td>
<td>0.042*</td>
</tr>
<tr>
<td>2. Do you feel the treatment has helped you?</td>
<td>4.1 (3.1)</td>
<td>7.0 (2.7)</td>
<td>0.002*</td>
</tr>
<tr>
<td>3. Has the pain / discomfort inside your knee improved?</td>
<td>3.5 (3.0)</td>
<td>6.7 (2.6)</td>
<td>0.001*</td>
</tr>
<tr>
<td>4. Has the mobility in your knee improved?</td>
<td>3.9 (3.0)</td>
<td>6.3 (2.6)</td>
<td>0.007*</td>
</tr>
<tr>
<td>5. The treatment was painful to receive.</td>
<td>0.5 (1.7)</td>
<td>0.6 (1.7)</td>
<td>0.874</td>
</tr>
<tr>
<td>6. Compared with other treatment (analgesic / anti-inflamm</td>
<td>4.2 (3.7)</td>
<td>7.4 (2.6)</td>
<td>0.002*</td>
</tr>
<tr>
<td>medication), I feel this treatment to be effective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I can perform general activities better than before the</td>
<td>3.8 (3.6)</td>
<td>6.5 (3.2)</td>
<td>0.013*</td>
</tr>
<tr>
<td>treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. The clicking and grinding sensations in my knee have</td>
<td>3.3 (3.4)</td>
<td>6.0 (3.2)</td>
<td>0.017*</td>
</tr>
<tr>
<td>improved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. The changes occurring in my knee have changed the mobility</td>
<td>2.5 (3.0)</td>
<td>2.8 (3.4)</td>
<td>0.815</td>
</tr>
<tr>
<td>in my hip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I feel that this type of treatment should be used in the</td>
<td>4.1 (2.7)</td>
<td>1.8 (2.1)</td>
<td>0.004*</td>
</tr>
<tr>
<td>management of knee pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. How would you rate this treatment program</td>
<td>4.6 (3.5)</td>
<td>7.8 (2.5)</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

* Significant at p<0.05
Discussion

The results indicated that the treatment group was successful in reducing the subjects' osteoarthritic knee pain. As it was a requirement of the study for the knee pain to have been a chronic stable condition, it is unlikely that the results can be explained in terms of a spontaneous remission, especially when compared to the placebo/control group. The results of the placebo/control group demonstrated a non-significant improvement in pain following the placebo/control intervention. The small non-significant improvement in the control group was possibly due to the expectation of the subjects being involved in a university research study, as no actual treatment was delivered to the placebo/control group. It may also be said that the condition was naturally resolving, and that the natural resolution could account for the improvement in symptoms. Whilst this is a possibility, there was a significant difference between groups after treatment and but not before treatment, and as such, changes discount the possibility of such a spontaneous improvement. This fact along with the random allocation and the chronic nature of the pain all act to minimise the likelihood of such spontaneous remission.

In a pilot study investigating the effect of this therapy on knee function performed prior to this study, it was found that the gross range of motion of the knee did not change with treatment, and the occasional patient complained about the assessment of knee range of motion. A finding consistent with my 15 years of clinical experience. However, the passive practitioner assisted joint play movements were improved as were the general pain of the patients. Because the only physical changes noted in the pilot were to the subjective palpation findings and pain scores, and not to the gross range of motion of the knee. This decision was taken to minimise unnecessary painful movement of the knee because to do otherwise would be deemed to be unethical.

Research into arthritis and particularly osteoarthritis (OA) has largely investigated medical interventions and physical therapy modalities including exercise. Much less emphasis has been placed on other manual therapy approaches to the clinical dilemma that is OA.
OA is a degenerative disorder of joints that has widespread distribution throughout the body (Mc Alinton 1992). The knee is the primary site of involvement of OA with in an aging population, and the most common cause of dysfunction in the knee of the elderly (Felson et al 1987). Whilst several studies have begun to investigate therapy of the knee (Mark et al 1995, Puett et al 1994), most of these studies employed protocols that included several forms of therapy. This study employed only one manual therapy type in the treatment group to achieve its goals of pain reduction. This study seems to be the first of its type that I am aware of to investigate the effects of myofascial mobilisation / manipulation in the treatment of OA of the knee.

Much has been said about the application of manual therapy techniques to spinal structures (Meade et al 1990) . In the recent past there has been great interest in research into the clinical efficacy of various forms of manual therapy (Manga et al 1994). Whilst this interest is both appropriate and desirable, much less attention has been focused upon manual therapy interventions directed towards the peripheral joint structures.

The attention that has been given to manual therapy management of peripheral joint structures has centred around traditional areas of manual therapy such as stretching techniques, joint mobilisations, electrophysical therapy, exercise therapy and combinations of these approaches. Also, most research on manual therapy of the knee has utilised relatively young sporting or young university based populations to investigate the management of peripheral injury. Little controlled research has been directed into the aging population with regard to manual therapy.

Recently, there has been discussion of the importance of the patellofemoral compartment in knee dysfunction and knee osteoarthritis (McAlinton 1993, Ledingham 1993). Disease of the patellofemoral articulation can cause much pain, and be responsible for a great deal of difficulty in the everyday activities of squatting, using steps and stairs, kneeling, and rising up from chairs (Iwano 1990). Malalignment of the patella laterally has been proposed as a cause of the much of the pain associated with many patellofemoral conditions (Morrissey 1989). These malalignment syndromes are often referred to as "tracking " problems
(McConnell 1986). This implies a rotary instability. Such rotary instability is often associated with wearing knees (Lechner 1993). Also noted by Lechner is the observation that chronic knee injury is also associated with a loss of sagittal mobility (flexion and extension). This is important in light of the fact that the terminal phase of extension can also be very painful in the injured knee (Jayson & Dixon 1970). Thus, chronically injured knees, such as that possible in advanced arthritic presentations, can present with a loss of flexion and extension, and painful terminal ROM.

The manual therapy protocol used in this investigation specifically mobilised the patellofemoral articulation in flexion and extension. It does so in the range of 0-90° of extension (the starting point at 90° of knee flexion). In this range, the patella is actively mobilised in a supero-inferior direction in a plane at a tangent to the angle of the knee. In this state, no compression load is placed upon the patellofemoral articulation. This allows the subject to actively articulate through knee flexion and not excessively tighten the quadriceps to cause a vector that compresses the patella onto the femur. This activity is usually painful on weight bearing, and mimics an orthopaedic manoeuvre referred to as Clark's sign (Magee 1992). It is the goal of the practitioner to elicit pain when compressing patellofemoral structures to enable accurate diagnosis. The result of the mobilisation used in this study was that the patient performed an active exercise against resistance through a full functional ROM. The procedure stretches the joint capsule in the sagittal plane and likely loosens adhesions of the patellofemoral articulation. According to Akeson et al (1980) connective tissue mobility is lost with immobilisation. It is said that due to a shift in the water content out of the proteoglycan molecules that make up the ground substance in cartilage, neighbouring connective tissue fibres can contact one another facilitating abnormal cross-linkage in the so formed intra-articular capsular fibroadipose adhesions (Akeson et al 1980). Manipulative therapy is said to reduce these adhesions (Burger 1983). Together these effects allow the knee greater mobility with less effort, restriction and pain.

The results of this mobilisation procedure have indicated an effectiveness of this form of manual therapy to improve the subjective
VAS questionnaire pain responses and the subjective patient reported function of a knee inflicted with OA.

Following the two week treatment trial, subjects collectively reported improvement in symptoms. As such, the use of the therapy outlined in this study and other manual therapies should be considered in the management of this and other similar degenerative disorders of joints.

Another important consideration revealed in the post treatment questionnaire was the issue of pain and discomfort created by the treatment. There is often a paranoia that surrounds the use of manual therapy in the elderly (Blackman & Prip 1988). Whilst practitioner precaution is advised in dealing with patient conditions causing bone weakness, ligamentous laxity, deformity, and tumour, much can be offered to the individual that has good bony and ligamentous integrity that also happens to suffer from arthritic consolidation of the knee.

In researching these techniques in the private practice setting prior to formally beginning the study, much experimentation was performed. Over several years of application it is one of few procedures that is equally tolerable to patients suffering a diverse range of conditions including patellofemoral dysfunction, anterior cruciate ligament (ACL) deficiency, and OA. Of the many conditions to which this procedure has been applied, only the leg with a marked degree of lateral instability (genu valgus or genu varus), or acute meniscal lesions seemed not to tolerate it. It has become a useful addition to many techniques often used by us to treat knee dysfunction.

In order to maximise the potential of this and other methods of treatment, future research needs to compare the disorders for which this and other forms of manual therapy are best suited. Further research should also attempt to address the amount of treatment required to be given to resolve or manage a condition, and to what frequency it should be given. Ideally, any such research should be of a design that incorporated a large randomly allocated clinical trial. Such a study should investigate measurements of function, pain, and inflammation. Parameters of the research could include: baseline measurements followed by a before and after repeat measurements of a series of
treatments. Importantly, a longer term follow up should be investigated to assess the duration of any treatment effect.

Once known, these data may be compared with the data gained from more orthodox (pharmaceutical) approaches to the treatment of osteoarthritis in the knee, and the pain and suffering that it causes on the older members of our communities.
Conclusion
The manual therapy protocol outlined in this research significantly reduced the short term pain suffered by subjects with knee osteoarthritis. In addition, the subjects reported that the treatment caused no discomfort to receive when compared with the placebo / control treatment. In light of these findings, manual therapy should be considered as a viable option for those persons not achieving satisfactory pain management with traditional approaches of exercises and medication.
Chapter Five:

Study Three

The effect of upper cervical or sacroiliac manipulation on hip flexion range of motion.
Abstract

Objectives
To compare the effectiveness of an upper cervical manipulation and a manipulation of the sacroiliac joint for increasing hip range of motion.

Design
Clinical cohort study

Setting
Macquarie University Centre for Chiropractic Outpatient Clinic

Method
A reliable hand held dynamometer was used to determine the end point of range of motion (ROM) before and after the application of a treatment. Three groups of subjects were treated: cervical manipulation, sacroiliac manipulation, and placebo / control. Range of motion of the hip in flexion (straight leg raise) was used as the independent variable.

Sample
52 randomly allocated university students aged between 18 and 34 years.

Results
The two manipulation treatments resulted in increased flexion range of motion (ROM) at the hip. Statistical analysis revealed that only the upper cervical manipulation procedure increased hip flexion ROM significantly.

Conclusion
The results suggest that manual therapy of the neck may have a role to play in the treatment of extra-spinal lower limb musculoskeletal conditions.

Key Words
Chiropractic, Manipulation, Hip, Sacroiliac joint, Neck.
Introduction

Therapy directed to the spine for the treatment of peripheral function is controversial. The idea that cervical manipulation can effect the function of peripheral joints is also controversial despite the fact that some practitioners within several manual therapy professions strongly believe in such (De Jarnette 1972, Walther 1981, Plaugher 1993). It is with this in mind that this study investigates one of these beliefs.

A recent paper by Pollard & Ward (1997) has demonstrated that hip flexion range of motion could be improved following the application of a stretch to the hip (hamstring), or a stretch to the sub occipital muscles. The authors demonstrated that the effect of the cervical stretch was greater than the effect of the locally applied stretch when measuring range of motion changes at the hip. These findings have lent some support to the methods that some manual therapists place in the effect of upper cervical treatment on the function of sites removed from the spine.

The next step in establishing data to test the hypothesis that the spine has a role to play in the management of peripheral joint function should involve some investigation with a manipulative protocol. As certain groups within chiropractic have continuously suggested that spinal treatments, and in particular upper cervical manipulations, can effect all manner of extraspinal function, it is important that upper cervical manipulations be examined for such effects (De Jarnette 1972, Walther 1981, Plaugher 1993).

Thus it was important to examine the effect of an upper cervical manipulation on the hip flexion range of motion in a reliable method similar to that used in an earlier study by Pollard & Ward (1997).

A manipulation to the sacroiliac joint to effect lower back and hip conditions has also been proposed as appropriate within certain sections of the manual therapy professions (Plaugher 1993). Belief in the treatment of the sacroiliac joint because it a source of low back pain has been strong (DonTigny 1985).
Loss of hip range of motion is associated with low back pain (McClune et al 1997). Much low back pain is said to have a sacroiliac source (DonTigny 1985). In fact a singular sacroiliac load can be doubled if a lumbar load is shifted laterally (Snijders et al 1992, Gramata & Moarran 1994). Despite the fact that sacroiliac joints generally display only minor movement capability (Egund et al 1978), proponents of this hypothesis would suggest that the loss of hip function could result in compensatory changes in the sacroiliac function mediated by the force distributed via the action of the thoracolumbar fascia (Snijders et al 1993) resulting in increasing pain and dysfunction. Therefore, the protection of the sacroiliac joint requires a co-ordinated action of the hamstrings, the gluteal, erector spinae and the latissimus dorsi (Noe et al 1992, Oddsen & Thorstensson 1990, Oddsen & Thorstensson 1987). It is through the action of the thoracolumbar fascia that a connection between the hamstring (via the long head of bicep) to the pelvis and thence to the latissimus dorsi can be made (Vleeming et al 1990a). An hypothesis supported by the indirect evidence that low back pain increases in association with increasing sacroiliac joint mobility associated with hormonal changes in post partum women (Snijders et al 1984).

This has especially been so after studies confirmed a specific distribution of pain with sacroiliac joint involvement (Fortin et al 1994). This specific pain map has made it possible to identify a reliable indicator for treatment in the absence of reliability with standard orthopaedic tests (Potter & Rothstein 1985), despite some authors indicating the opposite with various palpatory routines (Herzog et al 1989).

Studies demonstrating reduction of low back pain following sacroiliac joint manipulation has been favourable (Allan & Waddell 1989, Bernard & Cassidy 1981). However, to my knowledge no study has investigated the effect of sacroiliac joint manipulation on the function of the biomechanically related and near by hip joint.

Thus, it was the specific aim of this study to compare the effects of either a sacroiliac joint or an upper cervical joint manipulation on the hip flexion range of motion in volunteer subjects.
Materials And Methods
This study was performed as one in a group of consecutive studies performed by Pollard & Ward (1997) utilising similar methodology.

All 52 subjects were volunteer asymptomatic chiropractic students aged between 21 and 34. Subjects were randomly allocated one of three groups by drawing a number from a sealed container. Group 1 was a control group whose subjects received digital pressure over the mastoid processes bilaterally. Group 2 subjects received an upper cervical manipulative procedure, and Group 3 subjects received a sacroiliac manipulative procedure.

Full examination consisting of orthopaedic, neurological and muscular testing was performed on each subject to ascertain their suitability for manipulation. Any subjects displaying any of the exclusion criteria were omitted from this study. Subjects were excluded if they had reported acute low back, neck, hip, leg or hamstring muscle pain within the two weeks prior to the investigation, or if they tested positive to standard pre manipulative vertebrobasilar insufficiency testing (Terrett & Kleynhans 1992). All subjects provided informed written consent, and the study had been approved by the Macquarie University Centre for Chiropractic Human Ethics Committee and the University of Wollongong.

Measurement
Initially, each subject performed a five minute pre measure warm-up at an intensity of 75 revolutions per minute (metered by a metronome) on an exercise bike based on a protocol by Golden & Dudley (1992). Following this, subjects were weighed and then taken to a separate room where they lay supine on the treatment couch.

Subjects in both groups laid supine on the treatment table and a goniometer was attached to the lateral aspect of the calf in the sagittal plane. A digital goniometer (Ortho Ranger II MI Technic Inc.) was used to measure straight leg raise (SLR) and a digital force transducer (Nicholas Manual Muscle Tester Model 01160 Lafayette Instruments)
was used to standardise the SLR. Both the electrogoniometer and the hand held force transducer were calibrated prior to use.

The force transducer was placed at 90° to the long axis of the leg at the level of the calcaneus on the unshod foot. The first examiner drew a line between the lateral malleolus and the greater trochanter of the leg to be examined. This line represented the longitudinal axis of the leg and provided a reference for the accurate placement and replacement of the goniometer during SLR measurements. The end point of measure in the pre- and post - tests were determined by the second examiner using the force transducer. The passive end point goniometer reading (end point of ROM) was defined as that point reached by an application of 5% of the subject’s body weight. Such a determination of end point was essential to ensure an accurate reproduction of the measurement. In all measurements of straight leg raising the pelvis was secured to the treatment table. The subjects were strapped to the treatment table at the level of the anterior superior iliac spine (ASIS) to reduce unwanted pelvic rotation.

The importance of eliminating pelvic rotation in SLR measurements has been demonstrated by Gajdosik and coworkers (1993). Emphasis was placed on keeping the knee in the fully extended position at all times.

Several methods of measuring the change in flexibility of flexion ROM at the hip joint have been described (Etnyre & Abraham 1986, Andesson & Burke 1991, Etnyre & Lee 1987). Many of these studies utilized a goniometer or electrogoniometer to determine the angle or ROM of the hip. These procedures have been found to be a consistently acceptable measure for hip ROM (Etnyre & Lee 1987, Urbam 1986).

After initial range of motion measurements were completed bilaterally, each subject was randomly assigned to one of the following groups.

**Group A  Control Group**
This group received digital pressure on the mastoid processes bilaterally for 30 seconds. This procedures was repeated a total of three times. The side receiving the range of motion assessment was chosen at random.
Group B  Upper Cervical Manipulation Group
A chiropractic manual manoeuvre (rotary double index contact style manipulation) consistent with O’Neil and Esposito (1991) was applied to the first cervical segment. The side of manipulation was chosen at random.

Group C  Sacroiliac Manipulation Group
A chiropractic manual manoeuvre (lumbar roll position pisiform contact) consistent with O’Neil and Esposito (1991) was applied to the sacroiliac joint. The side of the manipulation was chosen at random.

The side receiving the manipulation in groups B and C also received the range of motion assessments. The rationale for the random allocation and assessment is given at the end of this section.

Following the intervention, the second examiner again determined the hip flexion range of motion within 30 seconds. All post treatment assessments took place 30 seconds after the intervention so that the elapsed time between intervention and assessment could be standardised. This was performed immediately following the intervention on all subjects in the same fashion as it was prior to the intervention. Pre-treatment measurement, treatment, and post-treatment measurement were all performed within a five minute period.

The unilateral range of motion assessment of the hip was chosen on the basis that hip flexion range of motion was considered to be representative of the general state of mobility in the hip (Green & Heckman 1994), and based on previous work by Murphy et al that demonstrated decrease in H-reflex amplitude on the side homolateral to the side of sacroiliac joint manipulation (Murphy et al 1995).

The author made no attempt to locate fixated joints, subluxations or any other lesions of the spine, sacroiliac or hip regions once subjects had been declared (by another examiner) suitable for inclusion into the study. This was done for two reasons. The general aim of this study was to investigate whether manipulation of spinal structures could influence peripheral structures. This was done to provide normative data on the effect of manipulation in a healthy population, to which later studies involving pain sufferers and other populations of homogeneous joint
conditions could possibly be compared. As the reliability of the palpatation of the spine and particularly the sacroiliac joint has been reported to be poor (Fortin et al 1994, Potter & Rothstein 1985), and as I was using an asymptomatic group, I could not use pain mapping as a guide to locate the lesion (Fortin et al 1994). This approach is supported by the findings of Dreyfuss et al (1994) who suggest that 20% of asymptomatic individuals test positive with many sacroiliac joints. As such, there was no guarantee that a side deemed to be lesioned was in fact lesioned. Thus, it was not possible to definitively determine the side receiving the intervention, and control of the side was not then possible in such circumstances.
Results
Data were analysed using descriptive statistics, student t-tests, and Analysis of variance (ANOVA) tests of significance. Significance was set at Alpha equal 0.05.

Table 5.1: Group changes in hip ROM

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Pretest</th>
<th>Posttest</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (SE)</td>
<td>16</td>
<td>66.4 (3.2)</td>
<td>67.1 (3.2)</td>
<td>1.0</td>
</tr>
<tr>
<td>Cervical (SE)</td>
<td>18</td>
<td>56.9 (2.8)</td>
<td>61.1 (3.0)</td>
<td>6.7</td>
</tr>
<tr>
<td>Sacroiliac (SE)</td>
<td>18</td>
<td>60.1 (2.2)</td>
<td>62.2 (2.4)</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 5.2. Pre test ANOVA reporting differences between the control, cervical and the sacroiliac groups in average Range of motion measured in degrees (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>338</td>
<td>2</td>
<td>169</td>
<td>1.18^</td>
</tr>
<tr>
<td>Error</td>
<td>7017</td>
<td>49</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7355</td>
<td>51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ p>0.05

Table 5.3: Post treatment differences in average group ROM measured in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16</td>
<td>-0.7</td>
<td>4.5</td>
<td>1.1</td>
<td>-3.91</td>
<td>0.001</td>
</tr>
<tr>
<td>Cervical</td>
<td>18</td>
<td>-4.1</td>
<td>3.7</td>
<td>0.9</td>
<td>-1.39</td>
<td>0.18</td>
</tr>
<tr>
<td>Sacroiliac</td>
<td>18</td>
<td>-2.2</td>
<td>4.5</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.4: Post treatment differences in average group ROM measured in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacroiliac</td>
<td>18</td>
<td>-2.2</td>
<td>4.5</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>18</td>
<td>-4.1</td>
<td>3.7</td>
<td>0.9</td>
<td>1.83</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Discussion

The results obtained in this study are consistent with earlier findings in this thesis that demonstrated a significant improvement in hip flexion range of movement following a cervical sub occipital muscle stretch (Pollard & Ward 1997). The effects of the two forms of manipulation on hip range of motion will be divided into a discussion of the cervical manipulation, which will precede the discussion of the sacroiliac joint manipulation.

The results of this study also demonstrate that a 1.03% increase in flexibility occurred in the control group after intervention. The result was bettered by both the sacroiliac and the cervical manipulation groups which had a 3.47% and 6.75% improvement respectively (table 3.3). Of the three groups, only the post intervention range of motion value in the cervical manipulation group was significantly improved compared with the pre intervention value (p<0.05).

This change was large enough to reveal a significant difference between groups post intervention (P < 0.05) (table 3.1). This result occurred despite a non-significant difference between groups prior to intervention (see table 4). Whilst the improvement in the cervical manipulation group was significant at the P<0.001 level, the change was not of a magnitude to be significantly different to the sacroiliac manipulation group (table 3.2).

This study together with my previous study investigating the effect of a cervical stretching procedure on hip flexion range of motion (Pollard & Ward 1997) provides evidence that some spinal treatments have peripheral manifestations. To my knowledge, this is the first study to demonstrate improvement in an objective range of motion measure of peripheral joint function after a single cervical manipulation, although a previous study by Nansel and co workers has demonstrated a change in soft tissue compliance in the lumbars following a lower cervical manipulative procedure (Nansel et al 1993).

The implications of these results are important to manual therapists who stylise spinal treatments to affect peripheral function. Such treatments have long been considered to be the realm of chiropractors. This is
particularly true for certain groups within chiropractic that choose to specialise their treatment to that of the cervical spine. These practitioners (often referred to as hole-in-one or upper cervical practitioners) have claimed whole body effects to their treatment for many years (Waagen & Strang 1980). So, whilst it is early to support such claims, it is important to acknowledge some potential in light of these findings.

The results of this study and that of my previous study suggest that treatment to the neck can improve hip flexion range of movement. The mechanism of these whilst untested and speculative in nature, has been discussed previously (Pollard & Ward 1997).

No attempt was made to assess the hip with the body in various positions, as it was known that various ancillary movements of cervical flexion (Lew et al 1994), pelvic rotation (Sullivan et al 1992), and ankle dorsiflexion/plantarflexion (Gajdosik et al 1985) have been shown to change the range of the straight leg raise method of assessment of hip flexion range of motion. I attempted to standardise the effects on the assessment on the variable of mobility by minimising this variability as suggested by Cameron et al (1994).

Given the inherent variability within the measures, and the conclusion by Cameron and co-workers that consistency of reporting was paramount to valid conclusions, I attempted to align this thesis with the bulk of the clinical and scientific literature on stretching which utilises a standardised assessment of passive straight leg raising with the neck, pelvis, knee and ankle fixed whilst using a predetermined objective end point of range of motion measurement (Etnyre & Lee 1987, Cameron et al 1994).

Several potential untested mechanisms exist to explain the effects noted. An increase in hip flexion ROM following a cervical manipulation could result from a change in the muscle spindle output of the sub occipital muscles causing reflex proprioceptive changes to centres controlling posture. This mechanism is supported by animal studies on tonic neck reflexes by several researchers (Richmond & Abrahams 1975, Abrahams & Falchelto 1969). If the tonic neck reflexes exist in
Adult humans, then it is likely that comparable lower limb flexion has resulted from stimulation of the sub occipital muscles and joint capsules associated with a cervical manipulation of the area.

A second mechanism involves a dural mechanism. The spinal dura attaches to the vertebral bodies of C1 and C2, the posterior longitudinal ligament (especially the lower lumbar spine), the second sacral tubercle and the filum terminale (Warwick & Williams 1973). Parke & Watanabe (1990) have shown that dural adhesions can occur secondary to degenerated spines. Other research on cadavers has demonstrated that neck flexion causes spinal cord movement in the lumbars, and that movement is greater than when the leg is flexed at the hip (Lew et al 1994). Thus, it is possible that obstruction of the dural movement by adhesion at any of these attachment points could limit the range of motion available to the lumbar spine and lower limb in movement through the sagittal plane (such as that occurring with the straight leg raise). Manipulation would act to release adhesion at these points of tether in such a fashion as to allow normal excursion of dural movement and ultimately full range of motion.

A third mechanism relates to the previous one and involves a dural stretch mechanism. Stretching of the dura to relieve selected spinal pain and referred pain syndromes has recently been popularised by Butler (1991). Also, other recent work by Hack and co workers (1995) has demonstrated attachments of a cervical extensor muscle to the dura. Therefore, it is likely that any manipulation of this region would likely effect both the muscle and the vertebra, possibly causing a direct stretching of the dura or the release of adhesions forming around such attachment points. The release of such restrictions would likely cause an increased movement. The increased movement would then be assessed by the increased length of dura as measured by straight leg raise, compared with one that was dysfunctional.

Whilst these mechanisms are capable of explaining an increase in flexion range of motion following a cervical manipulation, they are all speculative. Research is required on both animal and human subjects that investigates these mechanisms further. Manipulative studies on animals with and without analgesia to the cervical spine could provide information on the possible reflex nature of this phenomenon.
Manipulative studies on animals with and without tethering of the cervical dura could possibly shed light on the dural mechanisms. Importantly, studies are required in human subjects to investigate the effect of a series of treatments on the hip function in both normal and dysfunctional populations. In this fashion I observed if these changes were important in the management of peripheral injury, or whether they are a short term curiosity.

This study also investigated the effects of a sacroiliac joint manipulation on hip flexion range of motion. The effect of this treatment was compared to the effects of a cervical manipulation when attempting to increase hip flexion range of motion. The results demonstrate that manipulation of an asymptomatic sacroiliac joint could not significantly alter the mobility of the hip in the short term. This result is in opposition to some views (Lewit 1985) that suggest that sacroiliac joint function can directly effect the function of the biomechanically and structurally related hip and lumbar regions.

The sacroiliac joint is said to be important for transmitting forces to the hip in weight bearing (Noe et al 1992, Oddsson & Thorstenssen 1990, Oddsson & Thorstensson 1987). The application of the coupled movement (together with movement of the lumbars) in the sagittal plane is referred to as the lumbopelvic rhythm (van Wingerden et al 1995).

Proponents of this untested theory suggest that the closed kinematic chain of the lower limb can result in an increase in hip range of motion as a direct compensation for loss of movement at the sacroiliac and lumbar regions or vice versa (Cailliet 1995). However, as recent research has demonstrated that the sacroiliac joint has a few degrees of motion (Weisl 1955, Egund et al 1978, Sturesson et al 1989, Kissling & Jacob 1995), and that the hip range of motion is much greater (approximately 60° of flexion), it is possible that the hip could absorb the extra motion into its range and not be significantly altered in terms of that range of motion. This would be especially true in the presence of a large variance of hip range of motion. This insignificance of extra hip mobility could occur due to the presence of error associated with the measurement of the hip joint mobility (Hsieh et al 1983). This error of mobility whilst small (3-3.6 degrees) when compared to the overall excursion of hip movement (60 degrees), is large when compared to the
sacroiliac movement. This error could be resolved by reducing the variability of movement, or dramatically increasing the numbers participating in the research.

A potential reflex action of manipulation on long loop reflexes has been suggested as a possible mechanism for the increase of hip flexion range of motion following cervical manipulation. Support for the idea that joint or muscle proprioceptors of the sacroiliac joint are stimulated by sacroiliac joint manipulation has been provided by Murphy et al (1995). Their work demonstrated changes in H-reflex in soleus muscle activity after desensitisation of cutaneous afferents through the use of an anaesthetic cream. They concluded that the changes in the H-reflex must be mediated by joint and or muscle afferents (probably at segmental level). So whilst there was no significant change in the hip following sacroiliac joint manipulation in this group of subjects, such a result could be reversed in subjects suffering sacroiliac joint lesions, or those suffering low back pain in regions known to be associated with sacroiliac dysfunction.

Some methodological factors undertaken in this study were important for its outcome. The standardisation of tissue heating effects is one such variable. It was important to provide a light pre-measure warm-up to standardise the heat loading in the soft tissues. This was performed because temperature differences in muscle and ligament are known to effect their extensibility (Lehmann et al 1970), and therefore variability of temperature could have introduced an error into the range of motion (ROM) findings. A five minute warm-up consisting of light to moderate exercise was performed in all subjects. This degree of warm up has been used previously to heat muscles for the purpose of standardisation for range of motion measures (Golden & Dudley 1992).

The variables of sex and age have been shown to be important in the range of motion achieved by sacroiliac joints (Brooke 1924, Stewart 1984, Vleeming et al 1990). These variables were controlled in this study. Sacroiliac joint preparations from males over thirty five years of age display increased roughness of the joint surfaces with age (Stewart 1984). However, these features do not appear with female sacroiliac joints even of advanced age (Brooke 1924, Stewart 1984). These findings suggest that not only is it likely that range of motion will be
different between the sexes, but that range of motion would likely be
different between men of young and older age groups. Vleeming and
co-workers (1990) have demonstrated that sex differences parallel
differences in joint surface morphology. Therefore, standardisation of
both age and sex as factors in research associated with the sacroiliac
joint is essential.

The sacroiliac joint is a large tightly bound ligamentous joint. Because
of its anatomy, it may be appropriate to investigate methods of
treatment that help the ligaments of the joint to undergo creep to
achieve increased sacroiliac range of motion.

Optimum function of the sacroiliac ligaments is achieved when the
interosseous ligaments are stiff (Miller et al. 1987). These ligaments are
usually taut in the standing position (Noe et al. 1992). The tension is
assisted by the action of several muscles either side of the pelvis. The
tension is maintained in the sacroiliac joint by the action of the
thoracolumbar fascia and specifically by the lat dorsi and the
contralateral gluteus maximus, which both insert into the sacroiliac joint
ligaments (Noe et al. 1992). Together with the action of the long head of
the bicep (which inserts into the sacrotuberous ligament (Vleeming et al
1989) help to tension the sacroiliac joint in the standing position.

It is apparent that posture can effect this mechanism. The lumbar
posture in either extreme of hyper lordosis (standing) or hypolordosis
(sitting) has been generally viewed as being a stable state utilising the
above mechanism (Snijders et al. 1995). However, the transition
between the two points have been identified by Snijders et al (1995) as
relatively unloaded, and therefore potentially unstable and requiring of
the supportive tensioning action of the hamstrings (Esola et al. 1996).

As it is known that creep of ligaments does occur under periods of
prolonged loading (Kennedy et al. 1976, Woo & Tkach 1990), treatment
methods that involve prolonged mobilisation (such as that which occurs
by the placement of triangular wedges under the innominates to effect a
rotary torque of the pelvis) should be examined to see if they have an
influence on either of the sacroiliac or hip joint ranges of motion. These
treatments should then be compared to manipulative trials to ascertain
relative efficacy in improving hip and sacroiliac ranges of motion. To
my knowledge of the published data no such investigations have taken place.
Conclusion

I conclude that a single manipulation of the first vertebra of normal university students statistically improved the hip flexion range of motion. By contrast, a single manipulation of the sacroiliac joint did not significantly increase the hip flexion range of motion in the same population of subjects.

These results suggest that the manipulation of the upper cervical area may have a role to play in the treatment of extraspinal lower limb musculoskeletal conditions. These results support earlier work that demonstrates improved hip flexion range of motion following the application of a sub occipital muscle stretch. Further investigation of the effect of clinical protocols on normal and various pain populations is required to further investigate the hypothesis that upper cervical manual therapy can effect extraspinal musculoskeletal conditions.
Chapter Six:

Study Four

A study of two stretching techniques for improving hip flexion range of motion.
Abstract

Objectives
To compare the effectiveness of a spinal (suboccipital) stretching technique to a peripheral stretching technique.

Design
Clinical cohort study

Setting
Macquarie University Centre for Chiropractic Outpatient Clinic

Method
A reliable hand held dynamometer was used to determine the end point of range of motion (ROM) before and after the application of a treatment. Three groups of subjects were treated: cervical stretch, hip stretch, and placebo / control. Range of motion of the hip in flexion (straight leg raise) was used as the independent variable.

Sample
60 randomly allocated university students aged between 18 and 35 years.

Results
Statistical analysis revealed that the sub-occipital stretching procedure increased hip flexion ROM significantly.

Conclusion
The results show that manual therapy of the neck may have a future in the treatment of extra-spinal lower limb musculoskeletal conditions.

Key index terms
chiropractic, cervical spine, hip, muscle stretching
Introduction

Manual therapeutic approaches utilize spinal techniques to affect specific distal sites. An example of these techniques include the commonly used chiropractic techniques of Sacro-Occipital Technique (SOT) (Walther 1981) and Applied Kinesiology (AK) (De Jarnette 1972), amongst others (Plauger 1993).

This study investigated the effects of a proprioceptive neuro-muscular facilitation (PNF) procedure applied to the sub-occipital muscles on measures of hip range of motion (ROM) in flexion.

The PNF stretching method was chosen for this study because it had been found to be the most effective stretching technique for increasing ROM via muscle lengthening (Markos 1979). Several recent studies which compared the gain in ROM using different stretching methods concluded that there was superiority of the PNF forms (Holt et al 1970, Moore & Hutton 1980, Etnyre & Abraham 1986).

PNF is essentially a muscle mobilization technique using muscle facilitation and inhibition. It has been used by manual therapists for over forty years (Knott & Voss 1968, Kabat 1950), in treating joint mobility deficits in patients. PNF is based upon the manifestation of the inverse stretch reflex. This reflex demonstrates autogenic inhibition of a muscle and is manifested by the golgi tendon organ (GTO). The GTO's are located within the tendon of a muscle close to its tendinous insertion (Andesson & Burke 1991). Their role is to monitor tension within a muscle. The GTO is stimulated by the contraction of the muscle; the stronger the contraction, the stronger the GTO stimulation. The stimulation of the GTO causes the inhibition or relaxation of the muscle in which it is associated. The tendon receptors are supplied by the large group 1b afferent nerve fibres. Transmission from the GTO's may go to local areas within the spinal cord and through the spinal cerebellar tracts to the cerebellum.

The local signals result in excitation of interneurones which in turn act on the anterior α motor neurons of its own muscle and synergist whilst facilitating antagonists. The inhibitory nature of the GTO acts as a
protective mechanism for the muscle. Stimulation of the GTO prevents
the muscle from going past its structural capabilities and thus prevent
strain or tear (De Jarnette 1972).

At least two types of PNF stretch have been demonstrated. The first
type is denoted as the contract-relax (CR), and the second variety is the
contract-relax-antagonist-contract (CRAC). The CR method was used in
this study, since it best approximated the first part of a procedure called
'Pitch-Roll-Yaw-Tilt' (PRYT) that is used by the Applied Kinesiology
and Sacro-Occipital Technique practitioners referred to above. This
procedure is based upon a treatment approach used by SOT
practitioners (Walther 1981). The CRAC procedure is believed to be
superior to the CR method used in this study (Etnyre & Lee 1987).

To maintain consistency, the CR method was applied to the suboccipital
and hamstring muscles, and the effects of these procedures on hip ROM
were compared. The purpose of the study was to determine if the hip
ROM could be influenced by application of a muscle stretch to a
different proximal spinal site.

Several methods of measuring the change in flexibility of flexion ROM
at the hip joint have been described (Etnyre & Abraham 1986,
Andesson & Burke 1991, Etnyre & Lee 1987). Many of these studies
utilized a goniometer or electrogoniometer to determine the angle or
ROM of the hip. These procedures have been found to be a consistently

A problem exists with ROM assessments. The standardization of how
much force is used to determine the end point of measure should be
considered in any measure of ROM. In this study, the end point
measure of the passive SLR was determined by a standardized force
recorded by a hand held force transducer. This dynamometer was
chosen because it had a comparable reliability to both manual and
isokinetic strength testing devices in the range used for the study
(Marino et al 1982). The author of another study (Nicholas et al 1987)
concluded that the device was a reliable, reproducible and convenient
clinical tool. In addition to measuring hip flexion ROM (as determined
by hamstring muscle tightness), the SLR test is also widely used as a
neurological test for the measure of nerve root tension (Butler 1991).
Therefore the possible stretching of neurological tissue during testing should be considered.

Thus, in this study I specifically compared the effectiveness of a spinal technique to one applied distally in increasing range of motion in the distal joint.
Materials And Methods

This study had received approval by the Macquarie University and The University of Wollongong Human Ethics Committees prior to experimentation.

Sixty subjects were used in this study and were limited to the ages between eighteen and thirty-five. Subjects were divided randomly (random number generator) and equally into three groups by drawing a number from a sealed container. Group 1 received a suboccipital PNF procedure, Group 2 received the hamstring PNF procedure while Group 3 was a placebo / control group which received digital pressure over the mastoid processes bilaterally.

All subjects were treated by the same practitioner. The practitioner was well versed in the procedures being used and administered them with equal enthusiasm. All measurements were made by another person who did not treat the subjects. The treating practitioner was therefore blinded to the assessment.

Subjects were accepted for inclusion into the study if they were students who had provided informed written consent. The three groups were matched for sex and age; subjects were not accepted for inclusion if they had reported acute low back pain, a referred leg pain / paraesthesia or hamstring muscle injury within the two weeks prior to the investigation.

Determination of End Point of Range of Motion
A hand held dynamometer (Nicholas Manual Muscle Tester, Model 01160, Lafayette Instruments) was used to determine force, and to provide a definition for the end point of ROM. This dynamometer was chosen because it has comparable reliability to both manual and isokinetic strength testing devices and is reliable in the range of 0.2-250kg, the range used in this investigation.

Measurement
Subjects in all groups lay supine on the treatment table and an electrogoniometer was attached to the lateral aspect of the gastrocnemius muscle group in the sagittal plane. The force transducer was placed at
90° to the long axis of the leg at the level of the calcaneus on the unshod foot. The first examiner drew a line between the lateral malleolus and greater trochanter of the leg to be examined. This line represented the longitudinal axis of the leg and provided a reference for the accurate placement and replacement of the goniometer during SLR measurements.

Prior to the assessment of the ROM, the pelvis was strapped to the examination table at the level of the anterior superior iliac spine (ASIS) of the pelvis, to minimize any rotation of the pelvis. The importance of eliminating pelvic rotation in SLR measurements has been demonstrated by Gajdosik and coworkers (1993). Emphasis was placed on keeping the knee in the fully extended position at all times.

The SLR procedure was deemed to be a satisfactory measure of gross flexion ROM as the measurement was not compared between subjects (only average change group data was used), where average change ROM = post score ROM - pre score ROM), and only one session of testing occurred (removing the possibility of error occurring as a result of any diurnal variations).

The end point of measurement in the pre and post tests were determined by the second examiner using the hand held force transducer. The passive end point goniometer reading (end point of ROM) was defined as that point reached by an application of 5% of the subject’s body weight.

Much thought was given to bodyweight as a factor in measurement. After many trials prior to the start of the experimentation, it was found that 10% of bodyweight was too excessive for many people. A force using 10% of bodyweight often exceeded the painfree end of SLR ROM. It was imperative to standardize the amount of force used in the SLR test. Obviously, the greater the force used by the tester in the SLR, the greater the ROM that would be achieved. In addition, I deemed it inappropriate to used a fixed force (say 10kg), as such an absolute force would be minor to a large strong person but the same force would be too great for a less strong person. Thus, in an attempt to standardize the force of application, an arbitrary value of 5% of bodyweight was chosen.
Group 1 subjects lay supine in the neutral position. Subjects were told to actively extend their neck with maximal suboccipital muscle contraction for 10 seconds against the practitioner’s resisted hand placed under the subject’s occiput to resist the movement. This procedure was repeated twice, consistent with Hardy (1985). Group 2 subjects were supine in the neutral position and were told to actively flex the hip with the knee held in extension to a point designated as the end point of ROM of the hip joint in flexion. At this position, a contraction of the agonist (hamstring muscle) was held for 10 seconds against the practitioner’s resisting hand. This procedure was also repeated twice.

Group 3 subjects lay supine in the neutral position and the practitioner applied bilateral digital pressure over the subject’s mastoid processes for 8 seconds, this procedure also repeated twice.

All post-treatment assessments took place 30 seconds after the intervention, so that the elapsed time between intervention and assessment could be standardized.
Results

Calculated means and standard errors of the means for group pretest, posttest, and change scores are presented in Table 4.1. This table indicates an average increase of 9.1° in the post cervical stretch. In contrast, an increase of only 6.7° was noted in the hamstring PNF stretch group, and 3.6° in the control group. A one-way ANOVA of the change scores, as shown in Table 4.2, revealed a significant difference between the groups. A Newman-Keuls post hoc analysis showed that the manipulation group was significantly different to the placebo / control group and the hamstring stretch group.

Pretest scores were analysed using an ANOVA statistical procedure. The results of the pretest ANOVA are listed in table 4.3, and revealed no significant flexibility difference between the groups prior to intervention.

Table 6.1. Change in mean scores with standard error (in brackets) of angle of hip for groups (in degrees).

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical PNF</td>
<td>72.1 (13.3)</td>
<td>81.2 (12.4)</td>
<td>9.1 (4.3)</td>
</tr>
<tr>
<td>n=20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip PNF</td>
<td>72.1 (11.6)</td>
<td>78.8 (12.5)</td>
<td>6.7 (4.5)</td>
</tr>
<tr>
<td>n=20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placebo / Control</td>
<td>71.8 (12.3)</td>
<td>75.1 (11.0)</td>
<td>3.3 (2.8)</td>
</tr>
<tr>
<td>n=20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.2. Analysis of variance of average group data scores (post - pre treatment scores)

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum Squares (SS)</th>
<th>Degrees of freedom (df)</th>
<th>Mean Squares (MS)</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>331.3</td>
<td>2</td>
<td>165.7</td>
<td>11.75*</td>
</tr>
<tr>
<td>Error</td>
<td>803.5</td>
<td>57</td>
<td>14.1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1134.9</td>
<td>59</td>
<td>14.1</td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05

241
Table 6.3. Analysis of variance of before treatment ROM scores

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum Squares (SS)</th>
<th>degrees of freedom (df)</th>
<th>Mean Squares (MS)</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.00*</td>
</tr>
<tr>
<td>Error</td>
<td>8770</td>
<td>57</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8771</td>
<td>59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p>0.05
Discussion

The results of the three experimental groups demonstrated an increase in the hip flexion range of motion compared with the pre-intervention state. The changes represented 12.5%, 9.3% and 5.0% of the pre-test values for the cervical, hamstring, and control groups respectively.

While improvement occurred in all groups, Newman-Keuls post hoc testing of the changes (noted in table 4.1) demonstrate that there was an overall statistically significant change in the cervical flexion ROM compared with the control group (p<0.05). Although there was an increase in the hip flexion range of motion in the hamstring PNF group (9.29%), the change was not significantly different to the change noted in the control group (5.01%, P>0.05).

Although some studies failed to support the use of the CR form of PNF stretching (Hartley-O'Brien 1980), the lack of significant difference in the hamstring CR PNF procedure is surprising in light of other studies supporting its use (Walther 1981, Etnyre & Lee 1987). This discrepancy raises the possibility that the change noted in the hamstring group was in fact not significantly different to the control. Three other explanations of the results include a learning effect for the procedures, a placebo effect was operating, or an inadequate control procedure was used (i.e., the control group displayed a treatment effect). For these reasons, and the fact that this study only used small subject numbers, the possibility of a type II error exists. Larger studies are required to improve the statistical power and remove the chance of a type II error.

As an incidental observation, increases in hip flexion ROM, (as measured by SLR) achieved from the application of the suboccipital muscle release appeared to be only short term in duration compared with the longer term results observed for PNF of hamstrings. From this observation further research should be targeted at documenting the longer term effects of the suboccipital stretch, as the length of effect for hamstring stretches has been determined (Bandy et al 1997), and have been reported by several authors (Roberts & Wilson 1999, Borms et al 1987), but the length of the suboccipital effect has not been reported.
The suboccipital technique employed in this study approximates an Applied Kinesiology (AK) technique referred to as ‘Pitch-Roll-Yaw-Tilt’ (PRYT) (De Jarnette 1972). The application of this technique is used to find areas of spinal joint and muscle dysfunction that cause inappropriate communication between proprioceptors found in the neck and pelvis (De Jarnette 1972). The suboccipital muscle release employed in this study, however, is only a small component of the whole protocol used. (Other components may include muscle testing, muscle release, articular manipulation and other techniques). Further studies should investigate the component parts of the whole procedure, as well as observing the ‘treatment’ effects of the whole process.

No validated mechanism exists to explain the observations noted in this study. It was necessary to speculate on some untested theories to explain the observations. Thus, possible mechanisms that enabled the improvements to be achieved in hip ROM after the application of the sub-occipital muscle release can only be hypothesized. A mechanism to explain the possible influence of the application of the neck extensor PNF on SLR may lie with the role of cervical musculature as proprioceptors for postural control (Fitz-Ritzon 1984).

Richmond and Abrahams (1975) examined dorsal neck muscles of the cat for the density, distribution and morphology of muscle spindles. They found that the densities of muscle spindles in the large extensors of the cat neck were the highest of any muscle examined in the cat. In addition, the dorsal neck muscles also had morphology and physiology quite distinct to those of other skeletal muscle spindles. Following their work, other researchers have suggested that the uniqueness and complexity of the muscle spindle system of the cervical region is due to its specialized role in providing information for the maintenance of the reflex control of posture (Garlick 1982).

The PNF stretching procedure is also thought to use a reflex control of muscle. This form of stretching is thought to act through the neurogenic inhibition of the agonist muscle group, and is able to adjust the set length of the muscle, thus stimulating the muscle spindles. When a PNF stretch is applied to the sub-occipital muscles, the resultant afferent proprioceptive information could cause changes in postural tone via the mechanism described above. The precise central pathways involved
with these reflexes are still to be determined (Garlick 1982, Parke & Watanabe 1990); however, the three principles somatosensory pathways for proprioception in the human are the spinothalamic tract, the spinocervical tract and, generally, the dorsal columns (Warwick & Williams 1973). Some of the superior neural destinations of these afferents are the cerebral cortex, the superior colliculus, the vestibular nuclei, the main reticular formation and the cerebellar cortex (Fitz-Ritzen 1984). Efferent information regarding posture and proprioception is relayed to the limbs via these centres through descending vestibulospinal, reticulospinal and corticospinal tracts. The evidence that cervical musculature plays a critical role in influencing lower limb and upper limb function and posture comes mainly from empirical studies (Abrahams & Falchetto 1969, De Jong et al 1977).

Tonic neck reflexes are demonstrable on the decerebrate cat. Ventroflexion of the head relative to the body results in a reflex flexion of the forelimbs and extension of the hindlimbs (Berne & Levy 1988). Conversely, dorsiflexion of the head elicits extension of the forelimbs and flexion of the hindlimbs. If these tonic neck reflexes exist in humans, then it is hypothesized that comparable lower limb flexion has resulted through stimulation of muscle spindles in the cervical extensor muscles via the PNF stretch to give an increased hip flexion ROM.

Abrahams and Falchetto (1969) reinforced the importance of cervical musculature for postural control by demonstrating that a sectioning of the neck muscles of cats produced a whole body ataxia. De Jong et al (1977) demonstrated similar effects on human volunteers when local anaesthetic was injected into the cervical musculature of the volunteers and generalized ataxia, dizziness and unco-ordination resulted.

Such relationships between the cervical spine function, lower limbs, and posture emphasize the importance of changes in somatic afferent input into long loop reflexes. Spinal manual therapy of cervical muscles and joints may affect these reflexes to demonstrate changes in ROM, and ultimately in total body co-ordination.

Another explanation of the effects noted involves a dural mechanism. Spinal dura forms a loose sheath around the spinal cord. The dura attaches to the circumference of the foramen magnum and the posterior
aspect of the vertebral bodies of C1 and C2. There are also secondary attachments by fibrous slips to the posterior longitudinal ligament (PLL), especially in the lower lumbar spine. At the second sacral tubercle, the subdural space ends and the dura extends as the filum terminale to end at the coccyx. Laterally, the dura engulfs the existing spinal nerve roots at the level of the intervertebral foramen (Warwick & Williams 1973). Obstruction to movement of the dura at these sites can potentially affect the ROM available to the lower limb as it tensions the peripheral nerve roots in movements such as straight leg raising.

There are three areas of the spine where the dura is tethered to the bony canal, and these are called tension sites. The sites are located at C6, T6, and L4 (Butler 1991). The sites limit the dural movement between sites so that the dura does not float freely through the vertebral canal where it may be prone to injury by bony abutment. This tethering provides stability to spinal cord. One of the functions of dural tissue is to adapt to changing lengths of the vertebral canal during movement (Butler 1991). In the normal spine ie. without degenerative change or segmental dysfunction, the tension sites limit the range of motion or adaptive change of length of the dura (Hartley-O'Brien 1980, Siqueirria et al 1983). However this normal motion does not have an effect on limiting normal range of motion.

Parke and Watanabe (1990) showed that in a degenerated spine the dura can become adherent to opposing structures, resulting in adhesion formation. This may limit function of the dura and cause excessive stress in areas of the dura such that stretch must be obtained by increased length of the dural tissue beyond its limit of tension.

Another untested theory suggests that an increased range of motion of basic SLR can be achieved by a specific suboccipital muscle release via mechanism of dural stretch (Butler 1991). The sub-occipital muscles attach from SP and TP of C2 to the TP of C1 and the superior nuchal line of the occipital bone (De Jong et al 1977). The suboccipital muscles are made up of four muscles. The rectus capitus posterior major originates from the spinous process of the axis and inserts on the inferior nuchal line of the occiput. The second muscle of the four is the rectus capitus posterior minor. This muscle originates
on the tubercle on the posterior arch of the atlas and inserts on the inferior nuchal line and the occiput next to it. The third muscle of the four is the obliquus capitis inferior which originates on the apex of the spine of the axis and inserts on the transverse process of the atlas. The fourth muscle is the obliquus capitis superior which originates on the transverse process of the atlas and inserts on the occipital bone between the superior and inferior nuchal lines of the occiput (Warwick & Williams 1973).

A specific PNF muscle release applied to the suboccipital muscles initiates inhibitory reflexes relaxing the agonists, causing a relaxation of the suboccipital muscles. In a spine with upper cervical dysfunction, such a change may result in the limitation of dural function and the adaptability of movement due to the fixation of segments to which the sub-occipital muscles attach. Recent work by Hack and coworkers provides evidence for a direct link between a cervical extensor muscle (rectus capitus posterior minor) and the dura mater further strengthening this relationship (Hack et al 1995). The increased movement via a release of the attaching muscles is believed to cause an increased length of dura, compared to that of a dysfunctional spine therefore increasing the ROM available to the lower limb.

However, due to the anatomy of the dura and the dural attachments in a normal functioning spine, this motion should be limited via the tension sites. Therefore in a spine with segmental dysfunction the dura is limited due to sites of adhesion that are not found in a normal functioning spine; this can decrease the overall dural movement available. According to Butler, this immobility of neural tissue (including the dura) can lead to the production of symptoms distal to the site of impingement, and produce symptoms that are similar to many atypical somatic pain referrals (Butler 1991). The effect of neural tension on clinical pain syndromes is an interesting area of research that is currently undergoing considerable investigation. Another study is currently underway by the authors to investigate the effects of an upper cervical manipulation on the SLR using methodology similar to the current study.
Conclusion

This experiment tested a sub-occipital PNF procedure and a hamstring PNF procedure as measured by the SLR in flexion. Of the two experimental procedures, only the suboccipital PNF procedure showed a statistically significant increase at the p<0.05 level.

These results suggest that manual therapy of the neck may have a role to play in the treatment of extra-spinal lower limb musculoskeletal conditions. Further studies are required to determine if this curiosity is long term in nature, is additive with other treatments, and whether it has a role in the therapy delivered to dysfunction of the peripheral sites.

Acknowledgment

This study was supported by a grant from the Australian Spinal Research Foundation.
Chapter Seven:

Study Five

Strength change of quadriceps femoris following a single manipulation of the l3/4 vertebral motion segment: a preliminary investigation.
Abstract

Objectives
The purpose of this study was to investigate if a manipulation to the L3/4 motion segment of healthy individuals would effect the strength of the homolateral quadriceps muscle tested post manipulation.

Design & Setting
Clinical cohort study performed at the Macquarie University Centre for Chiropractic Outpatient Clinic

Method
Subjects underwent a simulated manipulation in the lumbar roll position. After these procedures all subjects were required to perform under controlled conditions a unilateral isometric maximal contraction of the quadriceps femoris muscle. A force transducer was used to provide a digital measurement of the force of contraction of the quadriceps femoris.

Sample
30 randomly allocated university students aged between 18 and 34 years.

Results
The study found that in an asymptomatic student population receiving a manipulation to the L3/4 motion segment that an overall statistically significant short term increase in quadriceps femoris muscle strength was observed when compared to a control group.

Conclusion
This establishes a relationship between the short term effects of a manipulation and the modulation of muscle strength, and supports anecdotal claims. Discussion is undertaken to describe further studies that can be performed to provide information on the way in which this relationship could possibly benefit sporting populations and rehabilitation therapists.

Key Words
Chiropractic, Manipulation, Lumbar, Quadriceps, Strength, Rehabilitation, Sport, Exercise, Training.
Introduction

Muscle weakness or muscle imbalances are characteristic of many neuromuscululoskeletal conditions. Deficits in strength may be due to many factors including aberrant neural involvement, fatigue, pain, strength weakness, or disease atrophy (Kendall et al 1993). Scientific knowledge of the effects of spinal manipulative therapy on muscle strength is absent, resulting in a restricted basis for therapy and treatment. It is known that neural integrity is vital to muscle function, yet the contribution, if any, of manipulation to muscle function has received little coverage even though some claims exists that suggests manipulation modulates neural activity (Vernon 1995).

The quadriceps femoris group receives its innervation from the spinal segments L 2,3 and 4. The nerve roots from these segments form the femoral nerve. Of these segments L3 is recognised as the main segmental supply (Moore 1985). The L3 nerve roots pass out of the central canal of the spinal column through the intervertebral foramina formed by the L3 and L4 vertebrae before joining the lumbar plexus on their respective sides (Moore 1985). I proposed that by adjusting the L3/4 motion segment, the L3 spinal segment and/or nerve roots would be affected altering quadriceps femoris function.

Skeletal muscle is made up of a series of many smaller functional motor units. These motor units in turn consist of muscle fibres which receive their innervation collectively from a single lower motor neurone emanating from the spinal cord. The strength or force of contraction of skeletal muscle depends mostly upon the number and size of the motor units recruited by a stimulus, and the frequency of action potentials to that motor unit and hence the rate at which they are activated (Schauff et al 1990).

The pattern of motor unit firing often distinguishes specific motor performance. There are two types of firing patterns. Synchronous firing occurs when motor units are recruited simultaneously and is common in power or strength events such as weight lifting and weight training. Asynchronous firing occurs when some units fire while others recover, and is common in endurance performance. Synchronous firing
allows a large force to be generated quickly, predominantly through the stimulation of fast twitch fibres (Binder-Macleod & McLaughlin 1997).

Synchronous firing of the muscle fibre has the potential to increase the motor output significantly (Binder-MacLeod & McLaughlin 1997). Recent hypotheses allude to the possibility of synchronous oscillation of the corticospinal tract being able to effect greater motor output by a more efficient recruitment of motor neurones than that possible with asynchronous firing rates alone (Baker et al 1999, Hari & Salenius 1999).

However this leaves the power or strength athlete prone to fatigue. Asynchronous firing, in contrast, stimulates the slow twitch fibres which are fatigue resistant. Asynchronous firing also allows a period of recuperation further resisting fatigue (McArdle et al 1986). Synchronous but oscillating firing offers the potential to more efficiently control contraction and reduce fatigue (Conway et al 1995).

The motor neurones that supply the motor units have many synaptic inputs within the spinal cord. Most inputs are from spinal interneurones (both excitatory and inhibitory) making up the interneuronal pool, while only a few inputs are from cerebral motor centres. All of these inputs can be responsible for the activation of the motor units (Schauff et al 1990).

The recruitment of motor units occurs in a hierarchical order, from smallest to largest. Small motor units are innervated by smaller neurones which have a low threshold and are easily activated by low stimuli, whereas the larger motor neurones require greater amounts of stimulation and innervate larger motor units (Gollnick & Hodgson 1986, Gollnick et al 1974). The result is that when larger forces are required of the muscle, progressively larger motor units are recruited. An impairment to either perceive the need for increased force or to recruit motor units may result in a decreased maximal force output (Astrand & Rodahl 1977).

Recent commentary by Patterson (1993) suggests the importance of the spinal cord segmental neurology, as well as inflammation in a related area, in causing and sustaining a level of hyper excitability in the spinal
cord. Consequently, this hyper activity could disrupt the normal muscle function. The description of hyper excitability used by Patterson is similar to the concept of facilitation (associated with the vertebral subluxation) that others have discussed previously (Dishman 1988, Gatterman 1995).

According to Patterson, these alterations can bring about both short term and relatively permanent changes in the neural characteristics of the cord and can also result in changes to peripheral structures.

Schmidt has reported changes that occur in the peripheral sensory receptors of the musculoskeletal system when inflammation occurs. When stimuli to these receptors occurs, such as an injury, the peripheral nerves convey the impulses to the spinal cord where they may be blocked from being sent to the brain (Schmidt 1992).

On their pathway to the spinal cord the impulses travelling through the fibres cause the release of peptides from the peripheral nerve terminals. These substances cause a cascade of events that results in sympathetic post ganglionic fibres being activated, ultimately resulting in inflammation. Once inflamed, the threshold for stimulation of the nociceptors decreases dramatically and when further stimulation to the area occurs there is an increase in the number of nociceptors activated (Schmidt 1992). This illustrates the increase in neural activity to the spinal cord, and hence in the interneuronal pool, that occurs when an injury is sustained to a joint or surrounding soft tissue.

The alterations that occur within the spinal cord manifest themselves as changes in spinal excitability independent of influences from higher centres (Patterson 1993). These processes occur at the cellular level within the neurones of the spinal cord and last varying times and have the potential to alter the functional capacity of the individual. The processes are referred to by Patterson (1993) as habituation, sensitisation, long term sensitisation and fixation.

Habituation is the progressive decrease in spinal excitability in response to a constant, repeated stimuli. Sensitisation is the opposite to habituation and occurs to a stronger stimuli and only lasts seconds to a few minutes. When sensitisation occurs repeatedly it results in a long
term sensitisation which may last hours. Fixation on the other hand is a form of alteration of spinal excitability where sustained stimulation at a high intensity sees a prolonged increase of spinal activity. Levels required for fixation to occur are seen with the inflammation process, which perpetuates the increased nociceptor activity which in turn stimulates the spinal cord at a sustained high intensity (Patterson 1993). Fixation as described here is analogous to the facilitated segment described by chiropractors and treated by them using manipulative techniques (Ward 1981).

When injury occurs to the musculoskeletal system, it is hypothesised that inputs from nociceptors to the spinal cord will, in most cases, produce habituation in the spinal circuits. However once the afferent activity reaches a certain level or intensity, sensitisation occurs and the interneurone pool produces more and more output. This results in the brain, muscles and structures associated with that segment becoming activated. If inflammation occurs, the increased sensory input to the segment may allow fixation or facilitation to occur. This hyper-excitable interneuronal pool is said to cause an increase in the output to muscles, which in turn causes an increase in their tone in an attempt to splint the affected area (Patterson 1993).

Once the cycle reaches this stage, normal movements greatly increase the input to the affected spinal centres. This is because movement occurring in association with the decreased threshold of the nociceptors will cause the nociceptors in the joints and surrounding soft tissue of the injured area to be stimulated much more readily. Once this cycle of hyper excitability or facilitation is in place, it has the possibility of causing disruption to normal body function, health, and muscle function.

As an illustration of these points, Anderson (1994), in an unrelated study to Patterson (1993), reported the presence of muscular non development in an amateur bodybuilder. He proposed that on the patient’s physical findings, which included CT scans, MRI, Dynamometer, and normal orthopaedic and neurological examinations, that the patient had muscular non-development in the left upper extremity. He hypothesised that the presence of a spinal dysfunction in the lower cervical spine caused the symptoms. However it is entirely
possible that the subject in question presented with muscle wasting secondary to disuse and painful neglect, as the subject also presented to the practitioner with sub acromial bursitis, a painful movement based injury common to bodybuilders and weight lifters. It is possible that successful treatment of the underlying bursitis allowed the return to normal function thereby hastening the return of the normal appearance.

The patient showed marked asymmetrical muscle strength and size. Factors which may have caused this phenomenon such as improper training and hand dominance were ruled out by Anderson (1994) by having the treating doctor and highly qualified athletic trainers observing the subject training on numerous occasions. The patient responded well to manipulations and treatment of the subacromial bursitis as well as to rehabilitation of the areas involved. Response was evidenced by muscle strength and size becoming more symmetrical as measured by changes in grip strength and by visualisation.

Although only a case study, Anderson's report (1994) was significant because it demonstrated a patient with the suggested criteria for a facilitated segment as outlined by Patterson (1993). Also of importance was the successful outcome of treatment of the weak and less developed musculature by a spinal manipulative approach.

Removal of motion restrictions by causing movement between two consecutive vertebra is generally thought to have an effect by reducing stresses on the facet joint and joint capsule, spinal ligaments, intervertebral disc and surrounding musculature therefore reducing reactive proprioceptive, nociceptive, and mechanical stimuli bombardment from these structures to the associated spinal segments (Wyke 1987). This bombardment of the associated spinal segments has been implicated as an initial cause or contributing factor to the vertebral subluxation complex (Araki et al 1984, Sato & Swenson 1984, Isa et al 1985, Kurosawa et al 1987).

If spinal cord hyper-excitability is the cause of altered physiological processes, ie muscle function and strength, then reducing or removing the hyper-excitability would reduce or correct the aberrant physiological processes affecting muscle function and strength (Dubnar & Ruda 1992, McMahon et al 1993, Eide 1998). According to
Chiropractic literature suggests that a manipulation can reduce spinal cord hyper-excitability (Haldeman 1992, Rydevik 1992). If so, then the effects of a manipulation should be to reduce or correct the aberrant physiological processes that are occurring, which in turn would allow muscle function to normalise.

Central excitability can be triggered by noxious stimuli (McMahon et al. 1993). The activation of the C fibres with strong chemical, mechanical or thermal stimuli can produce painful sensations that are enhanced during pathological states such as inflammation (Urban et al. 1994). Treatment can alleviate these sensations and act to improve spinal spasticity (Goulet et al. 1996). Through the action of mapping the central nervous system output in those with spinal cord injury (Eide 1998), it has been shown that the action of the central cord is enhanced by the action of the upper motor neurones (Mayer 1997).

As muscle function and specifically strength are affected by spinal cord hyper-excitability, they are also effectors of changes to that structure. By testing muscle strength before and after a manipulative procedure said to be able to normalise a dysfunctional state, a change in muscle strength may be expected.

A study by Bonci & Ratcliff (1990), observed the strength of the biceps brachii muscle (measured bilaterally by a digital myograph). This study failed to demonstrate a statistically significant change in biceps muscle strength after a spinal manipulation of C4/5. Bonci and Ratcliff (1990) suggested that further studies were necessary before a relationship between muscle strength and manipulation could be discounted. They also raised problems which may have accounted for the results that they obtained.

Isometric strength testing existed as a possible source of problems. Strength of the muscle was only measured at one joint angle and the strength values gave no indication of a possible change in strength throughout the entire joint range of motion. To try to overcome this, the position of maximal torque for the quadriceps femoris was used in this study for isometric muscle strength testing. This position, as determined by Fischer, Pendergast and Calkins (1990), is with hip extension at 180 degrees and knee flexion at 90 degrees. It was hoped
that if any change was present, whether an increase or a decrease, this position would show it.

Any change that occurred had to be solely attributable to the manipulation alone and so other factors such as muscle fatigue needed to be addressed. The problem of fatigue was overcome by having the subject perform a maximal contraction for only 5 seconds when tested and leaving 30 seconds between contractions according to an accepted protocol (Rodriquez et al 1991).

Bonci & Ratcliff (1990) tested musculature at 60 sec after the delivery of a manipulation and found no statistically significant change in strength. It is possible that any measurable change due to the manipulation could have manifested itself and resolved by the end of the 60 sec period. Such was seen in Patterson's (1993) model of sensitisation in which the effects of sensitisation lasts from 30 second to a few minutes.

This study proposed to duplicate the study by Bonci and Ratcliff (1990) by testing muscle strength at 1 minute. The present study did however choose a large predominantly fast twitch lower limb muscle rather than a smaller upper limb muscle. It was also proposed to retest at 1 minute after the manipulation to determine if any effect existed at the later time as a result of the manipulation.

Thus it was the aim overall to demonstrate a change in muscle strength of a peripheral predominantly type II muscle such as the quadriceps by manipulating the spinal vertebra (L3/4) relevant to the neuromere of supply of that muscle.
Methods And Materials

1. Subject Recruitment
Chiropractic students from the Macquarie University, Centre for Chiropractic, Sydney NSW who freely volunteered, met the inclusion criteria, and who read and signed an informed consent form were subjects for this study. This study had received approval by the Macquarie University and The University of Wollongong Human Ethics committees prior to experimentation.

2. Subject Sampling
15 experimental and 15 non-experimental control subjects were recruited. Both groups were matched for sex and age.

Subjects were chosen according to inclusion criteria. These criteria required subjects to have had recent lumbar X-rays (ie within last 12 months) to rule out pathology which would contraindicate a manipulation and have no history of recently (ie less than 1 month) diagnosed lumbar disc herniation, sprain, or other lumbar injury which might be aggravated by participation. The cohort chosen to act as subjects in this study were required by regulation to have spinal radiographs prior to participation in technique classes. As such all subjects received spinal radiographs in the previous 12 months. Subjects were also screened for any knee or hip injuries which may have affected their ability to perform the strength test. Subjects were over 18 years of age and also under 40 to eliminate the likelihood of degenerative joint disease complications. 30 healthy students were recruited and were randomly assigned to either the experimental or control groups by drawing a number from a sealed container.

3. Procedures
(a) WARM-UP: To prevent possible muscle strain, the same warm-up routine was performed by each subject. This involved cycling for 5 minutes on a cycle ergometer set at a light resistance (weight of the crank apparatus without any further loading of any type) and maintaining a cadence of 75 r.p.m (Golden & Dudley 1992).
(b) SUB-MAXIMAL CONDITIONING: A sub-maximal isometric contraction was performed to familiarise and pre-condition the quadriceps femoris muscle. This was performed immediately after the warm-up period.

The position of maximal torque for the quadriceps as determined by Fischer, Pendergast, and Calkins (1990) was with hip flexion at 180 degrees and knee flexion at 90 degrees. For the sub maximal and later contractions the following procedure was used.

The subject was supine (with hip and knees at the specified angles) on a padded treatment table. Straps across the shoulders and pelvis at the level of the anterior superior iliac spine (ASIS) and coracoid process on each subject and the instruction to hold onto the side of the couch prevented the subject from moving unnecessarily and possibly recruiting muscles other than the quadriceps femoris.

To further ensure testing consistency, the force transducer was positioned so that it was at the same anatomical site for each subject. The position chosen was in the groove anterior to the talotibial joint. This ensured internal consistency between subjects so that average group data could be used in any statistical analysis of the results. Strength was measured by a hand held force transducer over a contraction time of five seconds. The elbow and upper arm of the co-investigator holding the force transducer by hand was firmly braced against a solid wall. Another tester also stabilised the subject's leg from the side to prevent the leg from losing contact with the force transducer. The couch was stabilised from the other end to prevent movement of the couch.

In this equipment familiarisation and muscle pre-conditioning stage, the combined sub maximal contraction was held for 5 seconds.

(c) PRE-TEST: After a rest of 30 seconds (to ensure the muscle adequate time to recover), the first of two maximal isometric contractions were performed, and the force measured. A rest period of 30 seconds was then followed by the second contraction and measurement. The average of the two measurements was recorded as the pre-test measurement.
During each 5 second contraction, each subject was encouraged verbally to perform at their best by one of the assistants. The encouragement and motivation was performed by voice command by the same person at the same high intensity throughout the experiment for both the experimental and control group subjects.

(d) MANIPULATION: An experienced and registered chiropractor performed all the manipulations. Only one adjutive technique was employed for each group so as to further reduce the variables. Experimental subjects were placed in a basic lumbar roll (BLR) position and a BLR Anterior/Inferior thrust to the right side of the L3/4 motion segment was performed. All except four manipulations resulted in cavitations at the site of application. The manipulation chosen has been described by Byfield (1991) and Haldeman and Rubinstein (1993).

Placebo / control subjects were subjected to a simulated manipulation to the left side of the L3/4 motion segment whilst in the lumbar roll position. The sham involved a general non-specific, non-cavitating impulse into the soft tissues to help address the expectation of the subject that they were to receive a form of hands on procedure.

(e) POST TESTS: Following a period of 20 seconds after the manipulation, another series of two maximal isometric contractions were performed (30 seconds between each contraction) and the average group data recorded as the strength at 60 seconds post treatment.

Data Analysis
Means and standard deviations for the pretest, post test, and gain scores of each group were calculated. To determine whether a significant difference existed between the mean gain scores of each group, a one-way analysis of variance was utilised at a 0.05 alpha level. After obtaining a significant F value, Newman-Keuls post hoc comparisons were conducted to specify how the groups differed from each other.
Results

Calculated means and standard errors of the means for group pretest, posttest, and change scores are presented in Table 5.1. This table indicates an average reduction (2.06kg) in the post intervention performance of the isometric strength test in the control group. In contrast, an increase (3.03kg) was noted in the post intervention isometric strength test in the experimental (manipulation) group. A one-way analysis of variance of the change scores, as shown in Table 5.2, revealed a significant difference between the groups. A Newman-Keuls post hoc analysis showed that the manipulation group was significantly different to the placebo / control group.

Table 7.1. Change in means and standard errors of angle of isometric strength test value at 180° of hip extension and 90° of knee flexion for groups (in kilograms).

<table>
<thead>
<tr>
<th>Group</th>
<th>Scores</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manipulation n=15</td>
<td>Mean</td>
<td>58.1</td>
<td>61.1</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Standard Error</td>
<td>(5.4)</td>
<td>(4.4)</td>
<td>(1.5)</td>
</tr>
<tr>
<td>placebo / control n=15</td>
<td>Mean</td>
<td>57.2</td>
<td>55.1</td>
<td>-2.1</td>
</tr>
<tr>
<td></td>
<td>Standard Error</td>
<td>(4.6)</td>
<td>(4.3)</td>
<td>(1.7)</td>
</tr>
</tbody>
</table>

Table 7.2. One way analysis of variance of change in treatment scores

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>194.8</td>
<td>1</td>
<td>194.8</td>
<td>4.91*</td>
</tr>
<tr>
<td>Error</td>
<td>1110.1</td>
<td>28</td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1304.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05
### Table 7.3. One way analysis of variance of difference in pre-test groups

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>0.02&lt;sup&gt;^&lt;/sup&gt;</td>
</tr>
<tr>
<td>Error</td>
<td>10443</td>
<td>28</td>
<td>373</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10449</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup><small>^ p>0.05</small></sup>
Discussion

The results of the experimental group demonstrated a progressive short term strength increase with repeated tests. Using the same methodology, the results of the control group demonstrates a progressive strength decrease, or fatigue with repeated tests (Table 5.3). There was an overall statistically significant change between the experimental and control groups (Table 5.4). In contrast, there was no significant difference in group means at the start of experimentation (Table 5.1). This shows that in an asymptomatic student population a manipulation to the L3/4 motion segment resulted in a change in quadriceps femoris muscle strength. An overall increase in strength of approximately 4.6 % post manipulation was recorded. There was an overall decrease of 2.0 % in muscle strength in the placebo / control group. This change could be attributed to fatigue caused by repeated maximum voluntary contractions. At 1 minute there was a 5.2% increase in muscle strength that was statistically significant (p=0.035). A factor to be considered in the variability in the determination of voluntary contraction. As such, any determination of percentage of mean voluntary contraction would be hazardous and ill advised (Peach et al 1998).

Although both the control and experimental groups were similarly matched, only the control group suffered from the effects of fatigue. It would be reasonable to expect that fatigue also took place in the experimental group. If this was so, then the changes in strength that occurred in the experimental group would have been even greater as they overcame the effects of fatigue. Despite these likely changes, the experimental group subjects still showed an average increase in strength. In other words, if the effects of fatigue are seen in the control group, ie a decrease in strength of 2.0 %, then the overall difference, once the effects of fatigue are removed, would be a 6.6 % improvement in strength overall in the experimental group. Thus the changes demonstrated after the manipulation could be the result of overcoming fatigue, and/or the modulation of muscle strength.

The proposed mechanisms for the observed changes in the experimental group are based on the known alterations that occur within the spinal cord that manifest themselves as changes in spinal excitability as
described McMahon et al (1993), Urban et al (1994) and Patterson (1993). These processes occur at the cellular level within the spinal cord, last for varying lengths of times, and have the potential to alter the functional capacity of the individual (Patterson 1993). This is especially true of the cellular neuropeptides involved in chemical mediation of nociceptive processing within the spinal cord (Dubner & Ruda 1992).

According to the clinical literature (Haldeman 1992, Rydevik 1992) a manipulation can reduce or correct spinal cord hyper excitability. Rydevik (1992) suggests that the manipulation restores the motion to the joint involved and relieves soft tissue tensions. It is suggested from Rydevik's work (1992) that the manipulation promotes increased movement of fluids and thus normalises tissue chemistry and respiration to the affected areas. Patterson (1993) believes these phenomena also reduce afferent activity to the hyper-excitable spinal segment, allowing it to normalise. If so, the effect of a manipulation should be to reduce the effects of long term sensitisation processes. This would allow muscle function to normalise and produce a change in muscle strength. Sensitisation is only a short term spinal hyper-excitability (lasting a few seconds to a few minutes) and only becomes relevant when discussing the more immediate effects of an manipulation.

Although the subjects used in this experiment were healthy asymptomatic students, they could still have the processes described by Patterson (1993) taking place within their spinal segments. If this was the case, a manipulation could reduce the afferent input to the hyper-excitable spinal segment in the ways described earlier. The type of process and the length of time it had been present would determine how immediate the effects of the manipulation would be. Any processes that were present in the asymptomatic student subjects would be more likely to have only been present for a short time. Therefore the effects of the manipulation on the aforementioned processes may occur more readily in such a group rather than in the long standing dysfunction that may be present in the wider population. Further study of the differences between these groups is recommended because it may show that the two groups respond differently to the same stimuli in treatment.
These results demonstrate that there is a link between spinal manipulation and the strength of a peripheral muscle supplied by the neuromere that received the manipulation. Bonci and Ratcliff (1990) may not have found a similar change at 1 minute as his sample was taken from the general population and the change may have taken longer due to the chronicity of the conditions they encountered.

Conversely, it may be said that the use of chiropractic students may have precipitated the results due to their knowledge of the chiropractic procedure. Although a limitation of the study design, I attempted to minimise this variable by choosing junior / inexperienced students utilising a sham manipulation that closely resembled the manipulative procedure, and a 'vibrant' verbal encouragement by one of the assistant researchers during the strength testing sessions.

Manipulation may have effected the segmental hyper-excitability by directly modulating the interneuronal pool. This study hypothesises that this sensitisation could change muscle strength in the following manner.

When the subject contracted the quadriceps muscles the subject produced a central stimulus from the motor cortex which descends to the required spinal levels (Barr & Kiernan 1988). If the interneuronal pool activity at that spinal level is already hyper-excitable, the central stimulus compounds with the activity already present in the interneuronal pool. The resulting hyper-stimulus that reached the motor fibres would be larger than the original central stimulus. As higher potentials activate larger motor fibres which in turn innervate larger numbers of muscle fibres, this pre-stimulation or sensitisation of the interneuronal pool via the manipulation would lead to the activation of a greater number of muscle fibres. The result would be a stronger contraction for the same central stimulus.

I hypothesise that once the sensitisation was set up, it would tend to cause hyper-excitability to rise to a peak and then level off. This process could occur with the resultant peak being reached at a time shortly after treatment. To determine if this was the mechanism behind the change, further studies could measure strength at later times. Measuring at later times would also be beneficial if the sustainability of the change is to be investigated. The use of indwelling electromyography to measure
muscular activity or nerve conduction studies in addition to the gross strength changes would more clearly define any changes that were taking place. Repeat studies are required investigating the electromyographic parameters associated with muscle change. An ongoing problem of EMG analysis is that movement of the electrode creates artifacts on the electromyogram (Kraft 1990). Manipulation by definition is a high velocity thrust often positioning the patient in such a way as to render an EMG analysis ineffective or inappropriate.

In addition, there are known problems associated with the qualitative use of EMG rather than its quantitative use (Peach et al 1998). The combination of these effects makes the use of EMG particularly problematic for manipulation based studies.

When the study is replicated, and the mechanism determined, many areas of health care could be the beneficiaries. It is intuitive that a 5% change in strength would be extremely useful if strength and power athletes, as it would be, for the management of muscle weakness disorders, and rehabilitation of muscle injury.

Muscle rehabilitation may be enhanced by the use of manipulations in the following manner. A torn or injured muscle may precipitate substantial localised inflammation which according to Schmidt (1992) may lead to increased receptor activity. It also can lead to increased cellular activity within the cord (Dubner & Ruda 1992). This in turn leading to processes which alter spinal excitability resulting in muscle weakness. The use of manipulation to sensitise the cord of subjects with chronic conditions could allow a decrease in the weakness and wasting often accompanying such chronicity. Removing this common sequelae of injury could allow an accelerated passage through rehabilitation programs improving functional capacity, increasing the speed of resolution, and decreasing the concomitant cost of rehabilitation. Whilst this view remains highly speculative extrapolation, early evidence in support is emerging. Further experimentation may support or refute such a scenario.

Power and strength athletes, such as sprinters and weight lifters, could also benefit from this effect of a manipulation. As well as having a quicker recovery from muscle injury by rehabilitating in the method
just described, the potential higher intensity that could be achieved in normal training could allow a more efficient and productive training session.

Further, and probably of greater interest to the athletes, the manipulation could also be utilised in enhancing performance on the day of competition. The possible increase in muscle strength via a greater state of arousal available from a manipulation could provide the athlete with a temporary increase in power and strength. Whilst it is acknowledged that a maximum contraction is seldom delivered by an increased state of arousal (Gandevia & McKenzie 1988), they are possible in selected individuals who are highly motivated and or highly aroused.

Any discussion of strength changes due to therapy or training should consider the considerable input of early changes in strength profile being largely based on neural adaptations (Hakkinen et al 1985), with later changes (after six weeks) occurring with hypertrophic changes in the muscle (Sale 1987).

Given the short term nature of the strength improvement noted in this study, the mechanism would apparently likely fall into the neural category. Gandevia & McCloskey (1978) established in early work that motor controls could be crudely interpreted at the level of the spinal cord. Jones (1995) elaborated on this theme and demonstrated that the perceived magnitude of the force was also a central phenomenon. In another study it was demonstrated that somatic sensations (as that likely to be stimulated by manual therapy) contribute to the sensation of motor output (Sanes & Shadmehr 1995), and the sense of effort (perception) is determined from central sources operating across the motor system (Somodi et al 1995). From these studies it is likely that the mechanism of strength change occurs via a neural mechanism and involves the stimulation of various somatic receptors known to be stimulated by manipulation (Korr 1975).

For those athletes that perform feats of strength or power over a short period of time (such as Olympic weight lifters, sprinters, one kilometre time trial cyclists), a temporary improvement could increase their effectiveness at competition. More research into the sustainability of
change could enable the maximum beneficial effects over the greatest possible time to be controlled.

The use of manipulations to effect muscle strength in neurological weakening or wasting disorders could be beneficial for the overall management and rehabilitation of these disorders. If muscle strength can be altered it could prevent, minimise or at the very least delay wasting and encourage neural integrity through stimulation of the affected structures. It could also be effective for muscle retraining by stimulating the involved structures allowing a more responsive reaction to the same central stimulus.

The possibilities of a controllable change in muscle strength through the use of manipulations should make it clear that this relationship is an important one and has wide reaching benefits for the community. This study has demonstrated that a relationship exists, in contrast to the previous study by Bonci et al (1990).

However there were limitations in the methodology that should be recognised and remedied with further investigations. The student population could be viewed as a source of error. This error was introduced as students were more likely to know the difference between an effective manipulation and a sham manipulation. An attempt was made to overcome this by using a manipulative style with which the students were not familiar, and a practitioner and subject position that was the same in both the control and experimental groups.

As the force transducer was hand held, the force transducer may have provided a source of error in measurement as it was potentially prone to movement. Attempts were made to ensure little or no movement occurred, but further studies should utilise a mechanically braced force transducer to further reduce this error in measurement if one exists at all.

Whilst it is tenuous to compare changes in isometric strength to those measured isokinetically at different speeds, and to real life events incorporating rotary kinetics superior to any measurement device currently being used, it is a starting point worth noting. Future studies that utilise strength measurement that more closely approximate human
activity are called for, as it is known that strength changes are specific
to joint angle, speed and task (Wrigley & Grant 1995). On the "job"
activity regimes therefore would perhaps show more distinct changes.

Although there were inconsistencies in the methodology such as those
induced by the possibility of fatigue and a training effect, there was a
change which occurred in the experimental group that cannot be
entirely attributed to error. These inconsistencies may have affected the
magnitude of the change but not the significance of the result.
Addressing these variables with a larger scale trial could more
rigorously assess the strength changes associated with a lumbar
manipulation.
Conclusion

This study found that in an asymptomatic student population a manipulation to the L3/4 motion segment resulted in a statistically significant short term increase in quadriceps femoris muscle strength. This change could beneficially impact on rehabilitation protocols and the performance of strength athletes. I recommend that this study be followed by other more intensive and varied investigations to determine if the significance of the changes noted here are reproducible and significant in the health care and sports performance arenas.
Chapter Eight:

Discussion
Discussion

Manual therapy has been used for centuries (Haldeman 1992). Despite this use, it remains patently clear that much of what has been administered in the name of treatment for low back, pelvis and hip joint related conditions by doctors, physiotherapists, chiropractors and other therapists remain untested (Bogduk & Mercer 1995). With this noted shortcoming been heralded by the scientific community, there has developed a strong need to validate the use of techniques and treatments in the day to day running of musculoskeletal medicine. This thesis attempted to investigate in a controlled fashion, several treatments and approaches used by many in the family of musculoskeletal and manual medicine (Gatterman 1995, Grieve 1978, Greenman 1989).

The studies conducted in the this thesis utilised procedures most commonly used by practitioners in the field of manual medicine, with a particular focus being given to the therapy of manipulation used primarily by chiropractors and osteopaths. Whilst focus was given to manipulative perturbations, several experiments also investigated the effects of various stretching procedures common in the profession of physiotherapy (and to a lesser extent the chiropractic and osteopathic professions).

This approach to the investigation of these treatments attempted to answer important questions aimed at testing the validity of the commonly used procedures in a clinical setting. This setting was utilised to investigate both pain and non-pain subjects in either a clinical or experimental context. Such an approach is consistent with the tradition of the finest clinical trials (Meade et al 1995), and a requirement being requested of all treatments in medicine today (Bogduk & Mercer 1995). The results of the five studies in this thesis are an important contribution to the manual medicine literature from a singular or group perspective. Indirect evidence of this fact is provided by the many calls for reprints of published articles received from medical, physiotherapy, osteopathy and chiropractic researchers around the world (personal communication), and the acceptance of these experiments as podium presentations at public health and manual medicine conferences.

Several of the studies investigated the effect of treatment on the function of the hip. These studies investigated the effect of hip, neck, lumbar,
sacroiliac and knee treatments on the hip. In addition, one of the studies investigated the effect of a hip treatment on the lower back. This additional study was conducted on the basis that management of the back injury can also incorporate treatment to the hamstring and the hip, and these approaches are used in the manual therapy and are often proposed as a sound approach to follow when managing disorders of the hip (Vleeming et al 1990 a,b).

The first study began by testing the effect of a hip treatment on the function and pain status of chronic low back pain sufferers. The study commenced by testing the research question: does a hip treatment improve low back pain status", as many researchers have either implied (Stokes & Abery 1980, Gajdosik et al 1990, Gajdosik et al 1993) or stated (McClure et al 1997, Snijders et al 1993, Knolmayer et al 1997).

Whilst the mechanism for this effect was said to involve the dynamic interaction between the hip, pelvis and lumbar spine (Adams et al 1986, Stokes & Abery 1980, Gracovetsky et al 1990, Sihvonen et al 1991, Gajdosik et al 1993), there was conflicting evidence in the literature to support the association between low back pain and restricted hip function usually manifest through tight hip extensors including the gluteals (Leinonen et al 2000) and the hamstrings (McClure et al 1997, Knolmayer et al 1997). The evidence of the widespread belief by the medical community of the importance of the hamstrings in the generation of low back pain can be illustrated by the surgical procedure that is sometimes performed to cut spastic hamstrings in select groups of low back pain sufferers (Angles et al 1997).

Some authors have suggested that the effect of hamstring tightness was a protective mechanism brought about by the homeostatic drive of the body to minimise pain and dysfunction, rather than a cause of the low back pain (Mellin 1988, van Wingerden et al 1995, Esola et al 1996). Evidence has been presented by some researchers that the interaction of the hip, pelvis and lumbar spine in flexion, often referred to as the lumbopelvic rhythm (Cailliet 1995), was actually unchanged in the presence of tight or loose hamstrings (Li et al 1996). Other research proposes that the lumbar range of motion does not correlate with hamstring tightness (Hellsing 1988).
Explanation of this curiosity came from work into the mechanism of such movements, when Esola and co workers (1996) using an EMG analysis demonstrated that forward bending (or toe touch testing) of flexion could be divided into three discrete sub sections (Esola et al 1996, McClure et al 1997). They provided explanation of the dynamic concept of the lumbopelvic rhythm by demonstrating that there were three component parts (an early, middle and late phase) of movement that made up the overall range of motion into flexion. They found that whilst an overall range of motion would usually remain unchanged in the presence of variables that would change hip tightness, one of more of the component phases of movement could alter significantly the function of the lumbopelvic and hip interaction.

In this three part model supported by (McClure et al 1997), the early range of motion was determined by a quantitative EMG analysis to be associated with the lumbar spine movement. The middle range of motion was associated with activity in both the hip and the lumbar spine musculature, and the late range of motion was associated with the hip musculature (Esola et al 1996). Based on similar work by (Nelson et al 1995, Shirado et al 1995) and the work of Vleeming and co workers (Vleeming et al 1989 a,b, Vleeming et al 1990 a,b), the effects noted by Esola et al (1996) could be the manifestation of the action of the thoracolumbar fascia and its ability to connect both anatomically and biomechanically the upper and lower limbs via the trunk.

One could hypothesize based on the above work that if the lumbar spine was to reduce in stability (perhaps through injury or inactivity associated with previous injury), the action of the thoracolumbar fascia through it is multiple attachments could act to tension the lumbar spine through its continuous connection of the sacroiliac and sacrotuberous ligaments and thence through to the long head of the biceps (Vleeming et al 1995). Therefore, by increasing the tone of this system via an increase in the neural output or the active controlled increase in the tonus of the hamstrings (measured as a loss of range of motion at the hip in flexion), such a system could act to decrease low back pain rather than increase it as some authors have suggested (Burgess-Limerick et al 1995).

Additionally, connective tissue changes occurring in injured muscle and muscle undergoing chronic disuse could also increase the non-contractile
stiffness of the lumbopelvic system and act to reduce concurrent low back pain by stabilising it by non-contractile mechanisms (Akeson et al 1986, Magnusson 1998).

However, alternate opinions about the role of the hamstring in low back function also occur frequently in the literature (Hellsing 1988, Gajdosik et al 1990, Gajdosik et al 1992). It is known that injury to the back can increase its stiffness (Porter & Wilkinson 1997). Injury to the hamstring can also increase its stiffness (Sullivan et al 1992). Both of these causes of lumbopelvic stiffness could result in a loss of the total range of motion. Evidence has been presented that hamstrings become more prone to injury and become stiffer following injury (Jonhagen et al 1994). Yet further research has demonstrated an increase in low back pain associated with a loss of flexibility, and whilst this evidence was an indirect association and not a prospective causal relationship, it remains clear that those with tighter hamstrings / hip joints have a greater frequency of low back pain (Stokes & Aberly 1980, Revel 1995, Mellin 1986, Mellin 1988).

The increase in the tightness of the lumbosacral structures and hip extensors raises the "general tightness" or tension often noted in low back pain sufferers (Vivian 1991). Should an individual with such tight structures attempt a quick movement generating large instantaneous forces at a region not able to adapt to them because of inflexibility (usually in lumbar flexion and rotation) it could be reasonably expected that such structures may be injured (Knolmayer et al 1997), a scenario that is most apparent with many who suffer low back pain (Vivian 1991). Therefore, tight musculature could be both protective (Snijders et al 1993, Vleeming et al 1989a) and causative of low back pain, at the same time (Esola et al 1996).

Further support for this position comes from work that has demonstrated that improving hip flexion flexibility by treating the hamstrings results in improved LBP (McClure et al 1997, Esola et al 1996). A result also noted in the first study conducted in this thesis (table 3.20). The first study supports this position with a significant statistical finding (p<0.05). However, it is likely that this result is weak evidence in support because the error associated with the measurement process could have accounted for some of the change (Hsieh et al 1983). Thus, in order to address this effect further, a study should be designed to address the issues of
mechanism and treatment concurrently in a large scale prospective clinical trial. A trial that would investigate the effects of treatment in chronic low back pain patients who share a similar history of pain and duration of symptoms profile. Unfortunately, such a study would likely require hospital outpatient support and would be potentially very expensive to run (Meade et al 1995). Such a study would be the logical successor to this investigation. It should investigate the ability to flex the lumbar spine and the hip in the standing position whilst concurrently utilising an EMG protocol to investigate the overall range of motion. From this protocol the determination of the relative contributing regions to the range of motion in those who are both with, and without pain, could be determined over a period of time. Such a study should also try to perform several tests of hip flexibility, or utilise one assessment throughout all parts of the investigation, as it is known that different assessment protocols could produce different results (Cameron et al 1994). Subjective questionnaire based assessment of pain and disability profile could accompany the objective tests to complement the clinical usefulness of such data. This study if attempted should look to include a control group with those not having a painful condition to evaluate if function differs between the groups when all other variables are kept constant.

The first four studies of this thesis investigated the effect of hip treatment on the hip and also investigated the effect of treatment of other joints on the hip. One study investigated the effect of a knee treatment on the hip range of motion and knee pain. As chronic osteoarthritis of the knee has the potential to chronically change the joint range of motion of the knee (Carr 1999), a population of chronic advanced OA sufferers was chosen to receive the treatment to their knees. The subjects were selected by predetermined criteria (Dieppe 1992, Dieppe et al 1993) that included loss of joint range of motion and loss of joint shape. A novel untested manual therapy protocol was used as the treatment. The results demonstrated that the new manual therapy procedure was able to reduce the knee pain during the two weeks of the trial (table 4.4), but it did not alter the range of hip motion (table 4.3). Range of motion of the knee was not tested on the basis that the joint structure of the knees was abnormal on x-ray, and therefore would be unlikely to cause any short term change in range of motion. A pilot study confirmed this effect so it was determined that placing subjects through the ordeal of further testing for no tangible benefit was unethical and therefore not performed.
The other studies attempted to compare the effect of cervical stretching, cervical manipulation, sacroiliac manipulation or a myofascial hip manipulation on the range of motion of the hip. Many studies have previously investigated manual therapy of the spine, but few studies other than those utilising stretching techniques have targeted the hip (Etnyre & Lee 1987).

The study that demonstrated no relationship between a treatment of the hip and changed range of motion of the spine (table 3.10), also demonstrated a significant improvement in hip range of motion with a PNF stretching technique (table 3.7), and a hip manipulation technique (table 3.7). The result achieved in this study with the stretching protocol is consistent with previous investigations on the effect of stretching on the hip joint (Etnyre & Lee 1987).

By contrast, an extensive search of the literature found no reference to studies investigating the effect of manipulation on the hip joint. So the significant improvement in hip range of motion in the short term in chronic low back pain sufferers remains a unique contribution to the literature in the area of manual medicine. Despite the statistical increase in range of motion, it was likely that most of the change was due to the error associated with the test / re-test assessment protocol (Hsieh et al 1983). Therefore, despite a positive finding, one must conclude that this study only provides some evidence that hip range of motion increases following a manipulative protocol applied to the hip. Further studies with greater emphasis on subject number and treatment number / duration are required.

Other studies within this thesis investigated the effect of manipulation of the cervical spine or the sacroiliac joint (chapter 5) on the range of motion of the hip. Once again, a review of the literature revealed no study that investigated the effects of manipulation of these regions on the function of the hip as often proposed by some therapists (DeJarnette 1972, Walther 1981, Plaugher 1993).

Therefore the results presented earlier of significant improvement to range of motion of the hip following cervical muscle stretching (table 6.2), and cervical manipulation (table 5.3) represent significant original
contributions to the literature (Pollard & Ward 1997, Pollard & Ward 1998). The improvement demonstrated is consistent with the findings of previous studies on stretching of the hip, and is of a greater magnitude than the results obtained in the study testing the direct effect of stretching on the hip whilst using the same protocol (table 3.7). As this literature is in its infancy, further study needs to target the additional aspects of frequency, duration, and protocol that have already been determined in many studies on stretching at the hip (Etnyre & Lee 1987).

In contrast to the positive findings noted by treatments applied to the neck or the hip, treatment directed to the sacroiliac joint (Table 5.2) and the knee (table 4.3) had no effect on hip flexion range of motion (Pollard & Ward 1998). This unique finding was in contrast to those findings obtained by treating the cervical spine and the hip directly (Pollard & Ward 1997).

Whilst these results demonstrate a statistically significant result for these clinical treatments, they do not elucidate the mechanism of such changes. Much work has been targeted at determining the effects of manual therapy treatment procedures both directly and indirectly over the last 30 years (Haldeman 1992, Shekelle 1994). The following discussion presents an overview of the literature relevant to these mechanisms.

**Mechanism**

Despite the existence of several proposed mechanisms to explain the effect of passive movement therapies utilised by practitioners of manual medicine, no one theory appears to have conclusive evidence to support it (Rahlman 1987, Haldeman 1992, Austin et al 1995, Leach 1994). These mechanisms can be broadly broken down into those mechanisms that bring about the relief of pain by neurophysiological means (Leach 1994), those that are brought about by mechanical means (Rahlman 1987), and those that are brought about by psychogenic means (Zusman 1986).

The first of these mechanisms suggest that nociception is suppressed by the stimulation of non-noxious mechanoreceptors (Leach 1994). This mechanism has been proposed on the basis of original work completed by Wyke (1985). However, the work of Wyke (1985) has been challenged in recent times by Zusman (1986). Zusman (1986) suggests that based on the work completed by Anderson (1967), only a weak correlation has been demonstrated between the diameter of nerve fibres and the receptors
found in specific nerve endings. This finding does not support the type of specificity proposed by Wyke (1985) in his proposal. In addition, work by Boyd & Davey (1968), and Langford & Smidt (1982) suggests that the number mechanoreceptors proposed by Wyke was exaggerated, although they said so in slightly more diplomatic terms. In addition, Austin et al (1995) proposed that the success of mid range passive treatments (not utilised in this thesis) can not be explained by Wyke's proposal as the number of receptors firing in the mid range of a given range of motion would be far less than that proposed to occur by those procedures utilising end range of motion procedures (Grigg & Greenspan 1977), the procedures similar to those used in this thesis.

It is likely however, that several mechanisms could be in operation to explain the different procedures. One such mechanism that has been proposed by Lewit (1985) and Janda (1979), suggested that changes in muscle and joint function occur along predisposed patterns governed by the tonic or phasic nature of the muscle. In this theory which is gaining popularity (Leibenson 1990), muscles are said to tighten if they are tonic in nature, and weaken if they are phasic in nature. They undergo these changes when they are exposed to abnormal muscle and joint loading circumstances, and respond in a predictable fashion. Thus resulting in recognisable patterns of dysfunction currently receiving attention in the rehabilitation literature (Janda 1979, Lewit 1985, Leibinson 1990, Dettori et al 1995).

The second mechanism, a mid range stretching procedures could be expected to improve "tightened" muscles by a direct stretch mechanism or through reciprocal innervation proposed in the early work of Knott & Kabat (1952). Because passive movement stimulates both large and small fibre input (Schiable & Schmidt 1983a), it is unlikely the mechanism of action of passive movement therapies such as mobilisation and manipulation are specifically related to large fibre suppression of nociceptive input.

The third mechanism proposed that movement of a joint can reduce pain (Schiable & Schmidt 1983b). Guilbaud et al (1985) presented evidence of a rapid decrease (almost complete) in the conduction velocity of nociceptors in inflamed ankle joints. This study demonstrated several minutes of high quality pain relief following 30 seconds of mechanical stimulation in the
form of passive mobilisation. The pain was proposed to be reduced by the action of substance P and other chemical mediators of pain within the spinal cord (Zusman 1987).

Zusman et al (1989) investigated the effect of an opioid-anatagonsist called naloxone on the action of the endogenous opioid peptides said to be released by joint movement mediated pain relief (Rees 1987). Studies report conflicting evidence on the effect of this treatment which have variously been reported to be present, or not, or unchanged as related to different experimental protocols (Millan & Herz 1985). The results of the nalaxone study were not entirely supportive of the hypothesis because the action of the nalaxone was only manifest in exogenous opiates, whereas the endogenous opiates were unaffected by the nalaxone (Rees 1987). So once again, clinical evidence of a positive effect occurs in the absence of direct evidence of a specific mechanism (Jones et al 1985).

A fourth mechanism involves a hysteresis effect of neural discharge (Austin et al 1995). Grigg & Greenspan (1977) have demonstrated a reduction of joint discharge and the decreased torque of a joint capsule when it has been maintained at a given joint angle. They noted that a creep phenomenon occurred after a prolonged stretch, and the stretch resulted in a substantially decreased discharge for up to 10 minutes. Furthermore, they stated that the discharge occurred in all neural fibres types, and not just in a selected few (mechanoreceptors) as outlined by Wyke (Schiable & Schmidt 1983b, Iggo et al 1984).

A fifth mechanism presented by Butler (1991) suggested that passive movement may improve symptoms at a site far distal to the point of application by altering axoplasmic flow within a nerve. In this proposal axoplasmic flow could be altered by a disease state, nerve compression, or hypoxia resulting from a change in the degree of the anterograde or retrograde flow of nutrition and optimum function occurring in the nerve (Otten 1984). Thus, the mechanism implies a removal of nerve compression and the resultant partial deterioration (Wallerian Degeneration) of the nerve that would follow distal to the point of compression (Dahlin et al 1986).

The above mechanisms were presented as examples of neurophysiological hypotheses of the mechanism of action of passive manual therapies.
including stretching, mobilisation and manipulation. While the following mechanisms are related to the mechanical hypotheses proposed to explain the effects of passive movement therapy.

Joint mobility can be altered by a change in the intra-articular joint pressure secondary to an acute or chronic inflammatory event (Austin et al 1995). In such a scenario, increased joint pressures could lead to increased pain, stiffness and reflex muscle inhibition, manifest through an arthrokinetic reflex (Levick 1983). Passive movement therapy has been shown to increase the loss of fluid from a joint thereby reversing the above mentioned effects (O'Driscoll et al 1983). Whilst these effects are associated with continuous passive motion machines or apparatus used in post surgical rehabilitation, it is likely despite no direct evidence that similar changes can be associated with manual forms of passive motion (mobilisation and manipulation) according to Giovanelli-Blacker et al (1985).

It is interesting to this proposal that despite the changes associated with acute inflammatory states, the inflammatory state is a recognised contraindication to the use of manual therapy (Terrett & Kleynhans 1992). Thus, the above mechanism should be used to explain only treatment rendered to those subjects in the sub acute, non acute or chronic phases of treatment.

A second mechanical mechanism involves the reduction of joint locking. Early claims of joint locking mechanisms were based on notions of entrapped joint meniscoids (Lewit 1985) but have not been supported by anatomical evidence (Bogduk & Engel 1984), because entrapped meniscal rims were too short to be the cause of any subsequent locking. However, researchers have suggested that a fibro-adipose meniscoid could form to act as a loose body within the joint (Bogduk & Engel 1984).

Droz-Georget (1980) has proposed a nipping of synovial folds as another potential cause of intra-articular joint locking with associated hypertonicity of muscle spanning that joint segment via a gamma efferent discharge. Korr (1975) suggested that passive movement therapies and in particular manipulation, act to decrease the gamma effect discharge by effecting the movement sensed by the muscle spindle and the golgi tendon organ. A mechanism also proposed to explain the improvement in range of
motion associated with some stretching procedures (Etnyre & Abraham 1987)

Another hypothetical mechanism suggests that the release phenomenon occurring after the joint compression associated with manual therapy may lead to improvement in pain and range of motion (Marks 1992). It has been suggested that this type of joint loading facilitates and stimulates the blood flow in subchondral blood vessels improving the oxygenation of tissues, the removal of metabolic waste, and the delivery of nutrients for repair and growth (Austin et al 1995). This view is supported by work of Phillips et al (1967) who found injections into blood vessels in the subchondral bone reproduced the pain associated with osteoarthritis. However, Houlbrook et al (1990) provided evidence that movement without compression and compression without movement were both capable of stimulating and producing the growth of cartilage ground substance. In addition to this work, Gronbald et al have demonstrated the close association of neurofilaments within synovial membranes (Gronbald et al 1988). Taken together with facts established also by Simkin (1991) it shows that movement stresses the synovium, resulting in the approximation of structures very close to the joint surfaces. Therefore it is said that the improved joint nutrition mediated by passive movement therapies could improve the articular cartilage by reducing the irritating effects of the chemistry of pain on the free nerve endings located close to those structures, but the degree of any potential improvement would be relative to the severity of the damage initially incurred (Gronbald et al 1988).

Cyriax (1974) earlier proposed a mechanism of improvement associated with manual therapy. In it he proposes the idea that displaced discal material was being replaced by the passive movement supplied by manual therapy (especially manipulation). Support for such a position can be found from the autopsy studies that have demonstrated the existence of the proposed discal fissures (Vanharanta et al 1987). Despite this indirect evidence, Cyriax has not explained since, how a manipulation could have the very quick yet prolonged effect on joint locking often noted with treatment, despite the fact that a fissured disc (alluded by Cyriax to be the etiological cause of most back pain) would allow the sequestration of discal material as soon as normal weight bearing was attempted after the manipulation (Vanharanta et al 1987). That is, the manipulation could
provide a mechanism by which the disc sequestration could be relocated, but it does not provide a mechanism by which the sequestered disc would remain normally located. Also, joint fixation and pain occurs in joints that do not have a disc, therefore a disc mechanism can not be in operation all of the time. The likely mechanism probably involves a combination of some of the above mentioned mechanisms where the joint capsular structures are tensioned by the nature of the injury to the disc thereby producing pain. Manual therapy acts to stretch the joints thereby causing a decrease of joint pain via a mechanical action on the capsular and other joint structures, and causing a flushing of the blood vessels of the joint structures resulting in improved waste removal and improved joint nutrition.

In addition to the above mentioned joint effects, soft tissue mediated effects are proposed to occur. As it is known that connective tissue looses extensibility with immobilisation (Akeson et al 1986), stretching of these structures may act to reverse the formation of ground substance molecules (proteoglycans) in cartilage and connective tissue allowing the formation of cross fibres in tissues that have undergone injury and relative period of immobilisation caused by a secondary loss in volume mediated by the water loss (Buckwalter et al 1990). It is hypothesised that the loss of water in the ground substance associated with injury may predispose the joint to the formation of cross links between adjacent intra articular soft tissues. Manual therapy including manipulation can break the cross linking and intracapsular fibro-adipose adhesions resulting in increased mobility and reduced pain (Leach 1994, Rahlman 1987). Table 8.1 presents a summary of changes that are known to occur with immobilisation, changes potentially improved with passive movement therapies such as stretching, mobilisation and manipulation (Bergmann 1999).
Effects of Immobilization

Microscopic Effects:
Loss of parallelism of collagen fibers
Distorted cellular alignment
Increased randomness of matrix organization
Increased collagen cross-link formation

Periarticular Effects:
Thickening of joint capsule
Raised capsular tension
Connective tissue shrinking
Muscle atrophy
Bone demineralization

Intraarticular Effects:
Proliferation of fatty tissue
Obliteration of joint space
Pressure necrosis of the articular cartilage
Extension of marrow space into the subchondral plate
Cartilage erosion and ulceration in noncontact areas
Adhesions to articular cartilage
Articular cartilage tears at the site of adhesions

Biomechanical Effects:
Decreased ligament strength
Decreased lineal stiffness
Decreased energy absorbing capacity

Adapted from Akeson et al. 22

Table 8.1 Effects of immobilisation: p407 Stude (1999)

Despite the proposed neurophysical and mechanical mechanisms of passive movement therapies on both soft and hard tissues of the joints, another mechanism can also be proposed to explain at least, some of the effect operating in clinical studies presented in this thesis.

The psychological effects of the laying on of hands are well documented (Zusman 1986). Good manipulative / mobilisation trials should include a control that contain a procedure for the laying of hands rather than simply an inert control group with a machine set to zero (Paris 1983). The experiments completed in this thesis satisfied this important criteria and all
demonstrated good quality placebo control groups to nullify the effect of the placing of hands on the subjects (Pollard & Ward 1997, Pollard & Ward 1998).

Once a patient bonds with a therapist via a perception of genuine interest and concern, the treatment response can be heightened by the close physical contact that frequently occurs with skilled manual therapists (Paris 1983). In fact, close physical contact has been shown to have soothing properties in babies and adults alike. In a study where it was demonstrated that babies were removed from close contact with their mothers, it was demonstrated that the babies were prone to greater crying and grimacing, and increases of up to 30 beats per minute in heart rate (Gray et al 2000). Additionally, the study by Gray et al (2000) reports a decrease in the pain perceived by infants in close contact with their mothers. A similar finding also found in adults (Rosa et al 1997). Whilst not so dramatic, close contact in the form of hands-on treatment has been acknowledged to be one of the reasons why patient satisfaction with chiropractic treatments was higher than equivalent physiotherapy and medical treatment where the hands-on component of treatment was less than the chiropractic treatments (Meade et al 1990, Meade et al 1995, Shekelle et al 1995).

Zusman (1986) has proposed another psychological mechanism to explain the effects of manual therapy (particularly manipulation). It is said that manipulation may work by breaking a pain-fear cycle following the manipulative procedure. It is known that chronic pain often has a large component of psychogenically mediated pain (Kirkaldy-Willis 1983). In this proposal, chronic pain sufferers are said to become anxious about performing movements that aggravate their condition (Zusman 1986). When this approach is adopted for some time, deconditioning of the musculoskeletal system occurs actually enhancing the likelihood of aggravation and hence the anxiety associated with further movement (Zusman 1986). It is said that the "hands-on" approach utilised by manual therapists and particularly manipulators can reduce the chronic anxiety and fear (of pain and movement that causes pain) that pain sufferers may exhibit by breaking the cycle (Itman & Doré 1990, Zusman 1986).

The variability of the mechanism proposed to explain the effects of stretching, mobilisation and manipulation can be highlighted by the
literature on joint immobilisation. Many studies on the joint effects of immobilisation on the knee have been performed. The knee has been a target for research because of its importance in sport, and its propensity to undergo serious injury requiring surgery and long periods of expensive and intensive rehabilitation (Greenfield 1993).

The studies on immobilisation of the knee show that immobilisation is closely related to early joint degeneration and restricted mobility of the joint effected. The effects are nearly all confined to the muscle and tendon in the short term, and to the joint if immobilisation is prolonged (Evans et al 1960). In the latter stages of immobilisation, mobility appears to be restricted more by capsular and ligamentous stricture (Enneking & Horowitz 1972, Videman et al 1976) and finally, the formation of intra-articular joint adhesions (Spector et al 1982).

These changes may explain the potentially conflicting evidence regarding the role of the hamstrings and hip joints in the lumbo-pelvic-hip synergistic movement. It is likely that early changes to the lumbopelvic rhythm cause a compensatory increase in the hamstring tension resulting in a shortening of the muscle to increase its stiffness and its support of the lumbar spine (Mellin 1988). If left, these changes may result in a state of relative immobilisation of the involved joints (hip, sacroiliac, lumbosacral) where degenerative changes associated with disuse can manifest. It is these joints that frequently undergo degenerative change visible on the x-ray if left for long periods (Yochum & Rowe 1987). I hypothesise that under such conditions of immobilisation that these joint surfaces become subjected to abnormal joint loading forces led in part by the hamstring muscle (van Wingerden et al 1995), and the thoracolumbar fascia (Vleeming et al 1990). If left the changes can result in actual joint changes to stabilise and support an injured lower back which ultimately could result in the advanced stiffness often associated with chronic low back conditions (Mellin 1988). If left for long periods of time the increase in joint loading brought about by the compressive loading created by the chronic supportive action of the muscles, and particularly the hamstring via the thoracolumbar fascia (Aspden 1987, Snijders et al 1993, Nelson et al 1995), may act to abnormally load the joints to increase joint degeneration.
Now, should use of the lumbopelvic region require a dynamic range of motion as it often does in daily activity, it is likely that the muscles of the back and the hamstrings could undergo injury. Such injury would lead to further guarding of muscles of the lower back. Post contraction muscle soreness and spasm prevalent with eccentric activity of muscle could result from contraction associated with retarding forward bending movements, or prolonged forward bending postures associated with common activities such as gardening (Ernst 1998). Alternatively, weakness of supporting lumbar structures could lead to a cycle of inactivity based weakness resulting in injury and chronic pain which in turn leads to further inactivity because of pain. Chronic weakness and instability of the lumbar spine may result from such a scenario (Andersson 1999) a state which may predispose the scenario mentioned above.

Thus, it is possible that a loss of hip joint range of motion could result in a supporting mechanism in the presence of lumbar stability and once created, may actually lead to further injury to the joint that has become accustomed to decreased range of motion associated with a state of relative immobilisation (Mellin 1988, Esola et al 1996, Vleeming et al 1990). Increasing muscle tension generated by the immobility changes associated with the protective guarding (Esola et al 1996, Miller et al 1987), increases the joint compression and the pain at the joint thereby contributing to the development of osteoarthritis in the long term (Leach 1994). Such a vicious cycle has been described (Kirkaldy-Willis 1987, Andersson 1999), and is frequently associated with chronic pain syndromes (Andersson 1999, Faucett 1999).

Further variability in the resultant changes occurs because of some of the known effects of immobilisation. Depending on the degree of joint contraction, a greater degree of gross morphologic (Ralston et al 1952), biomechanical (Kurakami 1966, Flint 1972) and ultrastructural (Tomanek & Lund 1974) changes occur.

Shortened muscles show a reduction in tension, whilst the lengthened muscles retain their force generating capacity in direct proportion to their cross sectional area (Carpenter & Nelson 1999). Add to this the variability that has been proposed to occur in muscle according to Lewit (1985), and changes of a broad nature are likely. These muscle changes proposed by Lewit (1985) are based upon the phasic or tonic nature of a muscle. As a
result of these muscle, ligament and joint based changes, it would appear that the quest for a single based explanation of the effects of manual therapy is in fact a search for a holy grail. It is therefore likely that several mechanisms are in operation either singularly or in combination (Rahlman 1987). It is for this reason that a multitude of treatment approaches have been shown clinically to have a positive effect on joint range of motion and pain, and why there has been a general push in the literature toward the large scale randomised controlled trial (Bogduk & Mercer 1995).

I feel that the concept of relative immobilisation is an important concept to be added to this discussion. It is known that muscles and joints operating through a range of motion in which they habitually operate, adapt to that range through changes in that range of motion that can have a demonstrable effect on muscle, ligament and joints (Akeson et al 1980). Thus if one draws together the separate literature on joint and muscle immobilization and what is known of the proposed mechanisms of action of treatments such as manipulation, mobilisation and stretching, the literature may be drawn together to explain a complex phenomenon of changes associated with chronic low back pain. Such a discussion inevitably leads to the conclusion that many of the changes occurring at the lumbar spine are effects of dysfunction of nearby areas rather than solely the cause of local events.

Therefore, from these proposed mechanisms one could hypothesise that hamstring tightness and loss of hip flexion could be both a cause of, and a result of a lumbopelvic injury.

It is my interpretation that this is what is meant by many manual therapists when they propose treatments to regions of the body distant to the source of pain (DeJarnette 1972, Plauger 1993), and it is an example of an explanation that explains the action of the hamstrings and the hip in the genesis of low back pain (Nelson et al 1985, Esola et al 1996, McClure et al 1997), which in reality is a practical manifestation of the lumbopelvic rhythm.

In summary, I conclude that the mechanism of action of the manual therapy used in the manipulation, mobilisation and stretching protocols used in this thesis are probably multiple in nature, and therefore are likely
to contain neurophysiological, mechanical and psychogenic components. I further conclude that whilst research into these mechanisms has been conducted for at least 30 years, no single unifying mechanism has emerged to explain all the effects noted with a particular form of stretching, mobilisation or manipulation.

I further conclude that the results of the studies completed in this thesis are an original contribution to the theoretical and clinical literature, and they provide a springboard for further specific study of observations made within several of the studies.
Chapter Nine:

Conclusion
Conclusion

The purpose of this research was to investigate the effects of different forms of manual therapy on the hip joint and to provide some normative data on their outcomes and discuss their likely mechanisms. This was achieved by investigating several studies designed to quantify the effects of treatment directly on the hip, and other forms of treatment said to affect the hip.

The results of the first study demonstrated that a treatment of either manipulation or stretch applied to the hip could significantly increase the hip flexion range of motion. Importantly, these results were different depending on whether the measurements of range of motion were taken in the standing or supine positions. I conclude from this work that both forms of assessment increased range of motion statistically, however, the increase in range of motion can be explained entirely by the variation in the assessment procedures both in the standing position (closed kinematic chain) and the supine straight leg raising position (open kinematic chain).

Also under investigation in the first study was the question whether the increase in range of motion at the hip could alter the average range of motion of flexion at the lumbar spine when measured statistically. I conclude from the results of this first study that treatment of the hip could not significantly alter the lumbar flexion range of motion. However, the study did reveal that treatment applied to the hip was able to decrease the pain associated with chronic lower back pain in the population of back pain sufferers who took part in the study. I also conclude that a possibility exists that the treatment was showing the proposed effect, but that the effect needed longer to manifest in the chronic sufferer, (that the effect may be intra-articular), and as such any changes in gross lumbar range of motion would not be revealed, or that the treatment affected the lumbar spine directly (despite efforts to isolate it to the hip). In addition to these conclusions, I further conclude that the manipulation of the hip increased the hip flexion range of motion greater than did the PNF stretch of the hip.

The second study of the thesis represented the first of four studies to investigate the effect of treatment applied away from the hip on the
function of the hip. In the second study I applied a series of knee myofascial mobilisations to a population of chronic mild to moderate osteoarthritic knees. I conclude that the results of this study indicated that when compared to a placebo, the myofascial mobilisation could significantly improve the knee pain suffered by the osteoarthritic group. Another aim of this study was to evaluate whether such a treatment could alter the function of the next most proximal joint - the hip. I conclude that given the constraints of this investigation, that the knee treatment that successfully decreased knee pain, could not significantly alter the hip flexion range of motion, nor could it alter the subjective impression of increased mobility asked via a questionnaire.

The final three studies of the thesis attempted to investigate the effects of spinal treatment on the function of the hip. The third study attempted to investigate the effect of two different stretches on the hip joint range of motion. I conclude from these results that the PNF stretch applied to the hamstring group of muscles, and a PNF stretch applied to the suboccipital muscles of the neck both increased the hip flexion range of motion compared with a placebo control. However, I conclude that of these two procedures, only the suboccipital PNF procedure demonstrated a significant increase at the P<0.05 level.

The fourth study investigated under controlled conditions the effect of a single manipulation to the first cervical vertebra or the sacroiliac joint on the hip flexion range of motion. I conclude that using a methodology similar to the other studies that cervical manipulation significantly increased the hip flexion range of motion when compared to a similarly matched control group. I also conclude that under the same conditions that a manipulation of the biomechanically related sacroiliac joint could not increase the hip flexion range of motion.

In addition I conclude that the results of the third and fourth studies taken together suggest that there may be a role to play for neck manipulation in the treatment of extra spinal lower limb musculoskeletal joint limitations, particularly the hip. I conclude this because when the neck was treated (manipulated or stretched) I was able to demonstrate a significant improvement in hip flexion range of motion, and the increase in the stretching group was superior to the locally applied PNF stretch.
The fifth and final study of the thesis targeted the quadriceps muscle group. It was the aim of this study to demonstrate the effect of a single manipulation of the L3,4 motion segment on the quadriceps muscle strength. Although there were minor inconsistencies in the methodology that may have allowed the possibility of fatigue to emerge, or the possibility of the outcome being affected by a learning effect, I conclude that there was a significant change in the treatment group when compared to the placebo group. This could not be entirely attributed to error, as such effects should have occurred in both the treatment and the control groups. I conclude that these inconsistencies may have effected the magnitude of the change, but not the significance of the result.

In summary, I conclude that I have demonstrated that a manipulation of the hip, first vertebra, and a PNF stretch of the hamstrings and the suboccipital muscle groups all increased hip flexion range of motion under controlled conditions. Additionally, I conclude that sacroiliac manipulation and myofascial mobilisation of the knee did not effect the hip flexion range of motion.

Finally, I conclude that a treatment of the hip can decrease the pain associated with chronic lower back pain, but that the decrease in pain comes with a significant increase in hip flexion range of motion, but no significant change in lumbar range of motion. As no change in lumbar range of motion was noted, based on the limitations of this study, I cannot support the hypothesis of Cailliet (1995) who implied that such changes in lumbar range of motion would accompany improvement in restricted hip joint ranges of motion.

It is likely that any changes manifest in the lumbar spine following a treatment regime of the hip would require some time to manifest, and as such any further attempts to investigate this hypothesis should utilise a methodology that has a longer treatment phase and longer follow-up assessment phase, that is, a prospective longitudinal study.
Chapter Ten:

Recommendations
Recommendations

I recommend that the work begun in this thesis be further examined under controlled conditions in several important areas.

As these studies represent a first attempt to document the effects of the treatments cited, I feel that follow up studies should be conducted to both confirm these results, and to expand upon their scope. In doing so I recommend that examination occur over longer treatment periods. For example, nine to twelve treatments over the period of three to four weeks, and that the follow up assessment on the subjects be extended over a longer period of time to determine survival curve data. Ideally, a randomised control trial format could be used to specifically investigate these treatments of the hip with and without subjects that suffer from lower back pain, in the attempt to determine if the effects are additive and prolonged. Also, befitting the randomised control trial format would be an examination of the question of whether neck treatment can influence back and hip pain syndromes.

Finally, I feel that manual therapy of the knee is an under utilised resource. These results have demonstrated early improvement of knee pain in sufferers of mild to moderate chronic osteoarthritis. I feel that further examination of this and other manual therapy treatments should be undertaken. I suggest that further investigation in the form of randomised controlled trails (utilising survival curve data) could help to bridge the very large gap in care that exists between the intervention of analgesic and anti-inflammatory medication (plus exercises) and the intervention of surgery, in the management of this common osteoarthritis. I feel that the potential cost effectiveness of such simple treatment to limit the expense and suffering associated with surgery to be worthy of greater investigation.
Chapter Eleven:

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Chapter Twelve:

Appendices
Appendix One: Questionnaires

McGill Pain Questionnaire

Part 1. Where is your Pain?
Please mark on the drawings below the areas where you feel pain. Put E if external, or I if internal, near the areas which you mark. Put EI if both external and internal.
Part 2. What Does Your Pain Feel Like?

Some of the words below describe your present pain. Circle ONLY those words that best describe it. Leave out any category that is not suitable. Use only a single word in each appropriate category—the one that applies best.

- **Flickering**
- **Quivering**
- **Pulsing**
- **Throbbing**
- **Beating**
- **Pounding**
- **Flashing**
- **Shooting**
- **Jumping**
- **Shrieking**
- **Explosive**
- **Flaring**
- **Thrusting**
- **Piercing**
- **Puncturing**
- **Squeezing**
- **Squealing**
- **Screaming**
- **Rumbling**
- **Rattling**
- **Knocking**
- **Grinding**
- **Drumming**
- **Pounding**
- **Gnawing**
- **Pressing**
- **Pinching**
- **Cramping**
- **Crashing**
- **Spreading**
- **Radiating**
- **Penetrating**
- **Piercing**
- **Pricking**
- **Stabbing**
- **Lancinating**
- **Lacerating**
- **Cutting**
- **Boring**
- **Drilling**
- **Slaughtering**
- **Hot**
- **Tangling**
- **Itchy**
- **Burning**
- **Scalding**
- **Smarting**
- **Tearing**
- **Drawing**
- **Squeezing**
- **Tearing**
- **Tender**
- **Taut**
- **Rasping**
- **Splitting**
- **Tiring**
- **Exhausting**
- **Suffocating**
- **Heavy**
- **Punishing**
- **Gruelling**
- **Cruel**
- **Vicious**
- **Killing**
- **Tiring**
- **Exhausting**
- **Suffocating**
- **Wretched**
- **Blinding**
- **Annoying**
- **Troublesome**
- **Miserable**
- **Intense**
- **Unbearable**
- **Cool**
- **Cold**
- **Freezing**
- **Nagging**
- **Sickening**
- **Suffocating**
- **Agonizing**
- **Dreadful**
- **Torturing**
- **Annoying**
- **Troublesome**
- **Miserable**
- **Intense**
- **Unbearable**
- **Tight**
- **Nauseating**
- **Agonizing**
- **Dreadful**
- **Torturing**

Part 3. How Does Your Pain Change With Time?

1. Which word or words would you use to describe the pattern of your pain?
   - **Continuous**
   - **Steady**
   - **Constant**
   - **Rhythmic**
   - **Periodic**
   - **Intermittent**
   - **Brief**
   - **Momentary**
   - **Transient**

2. What kind of things relieve your pain?

3. What kind of things increase your pain?

Part 4. How Strong Is Your Pain?

People agree that the following 5 words represent pain of increasing intensity. They are:

- **Mild**
- **Discomforting**
- **Distressing**
- **Horrible**
- **Excruciating**

To answer each question below, write the number of the most appropriate word in the space beside the question.

1. Which word describes your pain right now?
2. Which word describes it at its worst?
3. Which word describes it when it is least?
4. Which word describes the worst toothache you ever had?
5. Which word describes the worst headache you ever had?
6. Which word describes the worst stomach-ache you ever had?
The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire
Department for Spinal Disorders

<table>
<thead>
<tr>
<th>Name:</th>
<th>Address:</th>
<th>Date:</th>
</tr>
</thead>
</table>

**Occupation: | Hospital No: |**
| | |

**How long have you had back pain?:**
<table>
<thead>
<tr>
<th>Years</th>
<th>Months</th>
<th>Weeks</th>
</tr>
</thead>
</table>

**How long have you had leg pain?:**
<table>
<thead>
<tr>
<th>Years</th>
<th>Months</th>
<th>Weeks</th>
</tr>
</thead>
</table>

**Please read:** This questionnaire has been designed to give the doctor information on how your back pain has affected your ability to manage in everyday life. Please answer every section, and mark in each section only the one box which applies to you. We realize you may consider that two of the statements in any one section relate to you, but please just mark the box which most closely describes your problem.

### Section 1 — Pain Intensity

- [ ] I can tolerate the pain I have without having to use pain killers.
- [ ] The pain is bad but I manage without taking pain killers.
- [ ] Pain killers give complete relief from pain.
- [ ] Pain killers give moderate relief from pain.
- [ ] Pain killers give very little relief from pain.
- [ ] Pain killers have no effect on the pain and I do not use them.

### Section 2 — Personal Care (Washing, Dressing, etc)

- [ ] I can look after myself normally without causing extra pain.
- [ ] I can look after myself normally but it causes extra pain.
- [ ] It is painful to look after myself and I am slow and careful.
- [ ] I need some help but manage most of my personal care.
- [ ] I need help every day in most aspects of self care.
- [ ] I do not get dressed, wash, or use the toilet.

### Section 3 — Lifting

- [ ] I can lift heavy weights without extra pain.
- [ ] I can lift heavy weights but it gives extra pain.
- [ ] Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, eg on a table.
- [ ] Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned.
- [ ] I can lift only very light weights.
- [ ] I cannot lift or carry anything at all.

### Section 4 — Walking

- [ ] Pain does not prevent me walking any distance.
- [ ] Pain prevents me walking more than 1/2 mile.
- [ ] Pain prevents me walking more than 1/4 mile.
- [ ] I can only walk using a stick or crutches.
- [ ] I am in bed most of the time and have to crawl to the toilet.

### Section 5 — Sitting

- [ ] I can sit in any chair as long as I like.
- [ ] I can only sit in my favourite chair as long as I like.
- [ ] Pain prevents me sitting more than 1 hour.
- [ ] Pain prevents me sitting more than 3/4 hour.
- [ ] Pain prevents me from sitting more than 10 mins.
- [ ] Pain prevents me from sitting all.

### Section 6 — Standing

- [ ] I can stand as long as I want without extra pain.
- [ ] I can stand as long as I want but it gives me extra pain.
- [ ] Pain prevents me from standing for more than 1 hour.
- [ ] Pain prevents me from standing for more than 30 mins.
- [ ] Pain prevents me from standing for more than 10 mins.
- [ ] Pain prevents me from standing at all.

### Section 7 — Sleeping

- [ ] Pain does not prevent me from sleeping well.
- [ ] I can sleep well only by using tablets.
- [ ] Even when I take tablets I have less than six hours sleep.
- [ ] Even when I take tablets I have less than four hours sleep.
- [ ] Even when I take tablets I have less than two hours sleep.
- [ ] Pain prevents me from sleeping at all.

### Section 8 — Sex Life

- [ ] My sex life is normal and causes no extra pain.
- [ ] My sex life is normal but causes some extra pain.
- [ ] My sex life is normally normal but is very painful.
- [ ] My sex life is severely restricted by pain.
- [ ] My sex life is nearly absent because of pain.
- [ ] Pain prevents any sex life at all.

### Section 9 — Social Life

- [ ] My social life is normal and gives me no extra pain.
- [ ] My social life is normal but increases the degree of pain.
- [ ] Pain has no significant effect on my social life apart from limiting my more energetic interests, eg dancing, etc.
- [ ] Pain has restricted my social life and I do not go out as often.
- [ ] Pain has restricted my social life to my home.
- [ ] I have no social life because of pain.

### Section 10 — Travelling

- [ ] I can travel anywhere without extra pain.
- [ ] I can travel anywhere but it gives me extra pain.
- [ ] Pain is bad but I manage journeys over two hours.
- [ ] Pain restricts me to journeys of less than one hour.
- [ ] Pain restricts me to short necessary journeys under 30 minutes.
- [ ] Pain prevents me from travelling except to the doctor or hospital.

**Comments:**
DALLAS PAIN QUESTIONNAIRE

Dallas Pain Questionnaire

Section I: Personal Care
How much does pain interfere with your personal care (getting out of bed, teeth brushing, dressing, etc.)?
None  Some  I cannot get out of bed
0% (________________) 100%

Section II: Lifting
How much limitation do you notice in lifting?
None  Some  I cannot lift anything as I did
0% (________________) 100%

Section III: Walking
Compared to how far you could walk before your injury or back trouble, how much does pain restrict your walking now?
I can walk  Almost the same  I cannot walk the same
0% (________________) 100%

Section IV: Sitting
Back pain limits my sitting in a chair to:
None  Some  I cannot sit at all
0% (________________) 100%

Section V: Standing
How much does your pain interfere with your tolerance to stand for long periods?
None  Some  I cannot stand
0% (________________) 100%

Section VI: Sleeping
How much does pain interfere with your sleeping?
None  Some  I cannot sleep at all
0% (________________) 100%

Section VII: Social Life
How much does pain interfere with your social life (dancing, games, going out, eating with friends, etc.)?
None  Some  No activities same as before total loss
0% (________________) 100%

Section VIII: Pain and Intensity
To what degree do you rely on pain medications or pain relieving substances for you to be comfortable?
None  Some  All the time
0% (________________) 100%

Section IX: Vocational
How much does pain interfere with your job?
None  Some  I cannot work
0% (________________) 100%

Section X: Anxiety/Mood
How much control do you feel that you have over demands made on you?
(No Change)  Total  Some  None
100% (________________) 100%

Section XI: Depression
How depressed have you been since the onset of pain?
Not depressed  Overwhelmed by Depression
0% (________________) 100%

Section XII: Emotional Control
How much do you think your pain has changed your relationships with others?
Not Drastically Changed
0% (________________) 100%

Section XIII: Social Support
How much support do you need from others to help you during this onset of pain (taking over chores, fixing meals, etc.)?
None  All the time
0% (________________) 100%

Section XIV: Punishing Response
How much do others express irritation, frustration or anger toward you because of your pain?
All  the time
0% (________________) 100%
Appendix Two: Publications

Appendix Three: Informed consent forms
ACCELERATIONS RECORDED FROM THE SPINOUS PROCESSES DURING SPINAL MANIPULATIVE TREATMENTS OF THE THORACIC SPINE  
Dr. Walter Herzog  Ph.D.  
Dr. Esther Suter  Ph.D.  
Dr. Philip J. Conway  D.C.  
Page  75

THE EFFECT OF SACROILIAC MANIPULATION ON HIP FLEXION RANGE OF MOTION  
Dr. Graham Ward  B.Sc., B.E., M.Sc., Ph.D.  
Page  80

A CASE SERIES OF MIGRAINE CHANGES FOLLOWING A MANIPULATIVE THERAPY TRIAL  
Dr. Peter J. Tuchin  B.Sc., Grad.Dip.(Chiro), Dip(OHS).  
Page  85

HEALTH PROMOTION IN A PRIMARY HEALTH CARE SETTING  
Neural Tube Defects and Folate  
Dr. Simon French  B.App.Sc.(Chiropractic).  
Page  92

ABSTRACTS  
Page  95

INSTRUCTIONS FOR AUTHORS  
Page  100
Peter Tuchin B.Sc., Grad.Dip.(Chiro), Dip.(OHS).

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THE EFFECT OF SACROILIAC MANIPULATION ON HIP FLEXION RANGE OF MOTION

DR. GRAHAM WARD  B.Sc., B.E., M.Sc., Ph.D.†

Abstract: Chiropractors claim to be able to influence sites far removed from the point of application of spinal adjustment. Little scientific research has, however, been conducted showing conclusively that the spine and associated structures have an influence on distal function. Demonstration of such influence on distal tissues would aid in the scientific validation of Chiropractic by other health professionals and facilitate treatment of peripheral injuries such as hamstring strains. This study aimed to investigate the effect of a manipulation of the sacroiliac joint on the mechanical function of the hip joint. The results demonstrate that the sacroiliac joint manipulation did not statistically alter the range of motion of the hip joint.

Key Indexing Terms: Chiropractic, manipulation, hip, sacroiliac joint, range of motion.

INTRODUCTION

The sacroiliac joint is a joint that chiropractors frequently treat. As these joints make up the major articulations of the pelvis, they are often implicated in anomalous function of the lumbar spine and the hip (1).

Biomechanists suggest that the function of the sacroiliac joint is intrinsically linked with that of the lumbar spine and the hip joint (2). This probably occurs through the action of the thoracolumbar fascia (3, 4). Based on this understanding, some clinicians suggest that treatment of all components of the lumbopelvic rhythm should be strongly considered in any dysfunction of any one component of this kinematic chain (1).

Furthermore, many forms of therapy have been constructed to treat the sacroiliac joint. These include, but are not limited to, passive and active procedures directed at either the sacroiliac joints or these surrounding soft tissues. Of these many treatments, chiropractors frequently report the success of managing non-specific low back and leg pain syndromes with the use of sacroiliac manipulation (5, 6).

Opposition to the use of such methods for the reduction of non specific back pain syndromes occur for two main reasons. Firstly, evidence shows that reliability in the examination of the sacroiliac joint is poor (7-9). The reason that treatment is by definition haphazard if one cannot reliably locate the region to be treated. Secondly, most researchers feel that only small movement in the range of 2-12°, and frequently less than 2° is possible at the sacroiliac joint, and they are unable to see evidence how such minimal movement impacts upon the lumbopelvic region to produce pain (10, 11).

These facts about the sacroiliac joint should be balanced by other pragmatic information about sacroiliac joints. The sacroiliac joint has been shown to be able to produce back, buttock and leg pain in characteristic locations following injection with saline solutions (12). These pain maps are distinctive and reproducible (12). This fact, together with the many reports of success with treatment of non specific back pain by manipulative treatment (5, 6) and corticosteroid injection treatment delivered to the sacroiliac joint (13), have allowed the sacroiliac joint to reach ‘quiet achiever’ status with some clinicians whilst others wonder what all the fuss is about.

The practitioners that support the notion that the sacroiliac joint is causative in some back pain feel that it likely develops restriction of movement (14). According to the untested theory of lumbopelvic rhythm, such restriction of motion should impact upon the overall function of the lumbopelvic kinetic chain potentially causing problems of function that may manifest as pain syndromes. Therefore it was the purpose of this study to investigate the effect of a sacroiliac manipulation on the mobility of the hip joint (as measured in flexion).

MATERIALS AND METHODS

This study was performed as one study in a group of consecutive studies performed by Pollard & Ward (15) utilising similar methodology.

In this study thirty four chiropractic university students acted as subjects, and were limited to the ages of twenty one to thirty-three years. Subjects were randomly allocated into two groups. Group 1 received a sacroiliac manipulative procedure. Group 2 was a control group which received digital pressure over the mastoid processes bilaterally. Subjects were excluded if they had reported acute low back, neck or hip pain, or leg referral or hamstring muscle injury within the two weeks prior to the investigation. All subjects provided informed written consent prior to participation.
A digital goniometer (Ortho Ranger II M Technic Inc.) was used to measure straight leg raise (SLR) and a digital force transducer (Nicholas Manual Muscle Tester Model 0160 Lafayette Instruments) was used to standardise the SLR. Both the electrogoniometer and the hand held force transducer were calibrated prior to use.

This study had received approval by the Macquarie University Human Ethics Committee prior to experimentation.

**MEASUREMENT**

Initially each subject performed a five minute warm-up at an intensity of 75 revolutions per minute (metered by a metronome) on an exercise bike based on a procedure by Golden & Dudley (16). Following this, subjects were weighed and then taken to a separate room where they lay supine on the treatment couch.

Subjects in both groups layed supine on the treatment table and the goniometer was attached to the lateral aspect of the calf in the sagittal plane. The force transducer was placed at 90° to the long axis of the leg at the level of the calcaneus on the unshod foot. The first examiner drew a line between the lateral malleolus and the greater trochanter of the leg to be examined. This line represented the longitudinal axis of the leg and provided a reference for the accurate placement and replacement of the goniometer during SLR measurements. The end point of measurement in the pre- and post-tests were determined by the second examiner using the force transducer. The passive end point goniometer reading (end point of ROM) was defined as that point reached by an application of 5% of the subject’s body weight. Such a determination of end point was essential to ensure an accurate reproduction of the measurement. In all measurements of straight leg raising the pelvis was secured to the treatment table. The subjects were strapped to the treatment table at the level of the anterior superior iliac spine (ASIS) to stop unwanted pelvic rotation.

Group A  Control Group
This group received digital pressure on the mastoid processes bilaterally for 30 seconds. This procedures was repeated a total of three times. The side receiving the range of motion assessment was chosen at random.

Group B  Sacroiliac Manipulation
A chiropractic manual manoeuvre (lumbar roll position pisiform contact) consistent with O’Neil and Esposito (17) was applied to the sacroiliac joint. The side of the manipulation was chosen at random. The side receiving the manipulation received the range of motion assessment. The rationale for the random allocation and assessment is given at the end of this section.

**THE EFFECT OF SACROILIAC MANIPULATION**

Following the intervention, the second examiner again determined the hip flexion range of motion within 30 seconds. All post treatment assessments took place 30 seconds after the intervention so that the elapsed time between intervention and assessment could be standardised. This was performed immediately following the intervention on all subjects in the same fashion as it was prior to the intervention. Pre-treatment measurement, treatment, and post-treatment measurement were all performed within a five minute period.

The unilateral range of motion assessment of the hip was chosen on the basis that hip flexion range of motion is considered to be representative of the general state of mobility in the hip, and based on previous work by Murphy et al that demonstrated decrease in H-reflex amplitude on the side homolateral to the side of sacroiliac joint manipulation (19). The authors made no attempt to locate fixed joints, subluxations or any other lesions of the spine, sacroiliac or hip regions once subjects had been declared (by another examiner) suitable for inclusion into the study. This was done for two reasons. The general aim of this study was to investigate whether manipulation of spinal structures could influence peripheral structures. This was done to provide normative data on the effect of sacroiliac joint manipulation in a healthy population, to which later studies involving pain sufferers and other populations of specifically lesioned joints could possibly be compared. As the reliability of the palpation of the sacroiliac joint has been reported to be poor (7, 8), and as we were using an asymptomatic group, we could not use pain mapping as a guide to locate the lesion (12). This approach is supported by the findings of Dreyfuss et al (20) who suggest that 20% of asymptomatic individuals test positive with many sacroiliac joints. As such, there was no guarantee that a side deemed to be lesioned was in fact lesioned. Thus, it was not possible to definitively determine the side receiving the intervention, and control of side was not then possible in such circumstances.

**RESULTS**

Data was analysed using descriptive statistics, student t-tests, and Analysis of variance (ANOVA) tests of significance. Significance was set at Alpha equal 0.05.

**DISCUSSION**

This project investigated the effects of a sacroiliac joint manipulation on hip flexion range of motion. The results demonstrate that manipulation of an asymptomatic sacroiliac joint could not significantly alter the mobility of the hip in the short term (tables 1-3). This result is in opposition to popularly held views that sacroiliac joint
The effect of sacroiliac manipulation

Table 1: Post treatment differences in average group ROM measured in degrees (Paired t-test)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16</td>
<td>-0.69</td>
<td>4.51</td>
<td>1.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sacroiliac</td>
<td>18</td>
<td>-2.17</td>
<td>4.50</td>
<td>1.06</td>
<td>-1.39</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Table 2: Post treatment differences between the control and the sacroiliac groups measured in degrees (Analysis of variance).

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>18.50</td>
<td>33.00</td>
<td>0.91</td>
<td>A p&gt;0.05</td>
</tr>
<tr>
<td>Error</td>
<td>649.90</td>
<td>32.00</td>
<td>20.30</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>668.50</td>
<td>33.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Changes in ROM for control and sacroiliac groups (in degrees relative to the vertical plane).

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th>Posttest</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group, (n=16 (SE))</td>
<td>67.06</td>
<td>66.37</td>
<td>1.03</td>
</tr>
<tr>
<td>Sacroiliac manipulation Group, (n=18 (SE))</td>
<td>62.22</td>
<td>60.66</td>
<td>3.47</td>
</tr>
</tbody>
</table>

function can directly effect the function of the biomechanically and structurally related hip and lumbar regions (21).

The sacroiliac joint is said to be important for transmitting forces to the hip in weight bearing (22). The application of the coupled movement (together with movement of the lumbar) in the sagittal plane is referred to as the lumbo-pelvic rhythm (1).

Proponents of this untested theory suggest that the closed kinematic chain of the lower limb can result in an increase in hip range of motion as a direct compensation for loss of movement at the sacroiliac and lumbar regions or vice versa (1). However, as recent research has demonstrated that the sacroiliac joint has a few degrees of motion (10, 23), and that the hip range of motion is much greater (approximately 120° of flexion), it is possible that the hip could absorb the extra motion into its range and not be significantly altered in terms of the range of motion. This could occur due to the presence of error associated with the measurement of the hip joint mobility. This error of mobility whilst small when compared to the overall excursion of hip movement is large when compared to the sacroiliac movement.

It is also possible that the sacroiliac joint does not contribute to hip range of motion in such a direct mechanical fashion. What cannot be answered by this research is the question that sacroiliac manipulation somehow affects the joint proprioceptors located in the joint through some neurophysiological mechanism. Support for the idea that joint or muscle proprioceptors of the sacroiliac joint are stimulated by sacroiliac joint manipulation was provided by Murphy et al (19). Their work demonstrated changes in H-reflex activity after desensitisation of cutaneous afferents through the use of an anaesthetic cream. They concluded that the changes in the H-reflex must be mediated by joint and or muscle afferents (probably at segmental level).

As the sacroiliac joint acts close to the centre of gravity of the body (usually located just anterior to the second sacral vertebra (24)), it is possible that any effects on the hip appear more in the way the sacroiliac joint pivots about the central axis of the centre of gravity. Hence, the effects of extra mobility may be magnified the further away from the epicentre one measures.

Whilst this idea is untested, it is supported by the idea that cervical manipulation is effective in increasing hip flexion range of motion (25). Another study by Pollard & Ward (15) demonstrated that a cervical stretching procedure was more effective in increasing hip flexion range of motion than is a locally applied stretch to the hip in flexion. Such results allude to the presence of a neurophysiological mechanism for improving joint range of motion at the hip, and that this effect is at least comparable to a local mechanical one.

Equally, much has been made of the effect of orthotics in lumbar range of motion and pain syndromes (26). We have been unable to locate any research that specifically related change in foot mechanics to the movement occurring at the sacroiliac joint, although research by Schuit and co-workers has described a fairly high degree of asymptomatic sacroiliac joint malalignment when leg length discrepancies were present (27). Research that measures both range of motion and joint/ muscle afferents in the sacroiliac joint as well as more proximal and distal joint structures are needed to unequivocally answer the questions about mechanism.

Some methodological factors undertaken in this study were important for its outcome. The standardisation of tissue heating effects is one such variable. A light pre-measure warm-up was used in this study to standardise the heat loading in the soft tissues. This was important because temperature differences in muscle are known to effect their extensibility (28), and therefore variability of temperature could have introduced an error into our range of motion (ROM) findings. A five minute warm-up consisting of light to moderate exercise was performed. This level of warm up has been deemed adequate to heat muscles for the purpose of standardisation for range of motion measures (16). Astrand and Rhodahl (29), have also reported that the warm up effect lasts for up to 45 minutes. It is for these reasons that all subjects were asked to warm up on an exercise bike immediately prior...
The variables of sex and age have been shown to be important in the range of motion achieved by sacroiliac joints (30-32). The variable of age was controlled in this study as demonstrated by non-significant differences between groups (tables 4 and 5). A non-significant difference in sex ratios between the two groups was also achieved (p>0.05). Sacroiliac joint preparations from males over thirty five years of age display increased roughness of the joint surfaces with age. However, these features do not appear with female sacroiliac joints even of advanced age (30, 31). These findings suggest that not only is it likely that range of motion will be different between the sexes, but that range of motion would likely be different between men of young and old age groups. Vleeming and co-workers (32) have demonstrated that sex differences parallel differences in joint surface morphology. Therefore, standardisation of both age and sex as factors in research associated with the sacroiliac joint is essential.

The results of this study should be further examined using different protocols including different sacroiliac manipulative procedures, and different populations of subjects including actual low back pain sufferers, as the results of the present group of subjects may differ to that of actual pain sufferers. Equally important is the establishment of a series of manipulations in a controlled randomised trial.

The sacroiliac joint is a large tightly bound ligamentous joint. Because of its anatomy, it may be appropriate to investigate methods of treatment that help the ligaments of the joint to undergo creep, and hence elongate causing increased sacroiliac range of motion. As it is known that creep of ligaments does occur under periods of prolonged load (33, 34), treatment methods such as prolonged mobilisation or the placement of triangular wedges under the innominates to effect a rotary torque at the pelvic region should also be examined to see if they have an influence on both sacroiliac and hip range of motion. These treatments should then be compared to manipulative trials to ascertain relative efficacy in improving hip and sacroiliac range of motion. To our knowledge, no such investigations have taken place.

**CONCLUSION**

That a single manipulation of the sacroiliac joint in healthy university students did not significantly effect the range of motion of the hip joint as measured in flexion. Further research should investigate the effect of sacroiliac manipulation on the hip in subjects actually suffering back or hip pain. Such research should also investigate other less common methods of achieving creep in sacroiliac ligaments in the treatment of sacroiliac joint dysfunction.

**ACKNOWLEDGMENT**

The authors wish to thank the following chiropractors for their assistance in conducting this project. They are: David Stransky, Evan Rogers, Ian Roberts, Paul Hillard, and Robert Koklich.

**REFERENCES**


CONSENT FORM: (PARTICIPANT COPY).

Graham Ward BSc, BE, MSc, PhD

Treatment of osteoarthritis of the knee using a mobilization technique

Our field of study is in the treatment of osteoarthritic knees in the elderly population, and your assistance and consent to participate in this week study would be greatly appreciated. Each year in Australia more and more people suffer from the effects of the degenerative disorder known as osteoarthritis (OA). Studies have shown that this condition is particularly prevalent and debilitating in the elderly population and several different modes of treatment have been offered towards controlling the effects of OA. In this study we propose to investigate one such form of treatment, that of passive mobilization of the involved joint, specifically the knee.

All mobilization procedures will be performed by Henry Pollard, who is a fully qualified and registered chiropractor as well as being a Chiropractic Lecturer at Macquarie University. As was explained above, the procedure to be used involves passive movement of the knee, an action which involves almost the same degree of movement as do most day-to-day activities and, as a result, poses very little risk to participants in this study. The requirements for participation in this study are as follows:

(a) All participants must be aged 50 years or over

(b) All participants must suffer pain, "grinding", "clicking", restricted movement in the knee(s) and/or a positive diagnosis of OA in the knee(s) by a General Practitioner.

(c) Any participants suffering from inflammatory types of arthritis (eg: rheumatoid arthritis); neoplastic changes or conditions where such therapy would be deemed traumatic will be excluded from participating due to the relative severity of their condition. The results of this experiment will be correlated and presented in a research paper, excluding all participant details and thus maintaining complete confidentiality.

I agree to carry out the research as described above.

Signature of Investigator: __________________________________________

Date: ____________________________
CONSENT:

I agree to participate in the study treatment of osteoarthritis of the knee using a mobilization technique and give my consent freely. I understand the project will be carried out as described and have retained a copy of this information. I realize that I can withdraw from the study at any time and do not have to give any reasons for withdrawing. I have had all the questions answered to my satisfaction.

Signature of Participant: _____________________________________________

Date: ____________________________

Witness: ________________________________

Date: ____________________________
A Comparison Of Affects Of Two Types Of Chiropractic Adjustments On Hip Flexion Range Of Motion As Measured By A Straight Leg Raise.

CONSENT FORM.

This is a study to investigate the effects of specific adjustments on lumbo-pelvic and hip range of motion. This study will involve the following groups:

**Group 1:** Only hip flexion range of motion will be measured in this group

**Group 2:** A pre-test will first be performed where lumbo-pelvic and hip range of motion will be measured using a goniometer via a straight leg raise (S.L.R.). An adjustment will then be performed on the neck. A post-test measurement of S.L.R. will then be made and measurements recorded.

**Group 3:** A pre-test will then be performed where lumbo-pelvic and hip range of motion will be measured using a goniometer via S.L.R. An adjustment will then be performed on the sacroiliac joint. A post-test measurement of S.L.R. will then be made and measurements recorded.

I understand the risks and benefits of this investigation. I understand that I may discontinue involvement in this investigation at any time without prejudice against me.

Should I have any complaints I may contact the Centre for Chiropractic Macquarie University.

I hereby agree to take part in this study, I have been informed of the procedure and have completed the attached questionnaire and understand what is required of me.

........................................

(signature)