REGIONAL MANUAL THERAPY AND MOTOR CONTROL EXERCISE FOR THE MANAGEMENT OF CHRONIC LOW BACK PAIN WITH HIP AND SPINE MOTION LOSS: A RANDOMIZED CLINICAL TRIAL

A DISSERTATION

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Jason Zafereo entitled "Regional Manual Therapy and Motor Control Exercise for the Management of Chronic Low Back Pain with Hip and Spine Motion Loss: A Randomized Clinical Trial." I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Physical Therapy.

Sharon Wang-Price, Ph.D., Major Professor

We have read this dissertation and recommend its acceptance:

Toni Roddey, Ph.D.

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Ann Medley, Ph.D. Director

Accepted:

Dean of the Graduate School

DEDICATION

All praise, honor, and glory to God for this work.

And, with all my love, I dedicate this work to my wife and sons.

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To Judy, for sacrificing the most of anyone to get me here. You are my soul mate. Thanks for being patient with me, and for staying up late with me so many nights over the past four and a half years. Even though I may have been working, at least I had you there with me. I can't wait for the post-Ph.D. phase of our lives to begin! I love you!

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ABSTRACT

JASON ZAFEREO

REGIONAL MANUAL THERAPY AND MOTOR CONTROL EXERCISE FOR THE MANAGEMENT OF CHRONIC LOW BACK PAIN WITH HIP AND SPINE MOTION LOSS:
A RANDOMIZED CLINICAL TRIAL

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Background: The purpose of this study was to determine the additive effects of regional thoracic, pelvic, and hip manual therapy to standard physical therapy (PT) for improving spine and hip range of motion (ROM), pain intensity, disability level, and perceived change in a homogenous subgroup of persons with chronic low back pain (CLBP) and movement coordination impairments.

Methods: Forty participants with CLBP and movement coordination impairments were randomly allocated into one of two treatment groups. The control group received standard PT, consisting of a motor control exercise program and local lumbar spine manual therapy. The experimental group received standard PT and regional manual therapy applied to the hips, pelvis, and thoracic spine. Both groups received treatment at an outpatient clinic twice a week for four weeks. Outcome measures included thoracic and lumbar spine sagittal plane ROM, hip ROM in the transverse and sagittal planes, pain intensity measured with the Numeric Pain Rating Scale (NPRS), disability level measured with the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ), and perceived change due to treatment measured with the Global Rating of Change (GROC) scale. All outcome measures were assessed at two weeks, four weeks, and 12 weeks from the start of treatment. A MANOVA with repeated measures was used to analyze spine and hip ROM ($\alpha = 0.05$). Two separate ANOVAs with repeated measures were used to analyze pain intensity and disability level ($\alpha = 0.05$). A Mann-Whitney U test was used to analyze GROC scores ($\alpha = 0.05$).

Results: There was no significant interaction for group by time for spine and hip ROM, pain intensity, or disability level, suggesting that there was no difference between groups for any of these variables over 12 weeks. A significant difference was found in the main effect of time for hip ROM ($p < 0.001$), pain intensity ($p < 0.001$), and disability level ($p < 0.001$), suggesting that both groups demonstrated an improvement in these variables across time. No significant difference was found in the main effect of time for spine ROM ($p = 0.105$). A significant difference was found between groups at all three time points for the GROC, with the regional manual therapy plus standard PT group demonstrating higher perceived change scores at two weeks ($p = 0.031$), four weeks ($p = 0.022$), and 12 weeks ($p = 0.047$).

Conclusion: A program of standard PT with or without regional manual therapy resulted in significant improvements in hip ROM, pain intensity, and disability level across time in a homogenous subgroup of persons with CLBP and movement coordination

impairments. The addition of regional manual therapy to a program of standard PT resulted in significantly higher GROC scores across time compared to a program of standard PT alone.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Despite ongoing advancements in diagnosis and treatment, chronic low back pain (CLBP) remains the most common cause of long-term disability in Western industrialized countries (Henchoz, de Goumoens, Norberg, Paillex, & So, 2010). The cost of low back pain (LBP) is tremendous, with estimates falling between $100 and $200 billion per year in the United States alone (Freburger et al., 2009). Approximately two-thirds of this cost stems from lost salary and productivity due to varying levels of physical disability, while the remainder is comprised of healthcare expenses associated with the condition (Katz, 2006). Physical therapists are uniquely qualified to manage the physical disability aspect of CLBP through the application of exercise and manual therapy. While evidence generally supports the use of physical therapy (PT) in CLBP management (Delitto et al., 2012), consensus is lacking on how best to administer specific combinations of PT treatments in order to maximize outcomes and limit physical disability.

Exercise is the most often recommended PT intervention for the management of CLBP. A Cochrane systematic review (Hayden, van Tulder, Malmivaara, & Koes, 2005) specific to CLBP concluded that evidence supports the general use of exercise for decreasing pain in those with CLBP. Debate continues regarding what specific type of exercise may be most effective. Early reviews and clinical trials found no difference between exercise approaches for the treatment of CLBP (Macedo, Maher, Latimer, & McAuley, 2009; May & Johnson, 2008). However, this finding has been disputed in a recent systematic review (Bystrom, Rasmussen-Barr, & Grooten, 2013) in which motor control exercise reportedly was superior to general exercise, manual therapy, and minimal intervention for the reduction of pain and disability at variable time intervals, depending on the comparison conditions.

In addition to exercise, physical therapists regularly utilize manual therapy in the management of CLBP. Manual therapy may be applied locally to the lumbopelvic spine or regionally to the thoracic spine and hips. A recent Cochrane review comparing spinal manipulative therapy to other interventions concluded that it was not superior to inert, sham, or other active treatments in heterogeneous subjects with CLBP (Rubinstein, van Middelkoop, Assendelft, de Boer, & van Tulder, 2011). This finding may be related to the lack of homogeneous subgroups used in the Cochrane-reviewed studies, as well as a strong emphasis on manipulative therapy applied exclusively to the lumbopelvic region. A more recent review of the evidence supports the application of both thrust and non-thrust mobilizations to the lumbopelvic spine, thoracic spine, and hips for the reduction of pain and disability in CLBP (Delitto et al., 2012). This recommendation is partially based on new evidence reporting the benefits of regional thoracic and hip manual therapy for CLBP when performed without any additional intervention to the lumbosacral region (Burns, Mintken, & Austin, 2011; Cecchi et al., 2010).

The notion of addressing regional motion loss in the hip joint or thoracic spine for CLBP can be derived from studies that have looked at the association between mobility and pain. For example, hip rotation loss has been reported in persons with sub-acute to chronic non-specific LBP (Cibulka, Sinacore, Cromer, & Delitto, 1998; Ellison, Rose, & Sahrmann, 1990; Vad et al., 2004; Van Dillen, Bloom, Gombatto, & Susco, 2008), along with hip flexion loss (Porter & Wilkinson, 1997; Wong & Lee, 2004), and hip extension loss (Van Dillen, McDonnell, Fleming, & Sahrmann, 2000). Additionally, studies investigating homogeneous subgroups with LBP (i.e. patients classified into a movement impairment of lumbopelvic rotation and flexion) have found a relationship between the direction of lumbar hypermobility/pain and the direction of hip motion loss, as well as the timing of hip muscle activation (Kim et al., 2013; Van Dillen, Gombatto, Collins, Engsberg, & Sahrmann, 2007).

While the association between hip mobility and CLBP is becoming well-established, the connection between spinal mobility and CLBP remains unclear. Global spine range of motion (ROM) loss has been previously associated with CLBP intensity, but the relationship is described as weak (Dickey, Pierrynowski, Bednar, & Yang, 2002; Nattrass, Nitschke, Disler, Chou, & Ooi, 1999). One reason for this finding may be that adjacent segments become hypermobile or hypomobile to compensate for the dysfunctional segment, thus balancing each other out and creating the appearance of normal global ROM. In support of this claim, abnormal segmental spine mobility has been suggested as a stronger predictor of LBP than global ROM, with lumbar hypermobility being the factor most identified with LBP generation (Dickey et al., 2002; Kulig et al., 2007). The presence of lumbar spine segmental hyper- or hypo-mobility has been used to predict a patient’s response to lumbar stabilization or mobilization-based treatment for patients with LBP (Fritz, Whitman, & Childs, 2005). Patients with lumbar hypomobility were significantly more likely to respond favorably to lumbar mobilization than stabilization, with the inverse occurring for patients with lumbar hypermobility (Fritz, Whitman, & Childs, 2005). However, no similar evidence exists for using thoracic spine segmental mobility assessment to predict low back treatment responses. Nevertheless, these findings support the relevance of segmental spine mobility assessment for placing persons with LBP into homogeneous subgroups receiving mobilization or stabilization-based treatments.

Numerous systems have been developed to subdivide persons with LBP into homogeneous subgroups based on their response to movement. The most common methods include the Treatment-based Classification (TBC) system, the Mechanical Diagnosis and Treatment (MDT) system, the O’Sullivan Classification System (OCS), and the Movement System Impairment (MSI) classification (Karayannis, Jull, & Hodges, 2012). While individual system proponents may argue the superiority of their techniques, the evidence has not supported such a claim. Rather, each set of guidelines has demonstrated effectiveness in the general management of patients with spine pain. With such a variety of approaches to PT spine care, clinicians and patients can become confused about which approach to select for optimal diagnosis and management.

The most recent clinical practice guidelines from the Orthopaedic Section of the American Physical Therapy Association (APTA) recommend the use of a newly developed classification scheme derived from the TBC (Delitto et al., 2012). This system builds on the primary categories of the TBC (specific exercise, manipulation, and stabilization) by including new categories that consider the healing stage of the patient, as well as the presence of affective tendencies and generalized pain, when selecting the best course of treatment. One new category that potentially could apply to the majority of patients with CLBP is termed “Chronic Low Back Pain with Movement Coordination Impairments.” The criteria for this category include one or more of the following impairments: 1) local or referred LBP that worsens with sustained end-range movements or positions, 2) lumbar hypermobility, 3) decreased trunk/pelvic strength and endurance, 4) movement coordination impairments during community/work activities, and 5) mobility deficits of the thorax and lumbopelvic/hip regions (Delitto et al., 2012). While the first four criteria suggest the presence of movement coordination impairments common to CLBP that may benefit from exercise, the fifth criterion suggests the presence of regional stiffness that may benefit from a regional manual therapy approach. Currently, no randomized clinical trials have investigated which combinations of PT treatment are most effective for managing patients in this newly developed subgroup.

Statement of the Problem

The LBP classification scheme proposed in the most recent Orthopaedic Section guidelines may represent the most comprehensive attempt at patient classification to date. The new system categories appear more mutually exclusive and exhaustive than the TBC categories, where 50% of patients with LBP evaluated were unable to be placed into a single classification group (Stanton et al., 2011). The new emphasis on combining mobilization and stabilization-based treatment approaches into one classification subgroup reflects the dual importance that mobility and motor control impairments appear to have for the majority of patients with CLBP. Although these general impairments can be used to characterize the CLBP with Movement Coordination Impairments category, there are no set definitions or criteria for the type or degree of testing required to establish the presence of these impairments.

For example, in regards to the criteria for lumbar hypermobility, there is no mention of how this should be assessed, or the degree to which it should be present to warrant treatment. Numerous studies consistently report poor reliability for manual segmental mobility assessments of lumbar spine mobility when raters were asked to compare each segment's motion to "normal," or when 9-point to 11-point Likert scales were used to grade mobility (Binkley, Stratford, & Gill, 1995; Maher & Adams, 1994), which calls into question the use of this form of testing to establish the presence or absence of lumbar hypermobility. Additionally, no accepted standards exist to define the presence of mobility deficits at the thorax and hips in persons with CLBP. Therefore, additional studies are needed to establish the type and degree of testing required to determine when patients meet the specific criteria for the CLBP with Movement Coordination Impairments category.

Additional studies are also warranted to support the treatments recommended in the new classification categories proposed by Delitto et al. (2012). While motor control exercise and regional manual therapy have shown promise as individual treatments in heterogeneous populations with LBP, they have not been tested as part of a multimodal treatment approach in a homogeneous subgroup with CLBP. This is especially true for the recommendation to perform regional manual therapy to the hips and thoracic spine for patients with CLBP. To date, the evidence directly supporting the use of regional thoracic and hip manipulation in CLBP is limited to case series or trials that examined only the immediate, isolated effects of regional manipulation (Burns, Mintken, Austin, & Cleland, 2011; de Oliveira, Liebano, Costa Lda, Rissato, & Costa, 2013). Although positive findings of reduced pain and disability have been reported in these studies, randomized clinical trials are needed to support the application of regional manual therapy in CLBP, especially in homogeneous subgroups with CLBP and movement coordination impairments.

Purpose of the Study

The first purpose of this study was to determine whether or not a multi-modal, standard PT approach (motor control exercises and lumbar spine manual therapy) could improve thoracolumbar spine ROM, hip ROM, pain intensity, disability level, and perceived change in a CLBP subgroup with movement coordination impairments. The second purpose was to determine whether or not adding regional thoracic, pelvic, and hip manual therapy to a standard PT approach could improve thoracolumbar spine ROM, hip ROM, pain intensity, disability level, and perceived change in a CLBP subgroup with movement coordination impairments more effectively than standard PT alone.

Research Questions

The following research questions were addressed in this study:

1. Will the addition of thoracic, pelvic, and hip manual therapy to standard PT be more effective than standard PT at improving thoracolumbar spine ROM, hip ROM, pain intensity, and disability level in a CLBP subgroup with movement coordination impairments at two, four, and 12 weeks after initiating treatment?
2. Will all participants who have CLBP with movement coordination impairments have improvements in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment?

3. Will the addition of thoracic, pelvic, and hip manual therapy to standard PT be more effective than standard PT at improving global rating of change (GROC) scores in a CLBP subgroup with movement coordination impairments at two, four, and 12 weeks after initiating treatment?

Hypotheses

Research Hypotheses

The following hypotheses were generated for this study:

1. In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will demonstrate greater improvements in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.
2. All participants who have CLBP with movement coordination impairments will demonstrate significant improvements over baseline levels in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment.
3. In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will demonstrate greater improvements in GROC scores at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.

Null Hypotheses

The following null hypotheses were generated for this study:

1. In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will not demonstrate greater improvements in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.
2. Participants who have CLBP with movement coordination impairments will demonstrate no improvements over baseline levels in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment.
3. In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will not demonstrate greater improvements in GROC scores at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.

Operational Definitions

For the purpose of this study, the following terms were defined:

1. CLBP: A participant had CLBP if they have had pain originating from the lumbar region that was persistent for greater than or equal to three months. No limitations were placed on which musculoskeletal structure was generating the

pain. However, pain should have been able to be altered (reproduced, increased, or relieved) with sustained postures, or with testing of range of motion (ROM), segmental spinal mobility, palpation, or special testing.

2. Spine ROM: Testing for this study was performed using the ValedoShape (Hocoma Inc. USA, Norwell, MA), which is a wheeled skin-surface device containing accelerometers that record inter-segmental distance and change of inclination of spinous processes. Information from the device was interfaced wirelessly to a personal computer 1-2 meters away, which contained normative values for segmental spine ROM based on the participant's age and sex. Any thoracic or lumbar spine ROM values greater than one standard deviation below the normative value were considered hypomobile, and values greater than one standard deviation above the normative value were considered hypermobile.
3. Hip ROM: An inclinometer was used to measure hip ROM in the sagittal and transverse planes as measured in degrees.
4. Hip ROM loss: The level of significant sagittal plane hip motion loss required for study eligibility as measured in supine was < 110° of flexion or lacking > 6° of extension on the Thomas test (Zafereo, Devanna, Mulligan, & Wang-Price, 2015). The level of significant transverse plane hip motion loss required for study eligibility as measured in prone was < 30°of rotation either internally or externally (Burns, Mintken, Austin, & Cleland, 2011).

5. Pain intensity: A subjective report of the participant's average low back pain intensity over the previous 24 hours as measured by the Numeric Pain Rating Scale (NPRS).
6. Disability level: A subjective report of the participant's average level of perceived disability with functional tasks due to LBP as measured by the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ).
7. Perceived change: A subjective report of the participant's perceived level of improvement or worsening from the point that they began treatment as measured by the Global Rating of Change (GROC) scale.
8. Motor control exercise: An exercise designed to build strength, coordination, and muscular endurance. The exercises sought to maximize motor recruitment in the target muscles through isometric muscle contractions while minimizing faulty movements or compensatory muscle contractions through an emphasis on spinal stabilization (Bystrom et al., 2013).
9. Regional manual therapy: Thrust or non-thrust mobilization techniques applied to joints or soft tissues of the thoracic spine, pelvis, or hips. The goal of these interventions was to decrease pain and increase mobility.
10. Local manual therapy: Thrust or non-thrust mobilization techniques applied to the joints or soft tissues of the lumbar region. The goal of these interventions was to decrease pain and increase mobility.

11. Regional interdependence: The concept that physical impairments in one or more regions of the body could contribute to the development and perpetuation of movement impairment and pain in a remote region of the body.

Assumptions and Limitations

Assumptions

The following assumptions were made for this study:

1. Participants were truthful on all self-report measures, including pain intensity, disability level, and perceived change.
2. Participants were truthful in reporting their compliance to home exercise recommendations.
3. Participants gave their maximal effort and focus while performing motor control exercises in the clinic and at home.
4. Participants gave their maximal effort for spine ROM testing.
5. Spine and hip ROM testing was performed consistently between trials and between testers.

Limitations

The following were limitations for this study:

1. Generalizability of spinal ROM findings may be limited to other methods of testing because we used a skin-surface device to determine spinal mobility.

2. Generalizability of hip ROM findings may be limited to other methods because we used the first onset of resistance for determining end-ROM.
3. The lack of control for medication use during the study. However, medication use was monitored and compared between groups.
4. The lack of control for depression, anxiety, fear avoidance, and catastrophizing. Although these variables were not used as outcome measures, they were assessed at baseline and compared between groups.

Significance of the Study

This study contributed to the APTA Clinical Research goal of evaluating effective patient/client classification methods to optimize clinical decision making for physical therapist management of patients/clients. The use of the Orthopaedic Section's clinical practice guidelines as inclusion criteria for this study provided for testing of a homogeneous subgroup. The use of valid and reliable measurement tools to identify the presence of hip and segmental spine ROM loss further defined the participants in this study, and served as a valuable outcome measure. The potential for finding superior outcomes in the group receiving regional manual therapy and motor control exercise could lead to more specific treatment recommendations for persons with CLBP with movement coordination impairments, specifically related to targeting regional interdependence through manual therapy. Future studies could determine other specific treatment preferences for different homogenous patient subgroups with LBP, thus leading to an overall reduction in the negative societal impact associated with this condition.

CHAPTER II

REVIEW OF THE LITERATURE

The following literature review provided the background for this investigation in chronic low back pain (CLBP) treatment approaches. The information reflected the most current, peer-reviewed evidence available for CLBP. The review begins with a description of the epidemiology of CLBP for the purpose of justifying the selection of this topic area for study. The review then includes an analysis of the current tests used for low back pain (LBP) pathology and impairment assessment. This section provides validation for the development of new testing procedures piloted for use in this study. In addition, the review highlights the most common practices for the physical therapy management of LBP. This section reflects the current emphasis on classification schemes and clinical prediction rules to guide treatment, and supports the need to develop new criteria to enhance evaluation and treatment of CLBP. Finally, the review concludes with a discussion of regional interdependence and movement impairment as they relate to CLBP. This section details the increasing body of evidence on the importance of these factors in CLBP management, and provides justification for a randomized controlled trial investigating their application in patient care.

The evidence used in this review was derived from searches to the medical literature using the following databases: CINAHL, PubMed, and Scopus. Searches took place between the months of January to April, 2013, and from April to May, 2014. Articles selected for inclusion in the literature review were less than 10 years from publication date unless they were a seminal work, and were chosen for their relevance to the methods and statistical analyses used in this dissertation study.

Epidemiology of CLBP

Prevalence

Estimates place the number of Americans with chronic pain between 2 and 40% of the population (Hardt, Jacobsen, Goldberg, Nickel, & Buchwald, 2008; Manchikanti et al., 2009; Portenoy, Ugarte, Fuller, & Haas, 2004). World-wide, approximately 5-41% of women and 4-29% of men are afflicted with chronic, non-minor pain (Gureje, Von Korff, Simon, & Gater, 1998). The significant variability observed in these prevalence estimates reflects the difficulty in assigning one prevalence rate to an entire nation, or to the world. The sample population and sampling method used in epidemiological studies significantly affects the stated prevalence. Studies that focus on industrialized populations, use mailed surveys to collect data, or ask participants to report pain occurrence over a set time (period prevalence) tend to report higher prevalence estimates. Studies that focus on current reports of pain (point prevalence), the presence of non-minor pain, or data collection through in-person/telephone interviews tend to provide the most conservative estimates of chronic pain occurrence (Hardt et al., 2008).

The following paragraphs review various reports of the prevalence data for CLBP in the United States (US).

The spine is consistently reported as the primary pain generator among people with chronic pain in the US. Despite this finding, agreement on the prevalence of CLBP is elusive. One of the most commonly cited sources for region-specific pain prevalence in the general population is the annually-occurring, federally-sponsored, National Health and Nutrition Examination Survey (NHANES). This instrument provides data from in-person interviews that can be used to identify chronic (> 3 months) pain that is current and non-minor. In a recent survey of 10,291 participants, a prevalence of 10.1% was found for chronic spine pain, compared to 7.1% for the legs/feet, 4.1% for the arms/hands, and 3.5% for headaches (Hardt et al., 2008). The effect of gender and race/ethnicity on chronic pain prevalence remains unclear, as the NHANES findings that reported minimal gender differences and lower rates of chronic pain among Mexican-Americans have not been supported in other studies. However, NHANES found a linear increase in LBP prevalence until the sixth decade of life, and this finding was supported in a separate study (Hoy, Brooks, Blyth, & Buchbinder, 2010).

A recent investigation of state-specific CLBP prevalence also supports the federally-reported levels listed above. Freburger et al. (2009) investigated the prevalence of CLBP over a 14-year interval in the state of North Carolina. Telephone surveys were performed to identify residents with current, non-minor back pain. A sample of 4,437 households reported a prevalence of 3.9% in 1992, increasing to a prevalence of 10.2% among 5,357 households in 2006. The significant increase in CLBP prevalence seen over the 14-year interval was not attributed to a change in survey methods, resident age, or resident ethnicity. Instead, the study authors hypothesized that increased obesity rates, increased rates of psychosocial impairments, and increased physical work demands may have affected prevalence rates over time.

The NHANES and North Carolina surveys each provide similar, conservative estimates of the point prevalence of chronic spine pain in the US. Placing the point prevalence of CLBP at 10% seems reasonable, considering that the estimated median and mean point prevalence of all (acute and chronic) episodes of LBP is 15% and 18.1%, respectively (Hoy et al., 2010). An across-the-board point prevalence rate of LBP at 15% is also consistent with data from the 2008 U.S. National Health and Wellness Survey, which assessed 30,868 working citizens between the ages of 20 and 64 (McDonald, DiBonaventura, & Ullman, 2011). Whereas these estimates of point prevalence provide one view of the occurrence of LBP, period prevalence estimates provide a different perspective on the epidemic.

Period prevalence estimates of LBP are markedly higher than point prevalence estimates because they allow for reports of pain to occur at any instance in a set timeframe. Due to the relapsing and remitting nature of LBP, these estimates may be a better description of the true prevalence of the condition. The National Health Interview

Survey (NHIS) placed the 3-month prevalence of LBP at 28% (Gaskin & Richard, 2012). This is consistent with other reports which have placed the 1-year prevalence rate for LBP between 22 and 65% over a 32-year span (Walker, 2000). Three-month period prevalence data from the NHANES and NHIS place the number of Americans affected by LBP at a staggering 59 million persons (Lawrence et al., 2008). Although investigators may offer differing views of the exact magnitude of chronic pain, they can at least agree on one trend: more Americans are now seeking treatment for chronic pain than for any other medical condition (Hardt et al., 2008).

Incidence

Incidence estimates are used to report the number of new cases of a condition. Studies on the incidence of LBP are less numerous and perhaps less informative than their prevalence counterparts. The reason for this difference is the relapsing and remitting nature of LBP, which makes it difficult to tell where one back pain episode ends and another one begins. The annual incidence of a first-time onset of LBP is reported between 6.3 and 15.4% (Hoy et al., 2010). This range widens to 1.5 - 36% when considering the annual incidence of combined new onset and remitting LBP episodes.

Steps to reduce the incidence of LBP should focus on the reduction of key risk factors found in the general population. Numerous individual, psychosocial, and occupational factors may contribute to the initial and subsequent development of LBP. Early risk factor identification and reduction is believed to be essential for the prophylactic management of LBP. The following variables have been reported among the predictors of a first occurrence of LBP: age (incidence highest in third decade of life), high birth weight (males), presence of a lifetime depressive disorder, working night shifts, and occupations requiring heavy physical work or whole-body vibration (Hoy et al., 2010; Manek & MacGregor, 2005).

The most useful variables for determining the presence of CLBP at three months to one year include: 1) high baseline functional disability, 2) presence of psychiatric comorbidities such as depression, 3) low general health status, 4) high levels of maladaptive behavior such as fear avoidance, and 5) the presence of nonorganic signs (Chou & Shekelle, 2010). The inclusion of depression on two different risk factor lists speaks to its significant role in predicting LBP occurrence and re-occurrence. Variables such as work environment, presence of radiculopathy, baseline pain, and history of prior LBP were not useful predictors of the development of CLBP (Chou & Shekelle, 2010).

Impact on Society

Despite ongoing advancements in diagnosis and treatment, CLBP remains the most common cause of long-term disability in the US and other Westernized countries (Henchoz et al., 2010). The cost of LBP is tremendous, with estimates falling between $100 and $200 billion per year in the US alone (Freburger et al., 2009). The majority of this cost stems from lost salary and productivity, while the remainder is comprised of healthcare expenses associated with the condition (Katz, 2006). Certain risk factors, such as negative beliefs about LBP and high fear avoidance on the work subscale of the Fear Avoidance Beliefs Questionnaire (FABQ), are predictive of work absence due to pain (Mannion et al., 2009). The following paragraphs elaborate on the effects of LBP in the workforce, as well as in the delivery of healthcare.

The two forces driving up workplace costs in those with LBP include absenteeism and presenteeism. Absenteeism, the illness-related absence from work, would appear on the surface to be a self-limiting phenomenon that decreases in frequency over time. Rather, data from the Arizona State University Healthy Back Study suggests that the percentage of people with LBP who returned to work after onset, but experienced intermittent absences, increased significantly from 26% at 30-60 days post-onset to 42% at one year post-onset (Johnson, 2005). Despite these trends, the absenteeism rate pales in comparison to the productivity losses (estimated at 28%) reported by those workers with LBP choosing to stay on the job (McDonald et al., 2011).

Presenteeism, the reduction of a worker's productivity while still at work, is the often overlooked consequence of LBP. Presenteeism is the largest contributor to lost productive work time, accounting for 85% of the $7.4 billion lost by US employers with workers limited by LBP (Ricci et al., 2006). Among these under-productive workers, 71% had an exacerbation of a chronic condition rather than a new onset of LBP. Therefore, in both absenteeism and presenteeism, the person with CLBP appears to contribute more to the costs of LBP than the person with acute pain.

Not surprisingly, those with CLBP are also responsible for the majority of the costs associated with LBP medical management. Evidence suggests that people with LBP have overall medical expenditures about 60% higher than non-spine pain patients (Luo, Pietrobon, Sun, Liu, & Hey, 2004). Furthermore, emergency room visits for patients with CLBP cost 1.7 times more than for typical non-spine pain patients, likely due to an overreliance on imaging studies common to emergency departments. Considering the frequency with which some patients with CLBP visit the emergency room, and the average per visit charge of $1,799 for this population, one must consider whether patients' drug-seeking and providers' over-billing are common occurrences in this population (Jorgensen, 2007) or not.

Course of LBP

Greater than 80% of the population experiences LBP at some point in their lives (Rubin, 2007). How many of these individuals go on to develop chronic pain remains a point of debate. By some accounts, 90-95% of those afflicted with LBP recover spontaneously within a few months of onset (Carey et al., 1995; Hestbaek, Leboeuf-Yde, & Manniche, 2003). Others estimate that 42-75% of the general population and 20-44% of the working population will continue to have pain one year from onset (Hestbaek et al., 2003; van Tulder, Koes, & Bombardier, 2002). With estimates suggesting that 85% of those with LBP will have subsequent episodes in their lifetime, the course of LBP may be best described as recurrent and variable as opposed to acute and self-limiting (Ricci et al., 2006; van Tulder et al., 2002).

Several classes have been developed to describe the recurrent and variable nature of LBP. People with CLBP can be labeled as having severe persistent pain, moderate persistent pain, mild persistent pain, or fluctuating (between severe and minimal) pain (Tamcan et al., 2010). The majority of patients at any given time can be placed in a class of moderate or mild persistent pain with brief periods of movement into and out of a severe persistent or fluctuating pain class. Gender, body mass index, education level, location of residence (urban versus rural), and the presence of certain co-morbidities, including depression, have not significantly contributed to an individual's class. Rather, age, level of physical dependence, and level of physical functioning were the primary predictors of class, with higher occurrences of each predictor being associated with placement in the progressively more moderate or severe persistent pain classes (Tamcan et al., 2010).

A multitude of physical and psychological deficits may accompany CLBP. These sequelae tend to occur most often in courses of CLBP that are either prolonged or of an intense nature. Psychological disorders, such as depression, are present in 33-46% of those with CLBP, compared to 8-10% of individuals who are pain-free or who have pain of a short duration (Gureje et al., 1998; Kinney, Gatchel, Polatin, Fogarty, & Mayer, 1993). Evidence also suggests that abnormal brain chemistry and loss of cortical gray matter accompanies prolonged episodes of CLBP, contributing to disturbances in memory and attention for this population (Apkarian et al., 2004; Grachev, Fredrickson, & Apkarian, 2000). Disturbed sleep is reported in up to 89% of chronic pain patients, with the degree of disturbance directly associated with pain intensity (McCracken & Iverson, 2002). Other variables associated with high pain intensity in CLBP patients include hypertension and impaired sexual dysfunction (Fine, 2011). The addition of these comorbidities undoubtedly contributes to the complexity of CLBP patients, requiring a holistic approach to evaluation and management.

Tests and Measures for CLBP

Approximately 85-90% of LBP cases are reportedly non-specific, with an unknown pain origin as determined by diagnostic imaging and physical examination (Jarvik & Deyo, 2002; Manek & MacGregor, 2005). The remaining cases are thought to have a specific cause, either associated with a medical red flag (e.g. cancer, infection, spinal fracture) or a neurological compromise of the cauda equina or nerve root. With the likelihood of finding a red-flag condition on lumbar spine imaging at less than 1%, the clinician typically focuses on identifying any neurological involvement first, and then identifying any potential barriers to recovery (Chou & Shekelle, 2010). Therefore, the use of history-taking, diagnostic imaging, and physical examination is valuable from the standpoint of identifying yellow flags (psychosocial findings that can delay recovery), possible pain generators (biological causes of pain), and the potential impairments to movement, such as alignment, stiffness, and weakness that can contribute to or result from the condition.

Biopsychosocial-Based Testing

Patient history and diagnostic imaging. The presence of yellow flags in the history or physical examination signals to the provider that the patient's prognosis for a full and timely recovery may be less favorable. Some of the most commonly reported yellow flags include elevated fear avoidance beliefs, depression, and stress in the work or family environments. Yellow flags are primarily identified through the patient history or by self-reported questionnaires. The FABQ and the Pain Catastrophizing Scale (PCS) have been recommended for use in the CLBP population. These questionnaires are highly reliable, with intraclass correlation coefficients (ICCs) ranging from 0.90 to 0.96. The FABQ and PCS also account for a more significant proportion of the depression, pain intensity, and physical disability typically seen in the CLBP population compared to other fear-avoidance measures (George, Valencia, & Beneciuk, 2010). Pain intensity and physical disability are often assessed with the Numeric Pain Rating Scale (NPRS) and the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ), respectively. The NPRS is an 11-point scale on which participants rank their current, best, and worst level of pain over the past 24 hours, with 0 representing "no pain" and 10 representing "worst imaginable pain". This instrument has been shown to be reliable and responsive in a sample of patients with LBP (Childs, Piva, & Fritz, 2005). The minimal clinically important difference (MCID) for the NPRS has been reported as 2 points. The ODQ is a low back-specific questionnaire that gauges a person's disability level on a scale of 0 to 50, with higher scores indicating higher levels of disability. The ODQ has been shown to be highly reliable, valid, and responsive in patients with LBP (Fritz & Irrgang, 2001). The minimal detectable change (MDC) for this outcome measure is 10.5 points (Davidson & Keating, 2002).

Self-report findings may be corroborated in the physical examination with range of motion (ROM), special testing, neurological testing, and palpation (Waddell, McCulloch, Kummel, & Venner, 1980). The presence of yellow flags may require alternative management strategies, either in the way of outside referrals to other providers, or through taking a more cognitive-behavioral approach to rehabilitation. Yellow flag screening and management in LBP is gaining increased attention, both as a way to keep those with LBP from becoming chronic, and as a way to specifically identify and address potential contributing factors in those patients already deemed to be chronic.

The identification of a possible pain generator can also aid the physical therapist in treatment planning. The information provided by the patient history and diagnostic imaging, as well as the ROM, special testing, neurological testing, and palpation portions of the physical examination can be used to focus treatment to the most likely painful tissue(s) contributing to a condition. Once red flag conditions have been excluded for the lumbar spine, testing seeks to identify the potential sources of remote, referred, or radiating pain associated with the spine. Testing for these pain sources primarily focuses on the spinal nerves, sacroiliac joints, zygapophyseal joints, lumbar discs, and soft tissue, as recent evidence suggests that acceptable diagnostic accuracy can be attained for certain clinical examination findings specific to these structures.

The patient history can provide a wealth of information regarding pain generator differential diagnosis. The presence or absence of pain when rising from sitting has been significantly correlated with pain stemming from either the lumbar disc or joint, respectively (Young, Aprill, & Laslett, 2003). Pain that is present when rising from sitting, unilateral, and absent from the lumbar spine has been significantly associated with a pathology arising from the sacroiliac joint. The diagnosis of certain spinal nerve compression conditions can be largely made from the patient history alone. Katz et al. (1995) reported a post-test probability of > 99% from a pre-test probability of 40% for lumbar spine stenosis when the following five variables were present: no pain or symptoms improved when sitting, age > 48 years, leg pain more than back pain, bilateral symptoms, and pain during walking or standing. The use of diagnostic imaging in the case of LBP should be considered for confirming and defining sources of pain rather than for finding them. Strong evidence exists to refute the use of routine diagnostic imaging in nonspecific LBP, limiting the application of this tool to severe or progressive neurological deficits, or when persons with radiculopathy or stenosis are potential candidates for surgery or epidural steroid injection (Flynn, Smith, & Chou, 2011).

Physical examination. After considering the history and imaging findings, movement testing can provide additional clarification on the differential diagnosis of spinal referred pain. The concept of centralization is reported as one major key to identifying pain of disc origin. The phenomenon of centralization occurs when referred pain relocates closer to its source through the performance of repeated spinal movements in a specific direction. Centralization is reported to occur in 80-100% of those individuals with positive discography, making for a highly specific finding for a disc pain generator (Laslett, Aprill, McDonald, & Oberg, 2006). The absence of centralization is not very sensitive, as 35-45% of individuals failing to centralize still had a positive discogram. Since not all patients will tolerate repeated movement testing or achieve centralization, two other tests may be used to distinguish disc pain. A moderate or major loss of spinal extension and a feeling of vulnerability during mid-range spinal flexion or rotation have been associated with positive discography. When these exam findings were either present together or accompanied by centralization, the likelihood of a disc pathology increased further, with a positive likelihood ratio of 6.7 (Laslett et al., 2006).

Aside from the intervertebral disc, the zygapophyseal joint is the other non-contractile, spine-specific structure most often associated with local or referred CLBP.

Movement testing testing via a combination of spinal extension-rotation can assist with the differential diagnosis of joint pain; however, the evidence conflicts as to whether this movement should be pain provoking or not. Revel et al. (1992) presented the first evidence on clinical predictors of a favorable response to facet injection, thereby implicating the zygapophyseal joint as the likely pain generator. The authors noted that positive responders were unlikely to experience exacerbation with lumbar flexion, lumbar extension, or lumbar extension-rotation. In a more recent study attempting to validate Revel's criteria, painful extension-rotation was found to be one of the strongest predictors of a beneficial response to facet injection, while pain-free extension-rotation demonstrated 100% sensitivity for identifying those subjects with no relief with facet injection (Laslett et al., 2006). Considering the conflicting nature of this evidence, ROM testing for the differential diagnosis of lumbar spine joint pain should be used with caution.

Special tests (e.g., straight-leg-raise, prone instability test, Gillet test), neurological testing, and palpation comprise the remaining tools used by clinicians to assist with differential pathology diagnosis. For the diagnosis of radiculopathy, findings of decreased muscle strength and sensory loss correlate relatively well to pathology, while straight-leg-raise testing is counted as the only special test consistently reported as sensitive for the diagnosis of sciatica due to a herniated lumbar disc (Rubinstein & van Tulder, 2008). Special testing for the diagnosis of sacroiliac joint pain also is integral in physical examination. The combination of at least three positive sacroiliac provocation tests that reproduce the patient's pain when stress is applied on the sacroiliac joint with the absence of centralization on repeated movements yields a positive likelihood ratio of 6.97 (Laslett, Young, Aprill, & McDonald, 2003). Finally, the use of palpation is best reserved for the detection of soft tissue pain sources. The pooled inter-observer (K = 0.42) and intra-observer (K = 0.65) reliability is acceptable for this form of testing, making palpation a suitable test for the identification of soft tissue pain (Rubinstein & van Tulder, 2008).

Impairment-Based Testing

Although biopsychosocial-based testing may partially aid in the differential diagnosis of spine pathology, the utility of this diagnosis is questionable. Knowledge of pathology does not always lead to knowledge of treatment, as not all patients with a disc herniation, for example, will benefit from the same interventions. Furthermore, biopsychosocial testing may not yield useful information in the case of patients with true non-specific, localized CLBP, or those in whom yellow flags are not a contributing factor. Therefore, the clinician can also use the individual's range of motion (ROM) and motor function to identify unique movement impairments, such as stiffness or poor motor control, which can inform treatment decisions. Excessive or reduced ROM at the spine or hips is assumed by most therapists to be a common contributing factor in CLBP (Chaitow, 2011). Identification and management of these contributing factors is considered by many therapists to be vital to the long-term recovery of the individual, as it allows treatment to be focused on the potential cause of pain, or on sequelae contributing to the perpetuation of chronic pain. The following paragraphs will summarize the literature on the reliability and diagnostic accuracy of spine and hip ROM and muscle function testing as a commentary on the actual and potential use of these tests in the evaluation of patients with non-specific CLBP.

Spine ROM. ROM testing is arguably the most valuable assessment in the orthopedic physical examination. ROM is typically assessed at the painful region and at least one region above and below the painful region (hips and thoracic spine in the case of LBP). Testing typically consists of active and passive movements, single and repeated movements, and osteokinematic and arthrokinematic movements. ROM testing provides valuable information on the integrity of both contractile and non-contractile structures, as well as the degree to which motion may be increased or limited compared to a standard normative value, adjacent spinal segment, or contralateral joint.

The association of spinal ROM to CLBP has been investigated many times in the literature. While global spine ROM has been previously associated with CLBP intensity, the relationship is often described as weak, which may explain why spinal ROM has not been consistently associated with functional disability levels (Dickey et al., 2002; Nattrass et al., 1999). One potential reason for this finding is that the vast majority of impairment-pain association studies use heterogeneous samples with CLBP, which does not account for the significant ROM variability seen among people of different genders, ages, and ethnicities (Trudelle-Jackson, Fleisher, Borman, Morrow, & Frierson, 2010). Furthermore, the use of heterogeneous samples does not account for the variability seen in ROM patterns for subjects classified with a particular movement impairment syndrome of the lumbar spine (Hoffman, Johnson, Zou, & Van Dillen, 2012). To account for this variability, future studies should compare homogeneous CLBP subgroups to age and gender-matched normal subjects to determine the impairment-pain association.

The other alternative to using global ROM assessments is to use segmental mobility impairment as a predictor of CLBP. Segmental mobility assessment provides greater detail about the function of the spinal levels closest to the subject's pain, which could allow for the observance of impairment not seen on global measures due to the likelihood of motion compensation. Abnormal segmental spine mobility has been suggested as a stronger predictor of LBP than global ROM, with hypermobility being the factor most identified with LBP generation (Dickey et al., 2002; Kulig et al., 2007). However, the relationship between CLBP and segmental mobility has been described as complex, nonlinear, and involving multiple interactions (Dickey et al., 2002). Future studies on homogeneous subgroups with CLBP may help to clarify the relationship between CLBP and segmental mobility.

Spinal ROM is typically assessed using kyphometers, goniometers, or dual inclinometers. While these devices have acceptable reliability and clinical utility, they do not allow for the objective assessment of the spine's segmental mobility (Mannion, Knecht, Balaban, Dvorak, & Grob, 2004). Segmental spine mobility is most accurately assessed through the use of diagnostic imaging. While accurate, imaging is not always the most practical assessment of mobility due to the costs and the possibility of radiation exposure to the patient. Currently, the most widely used methods for segmental mobility assessment include manual evaluation of joint gliding during passive accessory intervertebral motion (PAIVM) testing, or manual palpation of movement between spinous processes during passive physiological intervertebral motion (PPIVM) testing. However, despite their widespread acceptance, these methods have not consistently demonstrated satisfactory reliability and validity.

Numerous studies consistently report poor reliability for PAIVM assessments of lumbar spine mobility when raters are asked to compare each segment's motion to "normal," or when 9- to 11-point Likert scales are used to grade mobility (Binkley et al., 1995; Maher & Adams, 1994). Reliability was improved when raters were asked to select one most mobile and one least mobile segment in a region. This approach was utilized by (Landel, Kulig, Fredericson, Li, & Powers, 2008) to achieve good interrater reliability for identification of the most hypomobile segment (K = 0.71), while reliability was still noted as poor (K = 0.29) for the most hypermobile segment. The highest reported intratester reliability for PAIVM testing was achieved with the use of an assisted indentation instrument. Although achieving excellent agreement between trials for one rater, inter-rater reliability has yet to be reported, and the instrument may pose barriers to use in a clinical setting due to cost and ease of operation (Stanton & Kawchuk, 2009). The issue of validity in PAIVM testing has only received limited investigation. In the largest study performed to date, Landel et al. (2008) found poor agreement ($K < 0.01$) between PAIVM assessment and dynamic magnetic resonance imaging (MRI) of spinal mobility, calling into question the validity of the PAIVM assessment.

The use of PPIVM testing may provide a more valid means of assessing spinal mobility compared to PAIVM testing. Abbott & Mercer (2003) compared findings from PPIVM tests to radiographic assessments of spinal flexion and extension ROM. Segments classified as hypomobile on manual assessment carried a positive likelihood ratio (+LR) of 3.86 for detecting motion loss of more than two standard deviations from the mean on radiographs. When comparing each segment to “normal”, the reliability of PPIVM testing in the lumbar spine is marginally superior to the poor levels noted for PAIVM testing. In addition, Strender, Sjoblom, Sundell, Ludwig, & Taube (1997) reported fair interrater agreement ($K = 0.54$) for PPIVM testing when using a 3-point Likert scale for judging normal, hypomobile, or hypermobile segmental motion. Although not perfect in its current form, the use of PPIVM assessment may hold the most relative promise for the future of enhanced reliability and validity in segmental mobility testing.

New commercially-available devices could allow for more precise and accurate detection of movement between spinous processes. One such device, the ValedoShape (Hokoma Inc. USA, Norwell, MA), has demonstrated good reliability and validity as compared to x-ray for global spine ROM in an asymptomatic population (Mannion et al., 2004). The ValedoShape, formerly the Spinal Mouse, is a wheeled skin-surface device containing accelerometers that record inter-segmental distance and change of inclination of spinous processes. This information is wirelessly transmitted to a personal computer, where segmental and global spine ROM between T1 and S1 is displayed for analysis. Published reliability data using the ValedoShape on asymptomatic individuals is discussed in the next paragraph. In addition, reliability data on symptomatic individuals is included as part of the pilot work for this project (see outcome measures section in Chapter III).

Using the ValedoShape, between-day intrarater reliability for the global lumbar spine ranged from 0.61 - 0.92, standard error of the mean (SEM) = 3.81° - 6.92° (Kellis, Adamou, Tzilios, & Emmanouilidou, 2008; Mannion et al., 2004). The inter-rater reliability for global sagittal ROM assessment of lumbar spine ranged from 0.66 - 0.93 and SEM = 2.8° - 7.6°. The intra- and inter-rater reliability for segmental lumbar assessment were more variable, with between-rater intraclass correlation coefficients (ICCs) ranging from 0.34 - 0.76 and SEM = 1.7° - 3.6°, and within-rater ICCs ranging from 0.39 - 0.83 and SEM = 1.9° - 3.5°. Despite these greater variations, the lumbar segmental measurements using the ValedoShape were closely correlated with radiographic findings, except at L4/5 and L5/S1, where variability was highest for both techniques. Also, the global measurements using the ValedoShape were positively correlated with the measurements taken by both x-ray and other skin-surface devices such as goniometers, inclinometers, and 3-D kinematic instruments, providing acceptable convergent validity for the ValedoShape (Mannion et al., 2004).

Hip ROM. Although spinal ROM assessment is inherent to the examination of CLBP, hip ROM assessment is not always included as standard of practice. Adequate hip ROM is essential for full sagittal plane spine ROM, as well as standing and sitting postural alignment. Therefore, a thorough and standard clinical examination for LBP should always include assessment of hip ROM. Hip ROM can be reliably detected with either a goniometer or inclinometer, as the two instruments have demonstrated similar accuracy. However, readings from the two instruments are not interchangeable, as inclinometers typically overestimate sagittal plane motions, but underestimate rotational measurements in either prone or supine (Bierma-Zeinstra et al., 1998).

Intrarater reliability of hip ROM measurement is reported as excellent, with ICCs ranging from 0.76 to 0.97 (Prather et al., 2010). Interrater reliability is also reported as excellent for hip flexion (ICC = 0.87) and prone internal rotation (ICC = 0.79 - 0.99) (Ellison et al., 1990; Prather et al., 2010). However, greater interrater variability is seen with motions in other planes, such as rotation in supine (ICC = 0.63 – 0.75) or hip extension in prone (ICC = 0.44), where lumbopelvic stability is more difficult to achieve. The greatest reported interrater variation is found in supine frontal plane movements and prone external rotation, with the former showing moderate agreement (ICC = 0.34 - 0.54), and the latter showing agreement ranging from excellent (ICC = 0.95 – 0.97) to poor (ICC = 0.18). Enhanced accuracy can be achieved for prone rotation testing by stabilizing the pelvis and tibiofemoral joint, and for hip extension testing by use of the Thomas position with control of the knee flexion and hip abduction angles (Harris-Hayes, Wendl, Sahrmann, & Van Dillen, 2007; Van Dillen et al., 2000). With careful application, hip ROM in the sagittal and transverse planes should be considered a very reliable and useful form of testing.

Muscle function. After ROM, muscle function testing is arguably the most informative testing tool for the provider treating CLBP. Muscle function testing investigates movement under active control to determine pain provocation, force generation, and motor control. Muscle function testing may utilize a number of different tools to quantify motor output, including electromyographic (EMG) analysis, diagnostic ultrasound assessment, isokinetic testing, assessment of motor control, manual muscle testing (MMT), or isometric endurance testing. Given that these tools provide significant variability in the data produced and the cost and time associated with usage, clinicians should first consider the best evidence on the reliability of these tools and the strength of their association with CLBP.

Needle EMG analysis, in combination with nerve conduction testing, is considered to be the gold standard for the evaluation of neuromuscular function (Pullman, Goodin, Marquinez, Tabbal, & Rubin, 2000). However, due to the invasiveness of this procedure, it is not practical to use this form of testing on most patients in a clinical setting. Surface EMG and diagnostic ultrasound imaging are widely considered non-invasive alternatives to the gold standard. These tools have been shown to adequately discriminate between those with and without LBP when testing abdominal (e.g. transverse abdominis and oblique) and lumbar multifidus muscles (Hides, Gilmore, Stanton, & Bohlscheid, 2008; Pullman et al., 2000). Furthermore, muscle thickness changes seen on diagnostic ultrasound in these same muscle groups are positively correlated with EMG signaling changes, providing validity for the assessment of muscle function with ultrasound (Ferreira, Ferreira, & Hodges, 2004; Kiesel, Uhl, Underwood, Rodd, & Nitz, 2007). While these tools are valid, are reliable, and maintain the patient contact necessary for specificity of testing, they each carry a considerable expense to the clinician from the standpoint of time and equipment costs. For many, this expense is not justifiable, as similar information can be determined from other simpler testing methods.

Although isokinetic machines are faced with the same implementation challenges as ultrasound and EMG, they offset some of these barriers by having dual utility for testing and treatment. Most evidence supports that flexion and extension isokinetic and isometric machine-based testing has suitable diagnostic accuracy for CLBP, with the ability to distinguish patients with LBP from asymptomatic individuals, or those with other chronic conditions such as headache (Gruther et al., 2009). However, the stability of this testing has been questioned, as variability ranging from 45 to 160% has been reported for between-day isokinetic strength measurements of trunk flexion and extension. Interrater reliability for isometric strength testing is largely reported as excellent for extension, with ICCs between 0.81 and 0.97, but agreement is mixed for flexion, ranging from excellent to poor (Gruther et al., 2009; Roussel et al., 2008). As learning effects are suggested to contribute to the variability in testing, reliability has been improved by taking baseline measurements on two different days. However, the cost and time associated with repeated machine-based testing may make this option impractical.

Motor control assessment, MMT, and isometric endurance testing are most often utilized in a clinical setting because of their relatively low cost and ease of application. Angular assessment of motor control through joint position error (JPE) testing or observation of aberrant movements can be performed with readily available equipment such as goniometers or inclinometers. The importance of measuring motor control in CLBP patients is still uncertain, as multiple studies conflict on the level of association between these two variables. Part of the reason for this discrepancy may be the moderate variability that exists for inter-rater reliability of motor control testing.

Studies reported a range of reliability, from low agreement (ICC = 0.36 - 0.54) for JPE measurements during pelvic tilt in sitting and standing, to moderate agreement (ICC = 0.59) for aberrant motion testing of straight-leg-raising in sidelying, to high agreement (ICC = 0.72 - 0.76) for aberrant movement testing of straight-leg-raising in prone (Davis, Bridge, Miller, & Nelson-Wong, 2011; Henriksen, Lund, Bliddal, & Danneskiold-Samsoe, 2007; Murphy et al., 2006). The best potential for utility of motor control testing seems to be in the straight-leg-raising tests, where higher reliability is coupled with acceptable diagnostic accuracy (positive likelihood ratio of 2.68-4.59) for LBP (Nelson-Wong, Flynn, & Callaghan, 2009).

Multiple studies suggest that muscle weakness assessed using MMT and isometric endurance testing is significantly associated with the development of LBP (Gruther et al., 2009; Nourbakhsh & Arab, 2002). The back extensor isometric endurance using the Biering-Sorensen test demonstrated the highest association with LBP from among a list of variables including lumbar lordosis, lower quarter muscle length, foot position, pelvic inclination, and trunk/hip muscle strength (Gruther et al., 2009; Nourbakhsh & Arab, 2002). Intrarater reliability for the Biering-Sorensen test is reported as excellent (ICC = 0.98), while interrater agreement has been reported as good to excellent, with ICC = 0.59-0.95 (Gruther et al., 2009; Malliou, Gioftsidou, Beneka, & Godolias, 2006). The importance of adequate extensor strength is further supported in the work of Arab, Salavati, Ebrahimi, & Ebrahim Mousavi (2007), who found that the prone double straight-leg-raise test demonstrated excellent reliability (ICC = 0.83) and superior diagnostic accuracy for LBP compared to the Biering-Sorensen, supine chest-raise, and supine double straight-leg-raise endurance tests. The importance of abdominal weakness in LBP should not be discounted, as several studies have found a significant association between abdominal weakness and the presence of back pain (Lee, Ooi, & Nakamura, 1995; McNeill, Warwick, Andersson, & Schultz, 1980; Nourbakhsh & Arab, 2002).

Extremity MMT and endurance testing also holds promise for use in CLBP assessment. Hip MMT, the active-straight-leg-raise (ASLR), and the Trendelenburg testing have been investigated for reliability and diagnostic accuracy in LBP. Good interrater reliability (K = 0.70 – 0.75) and high sensitivity make the ASLR and Trendelenburg tests just as valuable for identifying LBP impairment as they are in hip and sacroiliac joint diagnostic testing (Roussel, Nijs, Truijen, Smeuninx, & Stassijns, 2007). Additionally, weakness of hip flexors and adductors has been suggested as occurring together, and being strongly associated to LBP (Nourbakhsh & Arab, 2002). Finally, the use of the double-leg-bridging test as a measure of hip extension strength is both highly reliable (ICC = 0.84) and able to discriminate persons with and without LBP, as demonstrated by average hold times of 76.7 seconds and 172.9 seconds, respectively (Schellenberg, Lang, Chan, & Burnham, 2007). In summary, the simplicity, reliability, and diagnostic accuracy of both trunk and extremity MMT and endurance testing make these assessments a sound choice for the evaluation of muscle function in patients with CLBP.

Management of CLBP

Classification Schemes

The preceding discussion indicates the importance of creating homogeneous subgroups of patients with LBP when attempting to associate impairment-based findings to the presence of non-specific spinal pain. Numerous systems have been developed to subdivide those with LBP according to their response to movement. Among the most-utilized models, only the Pathoanatomic-based Classification (PBC) system has attempted to identify a pain generator using the test criteria previously discussed. With reports of variable reliability (ranging from moderate to excellent), and the recognition that not all patients could be classified by pain source, this system largely has fallen out of favor (Petersen et al., 2004). Instead, impairment-based testing is utilized in conjunction with yellow-flag findings to determine those static positions or directions of motion that either provoke or relieve the person's primary complaint of pain. With this information in hand, clinicians can design biomechanically-oriented treatment programs designed to optimize posture and movement in such a way that stress on the spine and surrounding tissues is relieved, thus diminishing pain.

Currently, several valid and effective movement-based methods exist for the classification and management of patients with spine dysfunction. With such a variety of useful approaches to spine care, clinicians and patients can become confused about which approach to select for optimal diagnosis and management. The most common methods include the Treatment-based Classification (TBC) system, Mechanical Diagnosis and Treatment (MDT) system, O'Sullivan Classification System (OCS), and the Movement System Impairment (MSI) classification (Karayannis et al., 2012). While individual system proponents may argue the superiority of their technique, the evidence has not supported such a claim. Rather, each set of guidelines has demonstrated suitable effectiveness in the general management of patients with spine pain. One indicator of this effectiveness is the inter-rater reliability of the system. The highest reliabilities have been reported for the OCS and MSI systems, with all pooled Kappa values falling in the good to excellent range (Karayannis et al., 2012). The MDT has the next-best reported reliability, with pooled Kappa values falling primarily in the good range. Reliability for the TBC is generally reported as moderate, but can be improved to good if the traction category is removed from consideration.

A second indicator of system effectiveness is the validity of the classification categories. All four classification systems have subcategories that incorporate the concept of a directional preference to movement. This unifying theme allows for comparison of the categories across systems, which helps users to understand how the systems are similar despite their different philosophies. The three directional preference categories inherent to the four systems are flexion provocation, rotation/sidebend/side-glide provocation, and extension provocation. While the philosophy of the MDT and TBC systems is to centralize the pain-provoking movement(s) by inducing movement opposite the provocation, the OCS and MSI systems seek to decrease pain by limiting movements into the offending position(s) (Karayannis et al., 2012).

In the OCS and MSI models, the concept of a directional preference is used to identify those inverse movements that tend to provoke rather than to relieve a person's pain. Both the OCS and MSI hold that pain-provocation is primarily associated with hypermobility. Therefore, treatment is primarily directed at controlling excessive motion in one or more specific planes (flexion, extension, or rotation), which are labeled as the person's directional susceptibility to movement (DSM). The concept of designating a particular plane of dysfunction or DSM to guide stabilization exercise treatment has received limited support in the literature, with the evidence largely consisting of case reports (Harris-Hayes, Van Dillen, & Sahrmann, 2005; Van Dillen, Sahrmann, & Wagner, 2005). To date, the only study comparing DSM subgroups receiving appropriately or inappropriately-matched stabilization treatment reported no difference in outcomes between groups of patients with CLBP (Henry et al., 2014).

Strong evidence supports the validity of the directional preference categories for centralization (Delitto et al., 2012). These studies used the framework of either the TBC or MDT to determine whether outcomes were affected when treatment was matched correctly or incorrectly to a person's directional preference. In all cases, regardless of the system, the categories of flexion, lateral-shift, and extension were supported, as evidenced by a significantly greater benefit when matched treatment was received (Brennan et al., 2006; Long, Donelson, & Fung, 2004). Acceptable matched treatment in the case of the TBC and MDT consisted of ROM into the direction of centralization with or without manual therapy to the lumbar spine. The isolated use of spinal stabilization exercise or lumbopelvic manipulation has not been shown to be as effective in the management of patients with a directional preference and evidence of centralization (Browder, Childs, Cleland, & Fritz, 2007; Petersen et al., 2011).

The MDT and TBC systems also offer categories for persons who do not exhibit centralization. With reported prevalence rates in non-specific LBP at 60% (directional preference) and 41% (centralization), the need for alternative categories is apparent (Delitto et al., 2012). These categories seek to identify subgroups that would benefit from using either manual therapy or strength-based exercise as a primary treatment. Criteria for these categories are often based on the results of impairment-based tests, many of which have questionable reliability and validity. Therefore, it should come as no surprise that these specific categories demonstrate lower reliability than the centralization/directional preference categories, and that this difference largely accounts for the overall lower reliability for the MDT and TBC systems (Karayannis et al., 2012). Clinical prediction rules represent the most recent attempt to refine category criteria in a manner that improves reliability and ultimately, validity.

Clinical Prediction Rules

The clinical prediction rule (CPR) that has received the most attention in all of orthopedic physical therapy pertains to the application of lumbar manipulation. Unlike most other orthopedic CPRs, this test-item cluster has been validated in a follow-up study (Childs et al., 2004). The CPR for use of lumbar manipulation is most often linked to the criteria for the TBC's manipulation subcategory. Appropriately matched treatment to those persons fitting the lumbar manipulation CPR is a general lumbopelvic or a sidelying lumbar rotational thrust technique. Evidence also suggests that the use of non-thrust techniques in those who fit the CPR results in inferior outcomes (Cleland et al., 2009). However, the use of end-range repeated movements does appear to provide benefits equal to manipulation in patients fitting the CPR (Schenk, Dionne, Simon, & Johnson, 2012). As end-range repeated movements into the limited motion are considered appropriately matched treatment for the MDT's dysfunction subcategory, this new evidence provides a measure of cross-validation between the two systems, and expands the options for appropriate treatment in each system when lumbar manipulation CPR conditions are met.

Although the lumbar manipulation CPR has an important place in spinal rehabilitation, its utility is often limited in persons with CLBP. Two out of the five CPR criteria (duration of symptoms < 16 days and FABQ work subscale score > 19) are not likely to be satisfied in a chronic population, which lowers the chance of a significant benefit with thrust manipulation to 68% (Flynn et al., 2002). These reduced odds lead many clinicians to abandon the CPR for this patient population and rely on traditional findings of spinal ROM and segmental mobility findings. Evidence supports the general application of thrust and non-thrust mobilization and ROM techniques for the reduction of pain and disability in CLBP, but these interventions were not found to be superior to other treatments (Rubinstein et al., 2011). Questions remain as to whether or not segmental mobility assessment should still be considered in the decision to apply manual therapy procedures in CLBP patients. The MDT ignores segmental mobility findings in the criteria for its dysfunction (i.e. stiffness) subcategory. However, the TBC system continues to advocate use of segmental assessment in treatment planning, as supported by evidence suggesting that isolated PAIVM findings of hypo- or hyper-mobility can be used to distinguish those benefitting from a combination manual therapy and stabilization versus stabilization-only program (Fritz et al., 2005).

Lumbar stabilization training has received significant attention in the literature as a specific form of rehabilitation exercise. Much of this attention has been fueled by the belief that these exercises more specifically target core muscle weakness, which has been implicated as a major contributor to CLBP (O'Sullivan, 2000). A recent meta-analysis provides strong support for the general inclusion of specific stabilization training in rehabilitation of CLBP. Bystrom et al. (2013) reported that motor control exercise with an emphasis on spinal stabilization or isometric activation of core muscles was superior to general exercise, manual therapy, and minimal intervention for the reduction of pain and disability at variable time intervals, depending on the comparison condition. Whereas this finding speaks to the general importance of this form of exercise, it does not provide guidance on how the techniques should be applied (i.e., through OCS or MSI systems), or if a CLBP subgroup would benefit from stabilization at the exclusion of manual therapy and ROM for centralization.

A CPR for stabilization exercises has been proposed in an attempt to identify a subgroup that demonstrates a preference for this form of exercise over other treatments. This test-cluster contains four variables: age < 40, positive prone instability test, presence of aberrant movements, and straight-leg-raise > 91° (Hicks, Fritz, Delitto, & McGill, 2005). Although a recent study was unable to completely validate this CPR, it suggested that a modified version emphasizing the prone instability test and presence of aberrant movements may provide better predictive validity for defining the TBC's stabilization category (Rabin, Shashua, Pizem, Dickstein, & Dar, 2014). Another potential indicator of stabilization-training preference is the presence of radiographic instability. O'Sullivan, Phyty, Twomey, & Allison (1997) compared a traditional rehabilitation program to a specific stabilization program in a subpopulation with evidence of radiographic instability. They found a superior outcome for the stabilization group, not only at the end of the 10-week training program, but at 30-months post-treatment. With the declining use of diagnostic imaging in cases of non-specific LBP, other methods of identifying radiographic instability must be developed. Segmental mobility assessment may hold promise for this purpose despite issues with its reliability. The absence of hypomobility on PAIVM testing, coupled with the presence of hypermobility on PPIVM testing, appears to yield suitable diagnostic accuracy for identifying the presence of radiographic instability (Fritz, Piva, & Childs, 2005). To date, only the TBC includes potential indicators of radiographic instability in its guidelines.

A New Classification Scheme for LBP

The most recent clinical practice guidelines from the Orthopaedic Section of the American Physical Therapy Association (APTA) recommended updating and expanding the TBC system to better manage the pain and impairments associated with acute-chronic LBP (Delitto et al., 2012). One appeal of keeping the foundation of the TBC system is that it encompasses principles from other successful systems, allowing the clinician to select treatments from among MDT-based centralization exercises, orthopedic manual therapy, or spinal stabilization philosophies inherent to the OCS and MSI systems. Even though the actual categories of the TBC (specific exercise, mobilization, and stabilization) may be the best available blend of current treatments, the criteria used to place patients in a specific category, particularly mobilization and stabilization, are in need of refinement. The TBC categories cannot be viewed as either mutually exclusive or exhaustive, as 25% of patients fit into more than one category, and another 25% of patients do not fit any category (Stanton et al., 2011).

In an attempt to create more mutually exclusive and exhaustive treatment subgroups, the new classification guidelines considered the healing stage of the patient, as well as the presence of affective tendencies (i.e. tendency to elaborate physical symptoms due to emotional reasons), and generalized pain (Delitto et al., 2012). Six categories have been proposed: 1) acute or subacute LBP with mobility deficits, 2) acute, subacute, or chronic LBP with movement coordination impairments, 3) acute LBP with related (referred) lower extremity pain, 4) acute, subacute, or chronic LBP with radiating pain, 5) acute or subacute LBP with related cognitive or affective tendencies, and 6) CLBP with related generalized pain.

The category that could potentially apply to the majority of patients with CLBP is termed chronic LBP with movement coordination impairments (Delitto et al., 2012). The criteria for this category include one or more of the following impairments: 1) local or referred low back pain that worsens with sustained end range movements or positions, 2) lumbar hypermobility, 3) decreased trunk/pelvic strength and endurance, 4) movement coordination impairments during community/work activities, and 5) mobility deficits of the thorax and lumbopelvic/hip regions. Although the first four criteria suggest the presence of movement coordination impairments common to CLBP that may benefit from exercise, the fifth criterion suggests the presence of regional stiffness that may benefit from a regional manual therapy approach.

The recommendation to address mobility and motor control deficits together in one classification category reflects the dual importance that mobility and motor control impairments appear to have for the majority of patients with CLBP. Additionally, the recommendation to address mobility impairments at the lower thoracic spine and hip joints is reflective of the growing attention placed on regional interdependence, where impairments at a remote site can contribute to pain at a local site (Wainner, Whitman, Cleland, & Flynn, 2007). The following section will focus on the evidence suggesting a connection between LBP and thoracic-hip impairments.

Regional Movement Impairment in CLBP

The concept of regional interdependence is not novel to physical therapy. What is new is the growing body of evidence in support of this concept. McConnell (2002) was one of the first to publish on mobilization of the hips and thoracic spine as a compliment to lumbar stabilization training. This approach has since been applied successfully in multimodal treatment approaches for both lumbar spine stenosis and non-specific LBP (Pinto, Cleland, Palmer, & Eberhart, 2007; Whitman et al., 2006). To date, no sufficiently-powered, randomized-controlled studies have isolated out hip or thoracic spine manipulation as an independent variable in a multimodal treatment approach for CLBP. Case report and case series data is beginning to appear for the benefits of stand-alone thoracic or hip manipulation in patients with non-radicular leg pain and non-specific LBP. The past decade has uncovered a wealth of information about the use of regional thoracic manipulation for the management of neck pain. This coming decade could hold promise for the role of regional thoracic and hip manipulation in the management of LBP.

Hip-Based Treatment

A multitude of studies have established an association between hip motion loss and the presence of non-specific LBP. In persons with sub-acute to chronic non-specific LBP, hip rotation loss measured in prone-lying has been reported (Cibulka et al., 1998; Ellison et al., 1990; Vad et al., 2004; Van Dillen et al., 2008), along with hip flexion loss (Porter & Wilkinson, 1997; Wong & Lee, 2004), and hip extension loss (Van Dillen et al., 2000). To date, two studies have investigated ROM in homogenous subgroups of persons with LBP (Kim et al., 2013; Van Dillen et al., 2007). In these studies, subgrouping was performed according to the patient's DSM, which may be described as the direction into which the person moves that elicits pain, and for which the person demonstrates hypermobility at either a global or segmental level of movement (Sahrmann, 2002). Although these studies found some association between the direction(s) of the lumbar DSM and hip motion impairment for rotation and flexion, they did not address hip and lumbar motion deviation in the sagittal plane for extension. A pilot study that we performed in 2013 on 40 subjects with LBP concluded that considerable unidirectional hip motion loss in the sagittal plane was common among the LBP patient population, and yielded a strong positive association with the lumbar sagittal plane DSM (i.e., those in extension DSM categories were more likely to have a loss of hip extension) (Zafereo et al., 2015).

As association is not causation, subsequent studies are beginning to investigate the role of hip mobilization on LBP. To date, only case series data has been produced for this intervention. The first study used total hip replacement as an intervention for those with severe osteoarthritis of the hip and LBP. Following surgery, the patients demonstrated significant improvement in LBP and spinal function (Ben-Galim et al., 2007). The second study applied hip mobilization and hip stretching exercise to a sample of patients with hip stiffness and non-specific LBP. Patients receiving hip-only treatment demonstrated significant improvements in LBP disability and global rating of change score after the conclusion of one week of treatment (Burns et al., 2011). In each of these studies, treatment was specific to the hips, and did not include focused lumbar mobilization or stabilization training. Additional studies are needed to test the added effects of hip mobilization in a sample of patients with CLBP receiving multimodal lumbar mobilization and stabilization training.

Thoracic-Based Treatment

Evidence for the inclusion of thoracic-based evaluation and treatment in LBP is in its infancy compared to hip-based investigations. Support for an association between thoracic dysfunction and non-specific LBP is largely limited to expert opinion and knowledge of anatomy and kinesiology. The close proximity of the sympathetic ganglia trunks to the costovertebral joints could implicate the thoracic spine and ribs in autonomic nervous system dysfunction. Through extensive branching between sympathetic and somatic peripheral nerves, the spinal levels of T10-L2 are capable of referring symptoms into the lower quadrant. Additionally, movement occurring in the lower quadrant from a caudal to cranial direction is associated with motion in the thoracic spine up to the levels of T9-T12. Through this mechanism, it is plausible that thoracic spine postural deviation, stiffness, or hypermobility could alter biomechanics in the lumbar spine.

To date, a very limited amount of evidence exists to support the use of thoracic-based treatment for the management of non-radicular LBP with accompanying neural mechanosensitivity. A randomized-controlled trial on this population found that the use of slump stretching, as part of a multimodal program consisting of lumbar mobilization and stabilization, resulted in superior outcomes in functional disability, pain, and fear-avoidance beliefs compared to a program of local lumbar treatment in patients with CLBP (Nagrale, Patil, Gandhi, & Learman, 2012). Although the benefits of slump stretching cannot be isolated to the thoracic spine, the results of this study suggest that thoracic movement may be important for the management of lower quarter neural mechanosensitivity. A second randomized-controlled trial (de Oliveira et al., 2013) compared the immediate effects of thoracic versus lumbar spine manipulation in patients with CLBP. The study found that patients reported a similar reduction in LBP whether or not they received manipulation to T1-5 or L2-5 (de Oliveira et al., 2013). Additional evidence to substantiate this claim can be found in a case report of a patient with chronic bilateral non-radicular leg pain and an unremarkable physical examination of the lumbar spine (Geerse, 2012). Significant regional findings included a positive sympathetic slump test and stiffness to segmental mobility testing at T10-T12. Following four visits of targeted mobilization and ROM to the T10-T12 levels, the patient reported full resolution of symptoms and a return to her prior level of function. Additional studies are needed to understand the pain science behind such a response, and to determine which patients with CLBP or non-radicular leg pain may benefit most from thoracic spine treatment.

Summary

From this literature review, it should be apparent that CLBP is a growing epidemic that is placing a tremendous burden on the US and the rest of the Westernized world. The traditional, pathology-focused, biomedical model has given way to a more holistic, biopsychosocial model in an attempt to improve diagnosis, prognosis, and treatment of CLBP. In this new model, biomechanical impairments such as stiffness, weakness, and misalignment still are recognized for their potential contribution to CLBP. LBP classification allows for the prioritization and grouping of biomechanical impairments when planning for treatment. The newest classification guidelines from the APTA suggest the use of a combined manual therapy and exercise approach, delivered within a biopsychosocial framework, for the management of patients with CLBP. Although these recommendations are supported by expert opinion, there are currently no randomized clinical trials investigating which combinations of PT treatment are most effective for managing patients with CLBP in this newly developed classification scheme. Specifically, further studies are justified to determine the additive effects of treating thoracic and hip stiffness in conjunction with a multimodal lumbar mobilization and stabilization program.

CHAPTER III

METHODS

The low back pain (LBP) clinical practice guidelines from the Orthopaedic Section of the American Physical Therapy Association (APTA) include a new category for treating persons with chronic low back pain (CLBP) with movement coordination impairments (Delitto et al., 2012). Although the primary impairments for this category are defined in terms of limited strength, endurance, and motor control, patients in this category may also present with mobility deficits of the thorax and lumbopelvic/hip regions (Delitto et al., 2012). Evidence supports the application of exercise for improving pain and function in persons with CLBP (Hayden et al., 2005). However, no studies to date have investigated the additive benefits of regional manual therapy to a standard physical therapy approach in patients with CLBP.

The purpose of this study was to evaluate the effectiveness of adding regional thoracic, pelvic, and hip manual therapy to motor control exercise and lumbar spine manual therapy in a subgroup of patients with CLBP and movement coordination impairments for improving spine range of motion (ROM), hip ROM, pain intensity, disability level, and perceived change at two, four and 12 weeks after initiating treatment. Results from this study may support the recommendation made by the new clinical practice guidelines to identify and manage regional mobility deficits when treating persons with CLBP and movement coordination impairments. This chapter describes the research design, participants, investigators, outcome measures, procedures, and data analysis for this study.

Research Design

This study used a 2x4 factorial mixed design with two independent variables. The between-factor independent variable of group had two levels: 1) the experimental group who received regional thoracic, pelvic, and hip manual therapy and a standard physical therapy approach, which included motor control exercise and local lumbar spine manual therapy, 2) the control group who received the same standard physical therapy including motor control exercise and local lumbar spine manual therapy. The within-factor independent variable of time had four levels: baseline, two weeks, four weeks, and 12 weeks. The dependent variables included total spine ROM for thoracic and lumbar flexion and extension, total hip ROM for sagittal and transverse planes (flexion, extension, internal and external rotation), average pain intensity, disability level, and perceived change. With the exception of the perceived change, dependent variables were collected at baseline, two weeks, four weeks, and 12 weeks. The perceived change was collected at two weeks, four weeks, and 12 weeks.

Participants

An a priori power analysis was performed using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). In order to obtain a power of 0.80, a total of 36 participants were required using a small-medium effect size (f) of 0.20 for one of the primary outcome measures, the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ), and an alpha level of 0.05. Considering a 10% attrition rate, 40 participants with CLBP were recruited for this study. Participants were recruited from a consecutive sample of patients coming to physical therapy (PT) for treatment of non-specific CLBP at the University of Texas (UT) Southwestern Medical Center. Additionally, participants were recruited from flyers posted at the Dallas campuses of UT Southwestern and Texas Woman's University.

Participants were included in this study if they: 1) were between the ages of 18 and 65, 2) had an active complaint of non-specific LBP for at least three months, 3) demonstrated hypomobility of the thoracic or lumbar regions on at least one spinal level, 4) demonstrated at least two of the following unilateral or bilateral hip ROM deficits: supine-lying hip flexion < 110°, supine-lying hip extension loss > 6°, or prone-lying hip rotation < 30° internally or externally, and 5) demonstrated hypermobility with or without pain of the lumbar region on at least one spinal level, or diminished trunk or pelvic muscle strength and endurance. The age range of 18-65 was selected because it has been consistently utilized in other similar research studies that sought to represent adults across the lifespan (Hayden et al., 2005; Rubinstein et al., 2011). Additionally, this age range most closely reflected the population of persons with low back pain presenting for treatment to our outpatient orthopedic PT clinics. Criteria 3) - 5) were chosen to identify participants with spine and hip stiffness in the CLBP with Movement Coordination Impairments (Delitto et al., 2012) classification category.

Participants were excluded from this study if they exhibited: 1) evidence of red flags, including fracture, infection, spinal tumor, or cauda equina syndrome, 2) pain that could be centralized through repeated movements, 3) signs of hyporeflexia, hypoesthesia, or myotomal weakness indicative of nerve root compression, 4) pregnancy, 5) systemic inflammatory conditions such as rheumatoid arthritis or ankylosing spondylitis, 6) inability to safely tolerate manual therapy to the spine or hips, 7) reports of receiving an injection to the spine within two weeks prior to study enrollment, or 8) an ODQ score below 20%. Exclusion criteria eliminated participants with LBP of serious, non-mechanical, or systemic disease origin. Exclusion criteria also eliminated participants who could not tolerate manual interventions, or who may provide atypical ROM data due to pregnancy or the presence of ankylosing spondylitis or rheumatoid arthritis. Participants with nerve root compression signs or a directional preference and centralization were excluded from this study because they may preferentially benefit from treatments such as end-range repeated movements or traction that were not included in this study. Finally, since participants with low ODQ scores would likely have greater difficulty achieving further improvements on the scale, those with scores <20% were excluded.

Investigators

Two licensed physical therapists with an average of 9 years of experience in an outpatient orthopedic setting performed the pre- and post-treatment testing. Only one tester was present for each testing session, and the same tester was not always available to complete all testing sessions for a given participant. The testers were blinded to the participant's group allocation throughout the study. Prior to initiating the study, the testers completed four hours of training on the standardized spine and hip ROM testing procedures, and on the administration of self-report questionnaires. Inter-tester reliability between the two testers was excellent for testing spine and hip ROM, which is consistent with that reported in previous studies (Mannion et al., 2004; Zafereo et al., 2015; Ellison et al., 1990). In addition, six other licensed physical therapists administered treatment to the participants. These therapists had an average of 2.75 years of experience in an outpatient orthopedic setting. Prior to initiating the study, the treating therapists completed three hours of training on administration of the standardized motor control exercises and manual therapy techniques used in this study.

Outcome Measures

The outcome measures used in this study included: 1) spine ROM, 2) hip ROM, 3) pain intensity, 4) disability level, and 5) perceived change.

Spine ROM

Measurements of spinal mobility from C7 to S1 were made using the ValedoShape (Hokoma Inc. USA, Norwell, MA), a handheld electronic device that used spinous process angulation and position to determine segmental motion (Appendix A). The device has been shown to have good reliability and validity (compared to radiography) for global spine ROM assessment in an asymptomatic population (Kellis et al., 2008; Mannion et al., 2004). Despite greater variations for segmental assessment, the ValedoShape has been validated for lumbar segmental mobility testing using radiographic findings, except at L4/5 and L5/S1, where variability was highest for both assessment tools. We previously conducted a pilot study on 20 participants with CLBP to examine the intra-tester and inter-tester reliability of thoracic and lumbar spinal mobility testing using the ValedoShape. Global thoracic and lumbar flexion and extension end-range motion testing yielded fair-to-high intrarater reliability, with Intraclass correlation coefficients (ICCs) ranging from 0.76 to 0.96, and good-to-high interrater reliability with ICCs ranging from 0.82 to 0.98. In addition, interrater reliability was fair-to-high (ICC = 0.77 - 0.93) for segmental lumbar flexion measurements in subjects with CLBP. These results suggest that the ValedoShape demonstrated acceptable reliability for the assessment of segmental and global thoracolumbar spine mobility in people with CLBP. The ValedoShape was used to assess ROM of the thoracic and lumbar regions for flexion and extension at baseline, and retested at two weeks, four weeks, and 12 weeks after initiating treatment. The thoracolumbar flexion and extension ROMs were summed to attain a value of total spine ROM for each participant, which was used for data analysis.

Hip ROM

A Baseline® bubble inclinometer (Medline Industries, Inc.; One Medline Place, Mundelein, IL) was used to measure hip ROM in the sagittal and transverse planes (Appendix B). This device has been reported to have good-to-excellent reliability for ROM testing in people without hip pain (Bierma-Zeinstra et al., 1998; Ellison et al., 1990; Van Dillen et al., 2000). Hip flexion and extension was measured in supine according to the techniques described in Beirma-Zienstra et al. (1998) and Van Dillen et al (2000). Hip internal and external rotation was measured in the prone position with the inclinometer positioned on the medial aspect of the distal tibia as described by Ellison et al. (1990). We previously conducted a pilot study on 10 participants with CLBP to examine the intra-tester and inter-tester reliability for measurements of hip flexion and extension. ICCs revealed excellent intra-tester (ICC = 0.94 - 0.96) and inter-tester (ICC = 0.82 - 0.94) reliability for both hip flexion and extension measurements (Zafereo et al., 2015). Two measurements were collected for each direction tested, and the average of the two measurements was used for data analysis. Measurements were performed bilaterally. The averages of the bilateral hip flexion, extension, internal rotation and external rotation ROMs were summed to attain a value of total hip ROM for each participant. The total hip ROM was assessed at baseline, and at two weeks, four weeks, and 12 weeks after initiating treatment.

Pain Intensity

Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS) (Appendix C). The NPRS is an 11-point scale on which participants rank their current, best, and worst level of pain over the past 24 hours, with 0 representing "no pain" and 10 representing "worst imaginable pain". This instrument has been shown to be reliable and responsive in a sample of patients with LBP (Childs, Piva, & Fritz, 2005). The minimal clinically important difference (MCID) for the NPRS has been reported as 2 points. Pain intensity was assessed at baseline, and at two weeks, four weeks, and 12 weeks after initiating treatment. The average of the current, best, and worst reported pain levels was used for data analysis at each time period.

Disability Level

The ODQ was used to assess the participant's level of functional disability related to LBP (Appendix D). The ODQ is a low back-specific questionnaire that gauges a person's disability level on a scale of 0 to 50, with higher scores indicating higher levels of disability. Scores are typically multiplied by two and expressed as a percentage from 0 to 100%, where 0-20% represents minimal disability, 21-40% moderate disability, 41-60% severe disability, 61-80% crippled, and 81-100% bed-bound or evidence of symptom magnification (Fairbank & Pynsent, 2000). The ODQ has been shown to be highly reliable, valid, and responsive in clinical trials (Fritz & Irrgang, 2001). The minimal detectable change (MDC) for this outcome measure is 10.5 points (Davidson & Keating, 2002). Disability level was assessed at baseline, and at two weeks, four weeks, and 12 weeks after initiating treatment.

Perceived Change

The Global Rating of Change (GROC) scale was used to determine the participant's overall perception of change in their condition since baseline (Appendix E). Participants selected scores ranging from -7 being a very great deal worse, to 0 being about the same, to +7 being a very great deal better. Jaeschke, Singer, & Guyatt (1989) reported that scores of ±1 to ±3 represent small changes, scores of ±4 to ±5 represent moderate changes, and scores of ±6 to ±7 represent large changes. Perceived change was assessed at two weeks, four weeks, and 12 weeks after initiating treatment.

Procedures

Enrollment Procedures

Participant screening. Approval from the UT Southwestern Medical Center and Texas Woman's University Institutional Review Boards was obtained prior to any participant screening, enrollment, and data collection. All patients between the ages of 18 and 65 coming to PT for treatment of non-specific CLBP at UT Southwestern Medical Center were screened for eligibility during their initial evaluation for treatment. All participants were provided with information regarding the study and signed informed consents prior to undergoing testing. The initial subjective screening (Appendix F) included a history of the LBP episode and its related activity limitations, and a past medical history to identify the presence of comorbidities, yellow flags, and red flags (Magee, 2014).

The initial objective screening (Appendix G) included an evaluation of spine and hip ROM, palpation, neurological testing, accessory mobility testing, and strength/motor control testing for all participants (Magee, 2014). Spinal movement testing was performed to identify pain and global restrictions associated with motion in the cardinal planes of flexion, extension, sidebending, and rotation. Repeated movement testing of trunk flexion and extension in standing and lying (supine flexion and prone extension) was performed to ensure that no participants demonstrated a centralization response. Centralization can be defined as the change in location of referred pain from a more distal to a more proximal location in response to specific spinal movements (McKenzie & May, 2003). Hip ROM was tested for flexion, extension, internal rotation, and external rotation to ensure that restrictions were present that met inclusion criteria, although these measurements were not used for data analysis. Palpation in prone or supine-lying was performed to identify the location and condition of painful or tight tissues. Neurological testing was performed to ensure that no participants displayed nerve root compression signs consisting of lower extremity hyporeflexia on the deep tendon reflex assessment, hypoesthesia on the dermatomal pin-prick assessment, or key muscle weakness on myotomal muscle testing. Passive accessory intervertebral motion (PAIVM) testing was performed to initially screen for the presence of joint hypo- or hyper-mobility in the thoracic or lumbar spine, although findings from the ValedoShape were used to definitively identify spinal regions or segments with hypo- or hyper-mobility. Finally, muscle endurance testing for the trunk was used to identify a deficit of muscle endurance, noted as a grade of 3 or below on a 5 point scale.

After identifying impairments on an initial mobility screen and ensuring that no exclusion criteria were present, the investigators asked participants to schedule a baseline testing session within 5 days of the initial evaluation for physical therapy, which is a standard scheduling practice at the PT clinic of the UT Southwestern Medical Center. No treatment occurred before this time. At the baseline testing session, Investigator #1 (the principal investigator) or Investigator #2 collected basic demographic information and assessments of spine ROM, hip ROM, pain intensity, and disability level. If the detailed assessment of spine and hip ROM performed at this assessment revealed that the participant did not meet the inclusion criteria, the participant was excused from the study.

At the baseline testing session, data on age, sex, duration of symptoms, work status, weight, height, fear avoidance beliefs, catastrophizing behaviors, depressive symptoms, and pain medication usage was collected in order to describe the demographic characteristics of the participants. Fear avoidance beliefs were assessed with the Fear Avoidance Beliefs Questionnaire (FABQ), which contains five questions on how physical activity and 11 questions on how work either affect or would affect the participant's pain (Waddell, Newton, Henderson, Somerville, & Main, 1993). Scores range from 0-24 for physical activity, and 0-42 for work, with higher scores indicating higher pain-related fear. Catastrophizing behaviors were assessed with the Pain Catastrophizing Scale (PCS), which is a 13-item questionnaire designed to investigate the areas of magnification, rumination, and helplessness (Sullivan, Bishop, & Pivik, 1995). The maximum point value on the scale is 52, with higher scores indicating higher catastrophizing. Finally, the presence of depressive symptoms was screened with the following two questions: 1) During the past month, have you often been bothered by feeling down, depressed, or hopeless? 2) During the past month, have you often been bothered by little interest or pleasure in doing things? A "yes" response to either question has shown a sensitivity of 86% and a specificity of 75% for a diagnosis of depression (Spitzer et al., 1994).

Collection of outcome measures. Outcome measure testing began with an assessment of thoracic and lumbar spinal ROM (Appendix A). For this assessment, participants either wore a gown or were shirtless to allow the wheels of the ValedoShape to move along the midline of the spine or slightly paravertebrally in thin individuals with prominent spinous processes. Participants were instructed to stand with knees extended and feet hip-width before assuming the positions of relaxed standing posture, forward bending, and backward bending. Once participants had attained the testing position (i.e. relaxed posture or maximum end ROM for each direction), the investigator moved the ValedoShape along the spine, starting at the spinous process of C7 and finishing at the top of the anal crease (approximately S3). Actual and normative values for segmental spine ROM based on the participant's age and sex were provided by the device. In addition, any thoracic or lumbar ROM values less than one standard deviation below the normative value were considered hypomobile, and actual values greater than one standard deviation above the normative value were considered hypermobile.

Next, the investigator performed ROM testing of the hips (Appendix B). To assess hip flexion ROM, the participant was placed in supine on the treatment table with both hips and knees extended. The inclinometer was placed on the patient's thigh and set to zero degrees. Passive ROM was assessed with simultaneous hip and knee flexion in a straight sagittal plane while the investigator ensured no hip rotation, abduction, or adduction. To assess hip extension ROM, the participant was placed in supine hook-lying with their feet at the edge of the testing surface. The investigator put the tested leg into full knee extension, neutral hip rotation and abduction, and then zeroed the inclinometer at the maximal point of hip extension. Next, both hips were passively flexed until the investigator determined that the participant's low back first began to flatten against the treatment surface. Passive ROM on the tested leg was assessed as hip extension with the knee extended in a straight sagittal plane while the investigator ensured no hip rotation, adduction, or abduction. To assess hip rotation ROM, the participant was placed in prone with the knee of test leg flexed to 90°. The inclinometer was zeroed out to the medial malleolus with the hip in neutral rotation. Passive ROM was assessed for hip internal and external rotation while the investigator ensured no lumbopelvic rotation. For all hip ROM assessments, the examiner read and recorded the inclinometer value in degrees after determination of the ROM endpoint. The entire measurement process was repeated and an average of the two assessments was used for data analysis.

At this point, ROM test results were analyzed to determine which participants met the inclusion criteria for spine and hip motion loss and lumbar hypermobility. Any thoracic or lumbar ROM values greater than one standard deviation below the normative value were considered hypomobile, and met criteria for spine motion loss. Any lumbar segment with ROM values greater than one standard deviation above the normative value was considered hypermobile, and met criteria for movement coordination impairment. The presence of at least two of the following unilateral or bilateral hip ROM deficits met criteria for hip motion loss: hip flexion < 110°, hip extension loss > 6°, or hip rotation < 30° internally or externally. If a participant met inclusion criteria for spine and hip motion loss, but did not meet the lumbar hypermobility criteria for movement impairment, a strength assessment was performed using the muscle strength assessment listed in Appendix G. Any strength test with a grade of ≤ 3 out of 5 points met the criterion for movement coordination impairment. Upon completion of objective testing and final determination of participant eligibility, investigator #1 or #2 administered the NPRS and ODQ to the eligible participants. The GROC was only administered at the follow-up assessments.

Randomization and Group Assignment

After completing the data collection of demographic information and outcome measures, eligible participants were assigned an identification number for use on all subsequent data collections. This number helped to maintain participant confidentiality during data analysis. Then, the participant was asked to draw a number (1 or 2) from an envelope to determine their group assignment. To ensure an equal number of participants in each group, there were 40 cards, 20 marked “1” and 20 marked “2”, in an envelope. Participants who drew a “1” card were assigned to the experimental group, which received thoracic, pelvic, and hip manual therapy with standard PT, and participants who drew a “2” card were assigned to the control group, which received standard PT consisting of motor control exercises and lumbar spine manual therapy. If a participant in the experimental group withdrew from the study before the completion of the 12-week study, a card marked “1” was put back in the envelope. The participant’s group assignment was shown only to the treating therapist. Additionally, the treating therapist was given a summary of the spine and hip ROM testing, as these findings were important for treatment planning considerations.

Treatment Procedures

Six investigators served as the treating therapists for this study. In the event that investigator #1 and #2 served as a participant's primary treating therapists, they had no role in the data collection for that participant. Every effort was made to keep the same treating therapist for all treatments. Treatment took place twice weekly for four weeks, with each session lasting 30-40 minutes. Each session began with 5-15 minutes of local lumbar spine manual therapy for the control group or local lumbar spine manual therapy plus regional thoracic, pelvic, and hip manual therapy for the experimental group (Appendix H). Local lumbar manual therapy consisted of joint or soft tissue-based techniques to the lumbar spine, depending on the site of the participant's pain or stiffness. Joint techniques were limited to non-thrust posterior-anterior (PA) or translatoric glides over the lumbar vertebrae with the participant lying in prone. Soft-tissue techniques were limited to non-instrumented soft tissue gliding or ischemic pressure on the posterior aspect of the participant's body between L1 and L5. The decision to restrict the use of thrust techniques for the local lumbar manual therapy group was due to the likelihood that thrust techniques would include end-range mobilization or manipulation of the thoracic spine or pelvis.

Regional manual therapy consisted of joint or soft tissue-based techniques to the lumbar spine, thoracic spine and adjacent ribs, pelvis, and hips. Joint techniques included thrust and non-thrust manipulation to the lumbar spine, thoracic spine, ribs, pelvis, and hips. The use of thrust manipulation was encouraged, but not required, for all participants. Giving the treating therapist the flexibility to apply either form of manipulation was not believed to bias study outcomes, as evidence suggests no difference in outcomes for the use of thrust versus non-thrust spinal manipulation in patients with CLBP, and in those with LBP over the age of 55 (Cook, Learman, Showalter, Kabbaz, & O'Halloran, 2013; Learman, Showalter, O'Halloran, & Cook, 2013). Soft-tissue techniques were again limited to non-instrumented soft tissue gliding or ischemic pressure, but could be applied anywhere over the anterior, lateral, or posterior aspects of the hip, pelvis, lumbar, or thoracic regions. The choice of initiating or suspending a specific manual therapy technique and the grade and duration of treatment was left to the discretion of the treating therapist. The treating therapists were allowed to provide a home-based exercise for self-mobilization to participants in either group. The exercises were limited to the use of a foam roller or tennis ball to re-create PAs or ischemic pressure along the lumbar spine for the control group, or along the thoracic spine and adjacent ribs, lumbosacral spine, pelvis, and hips for the experimental group.

Each session concluded with 15-25 minutes of a motor control exercise program (Table 1) adapted from (Hicks et al., 2005) and (Sahrmann, 2002). The exercises in the program were grouped according to movement system impairment (MSI) category and target muscle region (Appendix I). Although all participants completed each exercise for each MSI category and target muscle group, the treating therapist may have introduced a specific MSI category or muscle group earlier or later in the rehabilitation program based on the participant having pain limiting movement in certain directions, or on manual muscle testing revealing weakness in one particular muscle in a synergy (e.g., obliques versus rectus abdominus).

Table 1

Motor Control Exercises

MSI	Muscle Group	Exercise
Extension	Lower abdominals	Abdominal drawing in maneuver (ADIM) Hook-lying leg slides and marching with ADIM Prone planking with ADIM
	Upper back extensors	Lumbar multifidus isometric Prone upper extremity extension with thoracic emphasis Prone trunk raise with thoracic emphasis
	Hip extensors	Gluteal isometric Prone hip extension with gluteal isometric Bridging with gluteal isometric
Flexion	Lower back extensors	Lumbar multifidus isometric Prone alt upper/lower extremity lifts with lumbar multifidus isometric Prone trunk raise with lumbar multifidus isometric Bridging with lumbar multifidus isometric
	Upper abdominals	Abdominal flaring obliques and rectus abdominis Trunk curl up with abdominal flaring
	Hip flexors	Hip flexor isometric Straight leg raise with hip flexor isometric Prone planking with hip flexor isometric
Rotation	Lateral trunk flexors	Abdominal flaring obliques Trunk curl up with abdominal flaring Sidelying double leg raise with abdominal flaring Side planking with abdominal flaring
	Hip abductors	Gluteal isometric Clamshell with gluteal isometric Side planking with gluteal isometric
	Hip adductors	Adductor isometric Adductor leg raise

Note. Exercises adapted from Hicks et al. (2005) and Sahrmann (2002).

Generally, exercises for each muscle group began with isolated isometric contractions to ensure adequate motor control, and progressed to open-kinetic-chain leg or trunk raises before moving to closed-kinetic-chain planking or bridging exercises. Instructions to gradually increase time under tension to a maximum of 30 seconds for four repetitions on each exercise were used in order to provide an element of graded-activity exposure and to reflect the tonic nature of stabilizing muscles. Once participants could perform 30 seconds of four repetitions without increasing pain and with good technique, they were advanced to an exercise with higher intensity, and were no longer required to perform the original exercise as part of their program. Participants unable to initiate all exercises in the program by the end of the fourth week were instructed on how to progress to the final exercises with their independent home exercise program.

Participants were asked to complete a home exercise program consisting of motor control exercises and self-mobilization on a daily basis during their four weeks of treatment. After participants completed four weeks of treatment, they were asked to complete their home exercise program at least three times per week. The home exercises sessions were expected to take 15 - 30 minutes to complete. Participants were asked to fill out an exercise log to track their compliance.

Outcome measures were assessed at two weeks, four weeks, and 12 weeks from the start of treatment by Investigators #1 or #2, who remained blinded to group assignment. These investigators collected the NPRS, ODQ, and GROC scores at all follow-up time points, as well as spinal and hip ROMs.

Data Analysis

Non-parametric statistics (Chi square) were used to determine between-group differences for non-parametric baseline data such as sex, work status, pain duration range, pain location, depression level, and medication usage. Independent *t*-tests were used to determine if there was a difference between groups at baseline for demographic data such as age, time since onset, weight, height, FABQ score, and PCS score, and for the outcome measures of spine ROM, hip ROM, NPRS score, and ODQ score. Spine ROM was reported as the aggregate of flexion and extension. Hip ROM was reported as the aggregate of flexion and extension, as well as internal and external rotation on the right and left sides. The NPRS score was reported as the average of the participant's current, best, and worst pain intensity. Means and standard deviations (SD) were provided for all ratio-level demographic data and outcome measures. Between and within-group differences were assessed for the outcome measures using three forms of statistical analysis. A repeated measures (RM) MANOVA was used on the spine and hip ROM data, while two separate RM ANOVAs were used on the NPRS and the ODQ scores ($\alpha = 0.05$). Post hoc analysis was performed if there was a significant interaction. A Mann-Whitney U test was used to compare the GROC scores between groups for each of the three follow-up assessments ($\alpha = 0.05$).

CHAPTER IV

RESULTS

Randomized clinical trials are needed to support the application of regional thoracic, pelvic, and hip manual therapy in a homogeneous subgroup with chronic low back pain (CLBP) and movement coordination impairments. The first purpose of this study was to determine whether or not the addition of regional thoracic, pelvic, and hip manual therapy to a standard PT approach (motor control exercises and local lumbar spine manual therapy) was better than standard PT alone at improving thoracolumbar spine ROM, hip ROM, pain intensity, and disability level in a CLBP subgroup with movement coordination impairments. The second purpose was to examine whether the group receiving thoracic, pelvic, and hip manual therapy would have a greater perceived change due to treatment than the group receiving standard physical therapy alone. This chapter reports participant characteristics and findings from the outcome measures collected pre-, mid-, and post-treatment.

Participants

Participants were recruited from a consecutive sample of patients coming to physical therapy (PT) for treatment of non-specific CLBP at the University of Texas (UT) Southwestern Medical Center. Additionally, participants were recruited from flyers posted at the campuses of UT Southwestern and Texas Woman's University. Eighty-three adults with CLBP were screened for eligibility between July 2014 and April 2015. Thirty-nine of those screened were ineligible for participation because they met at least one of the exclusion criteria, and four individuals declined to participate due to the time commitment required for the study. The remaining forty participants were enrolled in the study and randomly assigned to one of the two treatment groups. Six participants were unable to complete treatment or follow-up testing due to the following reasons: work conflicts for two participants, transportation limitations for three participants, and a knee surgery for one participant. As a result, 17 participants in the experimental group and 17 participants in the control group completed the study. Figure 1 summarizes the enrollment, allocation, follow-up, and analysis phases of the study.

Table 2 contains a description of participant characteristics, including age, sex, height, weight, BMI, duration of LBP (months), duration category of LBP (0-1 year, 1-5 years, > 5 years), location of symptoms, medication usage, work status, and responses to screening questionnaires for depression, catastrophizing, and fear avoidance beliefs. Additionally, Table 2 contains baseline values for the outcome measures of spinal ROM, hip ROM, pain intensity, and disability level. There was a significant difference between groups for the characteristics of age, sex, and height. Participants in the regional manual therapy plus standard PT group were significantly older ($p = 0.03$), shorter in height ($p = 0.02$), and more likely to be female ($p = 0.04$) as compared to participants in the standard PT group. A significant difference was also found between groups for BMI (p = 0.03), although the variable of weight was not significantly different between groups (p = 0.71). Although the duration of LBP (in months) appeared higher for the regional manual therapy plus standard PT group, the difference between groups was not statistically significant (p = 0.14). In support of this finding, the duration category of LBP was also not significantly different between groups (p = 0.26). No other significant differences were found between groups for the characteristics of location of symptoms, medication usage, work status, or screens for depression, catastrophizing, and fear avoidance beliefs. No significant differences were found between-groups at baseline for the outcome measures of spinal ROM, hip ROM, pain intensity, or disability level. Therefore, the groups were considered similar at the beginning of the study despite the previously reported differences between groups in age, sex, height, and BMI.

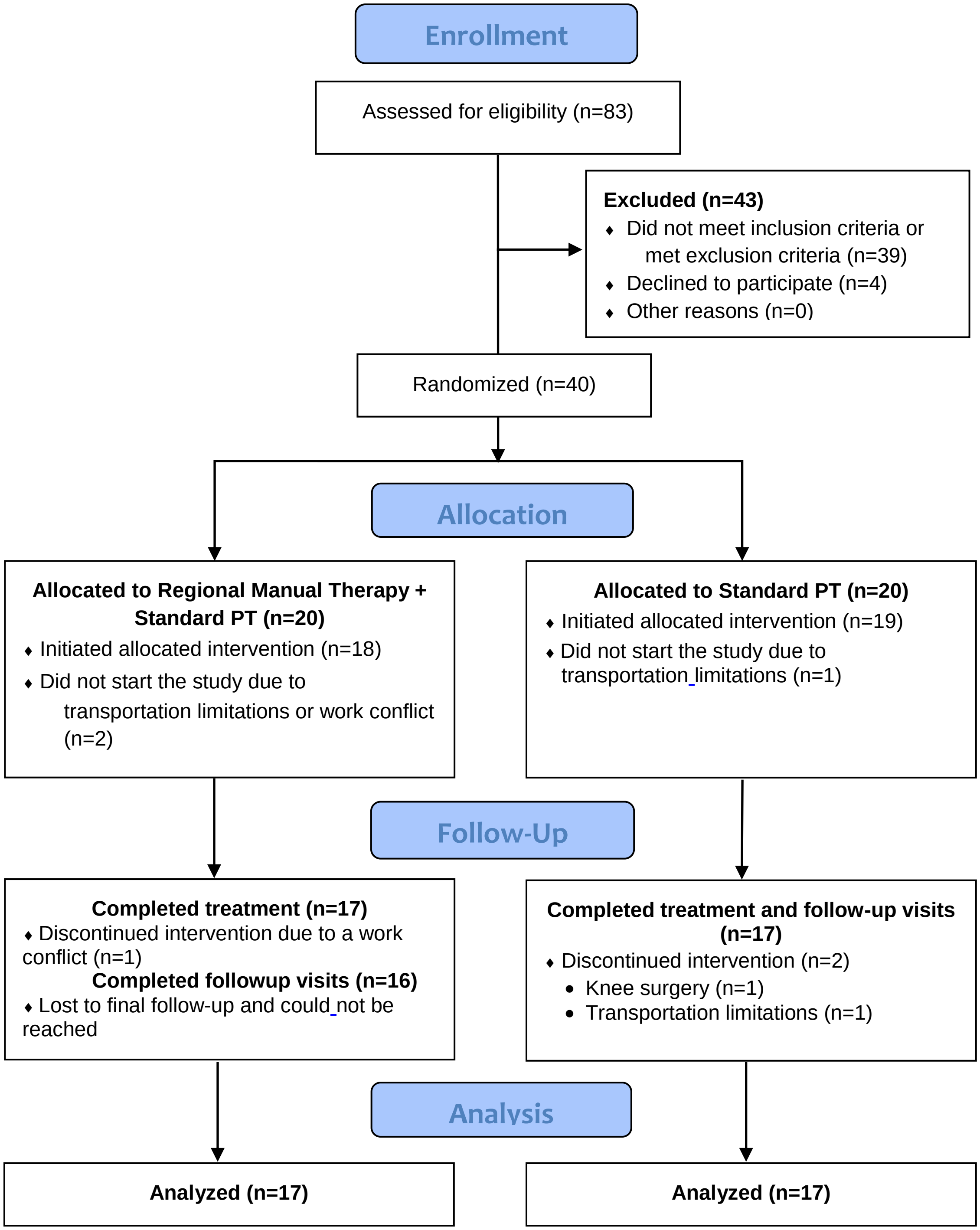

Figure 1. The Consort diagram for enrollment, allocation, follow-up, and analysis.

Table 2

Participant Characteristics

	Regional Manual Therapy + Standard PT (n=17)	Standard PT (n=17)	*P*-Value
Age (years)	45.6 ± 14.8	35.2 ± 11.9	0.031*
Sex			0.037*
Women	13	7	
Men	4	10	
Height (inches)	65.2 ± 4.4	69.0 ± 4.3	0.016*
Weight (pounds)	179.9 ± 45.0	174.6 ± 34.3	0.705
BMI (kg/m^2)	29.6 ± 6.2	25.6 ± 3.5	0.029*
Duration of low back pain (months)	116.9 ± 138.8	60.0 ± 69.8	0.141
Duration category of low back pain			0.270
Up to 1 year	2	6	
1-5 years	7	5	
>5 years	8	6	
Location of symptoms			0.486
Bilateral lumbar	8	6	
Unilateral lumbar	9	11	
Work status			0.753
Employed full time	13	13	
Student full time	2	3	
Not working/retired	1	1	
Disability	1	0	
Pain medication usage			0.322
Prescription	7	5	
Over the counter	7	5	
None	3	7	

(continued)

	Regional Manual Therapy + Standard PT (n=17)	Standard PT (n=17)	*P*-Value
Fear Avoidance Beliefs Questionnaire			
Physical activity	13.9 ± 6.5	15.1 ± 5.7	0.597
Work	11.1 ± 10.3	13.6 ± 6.4	0.407
Pain Catastrophizing Scale	14.8 ± 10.9	18.8 ± 12.5	0.321
Depression Questions			
Depressed or hopeless	3	2	0.628
Lost interest or pleasure	4	1	0.146
Spinal ROM	84.6 ± 27.3	100.0 ± 21.4	0.077
Hip ROM	355.4 ± 28.1	347.5 ± 23.8	0.385
Pain intensity (NPRS)	4.2 ± 1.3	4.2 ± 1.5	0.952
Disability level (ODQ)	27.6 ± 6.8	26.6 ± 8.0	0.681

Note. Pain intensity was assessed with the Numeric Pain Rating Scale (NPRS) and disability level with the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ). All values are mean ± SD except those reported for sex, location of symptoms, work status, pain medication usage, and depression questions. *P*-value for characteristics with a reported mean ± SD was determined with an independent *t*-test; all other *P*-values were determined with chi-square. * denotes a statistically significant difference between groups, $p < 0.05$.

Examination Findings

A physical screening examination was performed to assess neurological function, trunk strength, palpation tenderness, segmental mobility, and provocation of pain with spinal ROM testing. Neurological testing revealed no signs of nerve root compression in any enrolled subjects. The results of strength, palpation, and ROM testing are included in Table 3. No significant differences were found between groups in any of the physical impairments tested. The physical impairments described in Table 3 were only tested at baseline as a means of describing the study participants, and to ensure eligibility of the participants. Additional physical tests of spinal and hip ROM were collected as outcome measures for this study. The results of these tests and other outcome measurements are included in the following sections.

Table 3

Physical Screening Examination Findings

	Regional Manual Therapy + Standard PT (n=17)	Standard PT (n=17)	*P*-Value
Pain with lumbar spine PA	11	7	0.169
Pain with sagittal spinal ROM	10	9	0.730
Hypomobility with lumbar PA	9	10	0.730
Hypermobility with lumbar PA	5	7	0.473
Trunk endurance testing ≤3/5	14	12	0.419

Note. PT = physical therapy. PA = posterior-anterior glides. ROM = range of motion. *P*-values were determined by chi-square for all analyses.

Outcome Measurements

The outcome measurements used in this study were spinal ROM, hip ROM, pain intensity, disability level, and perceived change. Spinal ROM, hip ROM, pain intensity, and disability level were collected at baseline, and at two, four, and 12 weeks from the start of treatment. Perceived change was collected at two, four, and 12 weeks from the start of treatment. Table 4 lists the mean and standard deviations for each outcome measurement at each time point tested.

Table 4

Outcome Measurements at Baseline, 2 Weeks, 4 Weeks, and 12 Weeks Post-Treatment

	Regional Manual Therapy + Standard PT (n=17)	**Standard PT (n=17)**
Spinal ROM		
Baseline	84.6 ± 27.3	100.0 ± 21.4
2 weeks	77.6 ± 24.7	91.6 ± 21.2
4 weeks	78.4 ± 20.0	97.1 ± 20.4
12 weeks	77.5 ± 22.4	94.7 ± 19.7
Hip ROM		
Baseline	355.4 ± 28.1	347.5 ± 23.8
2 weeks	371.1 ± 34.1	374.5 ± 25.6
4 weeks	380.0 ± 24.8	379.1 ± 27.5
12 weeks	384.3 ± 23.3	383.5 ± 22.1
Pain intensity (NPRS)		
Baseline	4.2 ± 1.3	4.2 ± 1.5
2 weeks	2.8 ± 1.8	3.6 ± 1.4
4 weeks	2.7 ± 1.5	2.7 ± 1.9
12 weeks	2.7 ± 1.5	2.5 ± 1.8
Disability level (ODQ)		
Baseline	27.6 ± 6.8	26.6 ± 8.0
2 weeks	18.3 ± 8.9	21.7 ± 8.9
4 weeks	14.2 ± 11.1	17.4 ± 7.0
12 weeks	12.8 ± 10.9	16.1 ± 7.1
Perceived change (GROC)		
2 weeks	4.0 ± 1.5	2.6 ± 1.8
4 weeks	5.0 ± 1.6	3.6 ± 1.6
12 weeks	5.1 ± 1.6	3.9 ± 1.5

Note. Pain intensity was assessed with the Numeric Pain Rating Scale (NPRS), disability level with the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ), and perceived change with the Global Rating of Change (GROC) scale. All values are mean ± SD.

Spine and Hip Range of Motion

A repeated measures (RM) MANOVA was used to analyze between- and within-group differences in the outcomes of spine and hip ROM over 12 weeks. The assumption of multivariate normality was met since Shapiro-Wilk values all exceeded 0.05; however, the assumption for homogeneity of covariance matrices was not met based on Box's test ($p = 0.045$). However, due to an equal sample size of both groups, the multivariate test remains robust (Field, 2009) although the Box's test was significant. The assumption of homogeneity of variance (HOV) was met based on the results of Levine's testing ($p = 0.434$ for spinal ROM at baseline, $p = 0.730$ for spinal ROM at two weeks, $p = 0.978$ for spinal ROM at four weeks, $p = 0.420$ for spinal ROM at 12 weeks, $p = 0.466$ for hip ROM at baseline, $p = 0.605$ for hip ROM at two weeks, $p = 0.617$ for hip ROM at four weeks, $p = 0.765$ for hip ROM at 12 weeks). However, the assumption of sphericity was not met based on Mauchly's test ($p = 0.009$ for spinal ROM, $p < 0.001$ for hip ROM). Using Pillai's Trace, the RM MANOVA revealed no significant interaction for group by time (F = 0.38, $p = 0.887$), which suggests that there was no difference between the groups in spinal and hip ROM over 12 weeks. Using a Greenhouse-Geisser correction, a significant difference was found in the main effect of time, as both groups demonstrated an improvement in hip ROM across time ($p < 0.001$). Hip ROM was significantly increased between baseline and two weeks ($p = 0.002$), baseline and four weeks ($p < 0.001$), and baseline and 12 weeks ($p < 0.001$), but not between two and four weeks (p = 0.766), two and 12 weeks (p = 0.136), or four and 12 weeks (p = 0.319) (Figure 2). Spinal ROM was not significantly different over time (p = 0.105) (Figure 3).

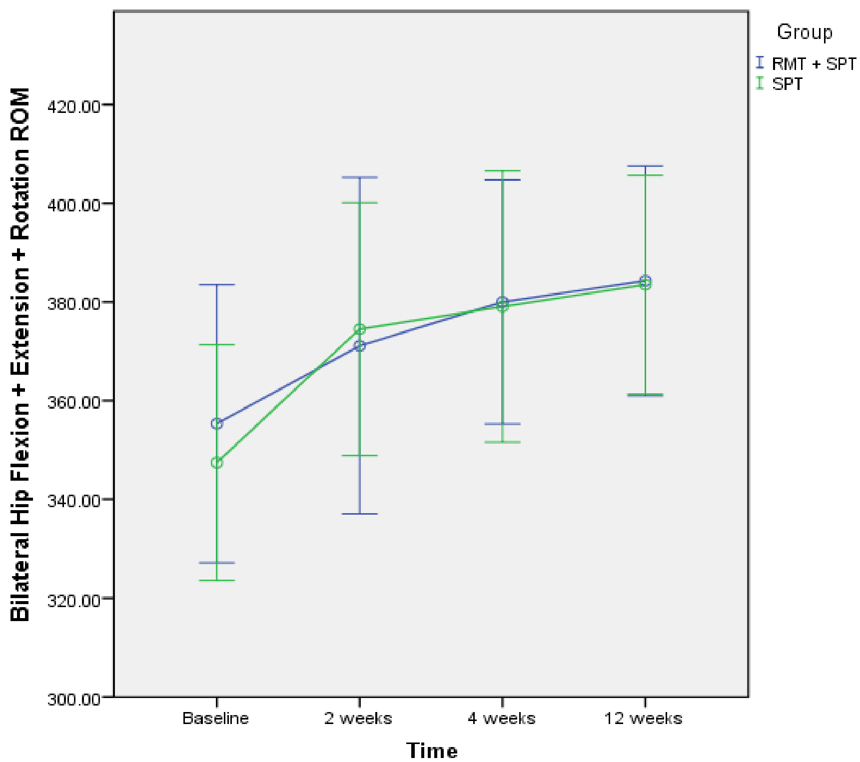

Figure 2. Hip Range of Motion: Bilateral hip flexion + extension + rotation range of motion (ROM) in degrees for regional manual therapy + standard physical therapy (RMT + SPT) and SPT groups at baseline, 2 weeks, 4 weeks, and 12 weeks.

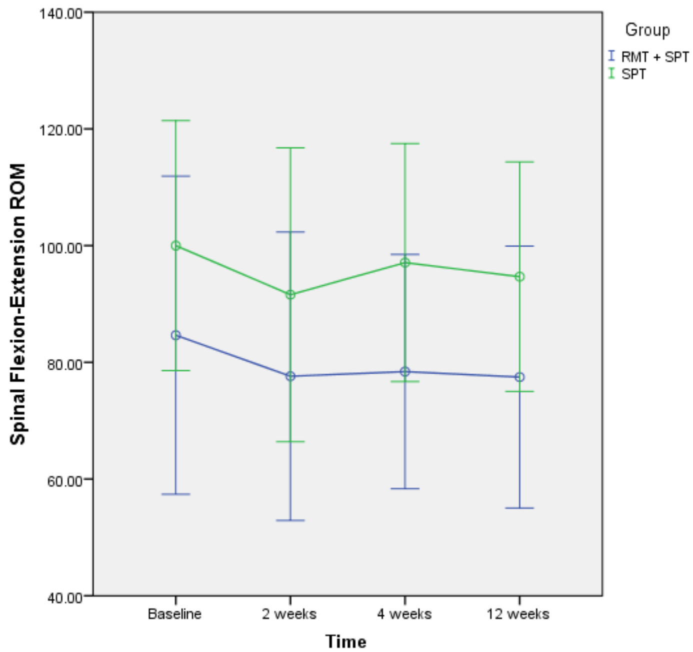

Figure 3. Spine Range of Motion: Spinal flexion-extension range of motion (ROM) in degrees for regional manual therapy + standard physical therapy (RMT + SPT) and SPT groups at baseline, 2 weeks, 4 weeks, and 12 weeks.

NPRS Score

A repeated measures (RM) ANOVA was used to analyze between- and within-group differences in the NPRS score over 12 weeks. The assumption of homogeneity of variance (HOV) was met based on the results of Levine's testing (p = 0.609 at baseline, p = 0.289 at two weeks, p = 0.619 at four weeks, p = 0.903 at 12 weeks). However, the assumption of sphericity was not met based on Mauchly's test ($p < 0.001$). Using the Greenhouse-Geisser correction, the RM ANOVA revealed no significant interaction for group by time (F = 1.96, p = 0.148), which suggests that there was no difference in the NPRS scores between the groups over 12 weeks. A significant difference was found in the main effect of time, as both groups demonstrated a significant reduction in pain intensity over time ($p < 0.001$). Post-hoc analysis revealed that the NPRS score was significantly reduced between baseline and two weeks ($p = 0.002$), baseline and four weeks ($p < 0.001$), and baseline and 12 weeks ($p < 0.001$), but not between two and four weeks ($p = 0.661$), two and 12 weeks ($p = 0.234$), or four and 12 weeks ($p = 1.000$) (see Figure 4).

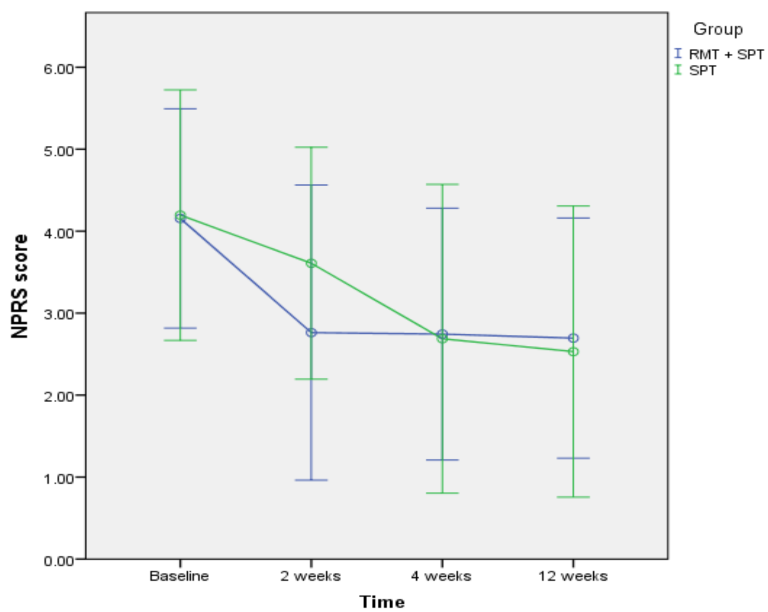

Figure 4. Pain Scores: Pain scores using the Numeric Pain Rating Scale (NPRS) for regional manual therapy + standard physical therapy (RMT + SPT) and SPT groups at baseline, 2 weeks, 4 weeks, and 12 weeks.

ODQ Score

A repeated measures (RM) ANOVA was also used to analyze between- and within-group differences in the ODQ score over 12 weeks. The assumption of homogeneity of variance (HOV) was met based on the results of Levine's testing (p = 0.937 at baseline, p = 0.632 at two weeks, p = 0.246 at four weeks, p = 0.304 at 12 weeks). However, the assumption of sphericity was not met based on Mauchly's test (p < 0.001). Using the Greenhouse-Geisser correction, the RM ANOVA revealed no significant interaction for group by time (F = 0.91, p = 0.395), which suggests that there was no difference between the groups in disability level over 12 weeks. A significant difference was found in the main effect of time, as both groups demonstrated an improvement in disability across time (p < 0.001). The ODQ score was significantly reduced between baseline and two weeks (p < 0.001), baseline and four weeks (p < 0.001), baseline and 12 weeks (p < 0.001), and two and 12 weeks (p = 0.009), but not between two and four weeks (p = 0.069) or four and 12 weeks (p = 0.122) (Figure 5).

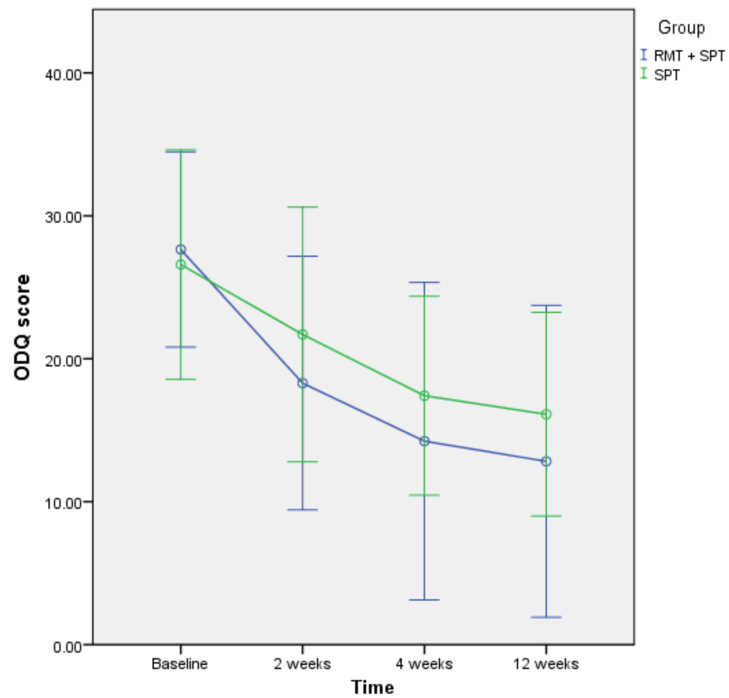

Figure 5. Oswestry Disability Questionnaire: Disability scores using the Modified Oswestry Low Back Pain Disability Questionnaire (ODQ) for regional manual therapy + standard physical therapy (RMT + SPT) and SPT groups at baseline, 2 weeks, 4 weeks, and 12 weeks.

GROC Score

The participants' perceived change as measured with the GROC was analyzed for between-group differences using the Mann-Whitney U test. A significant difference was found between groups at all three time points, with the regional manual therapy plus standard PT group demonstrating higher perceived change scores at two weeks (p = 0.031), four weeks (p = 0.022), and 12 weeks (p = 0.047) (Figure 6).

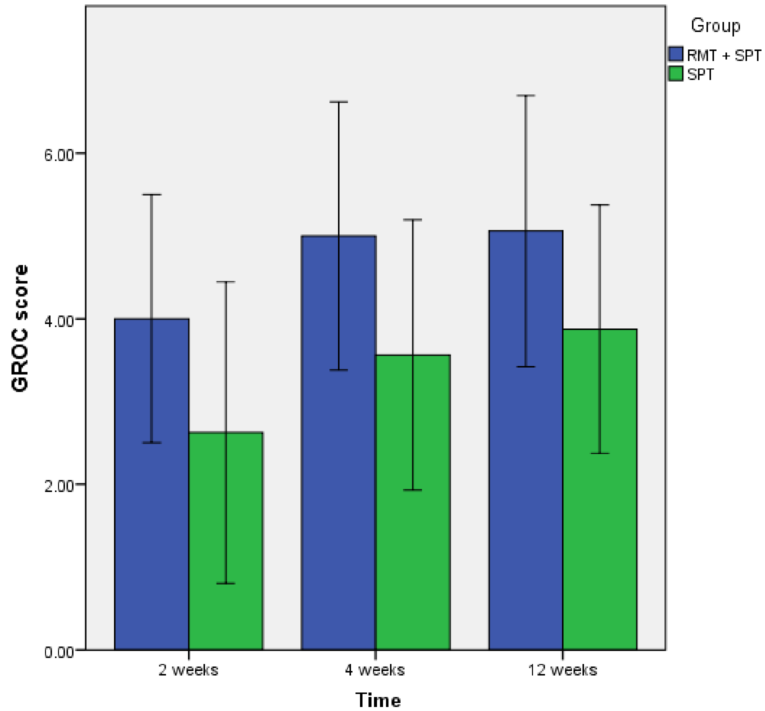

Figure 6. Perceived change scores using the Global Rating of Change (GROC) scale for regional manual therapy + standard physical therapy (RMT + SPT) and SPT groups at 2 weeks, 4 weeks, and 12 weeks.

Home Exercise Program Compliance

Participants were asked to report their compliance with the prescribed home exercise program during the four-week treatment phase and in the post-treatment phase between weeks 4 and 12. Participants were typically given eight exercises as part of their home program. Any days on which the participant performed two or more of their prescribed exercises was recorded as an exercise day. During the four-week treatment phase, participants in the regional manual therapy group completed 5.9 ± 0.9 exercise days per week, while participants in the standard PT group completed 6.2 ± 0.8

exercise days per week. In the post-treatment phase, participants in the regional manual therapy group completed 3.9 ± 1.3 exercise days per week, whereas participants in the standard PT group completed 4.5 ± 1.3 exercise days per week. Independent *t*-tests revealed that there were no significant differences between groups in exercise compliance during the four-weeks of treatment ($p = 0.506$) or the post-treatment phase ($p = 0.519$).

CHAPTER V

DISCUSSION

This study investigated which combinations of PT treatment were most effective for managing patients in a subgroup of patients with chronic low back pain (CLBP) and movement coordination impairments. The first purpose of this study was to determine whether or not the addition of regional thoracic, pelvic, and hip manual therapy to a standard PT approach (motor control exercises and local lumbar spine manual therapy) was better than standard PT alone at improving thoracolumbar spine ROM, hip ROM, pain intensity, and disability level in a CLBP subgroup with movement coordination impairments. The second purpose was to examine whether the group receiving thoracic, pelvic, and hip manual therapy would have a greater perceived change due to treatment than the group receiving standard physical therapy alone. This chapter provides a summary and discussion of the results, and offers conclusions, limitations, and recommendations for future studies.

Results of Hypothesis Testing

Hypothesis 1

In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will demonstrate greater *improvements in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.*

There was no significant difference between groups across time for thoracolumbar spine ROM, total hip ROM, NPRS score, or ODQ score. Therefore, research hypothesis 1 was rejected for the outcome measures of spine ROM, hip ROM, pain intensity, and disability level. Alternatively, null hypothesis 1 was accepted for these same four outcome measures.

Hypothesis 2

All participants who have CLBP with movement coordination impairments will demonstrate significant improvements over baseline levels in thoracolumbar spine ROM, hip ROM, pain intensity, and disability level at two, four, and 12 weeks after initiating treatment.

There was a significant main effect of time for total hip ROM, NPRS score, and ODQ score. Therefore, research hypothesis 2 was accepted for the outcome measures of hip ROM, pain intensity, and disability level. Alternatively, null hypothesis 2 was rejected for these same outcome measures. This finding suggests that all participants who had CLBP with movement coordination impairments demonstrated improvements in hip ROM, pain intensity, and disability level across time after initiating treatment. Hip ROM was significantly increased between baseline and two weeks, baseline and four weeks, and baseline and 12 weeks, but not between two and four weeks, two and 12 weeks, or four and 12 weeks, indicating the hip ROM was increased over 12 weeks with the most significant improvement made in the first two weeks. Similarly, the NPRS score was significantly reduced between baseline and two weeks, baseline and four weeks, and baseline and 12 weeks, but not between two and four weeks, two and 12 weeks, or four and 12 weeks, indicating pain level decreased over 12 weeks with the most significant pain reduction achieved in the first two weeks. The ODQ score was significantly reduced between baseline and two weeks, baseline and four weeks, baseline and 12 weeks, and two and 12 weeks, but not between two and four weeks or four and 12 weeks. The ODQ scores indicated that disability level improved over 12 weeks with the most significant improvement made in the first two weeks. Although the improvement slowed down after week 2, the continuous improvement made between week 2 and week 12 also was significant.

There was no significant main effect of time for thoracolumbar spine ROM. Therefore, research hypothesis 2 was rejected for the outcome measure of spinal ROM. Alternatively, null hypothesis 2 was accepted for this outcome measure. This finding suggests that all participants who had CLBP with movement coordination impairments did not demonstrate a change in spinal ROM across time after initiating treatment.

Hypothesis 3

In a CLBP subgroup with movement coordination impairments, participants receiving thoracic, pelvic, and hip manual therapy with standard PT will demonstrate greater improvements in GROC scores at two, four, and 12 weeks after initiating treatment compared to participants receiving standard PT.

There was a significant difference between groups across time for GROC score. Therefore, research hypothesis 1 was accepted for the outcome measure of perceived change. Alternatively, null hypothesis 1 was rejected for this same outcome measure. This finding suggests that in a CLBP subgroup with movement coordination impairments, participants receiving regional manual therapy with standard PT demonstrated greater perceived changes in recovery across time compared to participants receiving standard PT only. The GROC score was significantly higher for the regional manual therapy with standard PT group at two weeks, four weeks, and 12 weeks after initiating treatment.

Discussion of Findings

Spine ROM

The mean of the baseline thoracolumbar flexion-extension ROM for participants in the manual therapy with standard PT group was 84.6°, whereas the mean for participants in the standard PT group was 100.0°. The normal range of values reported for flexion-extension thoracolumbar spine ROM is 105° - 185° (Magee, 2014). Both groups in our study had lower thoracolumbar ROM before the treatment initiated than the normative data. Nineteen of the thirty-four subjects tested at baseline reported pain with sagittal plane motion, and all participants demonstrated hypomobility over at least one lumbar or thoracic segment as part of the inclusion criteria for the study. Either or both of these findings could explain why participants in this study had lower baseline flexion-extension spinal ROM compared to the range of values reported from normal subjects. As treatment was administered, the research hypothesis was that a participant's spinal ROM would improve to within a normal range of values due to improvements in pain during movement, segmental hypomobility, or some combination of the two. However, the results of the study did not support this hypothesis, as no change was found in spinal ROM across time for any groups. Because pain during motion and segmental hypomobility values were not collected after the initial screening session, it is not certain whether or not these variables continued to pose potential limitations to the participant's spinal ROM.

From baseline to two weeks, both treatment groups demonstrated an average 7° - 8° *decrease* in flexion-extension spinal ROM. An average 3° - 7° decrease in spinal ROM compared to baseline was maintained at the four- and 12-week assessments. Although these changes were not significant, the trend of finding a decrease in spinal ROM rather than an increase in motion requires some explanation. Two primary factors could account for this unexpected finding. First, considering that all participants displayed characteristics of CLBP with movement coordination impairments, it is possible that spinal movements were better controlled, and thus limited, through the motor control exercises administered. Studies have shown both a within-session and six week post-treatment improvement in lumbopelvic control during a hook-lying rotation task as a result of verbal instructions and movement system impairment classification-specific exercise, respectively (Hoffman, Johnson, Zou, Harris-Hayes, & Van Dillen, 2011; Scholtes, Norton, Lang, & Van Dillen, 2010) Secondly, it is possible that improvements in regional pelvic and hip ROM could have led to compensatory reductions in spinal ROM. If this were the case, it also might be expected that the regional manual therapy with standard PT group would demonstrate a greater and more continuous reduction in spinal ROM. However, this did not occur. Although pelvic motion was not specifically assessed in this study, other studies have demonstrated improvements in pelvic ROM after the application of pelvic-based strengthening exercise (Yoo, 2013; Yoo, 2014). Hip ROM as assessed in this study was significantly increased across time for all participants, which may provide vital information for understanding how patients with CLBP and movement coordination impairments learn to move differently as a result of manual therapy and motor control interventions.

Hip ROM

The mean of the baseline hip ROM for combined, bilateral sagittal and transverse plane motions was 355.4° for participants in the manual therapy with standard PT group, and 347.5° for participants in the standard PT group. The normal hip ROM values reported for combined, bilateral sagittal and transverse plane ROM is 360° - 450° (Magee, 2014). As was the case for spinal ROM, the participants at baseline in this study were considered below the range of values reported for normal subjects. This observation was expected since one of the inclusion criteria for the study was a significant amount of hip motion loss on at least one side and in at least two directions. Because no participants reported pain as a limitation to hip ROM testing at baseline, pain was not believed to contribute to the limited motion. Rather, hip motion loss was likely a result of some combination of joint and/or myofascial tightness.

Beginning at the two-week assessment, and continuing throughout the duration of the study, the mean hip ROM for all participants was found to be within the range of normal values reported for normal subjects. The results of this study suggest that hip ROM was significantly increased across time for all participants, with no differences found between groups at any time point. We hypothesized that the additive effect of manual therapy to the hip or surrounding soft tissue would result in a greater change in hip ROM than the effect of manual therapy applied to the lumbar spine. This hypothesis was not supported. Two factors could account for this finding. First, the performance of motor control exercise by both groups may have induced a neurophysiological effect whereby agonists were facilitated and antagonists were inhibited to contract, thus improving and balancing muscle tone and flexibility around the hip and pelvis. This mechanism may help to explain how a program of resistance exercise provided similar improvements in hip flexibility to a program of static stretching (Morton, Whitehead, Brinkert, & Caine, 2011). Secondly, it has been reported that the application of manual therapy to the lumbar spine causes reflexive inhibition and relaxation to lumbar-innervated muscles around the hip or pelvis (Herzog, Scheele, & Conway, 1999). Subsequently, this response may have also facilitated increased hip ROM.

Pain Intensity

The mean of baseline pain intensity on the NPRS scores for participants in both treatment groups was 4.2, which represents a moderate level of pain. Although statistical analysis revealed that both groups improved their pain scores equally across time, the regional manual therapy with standard PT group appeared to have a faster rate of improvement than the standard PT group. While both groups reported lower pain intensity at the two week assessment, pain intensity was nearly a full point less in the regional manual therapy group compared to the standard PT group. Pain intensity over the remainder of the study was nearly identical between groups, indicating that the standard PT group made up the one point discrepancy in pain intensity at the four-week assessment, and each group maintained this benefit through the 12-week assessment. At 12 weeks, the regional manual therapy with standard PT group had a mean reduction in pain of 1.5 points, and the standard PT group's mean reduction was 1.7 points. Neither group had pain reduction that exceeded the MCID or MDC of the

NPRS scores for persons with LBP (Childs, Piva, & Fritz, 2005). Although there was no difference found between groups, a faster reduction in pain intensity was noted in the combined regional manual therapy and standard PT group. Pain reduction in a shorter period of time may encourage clinicians to adopt this treatment approach. The benefits of achieving faster pain reduction may include increased patient satisfaction, improved exercise capacity and compliance at an earlier point in the episode of care, and the potential for a reduction in the number of treatment sessions required by patients.

Disability Level

The mean of baseline disability level on the ODQ was 27.6 for participants in the manual therapy with standard PT group, and 26.6 for participants in the standard PT group. Based on criteria established by Fairbank and Pynsent (2000), these scores represent a moderate level of disability. A moderate level of disability was required for inclusion in this study. Out of the 39 patients excluded for failing to meet all inclusion criteria, 23 were excluded because they reported minimal to no disability on the ODQ. This finding is significant because it demonstrates that the sample population for this study was relatively high-functioning despite complaints of chronic pain, which would suggest a more favorable treatment prognosis (Cook et al., 2013).

As the results indicated, both groups improved their disability level scores across time and there was no significant difference in disability level between groups. However, as was the case for pain intensity, the regional manual therapy with standard

PT group appeared to have a faster rate of improvement in disability level than the standard PT group. At the two-week assessment, the regional manual therapy with standard PT group could be classified as having minimal disability according to the criteria given by Fairbank and Pynsent (2000), whereas the standard PT did not reach this distinction until week four. Additionally, the regional manual therapy with standard PT group was able to exceed the MDC for the ODQ by week four, whereas the standard PT group was just able to meet the MDC at the 12 week assessment. Considering that the MDC for the ODQ is 10.5 (Davidson & Keating, 2002), an overall magnitude of change at 14.8 for the regional manual therapy with standard PT group appears more meaningful than the 10.5 point change for the standard PT group. Additionally, only the regional manual therapy with standard PT group achieved the minimum important difference of 12 points on the ODQ, which corresponds to a moderate change on the GROC (Abbott & Schmitt, 2014). A faster rate of improvement in disability would appear to replicate the same potential benefits listed for a faster improvement in pain intensity. A greater magnitude change in disability level for participants receiving regional manual therapy with standard PT could also have the potential to better increase these participants' activity capacity, which has been shown to reduce the likelihood of inactivity contributing to a recurrence of symptoms (Hurwitz, Morgenstern, & Chiao, 2005).

Perceived Change

Participants receiving regional manual therapy with standard PT demonstrated significantly higher GROC scores at two weeks, four weeks, and 12 weeks compared to participants receiving standard PT alone. At two weeks, the regional manual therapy with standard PT group achieved a mean GROC score of 4.0, which represents a moderate, positive change in the participant's perception of their condition (Jaeschke et al., 1989). In contrast, at two weeks, the standard PT group achieved a mean GROC score of 2.6, which represents a small, positive change in the participant's perception of their condition (Jaeschke et al., 1989). While perceived change scores continued to increase over time, the magnitude of the change was small, which meant that participants maintained their initial degree (small or moderate) of change in perception throughout the duration of the study, both during the treatment and after the treatment ended. As was the case for pain intensity and disability level, GROC scores demonstrated a faster improvement in the regional manual therapy with standard PT group. In contrast to the magnitude of change seen for pain intensity and disability level, the difference in scores between groups was statistically significant for the GROC. A recent study has suggested that GROC scores do not consistently correlate with disability scores across time (Schmitt & Abbott, 2015). Therefore, it is possible that a different outcome measure not reported in this study could better capture and explain the between-group difference found using the GROC.

Participant Characteristics

Significant differences were found between groups in the demographic characteristics of age, sex, height, and BMI. Participants in the manual therapy with standard PT group were more likely to be female, and were an average of 10 years older, four inches shorter, and five points higher in BMI than participants in the standard PT group. No significant difference was found between groups for duration of symptoms, yet the manual therapy with standard PT group reported having pain for nearly twice as long (10 years compared to 5 years) as the standard PT group. Prediction models for determining an individual's response to treatment for CLBP suggest that age and duration of symptoms may impact outcomes related to disability (Cook et al., 2013; Haxby Abbott & Kingan, 2014; Verkerk et al., 2013). Sex, height, and BMI have not been suggested as predictors of outcome in CLBP management (Verkerk, Luijsterburg, Miedema, Pool-Goudzwaard, & Koes, 2012). Younger age and shorter duration of symptoms have each been associated with lower disability rates immediately post-treatment, and at 5 months and 1 year post-treatment (Cook et al., 2013; Verkerk et al., 2013). Since the manual therapy with standard PT group was older and had a trend towards a longer duration of symptoms, this group may have been expected to demonstrate smaller improvements in disability compared to the younger and less chronic standard PT group. Rather, the regional manual therapy with standard PT group demonstrated a trend towards a greater improvement in disability. It is therefore possible that the between-group difference in disability may have been even greater if both groups were of a similar age and reported duration of symptoms as the standard PT group.

Six participants dropped out of the study before the two-week reassessment. The reasons provided for dropping out varied, but were not related to any reported adverse events experienced by the participants. A comparison of participant characteristics at baseline for those completing the study and those dropping out of the study revealed significant differences in several areas. First, participants completing the study had lower pain levels ($t(38) = -3.3$, $p = 0.002$) on the NPRS at baseline (4.2 ± 1.4) compared to participants who dropped out of the study (6.3 ± 1.7). Secondly, participants completing the study had lower disability scores ($t(38) = -2.4$, $p = 0.019$) on the ODQ at baseline (27.1 ± 7.4) compared to participants who dropped out of the study (35.3 ± 9.0). Finally, participants completing the study were less likely to be on disability or not working due to pain than participants who dropped out of the study ($\chi^2 = 8.4$, $p = 0.038$). Fifty percent of those who dropped out of the study, compared to 5.8% of those who completed the study, were on disability or not working due to pain. Lower pain intensity scores and more work participation at baseline have been associated with an improved course of disability for persons with CLBP at one year (Verkerk et al., 2013). Additionally, lower pain intensity at baseline has been positively associated with an earlier return to work for persons with CLBP (Verkerk et al., 2012). Higher disability scores at baseline have been associated with both favorable and unfavorable prognoses for persons with CLBP (Cook et al., 2013; Verkerk et al., 2013). Although a person with lower disability levels may be more amenable to active treatment, they may also have a more difficult time showing a change on functional disability measures due to a floor effect. In contrast, persons with higher disability levels may have less difficulty showing at least some magnitude of change on disability measures, although it is less likely that they will be able to achieve the magnitude of change required for absolute recovery (Verkerk et al., 2013).

Implications for Clinical Practice

Recent evidence generally supports the combination of manual therapy and exercise over exercise alone for the management of CLBP (Hidalgo, Detrembleur, Hall, Mahaudens, & Nielens, 2014). Aure, Nilsen, & Vasseljen (2003) were the first to show that an 8-week/16-visit program of mobilization and manipulation from T10 to the pelvis, combined with specific stabilizing and general exercise, was superior to exercise alone at improving pain and disability level up to one year after completion of treatment. These findings were further supported by the work of Balthazard et al. (2012), who found that a 4- to 8-week/8-visit program of spinal mobilization and manipulation combined with mobility and motor control exercises was superior to detuned ultrasound and exercise at improving pain and disability up to six months after completion of treatment. The present study sought to build upon the work of these authors by determining how the type and location of manual therapy performed would influence outcomes for the participants. Additionally, the present study was carried out on a homogeneous subgroup with characteristics suggestive of CLBP with movement coordination impairments of the spine and stiffness of the hips. The 50% reduction in disability seen in this homogeneous subgroup receiving regional manipulation and mobilization with exercise was comparable to that seen in heterogeneous samples with CLBP receiving similar interventions in previous studies. These results may indicate that the allocation of matched treatment according to homogeneous subgrouping does not provide superior outcomes to the prescriptive, regional application of manual therapy and motor control exercise in patients with non-specific CLBP.

Participants with CLBP and movement coordination impairments receiving a 4-week program of standard PT demonstrated an 8% improvement in hip ROM, a 35% improvement in pain intensity, and a 38% improvement in disability level at 12 weeks from the start of care. The addition of regional manual therapy to standard PT resulted in a faster rate of improvement for pain intensity and disability levels, a greater magnitude of change in disability level at 12 weeks (54% vs. 38%), and a significantly higher perceived change due to treatment at two weeks, four weeks, and 12 weeks from the start of care. Physical therapists should consider the additive benefits of regional manual therapy when determining treatment options for patients with CLBP.

Limitations of the Study

The results of this study should be interpreted in light of several limitations. First, this study lacked a true control group. The present study design does not preclude the possibility that other factors such as time may have impacted the results. However, the long duration of unchanging symptoms reported by the participants in this study makes it unlikely that improvements were a result of time alone. Additionally, the lack of a true placebo intervention in this study limits the conclusions that can be made regarding the true effect of the interventions. However, a prior study comparing manual therapy and exercise to placebo and exercise has shown superior results for treatment over placebo (Balthazard et al., 2012).

A second limitation to this study is the small sample size. A small sample size likely contributed to a significant difference between groups in some baseline demographic characteristics, although these differences were not believed to contribute to any Type I errors. Rather, a small sample size may have contributed to a greater likelihood of making a Type II error for some outcome measures. An a priori power analysis revealed that 36 participants would be required to achieve a power of 0.80 at an effect size of 0.20. A post-hoc power analysis performed with G*Power 3.1 (Faul et al., 2007) using an actual effect size (η^2) of 0.028 for the ODQ revealed a power of 0.189. With this lower than anticipated effect size, it is now known that 50 participants are required to achieve a power of 0.80. Additional data collection is planned to ensure that this study will be sufficiently powered.

A third limitation to the study was the method used for collecting spinal and hip ROM. Two testers blinded to group assignment performed all measurements throughout the duration of the study. The same tester was not always able to perform testing at each data collection point for the same participant. Therefore, there is a possibility that differences in measurement technique between testers could have accounted for some differences in spine and hip ROM values. This possibility was addressed by having the testers complete four hours of training on the testing and administration of outcome measures, and by ensuring that the inter-tester reliability for spine and hip ROM testing was good-excellent for the two testers. Additional information on the degree of pain accompanying spinal ROM testing and the degree of segmental stiffness on posterior-anterior (PA) glide testing would have provided valuable information on interpreting a participant's response to spinal ROM testing. However, this information was only collected at baseline, which limits any ability to infer the reason for spinal ROM limitations at any follow-up testing points.

A fourth limitation to the study is the lack of control for potentially confounding variables. Participants were allowed to continue using pain-relieving medications throughout the duration of the study. However, they were asked to refrain from starting any new medications or treatments while participating in the study. It is possible that the use of pain medications could have influenced the results of some outcome measures. Additionally, the presence of fear avoidance beliefs, catastrophizing, or depression could have negatively influenced the recovery of some participants. The process of randomization was used to address the potential for these variables to bias study results. Given that both treatment groups were similar in medication usage, fear avoidance beliefs, catastrophizing, and depression at baseline, these variables are not believed to have unduly influenced study results.

The results of this study should only be generalized to patients with CLBP tested and classified into a movement coordination impairment subgroup and displaying signs of hip stiffness with spinal hyper- and hypomobility. The hip ROM endpoint was based on the initial feeling of resistance to passive motion, coupled with the onset of compensatory motion at the pelvis. Because this method does not objectively quantify stiffness, it may not reflect the absolute ROM endpoint. Additionally, global and segmental spinal ROM was assessed using a skin surface device. Although a skin surface device has been shown to be reliable and valid compared to radiography, this measurement tool may not demonstrate agreement with instrumented or other manual assessments.

Conclusion

To the author's knowledge, this is the first randomized-controlled trial using manual therapy and specific exercise in a homogeneous subgroup with CLBP. The results of this study support in part the treatment recommendations made in the clinical practice guidelines published by Delitto et al. (2012) for using regional and local manual therapy with motor control exercise for treating patients with CLBP with movement coordination impairments. All participants had improvement in hip ROM, pain intensity, and disability level over 12 weeks, but no difference was found between groups. There was no difference in spinal ROM within participants over time or between groups. Finally, there was a significant difference between groups over time for GROC scores, with the group receiving regional manual therapy with standard PT reporting higher perceived change due to treatment at two weeks, four weeks, and 12 weeks from the start of care.

Recommendations for Future Research

Future studies should explore the impact of manual therapy and exercise on long-term healthcare utilization, overall health, and quality of life for patients with CLBP. These studies could help to determine how best to use manual therapy and exercise to impact the societal burden of CLBP, and inform policy-makers on how best to oversee management of the condition. Additionally, future studies should incorporate a multi-disciplinary approach to management for CLBP, in which manual therapy and exercise is combined with accepted treatments from other disciplines to determine optimal treatment strategies for holistic patient management.

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APPENDIX A

Spine ROM Testing with ValedoShape

Spine ROM Testing with ValedoShape

Extension posture

- Cross the arms over the chest (right hand on left shoulder, left hand on right shoulder).
- Bend the upper body backward as far as possible.
- The head should be in the neutral position (look straight ahead).
- No forward compensating movements of the hips.
- Feet should remain about hip-width apart.
- The knees should remain straight

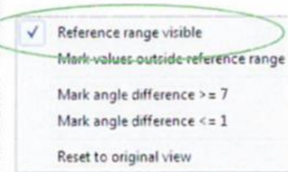
Flexion

- Bend the upper body as far as possible forward and downward (possibly "roll down from top to bottom").
- The head and arms should be allowed to relax and hang down.
- Feet should be about hip-width apart.
- The knees should remain straight.

Displaying reference values

The collected recorded data can be compared with standardised reference values. Reference values exist for the posture standing sagittal (6-11 yrs., 18-83 yrs.), sitting sagittal (18-83 yrs.) and Matthiass (18-83 yrs.).

Segment	Upr			Flex			Ext			U-F			U-E			E-F		
Th1/2	1	5	9	-1	4	5	3	7	10	-7	0	1	-4	2	6	-8	-3	0
Th2/3	4	5	8	3	2	8	3	4	9	-4	-3	2	-3	-1	3	-4	-1	2
Th3/4	3	6	7	3	4	7	4	9	9	-3	-2	3	-2	3	4	-4	-5	2
Th4/5	2	5	6	3	4	7	3	0	7	-1	-1	3	-2	-5	4	-3	4	3
Th5/6	3	4	7	3	4	7	3	2	7	-3	0	3	-3	-2	3	-3	2	3
Th6/7	3	5	7	3	3	7	2	2	6	-3	-2	3	-4	-2	2	-2	1	4
Th7/8	2	1	6	4	4	8	2	3	8	-1	4	5	-2	2	4	-2	2	4
Th8/9	1	5	5	4	6	8	1	1	7	0	2	6	-2	-4	4	-1	5	5
Th9/10	0	6	4	5	7	9	-2	5	4	3	2	7	-3	-1	1	3	3	9
Th10/11	-1	8	3	3	6	8	-3	1	1	1	-2	7	-5	-7	1	4	5	9
Th11/12	-4	3	2	2	3	6	-7	3	1	2	0	8	-6	0	2	4	0	11
Th12/L1	-5	-1	1	2	4	8	-9	-1	-1	4	5	11	-7	0	1	6	5	14
L1/2	-7	-1	-2	3	6	7	-9	-2	-3	6	7	12	-5	-1	1	8	8	15
L2/3	-10	-1	-2	5	9	10	-13	-6	-5	10	10	16	-8	-5	2	12	14	20
L3/4	-13	-1	-5	3	7	9	-17	-3	-9	10	8	20	-8	-2	0	14	9	24
L4/5	-11	-4	-3	3	2	9	-18	-4	-9	9	5	17	-10	-1	-2	14	6	24
L5/S1	-11	-4	-1	-3	3	5	-18	-5	-4	3	8	11	-10	-1	0	6	8	19
Sac/Hip J.	11	1	29	58	51	84	7	-5	25	39	49	63	-12	-6	4	45	56	65
Thoracic spine	31	52	47	45	48	65	24	37	52	5	-4	27	-16	-15	14	2	11	32
Lumbar spine	-44	-12	-24	22	31	38	-67	-21	-47	54	42	74	-35	-9	-11	77	51	97
Incl.	4	5	12	104	88	128	-24	-15	-6	98	83	120	-32	-20	-14	117	103	145
Length		503			553			468			49			-36			85	



APPENDIX B

Hip ROM Testing

Hip ROM Testing Procedure

Hip flexion:

Inclinometer 2 inches superior to the patella. Zero the inclinometer to the leg resting on the table. Passively flex test-side hip. Ensure sagittal plane ROM. Move to R1. Stop at first sign of movement of ipsilateral ASIS. Take 2 measurements. Test Bilateral.

Hip extension:

Inclinometer 2 inches superior to the patella. With the opposite leg semiflexed, zero the inclinometer to the thigh on table with hip in 0° abduction and knee extended. Flex opposite leg to the point of the back becoming flat to the treatment surface. Flex test-side hip to at least 30° Passively extend test-side hip (with knee extended) to R1, keeping the hip in 0° ABD. Stop at first sign of movement of sacrum/PSIS. Take 2 measurements. Test Bilateral.

Hip rotation:

Ipsilateral hip in 0° ABD. Inclinometer just proximal to medial malleolus. Zero the inclinometer when the long axis of the tibia is perpendicular to the table. Passively rotate hip. Ensure horizontal plane ROM. Move to R1. Stop at first sign of movement of sacrum/PSIS. Do not re-zero inclinometer between ER/IR assessments. Take 2 measurements. Test Bilateral.

APPENDIX C

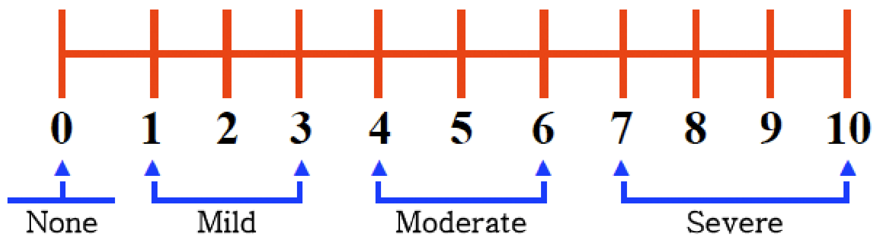
Numeric Pain Rating Scale

The Numeric Pain Rating Scale Instructions

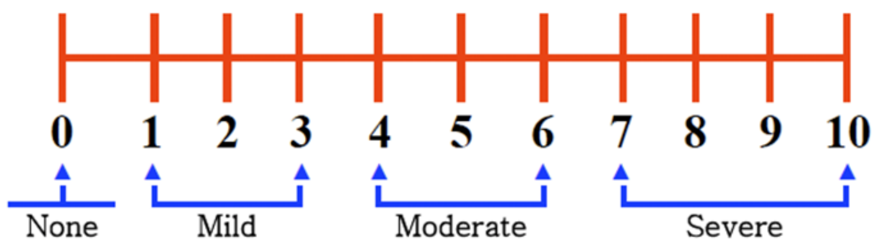
Patient Instructions:

"Please indicate the intensity of current, best, and worst pain levels over the past 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)"

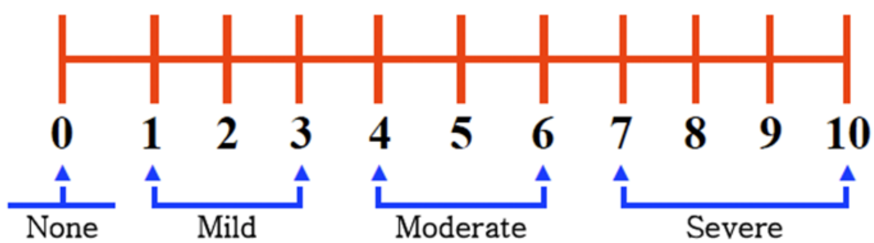
Current Pain



Best Pain



Worst Pain



APPENDIX D

Modified Oswestry Low Back Disability Questionnaire

Modified Oswestry Disability Index

This questionnaire has been designed to give your therapist information as to how your back pain has affected your ability to manage in everyday life. Please answer every question by placing a mark in the one box that best describes your condition today. We realize you may feel that 2 of the statements may describe your condition, but please mark ONLY the box that most closely describes your current condition.

Pain Intensity
□ I can tolerate the pain I have without having to use pain medication.
□ The pain is bad, but I can manage without having to take pain medication.
□ Pain medication provides me with complete relief from pain.
□ Pain medication provides me with moderate relief from pain.
□ Pain medication provides me with little relief from pain.
□ Pain medication has no effect on my pain.

Personal Care (e.g., Washing, Dressing)
□ I can take care of myself normally without causing increased pain.
□ I can take care of myself normally, but it increases my pain.
□ It is painful to take care of myself, and I am slow and careful.
□ I need help, but I am able to manage most of my personal care.
□ I need help every day in most aspects of my care.
□ I do not get dressed, I wash with difficulty, and I stay in bed.

Lifting
□ I can lift heavy weights without increased pain.
□ I can lift heavy weights, but it causes increased pain.
□ Pain prevents me from lifting heavy weights off the floor, but I can manage if the weights are conveniently positioned (e.g., 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.

Walking
□ Pain does not prevent me from walking any distance.
□ Pain prevents me from walking more than 1 mile. (1 mile = 1.6 km).
□ Pain prevents me from walking more than 1/2 mile.
□ Pain prevents me from walking more than 1/4 mile.
□ I can walk only with crutches or a cane.
□ I am in bed most of the time and have to crawl to the toilet.

Sitting
□ I can sit in any chair as long as I like.
□ I can only sit in my favorite chair as long as I like.
□ Pain prevents me from sitting for more than 1 hour.

□ Pain prevents me from sitting for more than 1/2 hour.
□ Pain prevents me from sitting for more than 10 mins.
□ Pain prevents me from sitting at all.
Modified Oswestry Disability Index (continued)

Standing
□ I can stand as long as I want without increased pain.
□ I can stand as long as I want, but it increases my pain.
□ Pain prevents me from standing for more than 1 hour.
□ Pain prevents me from standing for more than 1/2 hour.
□ Pain prevents me from standing for more than 10 minutes.
□ Pain prevents me from standing at all.

Sleeping
□ Pain does not prevent me from sleeping well.
□ I can sleep well only by using pain medication.
□ Even when I take medication, I sleep less than 6 hours.
□ Even when I take medication, I sleep less than 4 hours.
□ Even when I take medication, I sleep less than 2 hours.
□ Pain prevents me from sleeping at all.

Social Life
□ My social life is normal and does not increase my pain.
□ My social life is normal, but it increases my level of pain.
□ Pain prevents me from participating in more energetic activities (e.g., sports, dancing).
□ Pain prevents me form going out very often.
□ Pain has restricted my social life to my home.
□ I have hardly any social life because of my pain.

Traveling
□ I can travel anywhere without increased pain.
□ I can travel anywhere, but it increases my pain.
□ My pain restricts my travel over 2 hours.
□ My pain restricts my travel over 1 hour.
□ My pain restricts my travel to short necessary journeys under 1/2 hour
□ My pain prevents all travel except for visits to the physician / therapist or hospital.

Employment / Homemaking
□ My normal homemaking / job activities do not cause pain.
□ My normal homemaking / job activities increase my pain, but I can still perform all that is required of me.
□ I can perform most of my homemaking / job duties, but pain prevents me from performing more physically stressful activities (e.g., lifting, vacuuming).
□ Pain prevents me from doing anything but light duties.
□ Pain prevents me from doing even light duties.
□ Pain prevents me from performing any job or homemaking chores.

APPENDIX E

Global Rating of Change (GROC) Scale

GROC scale

Please rate the overall condition of your back ***from the time that you began treatment until now*** (check only one):

A very great deal worse (-7) A great deal worse (-6) Quite a bit worse (-5) Moderately worse (-4) Somewhat worse (-3) A little bit worse (-2) A tiny bit worse (almost the same) (-1)	About the same (0)	A very great deal better (+7) A great deal better (+6) Quite a bit better (+5) Moderately better (+4) Somewhat better (+3) A little bit better (+2) A tiny bit better (almost the same) (+1)

Any rating of lower than somewhat worse requires a comment from the therapist (i.e., speculate on the cause of status change).

APPENDIX F

Participant Screening Form

Patient Name: ___________________________ Sex: _____ Weight: __________
Height: __________ Age: ______ ID: _________

Duration of back pain (in days, weeks, months, or years): _______________

Patient Medical History

Referring Physician: ________________ Work status/Occupation: ______________________

Injury on the job: YES NO If yes, date of injury ___________
Claim filed? YES NO N/A

Motor vehicle accident: YES NO If yes, date of injury ___________
Claim filed? YES NO N/A

Are you involved in or considering litigation in regards to this injury?
YES NO

Does anyone come to your home to provide home health/medical services (Check blood pressure, draw blood, etc.)? YES NO

Last date worked: ________________ Date returned to work: __________________
Surgery for this condition: YES NO Number of surgeries: 1 2 3 4 ___
Type of surgery: ____

Are you currently taking any prescription or non-prescription medications? YES NO

Anti-inflammatory	_____	List medications or attach separate list
Muscle relaxers	_____	______________________________
Pain medication	_____	______________________________

Have you had any of the following medical or rehabilitative services for the injury/episode?

Chiropractor	YES	NO	CT Scan	YES	NO
Massage therapy	YES	NO	EMG/NCV	YES	NO
Occupational Therapy	YES	NO	MRI	YES	NO
Physical Therapy	YES	NO	Myelogram	YES	NO
Emergency room care	YES	NO	Discogram	YES	NO
Injection	YES	NO	X-rays	YES	NO

Other: ____

Please indicate whether you currently have, or have ever had, any of the following:

	YES	NO		YES	NO
Asthma, bronchitis, or emphysema	___	___	Bowel or bladder problems	___	___
Shortness of breath/chest pain	___	___	Severe/frequent headaches	___	___
Coronary artery disease or Angina	___	___	Vision/hearing difficulty	___	___
Pacemaker	___	___	Numbness or tingling	___	___
High blood pressure	___	___	Dizziness or fainting	___	___
Heart attack or surgery	___	___	Ringing in your ears	___	___
Stroke/TIA	___	___	Cauda equine syndrome	___	___
Neurological disease	___	___	Loss of coordination	___	___
Blood clot/emboli	___	___	Weight or energy loss	___	___
Epilepsy/seizures	___	___	Weakness	___	___
Thyroid irregularity/Goiter	___	___	Hernia	___	___
Autoimmune disease	___	___	Allergies	___	___
Ankylosing spondylitis/Rheumatoid arthritis	___	___	Fracture	___	___
Anemia	___	___	Pins/metal implants	___	___
AIDS/HIV	___	___	Joint replacement	___	___
Hepatitis/Tuberculosis	___	___	Neck injury/surgery	___	___
Spinal Infection/Infectious disease	___	___	Shoulder injury/surgery	___	___
Diabetes	___	___	Elbow/hand injury/surgery	___	___
Bone or tissue cancer/tumor/chemo/radiation	___	___	Back injury/surgery	___	___
Arthritis/swollen joints	___	___	Knee injury/surgery	___	___
Osteoporosis	___	___	Ankle/foot injury/surgery	___	___
Gout	___	___	Are you pregnant?	___	___
Sleeping Problems/pain during night	___	___	Do you smoke?	___	___
Emotional/psychological impairments	___	___	Do you drink alcohol?	___	___

During the past month, have you often been bothered by feeling down, depressed, or hopeless? **YES NO**
During the past month, have you often been bothered by little interest or pleasure in doing things? **YES NO**

List any other information that would assist us in your care: ______________________________________
Are you aware of what your diagnosis is? YES NO
What are your expectations/goals for rehabilitation? ____

Patient/Guardian signature: ____ Date: _________
Therapist signature: _______________________________________ Date: ____________

APPENDIX G

Participant Screening Examination

Participant Screening Examination

1. Neurological assessment
    a. Sensation testing with a pinwheel or pin over a small autogenous area that is most representative of dermatome, rated as diminished or intact compared to other dermatomes or the uninvolved side
        i. L2-anterior thigh
        ii. L3-medial knee
        iii. L4-medial malleoli
        iv. L5-distal dorsum of foot
        v. S1-lateral border of foot
        vi. S2-posterior/inferior calcaneus
    b. Deep tendon reflex testing with a reflex hammer over key points, rated as absent, diminished, normal, or hyper-reflexive compared to other root levels or the uninvolved side
        i. L3-4-patellar tendon
        ii. L5-medial hamstring
        iii. S1-achilles tendon
    c. Myotomal testing over key motor points, rated as intact if able to maintain test position against moderate to maximal resistance, or diminished if unable to hold test position against moderate to maximal resistance
        i. L1-2-hip
        ii. L3-quadriceps
        iii. L4-anterior tibialis (weight bearing/non weight bearing test)
        iv. L5-extensor hallucis longus
        v. S1-peroneals/gastrocnemius/soleus (weight bearing)
        vi. S2-hamstrings
2. Muscle strength assessment
    a. Isometric Abdominal Endurance Test with the patient in supine, hips at 45°, and knees at 90°. The patient tucks in the chin and curls the trunk off the bed.
        i. Normal (5) = hands behind neck, until scapulae clear table (20 - 30 second hold)

ii. Good (4) = arms crossed over chest, until scapulae clear table (15 - 20 second hold)
iii. Fair (3) = arms straight, until scapulae clear table (10 - 15 second hold)
iv. Poor (2) = arms extended, toward knees, until top of scapulae lift from table (1 - 10 second hold)
v. Trace (1) = unable to raise more than head off table

b. Isometric Extensor Endurance Test with the patient in prone, hips and iliac crests stabilized at the end of the examining table, and trunk hanging over in 30˚ flex, with arms supported by stool. Keeping spine straight, the patient is instructed to extend the trunk to neutral and then lower the head to the start position. Alternate position: Prone with trunk supported, attempt to clear ribs from bed.
    i. Normal (5) = with hands clasped behind the head, extends the lumbar spine, lifting the head, chest, and ribs from the floor (20 - 30 second hold)
    ii. Good (4) = with hands at the side, extends the lumbar spine, lifting the head, chest and ribs from the floor (15 - 20 second hold)
    iii. Fair (3) = with hands at the side, extends the lumbar spine, lifting the sternum off the floor (10 - 15 second hold)
    iv. Poor (2) = with hands at the side, extends the lumbar spine, lifting the head off the floor (1 - 10 second hold)
    v. Trace (1) = only slight contraction of the muscle with no movement

c. Double Straight Leg Lowering Test, with the patient supine, hips flexed to 90°, and knees straight. The patient then positions the pelvis in neutral by doing a posterior pelvic tilt and holding the spinous processes tightly against the examining table. The straight legs are eccentrically lowered. As soon as the ASIS start to rotate forward, the test is stopped and the angle is measured (plinth to thigh angle).
    i. Normal (5) = able to reach 0° to 15° from table before pelvis tilts
    ii. Good (4) = able to reach 16° to 45° from table before pelvis tilts
    iii. Fair (3) = able to reach 46° to 75° from table before pelvis tilts
    iv. Poor (2) = able to reach 75° to 90° from table before pelvis tilts

v. Trace (1) = unable to hold pelvis in neutral at all

d. Isometric Internal/External Abdominal Oblique Test, with the patient in supine with legs extended. The patient is asked to lift the head and shoulder on one side and reach over toward the opposite hip.
    i. Normal (5) = flexes and rotates the lumbar spine fully with hands behind head (20 - 30 second hold)
    ii. Good (4) = flexes and rotates the lumbar spine fully with hands across chest (15 - 20 second hold)
    iii. Fair (3) = flexes and rotates the lumbar spine fully with arms reaching forward (10 - 15 second hold)
    iv. Poor (2) = unable to flex and rotate fully
    v. Trace (1) = only slight contraction of the muscle with no movement
    vi. (0) = no contraction of the muscle
e. Isometric Horizontal Side Support Test, with the patient in a side lying position, knees flexed at 90˚, resting the upper body on his/her elbow. The patient is asked to lift the pelvis off the examining table and straighten the spine. The patient should not roll forward or backward when doing the test.
    i. Normal (5) = able to lift pelvis off examining table and hold spine straight (10 - 20 second hold)
    ii. Good (4) = able to lift pelvis off examining table but has difficulty holding spine straight (5 - 10 second hold)
    iii. Fair (3) = unable to lift pelvis off examining table and cannot hold spine straight (< 5 second hold)
    iv. Poor (2) = unable to lift pelvis off examining table

3. Palpation assessment
    a. Manual assessment of tenderness, temperature, muscle spasm, or other signs and symptoms in the region of pain that may indicate the source of pathology.
4. Lumbar ROM assessment
    a. Performed in standing for the cardinal planes of flexion, extension, sidebending, and rotation. Testing performed one time each direction, then repeated 10 times for flexion and extension test for centralization and peripheralization. Quadrant tests may be performed if the patient's

symptom is not reproduced by cardinal plane or repeated movement testing.

   b. Goals of testing:
      i. Determine quantity of motion, quality of motion, and pain response
      ii. Determine presence or absence of capsular/noncapsular pattern
      iii. Establish a baseline for improvement

5. Hip ROM assessment
   a. Performed in supine for the cardinal planes of flexion and extension, and prone for the cardinal plane of rotation. Testing performed one time in each direction.
   b. Goals of testing:
      i. Determine quantity of motion, quality of motion, and pain response
      ii. Determine presence or absence of capsular/noncapsular pattern
      iii. Establish a baseline for improvement

6. Passive accessory intervertebral movements (PAIVMs)
   a. Central posteroanterior pressures applied over the spinous process to determine the size of the segment's neutral zone, to determine the segment's end feel, and to determine whether pain is elicited.

APPENDIX H

Local and Regional Manual Therapy

Local Lumbosacral Techniques

L1-L5 "PA"

a. Lumbar spine only
b. Glide posterior to anterior in plane of facet
c. Glide across segment to induce rotation
d. Glide superior/inferior to induce flexion/extension
e. Treat centrally over SP or unilaterally over facet/TP
f. Sustained hold or oscillation to end range
g. Perform grades 3 - 4 to the point of improved mobility and/or decreased pain.

Soft tissue mobilization

a. Tissue gliding strokes parallel, perpendicular, oblique, or spiral directions
b. Ischemic pressure to trigger point
c. Sustained hold or oscillation
d. Perform to the point of improved mobility and/or decreased pain
e. **Limit techniques to lumbar paraspinals and quadratus lumborum**

Example Regional Thoracic, Pelvic, and Hip Techniques

T1-T12 PA

a. Thoracic spine technique
b. Glide posterior to anterior in plane of facet
c. Glide across segment to induce rotation
d. Glide superior/inferior to induce flexion/extension
e. Treat centrally over SP or unilaterally over facet/TP
f. Sustained hold or oscillation to end range
g. Perform grades 3 - 5 to the point of improved

mobility and/or decreased pain

Rib 3-10 Spring

a. Thoracic rib technique
b. Good technique for limited lumbar rotation/sidebend
c. Spring rib anterior/lateral
d. Can also include superior/inferior mobilization
e. For alternate approach, try posterior mobilization in sidelying with treatment side up
f. Incorporate mobilization with movement in sitting
g. Sustained hold or oscillation to end range
h. Perform grades 3 - 5 to the point of improved mobility and/or decreased pain

Supine HVLA thrust

a. Preferred thoracic technique, assuming no contraindications
b. Segmental rotation or sidebending over the involved level(s)
c. Perform to the point of cavitation, typically within two attempts

Lumbar gapping manipulation HVLA thrust

a. Preferred lumbar technique, assuming no contraindications
b. Gapping facets of involved level(s)
c. Patient’s most painful side up
d. Perform to the point of cavitation, typically within two attempts
e. Repeat on opposite side if no cavitation on painful side

Lumbosacral (LS) manipulation HVLA thrust

a. Preferred lumbosacral technique, assuming no contraindications
b. Posterior innominate rotation and glide
c. Manipulate side of anterior innominate (AI) displacement, or patient's most painful side
d. Perform to the point of cavitation, typically within two attempts
e. Repeat on opposite side if no cavitation on AI or most painful side

Rotation with sacral base stuck in extension (corrects AI)

a. Stand on side of dysfunction
b. Ulnar aspect of caudal hand on ipsilateral sacral base with fingers running cranially
c. Mobilize anterior

Downslip manipulation HVLA thrust (corrects upslip/AI)

a. May have assistant anchor lumbosacal region in anterior/superior direction
b. Therapist holds tibia and places hip of involved side in extension, abduction, and IR
c. Distract leg in caudal direction according to barrier

Posterior to Anterior Manipulation HVLA thrust (corrects PI)

a. Treatment side up
b. Flex top leg up to the level of SIJ and rotate spine down to the level of SIJ
c. Tuck patient's table side arm against their

trunk/abdomen

d. Therapist moves behind the patient, grasps their outstretched hand, and rotates their trunk **back until the patient's knee begins to rise off the table**
e. Therapist contacts patient's PSIS with a force directed **anteriorly and superior**
f. Take up slack anterior and slightly superior.
g. Have **patient resist you pulling them into additional trunk rotation**
h. **HVLA thrust of pelvis anterior an**d **inferior**

Soft tissue mobilization **anterior** trunk, pelvis, hip

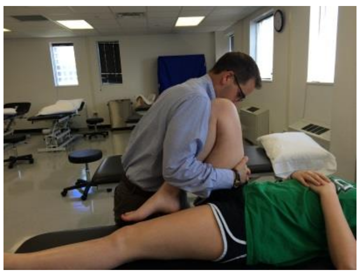
a. Iliopsoas technique
b. Tissue gliding strokes parallel or perpendicular or ischemic pressure
c. Sustained hold or oscillation
d. Perform to the point of improved mobility and/or decreased pain

Soft tissue mobilization post/lat trunk, pelvis, hip

a. Tissue gliding strokes parallel, perpendicular, oblique, or spiral directions
b. Ischemic pressure to trigger point
c. Sustained hold or oscillation
d. Perform to the point of improved mobility and/or decreased pain

Anterior-posterior hip mobilization

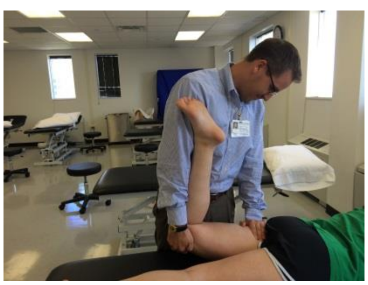
a. Hip in flexion, adduction, and internal rotation
b. Posterolateral force through femur
c. Sustained hold or oscillation to end range
d. Perform grades 3 - 4 to the point of improved mobility and/or decreased pain



Caudal hip mobilization

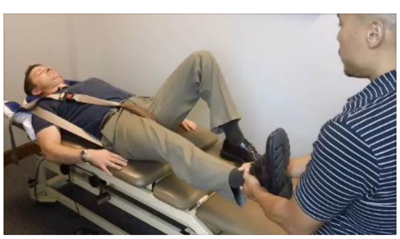
a. Hip flexed to 90-100° with neutral rotation
b. Distract femur in caudal direction
c. Sustained hold or oscillation to end range
d. Perform grades 3 - 5 to the point of improved mobility and/or decreased pain

Posterior-to-anterior hip mobilization



a. Knee flexed 90-100° with hip in neutral rotation and abduction
b. Passively extend hip to barrier
c. Apply posterior-to-anterior glide to proximal femur
d. Sustained hold or oscillation to end range
e. Perform grades 3 - 4 to the point of improved mobility and/or decreased pain

Hip distraction manipulation HVLA thrust



a. Stabilize pelvis with banana belt PRN
b. Put hip in slight flexion, ABD, and ER
c. Distract LE caudal according to barrier, which may be slightly posterior/inferior based on most restricted motion

APPENDIX I

Motor Control Exercises

CORE TRAINING

Muscle Training for Low Back Pain

The supporting muscles of your spine consist of an inner unit and an outer unit. Components of each unit may be affected, but the research suggests it is the inner unit that is most affected. The inner unit consists of a deep spinal muscle called the multifidus, a deep abdominal muscle called the transverse abdominus, the pelvic floor muscles, and the diaphragm. These muscles create a "corset" around your spine, and when functioning properly, work in harmony to stabilize the individual vertebrae of the spine and the sacroiliac joint. *The stabilization effects of these muscles only require low levels of contraction*. Isolating and training the inner unit is the initial focus of the program. As you gain control of the inner unit, exercises for the outer unit (oblique and rectus abdominal muscles, back extensors, gluteals) are initiated. All exercises are done in a neutral spine position.

Isolating the Inner Unit

Pelvic Floor

1. Relax. Focus on the genital area between your legs. Slowly draw that area up, as if pulling it internally. Hold the contraction as long as you can. You should progressively increase your hold time as able. Repeat for 2 minutes contraction time.
2. If you have trouble isolating the contraction, imagine that you are tightening the muscles that you would use to cut off a urine flow.

Transverse Abdominus

1. Establish a normal quiet breathing pattern. As you exhale, gradually draw your belly button up and in. You should feel your belly button move, and a light, deep tension just inside your pelvic bones. Maintain normal breathing and begin by holding the contraction as long as you can. You should progressively increase your hold time as you are able. Repeat for 2 minutes contraction time.

2. If you have trouble isolating the contraction, another way of activating this muscle is to imagine that the pelvis is an open book, and the hip bones are it's covers. Gently think about a force that would close the book covers.

Multifidus

1. Place your fingers on top of your lower spine to contact the target muscles. Imagine pulling the back of your waistband up (toward your head). This should create a "bulging" in the muscles over the top of the spine. Check this response at different levels of the spine. Focus your training on the levels where the contraction feels weakest. Breathe as directed above while performing this contraction. Hold this contraction as long as you can, increasing hold time as able. Repeat for 2 minutes contraction time.
2. If you have trouble feeling the contraction, use the image of the open book as listed above, this time making the bony prominences on the back of the pelvis its covers. Close the book covers. Another technique is to think about pulling your low back vertebrae deeper into your body without actually creating movement.

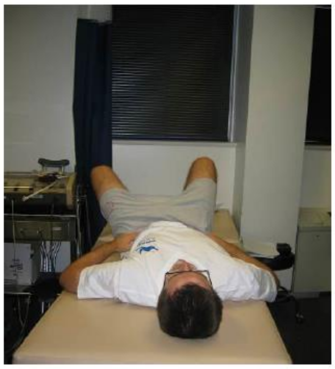
These exercises should be performed in lying, sitting and standing positions as directed by your therapist. These exercises should be repeated at least one time hourly, throughout the day, to facilitate muscle re-education.

You may have trouble with these exercises at first and may use the wrong muscles. Avoid the following:

- Fast or maximal contractions
- Tilting or movement your pelvis out of the neutral position.
- Bulging outward of your abdominal wall
- Excessive depression or elevation of your rib cage
- Holding your breath
- Tensing your buttocks or thighs

STABILIZATION TRAINING

Hold tension in core during all exercises. You may also attempt to simultaneously draw your hip into the socket, just tightening the muscles running across the front of the hip. Perform ___ sec hold. Repeat ___ times, for a total of ___ mins.



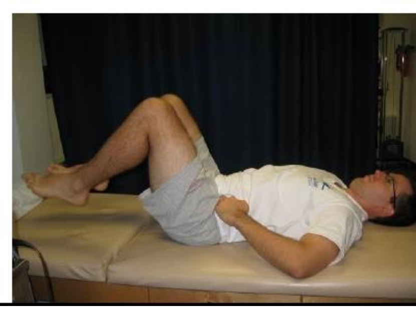
1). **Bent knee fallouts** – Slowly lower one knee out to the side. With your fingers, monitor for no movement at the pelvic bones.

2). **Alternate marching** – Lift one leg a few inches, keeping knee bent. Do not increase pressure on the opposite leg or let the pelvis move.

3). **Alternate slides** – Slide your leg out and back in, with/without foot contact with the surface. Do not increase pressure on the opposite leg or let the pelvis move.

4). **Unsupported march** – Hold one leg up, keeping knee bent. Lift your opposite leg a few inches, keeping knee bent. Do not let the pelvis move.

5). **Unsupported slide** – Hold one leg up, keeping knee bent. Slide your opposite leg out and back, with/without foot contact with the surface. Do not let the pelvis move.

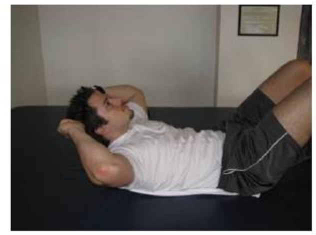


6). **Double leg raise** – Lift both legs a few inches, keeping knees bent. Do not let pelvis move. Progress to sliding legs out simultaneously.

TRUNK CURL UPS

Assisted curl up

Lie on your back with the knees bent. Place a towel down the length of your spine, up to your head. Reach your hands back to the towel and hold the top edges. Use your abdominal muscles to lift your chest off the bed. Do not lead with your head or shoulders. Assist as needed with the towel. Keep your feet down.



Hold _____sec(s).
Repeat _____ time(s), for a total of ___ mins.

Straight curl up

Lie on your back with the knees bent. Cross your arms over your chest. Use your abdominal muscles to lift your chest off the bed until your shoulder blades clear the surface. Do not lead with your head or shoulders. For an easier lift, reach your arms toward your legs. For a harder lift, place your hands behind your head. Keep your feet down.

Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

Oblique curl up

Lie on your back with the knees bent. Cross your arms over your chest. Use your abdominal muscles to lift your chest up and over to one side until both shoulder blades clear the surface. Do not lead with your head or shoulders. For an easier lift, reach your arms toward your legs. For a harder lift, place your hands behind your head. Keep your feet down.

Hold _____sec(s).
Repeat _____ time(s), for a total of ___ mins.

Side curl up

Lie on your side with the legs straight. Cross your bottom arm over your chest. Use your top-side abdominal muscles to lift your torso off the table. Reach your top arm toward the ceiling as you lift. Keep your feet down.

Hold _____sec(s).
Repeat _____ time(s), for a total of ___ mins.

THORACIC EXTENSOR TRAINING

CHEST RAISE

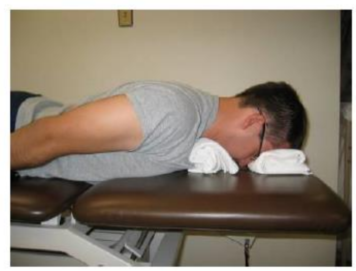
Lie down on your back with your knees bent. Arch your middle back (between your shoulder blades) away from the supporting surface. Your sternum should raise up to the ceiling. You should feel tension in the muscles along your spine, between your shoulder blades. **Do not let your low back tense or arch off the table**.

Hold______second(s).

Repeat______time(s).

Total of _____ mins.

SCAPULA LIFT



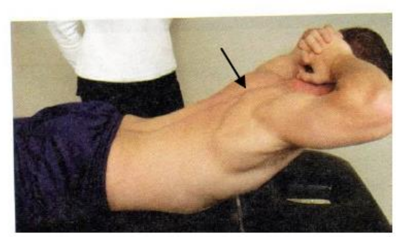
Support the head and chin with rolled towels to ensure that the neck stays relaxed throughout this exercise. Pull the collar bones back away from the table. Think of flattening your middle back as you perform this motion. Initially, keep your hands in contact with the table, and your arms away from the sides of your trunk, while performing this motion. Progress to lifting the hands off the table 1 inch. Tension should primarily be felt between the shoulder blades.

Hold______second(s).

Repeat ______time(s).

Total of _____ mins.

TRUNK LIFT



Lie down on your stomach, hands behind your head. Slowly lift the chest off the supporting surface with emphasis placed on the muscles of the **upper back, between the shoulder blades and closest to the spine.** Avoid over-activation of the neck or lower back. Hands can be placed at the sides instead of behind the head if the exercise is too difficult.

Hold______second(s).

Repeat______time(s).

Total of _____ mins.

LUMBAR EXTENSOR EXERCISES

SORENSEN POSITION

Allow upper torso to extend over the edge of a firm supporting surface. Tuck your arms over your chest, rounding out your middle back. Maintain your position using your low back muscles. Have someone hold your feet down to maintain balance and increase contraction of the low back muscles.

Hold______second(s).

Repeat______time(s).

Total time ____ mins.

PRONE DOUBLE LEG RAISE

Lie down on your stomach. Pre-tighten your core, lower back, gluteal, and hamstring muscles as directed by your therapist. Use these muscles to lift both legs off the table.

Hold______second(s).

Repeat______time(s).

Total time ____ mins.

ARM RAISE

Tighten your core muscles. Slowly raise both arms in front of you. Your core muscles (particularly over the spine) should tighten as you raise your arms. Use ____ lbs for resistance.

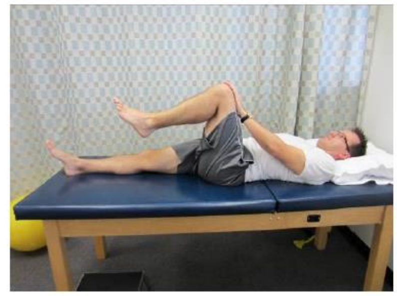
Hold______second(s).

Repeat______time(s).

Total time ____ mins.

ILIOPSOAS EXERCISES

LEG PULL



Lie down on your back with your hip bent to 90degrees. Using the muscles on the front of your hip, pull the hip into the socket, as if attempting to make your leg shorter. Add resistance to the top of the thigh as able. Isolate the effort to the front of the hip (not the thigh) as much as possible.

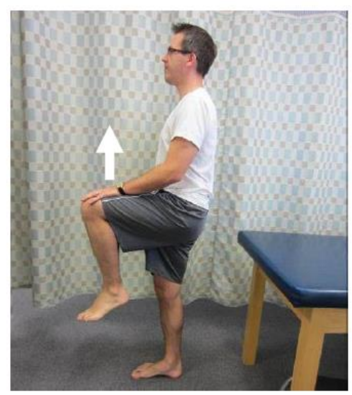
Hold______second(s). Repeat______time(s). Total time ____ mins.

SEATED LEG LIFT

Sit up straight. Using the muscles on the front of your hip, pull the hip into the socket, as if attempting to make your leg shorter. Add resistance to the top of the thigh as able. Isolate the effort to the front of the hip (not the thigh) as much as possible.

Hold______second(s). Repeat______time(s). Total time ____ mins.

STANDING LEG LIFT



Stand up straight. Using the muscles on the front of your hip, pull the hip into the socket, as if attempting to make your leg shorter. Add resistance to the top of the thigh as able. Isolate the effort to the front of the hip (not the thigh) as much as possible.

Hold______second(s).

Repeat______time(s).

Total time ____ mins.

STRAIGHT LEG RAISE

Lie down with involved leg straightened out. Using the muscles on the front of your hip, pull the hip into the socket, as if attempting to make your leg shorter. Slowly raise your straightened leg about 12-18 inches. Isolate the effort to the front of the hip (not the thigh) as much as possible.

Hold______second(s). Repeat______time(s). Total time ____ mins.

HIP EXTENSION

Single Leg Extension

Lean over a firm, supportive surface (bed or table). Tighten core and gluteals, then extend one leg straight back, with knee flexed, taking care not to extend the back at the end of the motion.

Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

Single Leg Extension with ABD and ER

Lean over a firm, supportive surface (bed or table). Tighten core and gluteals, then extend one leg back, with knee flexed, taking care not to extend the back at the end of the motion. Twist the leg out at the top of the motion.

Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

Prone Hip Extension with Leg Straight

Place a pillow underneath the pelvis as directed. Tighten the core and gluteal muscles of the leg to be raised. Keeping the leg extended, raise the heel towards the ceiling. Keep your back and thigh as relaxed as possible.

Hold _____sec(s).
Repeat _____ time(s), for a total of _____ mins.

Prone Hip Extension with Knee Bent

Place a pillow underneath the pelvis as directed. Tighten the core and gluteal muscles of the leg to be raised. Keeping the knee bent, raise the heel towards the ceiling. Keep your back and thigh as relaxed as possible.

Hold _____sec(s).
Repeat _____ time(s), for a total of ___ mins.

HIP ABDUCTION

Perform the following exercises on the floor or on another firm surface (bed)

Prone Hip Abduction

Place a pillow underneath the pelvis as directed. Tighten the core and gluteal muscles of the leg to be moved. Slide the leg out away from the body without raising the pelvis or low back.

Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

Clam

Tighten core and Gluteals. From a side-lying position, maximally turn top leg away from bottom leg. Don't let pelvis roll backward or let spine twist. Begin with keeping feet together. Try to keep thigh and back as relaxed as possible.

Progress to separating feet 1" – 2".

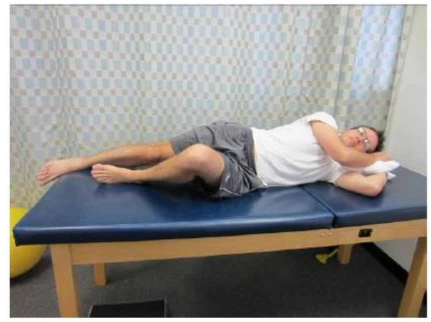
Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

Wall Slide

Tighten core and Gluteals. From a side-lying position against a wall, maximally raise top leg away from bottom leg. Maintain full contact from hip to foot with the wall. Try to keep thigh and back as relaxed as possible.

Hold _____sec(s).
Repeat _____ time(s), for a total of ____ mins.

HIP ADDUCTION EXERCISES



REVERSE CLAM

Tighten core and inner thigh. From a side-lying position, maximally turn bottom leg away from the table. Don't let pelvis roll backward or let spine twist.

Hold______second(s).

Repeat______time(s).

Total time ____ mins.

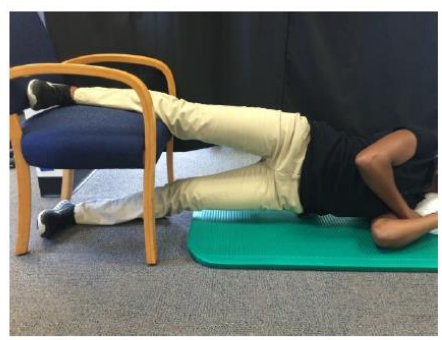
SIDELYING ADDUCTION

Tighten core and inner thigh. From a side-lying position, maximally lift bottom leg away from the table. Don't let pelvis roll backward or let spine twist.

Hold______second(s).

Repeat______time(s).

Total time ____ mins.



TRUNK RAISE

Lie down on your side with your leg resting on top of a chair. Tighten core and inner thigh. Press top leg into the chair using inner thigh muscles until you begin to lift off of the floor. As this gets easier, try to lift your bottom leg away from the floor.

Hold______second(s).

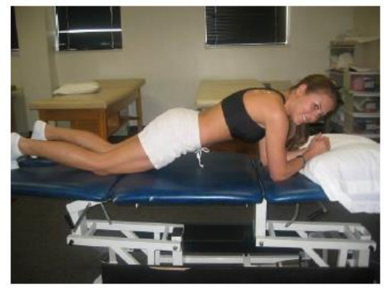
Repeat______time(s).

Total time ____ mins.

PRONE PLANKING EXERCISES

Prone Plank

Lie down on your stomach with your elbows tucked under your chest. Use your stomach muscles to help raise your trunk away from the table. Keep your trunk straight. Attempt to simultaneously draw your hip into the socket, just tightening the muscles running across the front of the hip, as you lift.



Hold ____second(s).
Repeat _____time(s), for a total of ____ mins

Prone Plank

Perform the plank as described above with support from your toes instead of knees.

Hold ____second(s).
Repeat _____ time(s), for a total of ___ mins

Plank with Leg Lift

Perform plank as described above. At the top of the motion, lift one leg off the table. Keep pelvis level.

Hold ____second(s).
Repeat _____ time(s), for a total of ___ mins

SIDE PLANK EXERCISES

Side Raise

Lie down on your side with hips and knees either straight or bent, as directed. Tighten the core and table side gluteal muscles Use these muscles, along with pressure through your shoulder and legs, to lift your bottom hip off the table.

Hold ____second(s).
Repeat _____time(s), for a total of ____ mins.

Side Plank Bent

Lie down on your side with your knees bent, hips straight, and elbow tucked under you. Tighten the core and table side gluteal muscles Use these muscles, along with pressure through your shoulder and legs, to lift your bottom hip off the table.
Progression: List your top leg away from your bottom leg.

Hold ____second(s).
Repeat _____ time(s), for a total of ____ mins.

Side Plank Straight

Lie down on your side with your knees and hips straight, and elbow tucked under you. Tighten the core and table side gluteal muscles. Use these muscles, along with pressure through your shoulder and legs, to lift your bottom hip off the table

Hold ____second(s).
Repeat _____ time(s), for a total of ____ mins.

Side Plank with Leg Lift

Perform plank as described above. At the top of the motion, lift your top leg out to the side, away from the bottom leg, using the outside hip muscles of the top leg to do so.

Hold ____second(s).
Repeat _____ time(s), for a total of ____ mins.

Bridging Exercises

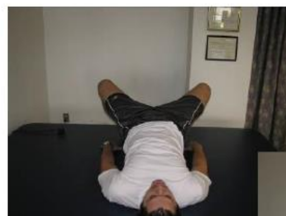
<u>BRIDGE</u>

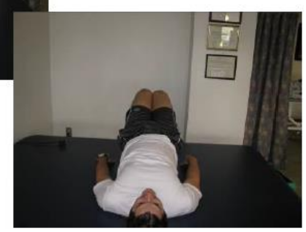
Pre-tighten core and gluteal muscles.
Use the gluteals to lift hips off of firm supporting surface.
Take care not to extend the back at the end of the motion.

Hold______second(s).

Repeat_______time(s), for a total of _____ mins.

<u>BRIDGE WITH ABDUCTION/ADDUCTION</u>





Perform the bridge as above. At the top of the movement, bring the knees out to the side while keeping the feet stationary. After bringing the knees out to the side, bring the knees back together until they touch.

Perform ______ knee movements.

Repeat_______time(s), for a total of ____ mins.

<u>PROGRESSION TO BRIDGES</u>

1) Cross one leg over the other. Then, perform the bridge as described above, keeping pelvis level.

2) Perform the bridge, then lift one leg off of the firm supporting surface, taking care to keep pelvis level.

3) Extend one leg out, then perform the bridge on one leg, maintaining the extended leg 6" off the supporting surface. Keep the pelvis level.

Hold______second(s).

Repeat_______time(s), for a total of ____ mins.