EFFECTIVENESS OF SPINAL STABILIZATION EXERCISES ON MOVEMENT PERFORMANCE IN ADULTS WITH SUBACUTE AND CHRONIC LOW BACK PAIN: A RANDOMIZED CLINICAL TRIAL

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

SCHOOL OF PHYSICAL THERAPY

COLLEGE OF HEALTH SCIENCES

BY

KHALID ALKHATHAMI, P.T., M.P.T

DENTON, TEXAS

AUGUST 2019

DEDICATION

I dedicate this achievement to my father and mother who taught me the value of education by investing in me.

I also dedicate this dissertation to my other half, Sarah, and my daughters, Yara and Linda, for being by my side throughout my PhD studies.

ACKNOWLEDGMENTS

My heartfelt thanks to the following people who influenced this dissertation:

First, I would like to express my profound gratitude to my major advisor Dr. Sharon Wang-Price for her incredible support and for her indispensable supervision during this journey. Thank you so much for the time and guidance you gave me throughout my PhD studies. I am very fortunate and proud to have you as my major advisor.

I would like to acknowledge and thank my committee members, Dr. Kelli Brizzolara and Dr. Mark Weber. Thank you for the input and feedback that you have provided me throughout this research project. This journey was challenging, and I would not have reached achievement without all the support and guidance I have received from all of you.

Most important, I would like to thank my parents, Misfer and Mazunah, for sacrificing the most of anyone to get me here and for always believing in me. I am very grateful for the continuous encouragement since I started seeking education and for the motivation you have given me to pursue my PhD studies.

To my lovely wife, Sarah, thank you for being patient with me, supporting me, being by my side, and motivating me throughout my PhD journey. I really found this journey easy and enjoyable with you.

I am also thankful for the best gifts that I got while I was pursuing my advanced education in the United States: my lovely daughters, Yara and Linda.

I would like to thank my brothers and my sisters for all their encouragement and support.

I would like to thank the Shaqra University for sponsoring and funding my education throughout these years.

I would like to express my appreciation to the Texas Physical Therapy Foundation for funding this project.

I would like also to thank my friends for being there for me throughout this journey.

Thank you very much, everyone!

ABSTRACT

KHALID ALKHATHAMI

EFFECTIVENESS OF SPINAL STABILIZATION EXERCISES ON MOVEMENT PERFORMANCE IN ADULTS WITH SUBACUTE AND CHRONIC LOW BACK PAIN: A RANDOMIZED CLINICAL TRIAL

AUGUST 2019

Background: The purpose of this study was to determine the effectiveness of spinal stabilization exercises (SSEs) on movement performance and reductions in pain intensity and disability level in adults with subacute and chronic low back pain (CLBP).

Methods: Forty participants (20 in each group) with CLBP were recruited and randomly allocated into one of two interventions: spinal stabilization exercises (SSEs) and general exercises (GEs). All participants received their assigned intervention under supervision one to two times per week for the first four weeks, and then were asked to continue their exercise program at home for another four weeks. Outcome measures were collected at baseline, two weeks, four weeks and eight weeks, including the Functional Movement Screen (FMS), Numeric Pain Rating Scale (NPRS), and Modified Oswestry Low Back Pain Disability Questionnaire (OSW) scores. Three separate 2 (group) x 4 (time) repeated measure (RM) ANOVAs were used to analyze the collected data for each of the three outcome measures. Post hoc analysis was performed when there was a significant interaction. The α level was set at 0.05 for all statistical analyses.

Results: The ANOVA results revealed a significant interaction for the FMS scores (p = 0.016), but not for the NPRS and OSW scores. Post hoc analysis showed significant between-group differences between baseline and four weeks (p = 0.005) and between baseline and eight weeks (p = 0.026). Further, the results demonstrated that all participants, regardless of group, had significant improvements in movement performance, pain intensity and disability level over time.

Conclusion: The results of the study favor SSEs over GEs in improving movement performance for individuals with CLBP, specifically after 4 weeks of the supervised SSE program. The results may provide clinicians with further evidence for the use of SSEs in the management of patients with CLBP.

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CHAPTER I

INTRODUCTION

Low back pain (LBP) is a musculoskeletal disorder that affects more than 80% of people in the United States at least once in their lifetime (Balagué, Mannion, Pellisé, & Cedraschi, 2012; Freburger et al., 2009; Rubin, 2007). LBP is considered to be one of the most common complaints prompting individuals to seek medical care (Waterman, Belmont, & Schoenfeld, 2012). In addition, LBP is a leading cause of disability, contributing to work absenteeism and loss of productivity worldwide. Consequently, LBP is a very costly condition (Fitzmaurice et al., 2015; Marini et al., 2017). The total direct and indirect medical spending for LBP is estimated between $100 and $200 billion a year (Freburger et al., 2009). Although a large proportion of individuals with an acute episode of LBP experience rapid improvement, the condition is often associated with high recurrence rates (Lehtola, Luomajoki, Leinonen, Gibbons, & Airaksinen, 2012; Pengel, Herbert, Maher, & Refshauge, 2003). It has been estimated that 50% of individuals with a history of LBP have a recurrence of LBP within one year, 60% in two years and 70% in five years (Hestbaek, Leboeuf-Yde, & Manniche, 2003; Hoy, Brooks, Blyth, & Buchbinder, 2010).

LBP often is managed based on the duration of symptoms: acute, subacute, and chronic (Merskey, 1994). LBP is considered acute when symptoms last less than six weeks, subacute when symptoms last between six weeks to three months, and chronic when symptoms continue for longer than

three months (Koes, Van Tulder, & Thomas, 2006). Researchers agree that the use of subgrouping methods (acute, subacute, and chronic) for LBP populations may improve clinical care (Delitto et al., 2012). About 80 to 90% of individuals who experience LBP recover within three months and many of them do not seek medical care, but 5% to 10% of patients who do not recover within this time frame progress into the chronic LBP (CLBP) phase (Carey et al., 1996; Chaffin & Andersson, 1999). However, once these patients progress into CLBP, the cost for medical care increases significantly, approximately by $96 million a year (Mehra, Hill, Nicholl, & Schadrack, 2012; Meucci, Fassa, & Faria, 2015).

Despite the high prevalence of LBP, there is no agreement as to the specific causes or mechanisms in the development of LBP (Byström, Rasmussen-Barr, & Grooten, 2013). Non-specific LBP (NSLBP) is solely a term that defines symptoms without a clear, specific cause and is not attributable to a known or specific pathology (Byström et al., 2013; Marini et al., 2017). About 90% of patients with LBP will be diagnosed with NSLBP after specific pathology is eliminated, for example, infection, spondylitis, tumors, osteoporosis, inflammatory diseases, fractures, radiculopathy, spinal stenosis, or cauda equina syndrome (Koes, et al., 2006). Therefore, NSLBP is considered to be a pathology of mechanical nature and most often caused by spinal instability (Fandiño & García-Abeledo, 1998). In addition to deficits in passive supporting structures, such as ligaments and joint capsules, incoordination and decreased contraction of the spinal stabilizers, specifically transversus abdominis (TrA) and lumbar

multifidus (LM) muscles, can significantly contribute to spinal instability (Gladwell, Head, Haggar, & Beneke, 2006). The function of these spinal stabilizers has been well-established in the literature. For example, decreased LM muscle size using ultrasound and magnetic resonance imaging was found in patients with LBP as compared to healthy individuals (Beneck & Kulig, 2012; Hides, Stokes, Saide, Jull, & Cooper, 1994; Hides, Gilmore, Stanton, & Bohlscheid, 2008). A delayed activation of the TrA muscle also was observed in patients with LBP (Ferreira, Ferreira, & Hodges, 2004; Hodges & Richardson, 1996; Cholewicki et al., 2005).

Clinically, aberrant movement patterns such as a painful arc, lateral shifting, or Gower's sign (i.e., patients walking their hands up their thighs to return from a flexed to an upright position), are associated with lumbar instability or movement coordination impairment (Biely, Silfies, Smith, & Hicks, 2014; Delitto et al., 2012). Furthermore, patients with CLBP often develop compensatory movement patterns to complete functional tasks, such as stepping over an obstacle and squatting (Ko, Noh, Kang, & Oh, 2016). Given the high recurrence of LBP (Pengel et al., 2003), abnormal or compensatory movement patterns may play an essential role in recurrence. Therefore, observation and analysis of movement quality may be key elements in LBP management, particularly for patients with subacute and chronic LBP (van Dijk et al., 2017).

The quality of movement has been measured in different ways, including the use of self-reported measures, impairment measures, and movement

performance measures. Self-reported questionnaires are commonly administered because they are based on the patients' own evaluation of their pain and function (Reiman & Manske, 2011). However, a concern with the self-reported measures is that these methods do not always distinguish as to whether or why a specific task is done properly or if it can be done at all (Simmonds, 2006). The self-reported questionnaires lack the description of movements and how the patient will perform the specific task, and only address whether the patient is able to do it or not. Therefore, to address the inadequacy of self-reported questionnaires, several functional performance measures have been developed not only for assessing the ability of performing specific functional tasks, but also for assessing the easiness and efficiency of performing these tasks. The Back Performance Scale (BPS) is a physical performance measure of trunk mobility-related activities, consisting of five tests: sock test, pick-up test, roll-up test, fingertip-to-floor test, and lift test (Panhale, Gurav & Nahar, 2016). The BPS has been found to be useful for assessing important aspects of physical performance in patients with long-lasting back problems (Strand, Moe-Nilssen, & Ljunggren, 2002). In addition to the BPS, the Physical Performance Test (PPT) and the Continuous Scale Physical Functional Performance (CS-PFP) were developed for assessing the level of functional movements (Cress, Buchner, Questad, Esselman, & Schwartz, 1996; Reuben & Siu, 1990). These two tests consist of different tasks, but they are similar in grading criteria. Each task is scored by the duration of time for completion and is scored as a zero when the

patient is unable to perform the task. Although these tests are better than any single function test alone for assessing function performances that are important for daily activities of life, neither test quantifies how well the individual tests are performed. In addition, these functional performance tests are not specific to the LBP patient population.

The Functional Movement Screen (FMS) is a quantitative assessment tool that was developed to assess movement performance by identifying limitations and restrictions of movement patterns and to determine whether abnormal movements are present (Cook, Burton, Hoogenboom, & Voight, 2014a; Cook, Burton, Hoogenboom, & Voight, 2014b). The FMS is used to predict which individual might become injured. Because of its ability to evaluate and treat injuries, it has been advocated as a tool for rehabilitation (Cook et al., 2014a). The FMS consists of seven test components, which are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg-raise, trunk stability push-up, and rotary stability (Cook et al., 2014a). Each test is scored on a scale of 0 to 3, with a total composite score ranging from 0 to 21 points (Cook et al., 2014b). FMS scores less than or equal to 14 have been found to be associated with a higher risk of musculoskeletal injury among firefighters, football players, and female collegiate athletes (Butler et al., 2013; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Kiesel, Plisky, & Butler, 2011).

The FMS has been used as an outcome measure to examine the effects of an exercise program on healthy people, and was found to be capable of

capturing the improvement of functional movement patterns after an exercise program (Bagherian, Ghasempoor, Rahnama, & Wikstrom, 2018; Stanek, Dodd, Kelly, Wolfe, & Swenson, 2017). In addition, a study conducted on female collegiate rowers showed that rowers with lower FMS scores had a high risk of injury and had a higher likelihood of sustaining LBP (Clay, Mansell, & Tierney, 2016). Moreover, a recent study found that patients with CLBP demonstrated lower FMS scores as compared to healthy controls (Ko et al., 2016). Therefore, the FMS potentially could be a useful functional assessment measure used to identify movement deficits in patients with CLBP (Ko et al., 2016).

A variety of treatments have been used by physical therapists for treating subacute and chronic LBP, including manual therapy, exercise programs (e.g., trunk coordination, strengthening, and endurance exercises), lower quarter nerve mobilization, traction, and patient education (Amatya, Young, & Khan, 2017; Delitto et al., 2012). Given the high prevalence of CLBP and high recurrence of LBP and the associated costs, clinicians have been advised to place a priority on interventions which can prevent recurrences and transitions to CLBP (Delitto et al., 2012). Among conservative treatments, therapeutic exercises are most widely used for management of LBP (Lizier, Perez, & Sakata, 2012). A plethora of evidence has shown that therapeutic exercises are moderately effective for subacute or chronic LBP (Chou & Huffman, 2007). A meta-analysis of exercise therapy for the treatment of NSLBP reported that therapeutic exercise was effective in decreasing pain in patients with CLBP and reported that graded

activity improved work absenteeism in those with subacute LBP (Hayden, Van Tulder, Malmivaara, & Koes, 2005). However, debates continue regarding what specific type of exercise may be most effective. More recently, spinal stabilization exercises (SSEs) have been advocated as the optimal choice in the rehabilitation of LBP because SSEs have a positive effect on supporting and stabilizing the lumbar spine, reducing pain, and enhancing proprioception as a result of LBP (Bliss & Teeple, 2005; Panhale et al., 2016). In addition, SSEs were found to be more effective than general exercises (GEs) in decreasing pain and improving physical function in patients with LBP (Wang et al., 2012), and were more effective than a placebo intervention in lumbar segmental instability in patients with NSLBP (Kumar, 2011).

Statement of the Problem

Literature indicates that abnormal movement patterns or compensatory movement may be associated with CLBP and may contribute to LBP recurrence (Ko et al., 2016; Shum, Crosbie, & Lee, 2007). In addition, lumbar instability has been identified as a primary contributor for abnormal and compensatory movement patterns (Biely et al., 2014; Cook et al., 2014a; Gladwel et al., 2006). In order to be able to objectively assess quality of functional movements (i.e., quantify compensatory movement patterns), the FMS was developed for such purpose. In addition, the patients with LBP were found to have lower FMS scores as compared to healthy controls (Ko et al., 2016). However, the FMS has not yet been used to examine the effectiveness of physical therapy interventions in the

LBP population. Although SSEs have been shown to be effective in treating patients with NSLBP, it is not known if SSEs would improve movement performance. To date, no study has been conducted for assessing the effects of SSEs on the quality of movement performance. Therefore, a randomized clinical trial is warranted to examine whether or not SSEs would have a favorable outcome on movement performance assessed by the FMS.

Purpose of the Study

The primary purpose of this study was to determine the effects of SSEs on movement performance in adults with NSLBP. Specifically, the differences in performance on the FMS were compared between patients with subacute and chronic LBP who received an SSE program and those who received a GE program at two weeks, four weeks, and eight weeks. The secondary purpose of this study was to examine whether the patients with subacute and chronic LBP receiving SSEs would have greater reductions in pain intensity and disability level at two weeks, four weeks, and eight weeks as compared to those who received a GE program.

Research Questions

The following research questions were addressed in this study:

1. Would there be differences in movement performance between participants with subacute and chronic LBP who receive eight weeks of SSEs and those who receive eight weeks of GEs?
2. Would all participants with subacute and chronic LBP have improved

movement performance at two, four, and eight weeks after the initiation of treatment?

3. Would there be differences in pain intensity and disability level between participants with subacute and chronic LBP who receive eight weeks of SSEs and those who receive eight weeks of GEs?
4. Would all participants with subacute and chronic LBP have reduced pain intensity and disability level at two, four, and eight weeks after initiating treatment?

Hypotheses

Research Hypotheses

The hypotheses of the study are as follows:

1. Participants with subacute and chronic LBP who receive eight weeks of SSEs would have a significant greater improvement in movement performance as compared to those who receive eight weeks of GEs.
2. All participants with subacute and chronic LBP would have significantly improved movement performance at two, four, and eight weeks after initiating treatment.
3. Participants with subacute and chronic LBP who receive eight weeks of SSEs would have a significant reduction in pain intensity and disability level as compared to those who receive eight weeks of GEs.
4. All participants with subacute and chronic LBP would have significantly reduced pain intensity and disability level at two, four, and eight weeks

after initiating treatment.

Null Hypotheses

The null hypotheses of the study are as follows:

1. There would be no significant difference in movement performance between participants with subacute and chronic LBP who receive eight weeks of SSEs and those who receive eight weeks of GEs.
2. There would be no significant improvement in movement performance at two, four, and eight weeks after initiating treatment for all participants with subacute and chronic LBP.
3. There would be no significant reduction in pain intensity and disability level between participants with subacute and chronic LBP who receive eight weeks of SSEs and those who receive eight weeks of GEs.
4. There would be no significant reduction in pain intensity and disability level at two, four, and eight weeks after initiating treatment for all participants with subacute and chronic LBP.

Operational Definitions

The definitions used for this study included the following:

1. NSLBP: Pain or discomfort reported anywhere below the costal margin to the lower gluteal fold, with or without referred pain to the lower extremity, but not attributable to a known or specific pathology (Burton et al., 2006). No limitation is placed on which musculoskeletal structure is generating the pain. However, pain should be alterable (reproduced, increased, or

relieved) with sustained postures or with testing of the range of motion (ROM), segmental spinal mobility, palpation, or special testing.

2. Subacute LBP: Pain originating from the lumbosacral region and persisting for six weeks to three months.
3. Chronic LBP: Pain originating from the lumbosacral region and persisting for greater than or equal to three months.
4. Exercise compliance: Determined by the number of exercise sessions completed out of 40 possible exercise sessions in this dissertation study.
5. Pain intensity: Pain level determined using a subjective report of the participant's perceived pain localized to the lumbosacral spine over the past week on the Numeric Pain Rating Scale (NPRS).
6. Disability: The level of disability associated with LBP determined by using the Modified Oswestry Back Pain Disability Questionnaire (OSW).

Assumptions and Limitations

Assumptions

The following assumptions were made for this study:

1. Participants understood and were honest on all self-reported measures, including pain intensity on the NPRS and disability level on the OSW.
2. Participants reported the LBP intensity which best reflected their perception of LBP.
3. Participants understood the investigator's instructions and gave their best effort during the FMS.

4. Participants gave their maximal effort when performing SSEs and GEs during their on-site visits and at home.
5. Participants honestly reported compliance with home exercise.

Limitations

The following were limitations for this study:

1. Participants may not have understood the instructions completely during the FMS test and therefore did not perform the test that was reflected their abilities.
2. The results can be generalized only to the patient population with subacute and chronic LBP and to those with low-to-moderated disability level in order to complete the FMS.
3. The study was unable to control the participant's activity level between and after treatment visits. However, participants were advised not to engage any activity that may increase their LBP.
4. The study was unable to control the participants' depression level and fear-avoidance level. These variables were not used as outcome measures, but were collected from each participant. If there was a significant difference in depression level or fear-avoidance level between the groups, these variables were included in data analysis as covariates.
5. The study was unable to control the participants' use of medication during the study. However, information about medication use was collected. If there was a significant difference in medication use between the groups,

medication use was included in data analysis as a covariate.

Significance of the Study

To date, randomized clinical trials have not yet been conducted to assess the effects of SSEs on quality of movement using a battery of standardized functional tests. The results of this research would provide evidence for the effects of SSEs on the level and quality of functional performance, and as such, would help to identify the role of SSEs in the management of LBP and further the evidence in this area. Additionally, the results of this proposed research study could shed light on the clinical use of the FMS for assessing movement performance in patients with subacute and chronic LBP. Evaluating functional movements of the whole-body is important in order to further understand their impairments. A better understanding of impairments associated with low back injury would assist clinicians in developing personalized intervention programs to address those identified at high risk for re-injury and in individualizing prescriptive exercise programs.

CHAPTER II

REVIEW OF THE LITERATURE

LBP is defined as pain or discomfort reported anywhere below the costal margin to the lower gluteal fold, with or without referred pain to the lower extremity (Burton et al., 2006). LBP is considered one of the most common complaints prompting individuals to seek medical care (Waterman et al., 2012). The total direct and indirect medical spending for LBP is estimated between $100 and $200 billion a year (Freburger et al., 2009). The behavior of fear-avoidance related to LBP and the presence of pain in people with LBP necessitate an attempt to reduce pain by restricting movements of the spine (Lamoth, Meijer, Daffertshofer, Wuisman, Beek, 2006). Lumbar exercises have been shown to improve stability of the lumbar spine, reduce pain, and enhance proprioception related to the dysfunction (Panhale et al., 2016). Specifically, SSEs have resulted in favorable outcomes in treating patients with LBP (Bliss & Teeple, 2005; Ferreira, Ferreira, Maher, Herbert, & Refshauge, 2006; Searle, Spink, Ho, & Chuter, 2015; Wang et al., 2012). However, no randomized clinical trials have assessed the effects of SSEs on quality of movement performance in patients with subacute and chronic LBP.

The primary purpose of this study is to evaluate the effectiveness of SSEs in patients with subacute and chronic LBP on movement performance, pain intensity, and disability level. The following areas relevant to the purpose of this dissertation study are discussed in this chapter: (a) epidemiology of LBP, (b)

stages of LBP, (c) factors associated with LBP, (d) lumbar instability in LBP, (e) common impairments in LBP, (f) movement impairments in LBP, (g) treatment of LBP dysfunction, and (h) outcome measurements for LBP.

Epidemiology of LBP

Musculoskeletal disorders have been identified as the most widespread problems in people aged up to 65 years in the United States (Andersson, 1999). Impairments due to musculoskeletal disorders cause more functional limitations in the adult population than any other groups of disorders in most states (Woolf & Pfleger, 2003). Specifically, impairments in the spine are the most frequently reported (51.7%) (Andersson, 1999). Musculoskeletal disorders are a major source of long-term disability in all countries and economies as reported in the Ontario Health Survey, which stated that musculoskeletal disorders caused 40% of all chronic conditions, 54% of all long-term disability, and 24% of all limited activity days (Woolf & Pfleger, 2003).

Among musculoskeletal disorders, LBP has been found to have a significant impact on both patients and society because of its frequent occurrence (Woolf & Pfleger, 2003). About 58-84% of people in the United States have experienced LBP at least once in their lifetime (Goubert, Crombez, & De Bourdeaudhuij, 2004). A 2017 publication by the Centers for Disease Control and Prevention's National Center for Health Statistics reported that 29.1% of adults older than 18 years had experienced LBP in the previous three months (National Center for Health Statistics, United States, 2017). In addition, approximately one-

fourth of adults in the United States reported having LBP lasting at least 24 hours within the previous three months, and 15% of adults reported frequent back pain or pain lasting longer than two weeks annually (Deyo, Mirza, & Martin, 2006). Furthermore, LBP was reportedly more common in females (30.4%) than males (27.6%), and also in ages 45 - 64 (35.4%). The prevalence of LBP is highest in American Indian and Alaska Natives racial groups (34.1%), whereas Asian Americans have the lowest prevalence, 19.1% (National Center for Health Statistics, United Sates, 2017). LBP is considered one of the most common complaints prompting people to seek medical care (Waterman et al., 2012). In the United States, back pain is the second most common reason for visits to physicians, the fifth-ranking reason for hospital admission, and the third most frequent cause of surgical procedures (Andersson, 1999). The incidence of LBP first episodes varied from 14% to 93% annually (Cassidy, Côté, Carroll, & Kristman, 2005). LBP incidents have been shown to be associated with workload and low job satisfaction (Frank et al., 1996; Van Poppel, Koes, Deville, Smid, & Bouter, 1998). In addition, the presence of depression has increased the incidence of LBP. Further, poor physical activity could be a cause of occurrence and developing LBP (Thiese, Hegmann, Garg, Porucznik, & Behrens, 2011).

LBP is considered to be a very costly condition (Fitzmaurice et al., 2015; Marini et al., 2017). The high prevalence of LBP comes with a large economic burden, which appears to be growing. In 2009, the total direct and indirect medical spending for LBP was estimated to be between $100 and $200 billion a

year, with one third correlated with direct medical expenses and the remaining two thirds due to indirect costs from absenteeism and productivity loss (Freburger et al., 2009). Martin et al. (2008) evaluated expenditures of health care in the United States from 1997 to 2005 for treating back and neck problems. They analyzed data collected from the Medical Expenditure Panel Survey and found these expenditures to be approximately $86 billion. In addition, the results of this survey showed that the most common diagnoses were unspecified disorders of the back (52.9%), followed by intervertebral disc disorders (15.9%) and sprains and strains of unspecified parts of the back (9.3%) in 2005. In 1997, the average medical costs for people with spinal problems were $4,695 (95% confidence interval [CI], $4,181-$5,209) as compared to $2,731 (95% CI, $2,557-$2,904) among those without spine problems. In 2005, the average medical expenditure for individuals with spine problems was $6,096 (95% CI, $5,670-$6,522) as compared to $3,516 (95% CI, $3,266-$3,765) among those without spine problems. Consequently, the total inflation-adjusted expenditures of healthcare for United States adults with spine problems increased 65% from 1997 to 2005 (Martin et al., 2008). Furthermore, 75% of the total treatment costs associated with managing LBP are due to chronic LBP (CLBP; National Center for Health Statistics, United Sates, 2017). Therefore, medical professionals and policy makers advocate determining and using effective interventions during the early stages (acute and/or subacute) of LBP to help prevent or improve the

disability associated with chronic low back disorders (National Center for Health Statistics, United Sates, 2017).

The high incidence of LBP has a profound impact on society and has a variety of social and economic consequences on people who suffer from this condition (Maher, Underwood, & Buchbinder, 2017). LBP is the most frequent cause of activity restriction in individuals younger than 45 years in the United States (Andersson, 1999). More than one in three adults reported that LBP prevents them from carrying out everyday activities fully and affects their quality of life (American Physical Therapy Association, 2012). Consequently, LBP has a negative impact on personal life and function at work (McGorry, Bspt, Snook, & Hsiang, 2000).

Stages of LBP

Based on the duration of pain, LBP often is categorized into three stages: acute, subacute, and chronic (Merskey, 1994). To date, researchers and clinicians agree to use this subgrouping method (acute, subacute, and chronic) to study LBP populations and to plan for clinical care (Delitto et al., 2012). LBP is considered acute when symptoms last less than six weeks, subacute when symptoms last between six weeks to three months, and chronic when symptoms continue for longer than three months (Koes et al., 2006). About 80 to 90% of individuals who experience LBP recover within three months, and many of them do not seek medical care. However, 5 to 10% of the patients who do not recover

within this time frame progress into the chronic stage (Chaffin & Andersson, 1999).

For individuals in the acute phase, the pain is characterized as the pain that occurs with initial to mid-ranges of active or passive motions (Delitto et al., 2012). In addition, people with the pain have the pain-related fear, an exaggerated negative appraisal of pain and its meaning. Pain-related fear is an essential factor affecting daily activities and appears to be prominent factor impeding functional recovery from an acute LBP episode (Peters, Vlaeyen, & Weber, 2005; Swinkels-Meewisse, Roelofs, Oostendorp, Verbeek, & Vlaeyen, 2006). In addition, individuals in the acute phase demonstrate restricted spinal ROM and segmental mobility (Delitto et al., 2012).

People in the subacute stage of LBP often have mobility deficits and movement coordination impairments as well as having pain which occurs at mid-to-end ranges of active or passive motions (Delitto et al., 2012). A key physiologic predictor in patients with subacute LBP has been associated with impairments in the LM muscle, a muscle which has been shown to play a significant role in lumbar stabilization and proprioception (Hebert, Koppenhaver, Magel, & Fritz, 2010; Lonnemann, Paris, & Gorniak, 2008). In addition, it has been noted that the LM atrophies rapidly in patients with subacute LBP (Hides et al., 1994).

The pain associated with patients with CLBP occurs at the end range of movements or positions or after a prolonged stay at the end of motions, as well

as being associated with movement coordination impairments (Delitto et al., 2012). A recent study showed that CLBP could affect coordination of lower limbs, pelvis and trunk during walking, particularly the motions in the sagittal plane (Ebrahimi, Kamali, Razeghi, & Haghpanah, 2017). These coordination impairments in the individuals with CLBP were hypothesized as the results of compensatory strategies of the motor control system.

Factors Associated with LBP

LBP has been shown to be associated with the weakness of abdominal muscles, old age, excess body weight, and lack of physical fitness (Delitto et al., 2012). Weakness of abdominal muscles is common in people with LBP (França, Burke, Caffaro, Ramos, & Marques, 2012; Hides, Richardson, & Jull, 1996). Weakness of abdominal muscle can create an imbalance between the abdomen and back and results in reduced lumbar stability, thus leading to LBP (Jeong, Sim, Kim, Hwang-Bo, & Nam, 2015). Evidence has shown changes in muscle activation are either delayed or reduced, in deep muscles of lumbar spine, such as the TrA and LM muscles (Ferreira et al., 2009; França et al., 2012; van Dieën, Selen, & Cholewicki, 2003). In addition, a recent study showed difference in muscle activation between anterior and posterior muscles of low back for participants with LBP, with the anterior muscles having lower activation than the posterior muscles (Hanada, Johnson, & Hubley-Kozey, 2011). However, the posterior site had greater activation in the posterior muscles of low back in the control group.

A recent systematic review showed that the chances of having CLBP increase as an individual gets older than 60 years old and that CLBP is more common in women (Meucci et al., 2015). The reason for the increase LBP in elderly people could be that aging leads to muscular dysfunction by a loss of muscular strength and mass, which places more load on the spine (Irandoust & Taheri, 2015). In addition, the postmenopausal osteoporosis could be possible reasons that LBP is higher in elderly women (Chou, Shih, Lin, Chen, & Liao, 2013; Hoy et al., 2012). Lastly, older people with CLBP were found to have worse physical function when compared to those without CLBP (Sions, Coyle, Velasco, Elliott, & Hicks, 2017). Obesity is considered to be another common risk factor for LBP. Excessive body weight can cause disc degeneration through wear and tear on discs and joints and can also increase the physical loads on muscles and ligaments (Ewald, Hurwitz, & Kizhakkeveettil, 2016). Further, low levels of physical fitness are associated with LBP and higher disability level. In addition, a low level of physical activity has been identified as a predictor for development of high levels of disability in patients with CLBP (Lin et al., 2011).

In addition to the physiological characteristics mentioned above, many psychological factors can be attributed to LBP. Psychological factors such as anxiety, emotional instability, and depression are associated with high incidence of LBP (Delitto et al., 2012). In addition, a study conducted by Bener et al., (2013) demonstrated a significant association between psychological distress such as anxiety, depression, and somatization and the prevalence of LBP (Bener

et al., 2013). Moreover, occupational factors, such as heavy work, pulling, pushing, lifting, twisting, and bending, as well as workplace psychological variables, such as job dissatisfaction, are playing an essential role in the incidence of CLBP as well as being considered important factors for the development of LBP (Esquirol et al., 2016; Shaw, Main, & Johnston, 2011).

Lumbar Instability in LBP

Lumbar spinal instability has been considered to be the underlying pathology for development of LBP (Fandiño & García-Abeledo, 1998). Spinal instability is defined as a disruption of the spinal stabilization system (Biely, Smith, & Silfies, 2006). Panjabi (1992a) presented a model of the spinal stabilization system consisting of three subsystems: passive subsystem, active subsystem, and neural and feedback subsystem. He suggested that these three subsystems are conceptually separated and function independently, providing stability to the spine to meet static and dynamic loads. The passive subsystem consists of vertebrae, intervertebral discs, joint capsules, facet joints, and spinal ligaments, which contribute to stability at the end of the ROM by a reactive force that resists the movement of the spine. The transducers (i.e., mechanoreceptors) in the spinal ligaments also act in a neutral spinal position to monitor vertebral positions and motions without functioning as stabilizers (Panjabi, 1992). The active subsystem consists of the muscles and tendons that surround the spine. This system is responsible for producing force to move body segments and for providing the required stability to the spine in the neutral position and during the

movement. Finally, the neural control subsystem consists of both the force and motion transducers that are located in the active subsystem (i.e., tendons and muscles) and the passive subsystem (i.e., ligaments). The neural control subsystem receives the information from transducers in the active and passive subsystems, decides on a specific requirement for spinal stability by adjusting and measuring each individuals muscle tension until the required stability is achieved, and helps the active subsystem to achieve stability (Panjabi, 1992).

Several authors have confirmed that no single muscle is responsible for spinal stability. Spinal stability depends on the relative activation of all spine muscles (Cholewicki & Vanvliet Iv, 2002; Kavcic, Grenier, & McGill, 2004). The relative contribution of each muscle varies based on the task being performed in order to sustain a posture or create a movement (McGill, Grenier, Kavcic, & Cholewicki, 2003). The core of the lumbopelvic-hip complex is defined as a box with muscular boundaries: diaphragm muscle as a roof, abdominal muscles in the front, paraspinal and gluteal muscles as the posterior boundary, and pelvic floor and hip girdle as the floor (Huxel Bliven & Anderson, 2013).

Bergmark (1989) provided a helpful classification system of muscle function in which he categorized the spinal muscle system into two main muscle systems (local and global) for producing and controlling movements of the trunk. The local system is used to control the posture (curvature) of the lumbar spine and to give sagittal and lateral stiffness to maintain the mechanical stability of the lumbar spine. The main role of the global system acts to balance the outer load

(Bergmark, 1989). The core muscles, particularly LM and TrA, play an important role in providing mechanical stability and controlling the movement of the lumbar spine and trunk. When the core muscles function normally, they can maintain spinal stability and reduce the stress affecting the lumbar vertebrae and intervertebral discs (Chang, Lin, & Lai, 2015). As these muscles have been noted to contribute to the local or global stabilization of the spine, any disturbance of normal muscle function can threaten the integrity of the spine, placing it at risk for excessive stress or injury.

Common Impairments in LBP

Impairments are defined as dysfunctions or significant structural abnormalities in a specific body part or system (Verbrugge & Jette, 1994). Findings of reduced joint mobility, motor function, muscle performance, ROM, and sensation are considered to be problems which are limited to the impairment level (American Physical Therapy Association, 2001). LBP has been associated with decreased muscle strength, flexibility and proprioception (Karimi, Ebrahimi, Kahrizi, & Torkaman, 2008). These impairments, alone or in combination, can contribute to limited function and ultimately may have consequences for quality of life as will be explained more in details for each one in this section (Reiman & Manske, 2011).

Both back muscle strength and flexibility deficits have been found to be associated with the development of LBP (Lee et al., 2012; Rostami, Ansari, Noormohammadpour, Mansournia, & Kordi, 2015). Individuals with LBP often

have reduced trunk muscles strength and endurance, which may affect the functional capacity of the spine and increase the likelihood of injury (Sung, 2013). In addition, patients with LBP often have decreased hamstring flexibility (Mistry, Vyas, & Sheth, 2014). It has been hypothesized that the hamstrings tightness could create a posterior pelvic tilt and reduce lumbar lordosis, thus resulting in LBP (Mistry et al., 2014; Schafer, 1987).

Patients with LBP often have proprioception impairments (Lee, Cholewicki, Reeves, Zazulak, & Mysliwiec, 2010). It has been noticed that the increase in repositioning error of LBP patients during flexion indicates that some aspects of proprioception is lost in LBP patients (Newcomer, Laskowski, Yu, Johnson, & An, 2000). Proprioceptive deficit has been suspected to be one of the possible causes for balance impairments in LBP (Karimi, Ebrahimi, Kharizi, & Torkaman, 2011). Researchers hypothesized that the decrease in proprioception may affect the quality of sensory information and interrupt the relation between postural responses and sensory information (Karimi et al., 2008). More recently, evidence revealed that dynamic balance is reduced in individuals with CLBP as compared to healthy counterparts (Ganesh, Chhabra, & Mrityunjay, 2015; Hooper et al., 2016). Specifically, patients with LBP tend to develop postural control deficits, relying more on ankle movement and less on hip movement while maintaining upright standing posture. Furthermore, once individuals with LBP lose their balance, they have more difficulty regaining it, and these deficits may continue even after LBP has resolved (Hooper et al., 2016). Patients with LBP

are usually fearful of performing dynamic tasks due to fear of additional pain and injury in response to the movement (Rainville et al., 2011).

Movement Impairments in LBP

It has been found that people with LBP move differently (Gizzi, Röhrle, Petzke, & Falla, 2018). Abnormal movement patterns, or deviations from the normal or expected movement pattern, are among the common impairments observed in patients with LBP (Biely et al., 2014; Corkery et al., 2014). Patients with LBP frequently present with movement impairments of their lumbar spine and pelvis (Vaisy et al., 2015). Abnormal patterns of lumbopelvic rhythm have been reported in patients with LBP. For example, hip motion is greater than lumbar spine motion during the first part of forward bending, but is much less during the last part of forward bending (Biely et al., 2014; Esola, McClure, Fitzgerald, & Siegler, 1996; Scholtes, Gombatto, & Van Dillen, 2009; Shum et al., 2007). In addition, aberrant movement patterns, such as painful arc, lateral shifting, or Gower's sign (thigh climbing to return from a flexed to an upright position) have been associated with lumbar spinal instability, which is considered to be the underlying pathology for development of LBP as discussed earlier (Biely et al., 2014; Delitto et al., 2012).

Incoordination and decreased contraction of the spinal stabilizers, specifically TrA and LM muscles, can significantly contribute to spinal instability (Gladwell et al., 2006). This inadequate muscle performance often leads to movement impairments and functional activity limitations in individuals with LBP

(Cho et al., 2014; Larivière, Gagnon, & Loisel, 2000; van Dieën et al., 2003). In addition, Gardner-Morse et al.'s (1995) study determined that spinal instabilities from previous injuries, fatigue or stiffness can result in degenerative changes of muscle activation pattern, such as delayed muscle recruitment, (Gardner-Morse, Stokes, & Laible, 1995). Therefore, proper function of abdominal and trunk muscles is necessary for stability of the lumbar spine in order to perform functional activities (Chang et al., 2015; Gardner-Morse & Stokes, 1998; Shirey et al., 2012; Haladay, Denegar, Miller, & Challis, 2015; Hodges, Richardson, & Jull, 1996).

Impaired neuromuscular activation of the lumbar spinal stabilizers associated with LBP has been studied extensively by observing changes in muscle morphology using ultrasound (US) imaging and magnetic resonance imaging (MRI). For example, decreased LM muscle size (i.e., cross-section area), measured using US imaging and MRI, was found in patients with LBP as compared to healthy individuals (Beneck & Kulig, 2012; Hides et al.,1994; Hides et al., 2008). In addition, a drawing-in maneuver has been shown to be able to target TrA contractions by observing an increase in muscle thickness of the TrA (Hides et al., 2006). Impaired neuromuscular activity associated with LBP also was identified by observing timing of muscle activation using electromyography (EMG). For example, a delayed onset of TrA EMG activity was observed in patients with LBP during limbs movements (Ferreira et al., 2004; Hodges & Richardson, 1996). Reduced and/or delayed activation of TrA is found

consistently in patients with LBP, and similar alterations have also been shown following experimental induced pain (Hodges, Moseley, Gabrielsson, & Gandevia, 2003). Delayed EMG activation of deep back muscles (e.g., LM) was observed on the previously painful side when compared to the non-painful side. In addition, short muscle fibers activated before long muscle fibers in the healthy participants and on the non-painful side of participants in the LBP group, but it was not observed on the previously painful side of participants in the LBP group. Therefore, the abnormal pattern of muscle activity, in the absence of pain, may leave the spine exposed to re-injury and increase the chance of recurrent episodes of LBP (MacDonald, Moseley, & Hodges, 2009).

The impaired neuromuscular activations in patients with CLBP are considered to contribute to movement coordination impairment (Cho et al., 2014, Hodges & Richardson, 1996; Panjabi, 2003; Silfies et al., 2009). Hodges et al. (2003) speculated that people with LBP may prioritize patterns of muscle activation in an attempt to avoid provocation of the pain (Hodges et al., 2003). Conversely, it is proposed that motor control changes in patients with LBP are functional in that they enhance spinal stability (van Dieën et al.,2003).

Impairments in activation and coordination of the TrA and LM muscles also have been identified in patients with CLBP (Cho et al., 2014). Radebold et al. (2001) found that the patients with CLBP had poorer postural control of the lumbar spine as compared to healthy control volunteers in the absence of visual feedback (Radebold, Cholewicki, Polzhofer, & Greene, 2001). These authors

speculated that the significant postural sway in patients with LBP could be due to longer trunk muscle response. The authors further speculated that individuals who are unable to compensate using appropriate muscle activation and contraction patterns or who have improper coping strategies which can result in changed tissue loading likely will demonstrate signs and symptoms of movement coordination impairment (O'Sullivan, 2005; Panjabi, 2003; Sahrmann, 2001).

Patients with CLBP often have inadequate movement performance to complete functional tasks such as stepping over an obstacle, squatting, and active straight-leg-raise (ASLR) (Ko et al., 2016). The movement limitation can be explained by the restricted lumbar spine and hip joint mobility as well as having difficulty properly recruiting the trunk stability muscles before moving the limbs, as is required for movements such as the ASLR (Ko et al., 2016; Lee et al., 2014). Avoiding lumbar and hip flexion and reducing velocities and accelerations of movement can minimize pain and protect injured tissues but may result compensatory changes in movement (Shum et al., 2007). In addition, the limitation of lumbar and hip flexion in patients with LBP could be a result of decreased hamstrings flexibility (Mistry et al., 2014). A recent study found that the more the hamstrings tightness, the higher the severity of LBP that patient experienced (Radwan et al., 2015).

In summary, aberrant movements in patients with LBP may be a sign of muscle dysfunction or impairments of motor control, which can contribute to the recurrence of symptoms (Hides et al., 1996; MacDonald et al., 2009) The TrA

and LM muscles are considered to play an essential role in lumbopelvic stabilization. Therefore, strengthening and properly timing activation of these muscles should be one of the main goals of the LBP treatment (Rostami et al., 2015).

Treatment of LBP Dysfunction

A variety of interventions, both pharmacological treatments and non-pharmacological approaches, have been used to relieve symptoms and increase function for patients with LBP (Chou, 2010). Pharmacological treatments, such as non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, muscle relaxants, and opioids can be used for reducing pain and muscle spasms (Chou et al., 2017; Kuijpers et al., 2011; Weiner & Nordin, 2010). A recent systematic review showed that NSAIDs and opioids could be useful to relieve pain in the short term for patients with CLBP who experienced with an aggravation of their symptoms after discontinuing their medication (Kuijpers et al., 2011). However, clinical practice for the long-term management of CLBP remains debated considering the possible adverse effects with long-term use of prescribed medication (Deshpande, Furlan, Mailis-Gagnon, Atlas, & Turk, 2007; Kuijpers et al., 2011). Further, opioids seem to have a minimal effect in improving function for patients with CLBP (Deshpande et al., 2007). Other factors, such as costs of medications, could be limited using pharmacological treatments for subacute and CLBP (Chou & Huffman, 2007).

Physical therapy (PT) is another conservative treatment commonly used to help improve or restore mobility and reduce pain for patients with LBP. Studies have suggested that early PT interventions can help to prevent acute LBP from progressing to chronic symptoms (Gatchel et al., 2003; Heneweer et al., 2007; Linton, Hellsing, & Andersson, 1993). The American Physical Therapy Association (APTA) recommends the following treatments for LBP: manual therapy, exercise programs (e.g., trunk coordination, strengthen, and endurance exercises), lower quarter nerve mobilization procedures, traction, and patient education and counseling (Delitto et al., 2012). Clinical practice guidelines (CPGs) for LBP proposed by the APTA recommended using lower-quarter nerve mobilization for reducing pain and disability level in patients with subacute and CLBP and radiating pain (Delitto et al., 2012). In addition, patient education was recommended to be an effective intervention in reducing pain level using counseling methods, either directly or indirectly, for minimizing the perceived threat or fear associated with LBP (Delitto et al., 2012). Furthermore, Senna and Machaly (2011) demonstrated long-term benefits of spinal manipulation therapy (SMT) for patients with CLBP with a recommendation of 12 treatments session of SMT in the first month followed by SMT once every two weeks for the following nine months (Senna & Machaly, 2011). In addition, moderate-quality evidence supports the use of manipulation rather than mobilization for pain reduction and function improvement for patients with CLBP (Coulter et al., 2018). However, manipulation was not found to be superior to other interventions in the long term

(Rubinstein et al., 2013). SMT found to have the same effect as SSEs in produce improvement in function levels for patients with CLBP and better than GEs in the short term eight weeks, but was not different from GEs in the intermediate or long terms six and 12 months (Ferreira et al., 2007).

Exercise therapy is the most widely used conservative treatment for LBP (Lizier et al., 2012). Exercise therapy is defined as “a sequence of specific movements with the aim of training or developing the body by a routine practice or physical training to promote good physical health” (Hayden et al., 2005). Exercise can be general or can target specific muscles, and can aim to improve ROM, flexibility, strength, endurance, balance, and neuromuscular control. A meta-analysis of exercise therapy reported that therapeutic exercise was effective in decreasing pain for patients with CLBP (Hayden et al., 2005). A review by the American Pain Society and the American College of Physicians has shown that therapeutic exercises are effective for chronic or subacute LBP with moderate evidence (Chou & Huffman, 2007). In addition, based on the 2012 CPGs recommended by the APTA, clinicians should consider using strengthening, trunk coordination, and endurance exercises to decrease pain and disability in patients with chronic LBP (Delitto et al., 2012). Furthermore, high-quality evidence shows that exercises targeting strength, endurance, and flexibility of abdominal and back extensor muscles are more effective for relieving pain and improving function in individuals with CLBP than other interventions (Bigos et al., 2009). To support this evidence, a recent systematic review was

conducted and identified that coordination/stabilization and strength/resistance exercises are more effective than other interventions in the treatment of CLBP (Searle et al., 2015).

According to the European guidelines for management of chronic NSLBP (CNSLBP), supervised exercise treatments are among the most commonly recommended treatments for individuals with CNSLBP (Airaksinen et al., 2006; Macedo et al., 2012). Bronfort et al., (2011) compared the effects of supervised exercise, SMT, and home exercise for CLBP. The target population was adults ranging from 18 to 65 and had LBP for six weeks or longer, with or without radiating pain to the lower extremities. Participants (n = 301) were randomly assigned in one of the three treatments. All participants were treated for 12 weeks. The participants in the supervised exercise group received exercises focusing on trunk muscle endurance, trunk stability and core strengthening. The SMT group received SMT, which was applied to specific areas of the low back and sacroiliac regions. The home exercise group was instructed with home exercises and advice for self-care, such as the use of heat and ice, ergonomics for home and work, as well as proper lifting techniques. The study showed that the supervised exercise intervention had significantly greater effects on treatment satisfaction and trunk muscle endurance as compared to the SMT and home exercise interventions (Bronfort et al., 2011).

Debates continue regarding which specific type of exercise may be most effective. Recently, there has been an emphasis on exercises which target

maintaining spinal stability, and SSEs have typically been prescribed for patients with spinal instability (Biely et al., 2006; Richardson & Jull, 1995). Several research groups have shown favorable outcomes of use of SSEs for LBP including improving neuromuscular control and endurance, retraining and strengthening deep spinal muscles, reducing pain, and enhancing proprioception related to the dysfunction (Bliss & Teeple, 2005; Grenier & McGill, 2007; Panhale et al., 2016). The SSEs are designed to train the TrA and LM muscles, as atrophy and decreased function of these muscles were observed in patients with CLBP (Bronfort, Haas, Evans, Kawchuk, & Dagenais, 2008; O'Sullivan, 2000). Therefore, exercise specific to the TrA and LM has been recommended to achieve spinal stability (Grenier & McGill, 2007; MacDonald, Moseley, & Hodges, 2006). Additionally, SSEs have been shown to reduce recurrent episodes of LBP in the adult population (Ferreira et al., 2006; Hides et al., 2001). In particular, a long-term follow-up randomized control trial by Hides, Jull, and Richardson (2001) showed that adults who received spinal stabilization exercises in addition to medical management were more than two times less likely to have recurrent LBP when compared to a control group who received medical management alone (Hides et al., 2001).

The effects of SSEs on individuals with CLBP has been compared to other interventions. A randomized clinical trial conducted by Rasmussen-Barr et al. (2003) compared the effects of stabilization training with those of the manual treatment of patients with sub-acute or CLBP. Forty-seven patients aged from 18

to 60 years experiencing LBP for at least six weeks, with or without radiating pain, were randomly assigned either to a stabilizing training group or to a manual treatment group. The patients participated in a six-week treatment program on a weekly basis. In both groups, pain, health and functional disability levels were assessed at the baseline, after treatment, and at three-month and 12-month follow-ups. The findings of the study suggest that stabilizing training appeared to be more effective than manual treatment after the treatment period, at the three-month follow-up, and in the long term. In addition, during the long-term follow-up visit, the participants who received stabilizing training showed a decreased need for recurring treatment (Rasmussen-Barr, Nilsson-Wikmar, & Arvidsson, 2003).

Akhtar et al. (2017) studied the effectiveness of SSE and routine exercise therapy in the treatment of pain in CNSLBP. The 120 participants with CNSLBP in their study were adults from 20 to 60 years of age. Participants were randomly assigned into two treatment groups, one treated with SSEs and the other group treated with routine exercises that were not specifically targeting the core muscles such as hamstring stretching. The researcher added transcutaneous electrical nerve stimulation (TENS) and ultrasound as therapeutic modalities to both treatment groups. The outcome measure of pain level was collected using the VAS at two weeks, four weeks, and six weeks after treatment. The results of this study demonstrated that the effect of SSEs was greater than routine exercises regarding reduction in pain in patients with CNSLBP (Akhtar, Karimi, & Gilani, 2017).

In addition, a randomized clinical trial conducted by Inani and Selkar (2013) was undertaken to determine the effect of SSEs as compared with conventional exercises, stretching exercises, isometric exercises of the spine, and graded active flexion and extension of the spine, on pain and functional status in patients with NSLBP. Thirty patients with NSLBP aged from 20 to 50 years were assigned randomly into one of two treatment groups, 15 in each group. The outcome measures used in this study were pain severity using a VAS and disability level using the OWS, and were collected before and after the three-month treatment. Similar to the Akhar et al. (2017) study, the study's results showed that SSEs were more effective in decreasing pain and disability in patients with NSLBP as compared to conventional exercises (Inani & Selkar, 2013).

Furthermore, a meta-analysis published by Wang et al. (2012) investigated the effects of SSE versus GE for patients with CLBP. Randomized controlled trials published from 1970 to October 2011 and a total of five studies involving 414 participants were included in their analysis. They concluded that SSEs are more effective in decreasing pain and may improve physical function in patients with chronic LBP than GEs in the short term (three months). However, no significant differences in pain intensity were found between patients who participated in SSEs versus those who received GEs at six or 12 months (Wang et al., 2012).

In summary, as evident in the above-mentioned studies, SSEs appear to be more effective for decreasing pain, disability, medication use, and recurrence rates than other interventions over time in treating CLBP (Freeman, Woodham, & Woodham, 2010; Inani & Selkar, 2013). Additionally, literature provides strong supportive evidence that exercises with an emphasis on spinal stabilization or isometric activation of core muscles were more effective than manual therapy, GE, and minimal intervention for pain and disability reduction for CLBP (Byström et al., 2013).

Outcome Measures for Movement Performance

With regard to the optimal outcome measures in the diagnosis and treatment of LBP, the optimal assessment of outcomes for LBP treatment remains debated. Just as the proposed etiologies for LBP are varied and wide-ranging, the methods described for LBP outcomes measurement are equally diverse, and many outcome measures have been utilized and have been reported in the literature. These outcome measures lack equivalence and measure different aspects of patient satisfaction and LBP improvement. For example, some outcome measures focus on pain, whereas others focus on function, and physical performance (Chapman et al., 2011). Therefore, the choice of appropriate outcome measures should be determined by the study objectives and design, as well as the properties of the particular measures that are related to LBP. This section describes instruments used as outcome measures applicable to patients with LBP based on a literature search.

Clinical Measures of Movement Performance

The quality of movement has been measured in different ways, including the use of self-reported measures, impairment measures, and movement performance measures. Self-reported questionnaires are commonly administered because they are based on the patients' own evaluation of their pain and function (Reiman & Manske, 2011). However, a concern with self-reported measures is that these methods do not always distinguish whether or why a specific task is performed properly, or if the patient can perform a specific task at all (Simmonds, 2006). The self-reported questionnaires often lack the description of the movement and how the patient should perform the specific task. Instead, they only address whether or not the patient is able to perform the task. Therefore, to address the inadequacy of self-reported questionnaires, several functional performance measures have been developed, not only for assessing the ability to perform specific functional tasks, but also for assessing the ease and efficiency of performing these tasks. The BPS is a physical performance measure of trunk mobility-related activities, consisting of five tests (sock test, pick-up test, roll-up test, fingertip-to-floor test, and lift test) (Panhale et al., 2016). The BPS has been found to be useful for assessing important aspects of physical performance in patients with long-lasting back problems (Strand et al., 2002). In addition to the BPS, the PPT and the CS-PFP were developed for assessing functional movements (Cress et al., 1996; Reuben & Siu, 1990). The PPT includes functional tasks such as writing a sentence, simulated eating, lifting a book and

putting it on a shelf, donning and removing a jacket, picking up a penny from the floor, turning 360 degrees, walking 50 feet, and climbing stairs. The individual is given a score from 0 to 4 based on the time to perform the tasks (Reuben & Siu, 1990). The CS-PFP consists of 15 tasks, which include physical domains of upper body strength, upper body flexibility, lower body strength, balance and coordination, and endurance. The physical functional performance is assessed by time, weight, or distance based on the type of task. The score is standardized and is scaled from 0 to 12 (Cress et al., 1996). These two physical performance tests (PPT and CS-PFP) consist of different tasks, but they are similar in grading criteria. Each task is scored by the duration of time for completion and is scored as a zero when the patient is unable to perform the task.

Although the above-mentioned measures were better than any single function test alone for assessing function performances that are important for daily activities, neither measure quantifies how well the individual tests are performed. In addition, these measures lack comprehensive movement patterns, which challenge whole-body parts and help therapists to observe an individual's weaknesses and/or imbalances. Furthermore, the subtests of these measures cannot be assessed by using one specific tool which can be easily carried and used anywhere. Therefore, a different outcome measure is needed to meet the purpose of this dissertation study. In addition, such a tool must be appropriate for the LBP population of this dissertation study, including both young and older adults.

Functional Movement Screen

In the past decade, the FMS has been used as an objective and standardized procedure by clinicians to measure movement performance (Chimera, Smith, & Warren, 2015; Cook, 2010; Goss, Christopher, Faulk, & Moore, 2009). The FMS was developed by Gray Cook and Lee Burton in 1995 to assess movement performance by identifying limitations and restrictions of human movement patterns, including assessing trunk and core strength and stability, neuromuscular coordination, asymmetry in movement, flexibility, acceleration, deceleration, and dynamic flexibility (Cook, 2010; Koehle, Saffer, Sinnen, & MacInnis, 2016). The FMS allows for the grading and ranking of performance of specific movement patterns with standardized criteria. The FMS originally was intended to be used to predict which individuals might become injured, but has been advocated for use in evaluating and treating injuries (Cook et al., 2014a). To complete the FMS tests appropriately, integration of core stabilization, scapular stability, and coordination between upper and lower extremities must occur (Koehle et al., 2016).

The FMS consists of seven different test components, including the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, rotary stability and trunk stability push-up (Cook et al., 2014a). The FMS movements can be divided into two categories. The deep squat, hurdle step, and the inline lunge are functional tests, which are complex, dynamic, and require more stability and neuromuscular control. The shoulder mobility, straight leg raise,

trunk stability push up, and rotary stability are considered to be fundamental tests. Therefore, correcting errors or imbalances in these four movements will consequently lead to better overall movement quality and higher scores on the big three or functional tests (Cook, 2010).

Each FMS test component is scored on a scale of 0 to 3 and is based on the quality of each movement, with the total composite score ranging from 0 to 21 points. A score of 3 is given if the movement task is performed perfectly without compensations as defined by the FMS scoring criteria. A score of 2 is given if completion of the task requires compensatory movement. A score of 1 is given if the participant is unable to perform the movement as required, and if a participant feels pain during any movement task, a score of 0 is given (Cook et al., 2014a). FMS scores less than or equal to 14 have been found to be associated with a higher risk of musculoskeletal injury among firefighters, football players, and female collegiate athletes (Butler et al., 2013; Chorba et al., 2010; Kiesel et al., 2011).

In addition, there are three clearing screen tests: the impingement-clearing test, the prone press-up clearing test, and the posterior rocking clearing test. The clearing screen tests are similar to the pain provocation tests, and their purpose is to assess whether the participants have pain associated with internal rotation and flexion of the shoulder, spinal flexion, and spinal extension (Cook, 2010). These three clearing tests are performed after their associated FMS test components: the impingement-clearing test is performed after the shoulder

mobility test, the posterior rocking clearing test is performed after the rotatory stability test, and the prone press-up clearing test is performed after the trunk stability push-up test. The clearing tests are scored as positive or negative. If the clearing test is positive, the overall score for the associated test will be zero (Cook et al., 2014a).

Each movement pattern that is assessed in the FMS requires a specific amount of mobility and stability to be performed correctly. Mobility is characterized by unrestricted freedom of movement without a support aid. Static stability involves little to no movement and maintaining appropriate alignment of the body with the presence of segmental movement or mass displacement, whereas dynamic stability is the ability to maintain an adequate alignment while demonstrating unrestricted movement in a supportive situation. Both mobility and stability are necessary to complete the movements and are observed during the performance of the FMS (Cook, 2010).

The Reliability of the FMS

Several recent studies have investigated the reliability of the FMS in different healthy populations (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017; Cuchna, Hoch, & Hoch, 2016; Moran, Schneiders, Major, & Sullivan, 2016). These studies have used different methods of assessing the FMS, such as real-time and videotaped scoring by raters with different levels of experience with the FMS, and also by raters who are FMS-certified versus those who have not been certified (Bonazza et al., 2017; Cuchna et al., 2016; Moran et al., 2016). The

interrater reliability of the FMS composite scores in these studies ranged from good (ICC = 0.76) to excellent (ICC = 0.98) (Bonazza et al., 2017). Teyhen et al. (2012) reported the standard error of measurement (SEM) for interrater reliability of the FMS composite score to be 0.92 points and the minimum detectable change at 95% confidence level (MDC_{95}) to be 2.54 points on the 21-point scale (Teyhen et al., 2012). However, a systematic review study revealed that the FMS reliability studies had been done only on physically active populations such as physically active adults, active-duty service members, and athletes (Cuchna et al., 2016). Therefore, the SEM and MDC values could have been under-estimated for the general population or patient populations.

A pilot study conducted prior to this dissertation study showed an excellent inter-rater reliability (ICC = 0.98) of the FMS composite scores in both groups (n = 44), a asymptomatic group (ICC = 0.96; n = 22) and group with existing LBP (ICC = 0.99; n = 22) using a modified scoring system. As a group of the participants in this pilot study had LBP, the FMS scores were modified so that a zero score was given only when the participant reported an increase in the LBP, not for simply the presence of LBP. In addition, two spinal clearing tests (prone press-up clearing test and posterior rocking clearing test) were assessed using the modified scoring system. However, an increase pain in other areas such as knees, shoulders pain did not affect the result of the score. This pilot study showed that the FMS to be a reliable assessment for the quality of movement in patients with LBP when a modified scoring system is used.

Application of the FMS

Recently, the FMS has been used to assess functional performance in patients with LBP using the original scoring system (Bagherian et al., 2018). These authors studied the effects of an 8-week core stability program on functional movement patterns using the FMS on one hundred collegiate athletes who were assigned randomly into one of two groups: the intervention group or the control group. The intervention group was required to perform core stability exercises three times per week for 8 weeks but the control group received no intervention. They found that the intervention group demonstrated greater improvements in the FMS scores as compared to the control group ($p < 0.001$). In addition, they found that the core stability exercises were more effective for those with poor movement quality (i.e., baseline FMS score ≤14) than for those with higher movement quality (i.e., baseline FMS score > 14) (Bagherian et al., 2018).

Stanek, Dodd, Kelly, Wolfe, and Swenson (2017) examined the effects of an 8-week individualized corrective exercise-training program in 56 male, active-duty firefighters. All subjects completed a baseline FMS and another FMS at the 8-week follow-up. Based on their performance on the baseline FMS, corrective exercises were developed for each participant. At four weeks, a new corrective exercise-training program was given for each participant based on their progression. They found a significant increase in the total FMS score at the 8-week follow-up (12.09 ± 2.75 at baseline, 13.66 ± 2.28 at the 8-week follow-up).

The results indicate that an 8-week individualized corrective exercise program was effective in improving physical performance and movement patterns (Stanek et al., 2017).

The FMS also has been used to study the functional performance in patients with CLBP (Ko et al., 2016). Ko et al. evaluated 40 participants including 20 participants with CLBP (17 females and three males) and 20 healthy control subjects (17 females and three males). The FMS score for the CLBP participants was significantly lower on the total composite scores as compared with the healthy control group (10.95 ± 2.2 vs. 14.40 ± 1.8 points, respectively; $p < 0.001$). The CLBP group also had significantly lower scores on the following individual FMS tests: deep squat (1.55 ± 0.7 vs. 2.20 ± 0.5 points, $p = 0.002$), ASLR (1.85 ± 0.7 vs. 2.55 ± 0.8 points, $p = 0.005$), hurdle step (1.95 ± 0.4 vs. 2.45 ± 0.5 points, $p = 0.002$), and rotary stability (1.15 ± 0.4 vs. 1.80 ± 0.4 points, $p < 0.001$). However, there were no significant differences between CLBP and the control groups on the in-line lunge (1.90 ± 0.7 vs. 2.25 ± 0.7 points, $p = 0.133$), trunk stability push-up (0.95 ± 0.5 vs. 1.30 ± 0.6 points, $p = 0.056$), and shoulder mobility (1.75 ± 0.9 vs. 1.85 ± 0.6 points, $p = 0.811$) (Ko et al., 2016). The result showed that patients with CLBP demonstrated lower scores when they performed the deep squat, hurdle step, active straight leg raise, and rotary stability tasks of the FMS compared to healthy people. The authors explained that lower scores in the CLBP population were likely due to the restricted ROM in the hip, knee, and ankle joint and poor movement quality in the tasks that require

proper stability and coordination.

The FMS was designed primarily for predicting injury risk. Clay, Mansell, and Tierney (2016) conducted a study in the United States on 37 female collegiate rowers. Investigators performed a pre-season FMS in addition to administering the OSW on each of these rowers. Next, each participant was assigned to a high-risk group or a low-risk group based on their FMS scores, and were given a follow-up regarding their injury over a season. LBP was noted in 25 out of the 37 rowers over the season. The rowers in the high-risk group were significantly more likely to experience LBP during the season ($p = 0.036$) than those in the low-risk group. In addition, the rowers with a history of LBP were six times more likely to suffer LBP during the season ($p = 0.027$), and the rowers with more years of rowing experience had a higher likelihood of sustaining LBP. These results were attributed to chronic overuse associated with the rowing motion (Clay et al., 2016).

In summary, the FMS appears to be capable of assessing movement performance and movement quality in healthy individuals as well as individuals with LBP. In addition, the FMS has been recommended as a functional assessment tool used to identify functional deficits in patients with CLBP (Ko et al., 2016).

Clinical Outcome Measures for LBP

Pain Intensity

The most common pain outcome measures cited in the literature, for evaluating the effectiveness of treatment for LBP, are the brief pain inventory (BPI), the pain disability index (PDI), the McGill pain questionnaire (MPQ), the VAS, and the NPRS (Childs, Piva, & Fritz, 2005; Cleeland & Ryan, 1994; Crichton, 2001; Melzack, 1987; Tait, Pollard, Margolis, Duckro, & Krause, 1987). Only the NPRS and the VAS have been found to be responsive in the treatment of CLBP, as the others have not been validated in the desired target population (Chapman et al., 2011). The NPRS and VAS are often considered to be gold standards for pain measurement (Chapman et al., 2011). The VAS is a horizontal line, which is 100 mm in length anchored by descriptive words at each end. The individual marks on the line the point that they feel represents their current pain status. The VAS score is calculated by measuring in millimeters from the left end of the line to the point marked by the patient. However, the NPRS appears to have some advantages compared to the VAS. First, individuals who are older or less educated, or who have sustained trauma, have less difficulty completing the NPRS as compared to the VAS (Spadoni, Stratford, Solomon, & Wishart, 2004). In addition, the NPRS is quicker and easier to score than the VAS. The NPRS has an ability to detect changes that is better than many self-reported functional status measures (Spadoni et al., 2004).

The NPRS is an 11-point scale with “0” representing “no pain” and “10”

representing “worst imaginable pain” (Childs et al., 2005). The NPRS has been shown to be reliable and responsive to be used in both the clinical and research settings in patients with LBP (Childs et al., 2005). NPRS was found to have fair-to-excellent test-retest reliability at one-week and four-week follow-ups when measuring the pain level for adults with LBP (ICC = 0.72 and 0.92, respectively). The NPRS has been shown to have concurrent and predictive validity as a measure of pain intensity (Childs et al., 2005; Jensen, Turner, Romano, & Fisher, 1999). The minimal clinically important difference (MCID) and the MDC for the NPRS have been reported to be two points in patients with LBP that represents a clinically significant change in a patient’s perceived level of pain (Childs et al., 2005; Jensen et al., 1999).

Disability

The most common questionnaires used to measure self-reported disability related to CLBP are the Roland Morris Disability Questionnaire (RMDQ) and the Oswestry Disability Index (ODI) (Chapman et al., 2011).

The RMDQ is a self-reported health status measure, which is completed by patients. It was developed in 1983 to measure physical disability due to LBP. The questionnaire consists of 24 items related to the normal activities of daily living. The total score is the sum of all questions answered in the affirmative and ranges from 0, indicating no disability, to 24, indicating maximum disability, (Roland & Fairbank, 2000). The recommended MCID for the RMDQ is two to three points (Bombardier, Hayden, & Beaton, 2001).

The Oswestry Disability Index (ODI) has been used to assess the individual's disability related to LBP. The ODI, first described by Fairbank et al. in 1980, consists of 10 items, including pain intensity, lifting, personal care, walking, standing, sitting, sleeping, social life, travelling, and sex life (Fairbank & Pynsent, 2000, Vianin, 2008). Each item consists of six statements (0-5), and the patients are asked to check the statement most closely representing their status with a total score range 0-50. The ODI score is typically multiplied by two and expressed as a percentage from 0 to 100%, where 0-20% represents minimal disability, 21-40% represents moderate disability, 41-60% represents severe disability, 61-80% represents crippling back pain, and 81-100% represents bed-bound or exaggeration of symptoms (Fairbank, Couper, Davies, & O'brien, 1980; Fairbank & Pynsent, 2000). Because the "sex life" item was left blank most of the time, a modified version of ODI, Modified Oswestry Low Back Pain Disability Questionnaire (OSW), was developed and the "sex life" item was replaced with "employment and home-making ability" (Fritz & Irrgang, 2001). The modified OSW has been shown to have excellent test-retest reliability (ICC ≥ 0.90), and responsiveness as compared with the Quebec Back Pain Disability Scale for patients with LBP (Fritz & Irrgang, 2001; Hick & Manal, 2009). The MDC for this outcome measure is 10.5 points (Davidson & Keating, 2002), and the MCID is six points (Fritz & Irrgang, 2001). The OSW is broadly used in clinic and in research settings for patients with LBP.

A recent systematic review and meta-analysis concluded that there are no strong causes to favor either of these two instruments, RMDQ and ODI, over the other to measure physical functioning in patients with nonspecific LBP (Chiarotto et al., 2016). The OSW, which has become widely used for outcome studies in patients with LBP, was used for this dissertation study.

Fear Avoidance Beliefs

The most common questionnaires used to measure fear avoidance beliefs is Fear-Avoidance Beliefs Questionnaire (FABQ). The FABQ is a self-reported questionnaire and was originally developed to assess the patient's fear-avoidance level. It is a commonly-used measure of pain-related fear for patients with LBP (Waddell, Newton, Henderson, Somerville, & Main, 1993). The FABQ consists of two subscales: the physical activity subscale (items 1 – 5) and the work subscale (items 6 – 16) (Poiraudeau et al., 2006). Each item is scored from 0, "do not at all agree" to 6 "completely agree" (Waddell et al., 1993). For scoring purposes, only four items from the physical activity subscale and seven items from the work subscale are included for scoring. A score of 0-14 points for the physical activity subscale indicates low fear and a score of 15 points or higher indicates high fear for performing physical activity of daily life. A score of 0-33 for the work subscale score indicates low fear and a score of 34 points or higher indicates high fear for performing work activities (Poiraudeau et al., 2006). This questionnaire has a concurrent validity with a moderate correlation to the Tampa

Scale for Kinesiophobia (TSK) (r = 0.33 to 0.59) (Swinkels-Meewisse, Swinkels, Verbeek, Vlaeyen, & Oostendorp, 2003).

Patient-Reported Outcomes Measurement Information System (PROMIS-29)

The PROMIS-29 is a comprehensive self-reported questionnaire and consists of a 29-item questionnaire (Cella et al., 2007). It consists of eight sub-domains, which are physical function, anxiety, depression, sleep disturbance, fatigue, satisfaction with social role, pain intensity and pain interference (Alcantara & Ohm, 2013). Each item response is based on a five-point scale, and higher scores indicate higher intensity of the symptoms (Highland et al., 2018). In addition, pain intensity is measured with a single scale ranging from 0 to 10. The PROMIS-29 scales were scored using a T-score metric method, which allows the use of population norms for interpretation. As such, a score of 50 points represents the population mean for each scale, and 10 points represent one standard deviation. Higher scores indicate more of the particular scale's construct, which may represent a desirable outcome or an undesirable outcome. Three points are considered to be a minimal clinically important difference (Deyo et al., 2015). The PROMIS-29 has shown to have good-to-excellent internal consistency (Cronbach α=.81 and.95) for people with chronic musculoskeletal pain (Deyo et al., 2015).

Summary

From this literature review, it is apparent that CLBP is a disorder with increasing prevalence, and is placing a tremendous burden on the United States

and the rest of the world. This literature review gives an overview of the research related to spinal instability and low back pain in adults. Causes of LBP, physical impairments relating to LBP, treatments for LBP, and outcome measures for LBP were discussed. Some studies have investigated the effects of exercises to improve LBP in short-term and long-term follow-ups. However, no randomized clinical trials have been conducted to examine the effectiveness of SSEs on functional performance or quality of movement in patients with LBP.

CHAPTER III

METHODS

The purpose of this study was to determine the effects of SSEs on movement performance, LBP intensity, and disability level in patients with sub-acute and chronic LBP. Specifically, the differences in movement performance, pain intensity, and disability level were compared between participants who received SSEs and those who received a GE program, which included ROM and flexibility exercises. The primary hypothesis was that participants who received eight weeks of an SSE program would have greater improvement in their movement performance, pain intensity and disability level, as compared to participants who received eight weeks of a GE program. The research design, sources of data, outcome measures, data collection, and data analysis are discussed in this chapter.

Research Design

This study was a randomized clinical trial, comparing two groups: (1) the SSE group, who received exercises designed specifically to improve lumbar stability, and (2) the GE group, who received general ROM and flexibility exercises. The research design was a prospective two-way (2 × 4) mixed design. There were two independent variables, one between-group variable: group, and one within-group variable: time. The group variable had two levels, SSEs and GEs, and the time had four levels, baseline, two weeks after intervention, four weeks after intervention, and eight weeks after intervention. The three dependent

variables were movement performance, pain intensity, and disability level in adults with LBP. Specifically, movement performance was measured using the FMS, pain intensity was measured using the NPRS, and disability level was measured using the OSW.

Participants

To determine an adequate sample size for this study, an *a priori* power analysis was performed using G*Power 3.1.9 (Faul, Erdfelder, Lang, & Buchner, 2007). Using a small-to-medium effect size of 0.20 and an alpha level of 0.05, a sample size of 40 participants was needed to ensure an adequate power level of 0.80 for a mixed-model 2 x 4 analysis of variance (ANOVA) test. Participants of any ethnicity, sex, or race were recruited through flyers, word-of-mouth marketing, emails, and direct mail advertisements distributed throughout the local communities in the Dallas-Fort Worth metropolitan area. Approval from the Texas Woman's University (TWU) Institutional Review Board was obtained prior to participant enrollment and data collection. Once the participants agreed to participate in the study, each participant was asked to sign a written informed consent form. Next, the participants were screened for their eligibility for the study, and those who were qualified were assigned randomly to one of the two groups.

Participants were included in this study if they: (1) were 18 to 65 years of age, (2) had subacute LBP (LBP for a duration of six to 12 weeks after onset of symptoms) or CLBP (LBP for a duration of more than 12 weeks) (Marin et al.,

2017), (3) had the ability to understand and speak English, and (4) had a minimum pain score of 2/10 in the past week using the NPRS. Adults older than 65 are likely to have age-related balance deficits and other medical comorbidities. Therefore, consenting adults who were 18 to 65 years of age were eligible for the study. In addition, eligible participants must have experienced LBP of at least 2/10 on the NPRS, because the MDC of the NPRS in patients with LBP has been shown to be two points (Jensen et al., 1999).

Participants were excluded if they had (1) serious spinal conditions, such as fracture, infection, or tumor, (2) signs of nerve root compression, (3) a history of lower extremity or lumbar spine surgery, (4) a history of hip, knee, or ankle pain in the previous two years, (5) current pregnancy by self-report, (6) systemic joint disease (e.g., rheumatologic or neurological disorders), (7) vestibular or other balance disorders, (8) ongoing treatment for inner ear, sinus, or upper respiratory infection, (9) a history of falls or fear of falling, or (10) a need for any form of walking aids (e.g., cane or walker). All of these exclusion criteria likely could have affected the performance of the FMS.

Investigators

Two investigators were responsible for data collection for this study. The principal investigator (PI), investigator #1, was the treating therapist. Investigator #2 was responsible for collecting outcome measures. Both investigators #1 and #2 were doctor of philosophy (PhD) students with three to four years of clinical experience in treating patients with orthopedic disorders. In addition, both

investigators developed and designed both the SSEs and GEs and standardized exercise progression for each exercise program. Because the PI was responsible for group allocation and administering the intervention, the PI was blinded to the results of the FMS, NPRS, and OSW.

Instrumentation

The instruments which were used in this study for outcome measures include the FMS (see appendix A), NPRS (see appendix B), OSW (see appendix C). In addition, the Fear-Avoidance Beliefs Questionnaire (FABQ) (Appendix D) and the Patient-Reported Outcomes Measurement Information System (PROMIS-29) (Appendix E) were collected at baseline to describe the characteristics of the participants.

Functional Movement Screen

The FMS Test Kit (Functional Movement Systems Inc., Chatham, VA) was used to assess movement performance of seven different movement patterns for this dissertation study. The FMS Test Kit consists of a two-inch by six-inch board, one four-foot long dowel, two shorter dowels, and an elastic cord (Cook, 2010). The FMS (Appendix F) includes seven test components, which are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg-raise, trunk stability push-up, and rotary stability. Additionally, there are three clearance screens, including impingement-clearing test, press-up clearing test, and posterior-rocking clearing test. These three clearance screen tests are used to determine the presence of pain associated with internal rotation and flexion of the

shoulder, spinal flexion, and spinal extension. It takes approximately 12-15 minutes to administer the entire FMS. Each test component of the FMS is scored on a scale of 0 to 3. When the test component is performed correctly without compensations, a score of 3 is given. When completion of the test component required compensatory movement, a score of 2 is given. When the participant is unable to perform the test component as required, a score of 1 is given. Lastly, a score of 0 is given when there is an occurrence of pain during the test component. A composite score ranges from 0 to 21 to indicate the quality of movement performance, with a higher score indicating higher quality of movement performance. In addition, a score of 14 or lower on this original scoring FMS system indicates that the participant could have a higher risk for future injury (Butler, et al., 2013; Cook et al., 2014a).

However, as all of the participants had LBP in this study, the FMS scores were modified so that a zero score was given only when the participant reported an increase in the LBP, not simply for the presence of LBP. Therefore, the composite score still ranged from 0 to 21 and was used for statistical analysis. The FMS with the original scoring system has been shown to have good intra-rater reliability (ICC = 0.87) and inter-rater reliability (ICC = 0.84) (Bonazza, et al., 2017). Additionally, the results of a pilot study conducted prior to this dissertation study showed an excellent inter-rater reliability (ICC = 0.98) of the modified FMS composite scores in both groups asymptomatic participants (ICC = 0.96; n = 22)

and in those with LBP (ICC = 0.99; n = 22), using the modified scoring system as mentioned above.

Numeric Pain Rating Scale (NPRS)

The NPRS was used to assess pain intensity and is an 11-point Likert scale with “0” representing “no pain” and “10” representing “worst imaginable pain” (Childs et al., 2005). It also has been shown to be reliable and responsive in a sample of patients with LBP (Childs et al., 2005). In addition, the NPRS has been shown to have concurrent and predictive validity as a measure of pain intensity (Childs et al., 2005; Jensen et al., 1999). The MCID and the MDC for the NPRS have been reported to be two points in patients with LBP (Jensen et al., 1999). For this dissertation study, the NPRS was assessed at baseline, and then at two weeks, four weeks, and eight weeks after the initiation of treatment. Each participant was asked to rate their current, least, and worst levels of pain over the past week to determine the eligibility for this study using the NPRS. In addition, the NPRS score for current pain was used to monitor pain level during the FMS testing and for statistical analysis.

Modified Oswestry Low Back Pain Disability Questionnaire (OSW)

The OSW was used to determine LBP-related disability. This questionnaire consists of 10 items assessing different aspects of pain and function related to LBP. Each item consists of six statements that are scored 0 to 5, thus making a total possible score ranging from 0 to 50 (Fritz & Irrgang, 2001). Scores are typically multiplied by two and expressed as a percentage from 0 to

100% where 0-20% representing minimal disability, 21-40% moderate disability, 41-60% severe disability, 61-80% crippling back pain, and 81-100% bed-bound or exaggeration of symptoms (Fritz & Irrgang, 2001). Therefore, the higher scores represent greater disability. The OSW has been shown to be reliable, valid, and responsive in clinical trials (Fritz & Irrgang, 2001). The MDC for this outcome measure is 10.5 points (Davidson & Keating, 2002), and the MCID is six points (Fritz & Irrgang, 2001). The OSW is broadly used in clinical and research settings for patients with LBP, and has been shown to be reliable in patients with LBP (ICC > 0.90) (Hicks & Manal, 2009). For this dissertation study, the OSW was assessed at baseline, and then at two weeks, four weeks, and eight weeks after the initiation of treatment.

Fear-Avoidance Beliefs Questionnaire (FABQ)

The FABQ is a self-reported questionnaire and was originally developed to assess a patient's fear-avoidance level. It is a commonly-used measure of pain-related fear for patients with LBP (Waddell et al., 1993). The FABQ consists of two subscales: the physical activity subscale (items 1 – 5) and the work subscale (items 6 – 16) (Poiraudeau et al., 2006). Each item is scored from 0, "do not at all agree" to 6 "completely agree" (Waddell et al., 1993). For scoring purposes, only four items from the physical activity subscale and seven items from the work subscale are included. A score of 0 to 14 points for the physical activity subscale indicates low fear and a score of 15 points or higher indicates high fear for performing physical activities of daily life. A score of 0-33 for the work subscale

score indicates low fear and a score of 34 points or higher indicates high fear for performing work activities (Poiraudeau et al., 2006). This questionnaire has a concurrent validity with a moderate correlation to the Tampa Scale for Kinesiophobia (TSK) (r = 0.33 to 0.59) (Swinkels-Meewisse et al., 2003). The FABQ was collected from each participant at baseline and was used to describe the characteristics of the participants in this study.

Patient-Reported Outcomes Measurement Information System (PROMIS-29)

The PROMIS-29 is a comprehensive self-reported questionnaire and consists of 29 items (Cella et al., 2007). It includes eight sub-domains, which are physical function, anxiety, depression, sleep disturbance, fatigue, satisfaction with social role, pain intensity and pain interference (Alcantara & Ohm, 2013). Each item response is based on a five-point scale, and higher scores indicate higher intensity of the symptoms (Highland et al., 2018). In addition, pain intensity is measured with a single scale ranging from 0 to 10. The PROMIS-29 scales were scored using a T-score metric method, which allows the use of population norms for interpretation. As such, a score of 50 points represents the population mean for each scale, and 10 points represent one standard deviation. Higher scores indicate more of the particular scale's construct, which may represent a desirable outcome or an undesirable outcome. Three points are considered to be a minimal clinically important difference (Deyo et al., 2015). The PROMIS-29 has been shown to have good-to-excellent internal consistency (Cronbach α = 0.81 and 0.95) for people with chronic musculoskeletal pain (Deyo

et al., 2015). The PROMIS-29 was collected from each participant at baseline and was used to describe the characteristics of the participants in this study.

Procedures

Participant Screening

This dissertation study was approved by the Institutional Review Board at TWU, and was conducted at TWU - Dallas and Denton campuses. To determine participants' eligibility for the study, and to provide baseline data, each participant filled out an intake form (Appendix G), including demographic data such as age, gender, height, weight, duration of symptoms, limb dominance, leg length, occupation, and surgical and medical history. Next, each participant was asked to complete the NPRS and OSW. The PI then performed neurological tests (Appendix H) to further screen for each participant's eligibility. Once a participant was determined to be eligible for the study, a physical therapy examination (Appendix I) was conducted, including active ROM measurements of the lumbar spine (flexion, extension, right and left side-bending), right and left straight-leg-raise (SLR) tests, side-support test, extensor endurance test, active and passive bilateral SLR tests, posterior-anterior (PA) stress tests, prone instability tests, and lumbar segmental testing for mobility. Next, the participant was given an identification number and assigned randomly into either the SSE group or the GE group. An envelope consisting of 20 cards marked "Group A" for the SSE group and 20 cards marked "Group B" for the GE group was used for the randomization procedure in order to get an equal number of patients for both groups. If a patient

dropped out, a card with the patient's assigned treatment group was replaced in the envelope. The investigator who performed the group assignment was the one who administered the intervention. Therefore, the other investigator, who administered the FMS, NPRS, and, OSW was blinded to the intervention.

During the FMS, each participant performed all seven test components of the FMS in the same order as described by Cook et al. (2010). No warm-up was required before the start of the measurement. Each participant performed three trials for each of the seven FMS test components, and the best score from the three trials was recorded. However, the participants performed the three clearance screens only once. Therefore, when a participant had no pain with a clearance screen, the screen was considered negative. If there was an increase in LBP, not simply the presence of LBP with a clearance screen, the screen was considered positive and the associated test was scored zero. Three FMS test components are associated with a clearance screen: the shoulder mobility test with the impingement clearance screen, the push-up test with the press-up clearance screen, and the rotator stability test with the posterior rocking clearance screen. Five of the seven FMS test components were performed bilaterally: hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability test. Each participant performed these five tests first on the right side and then on the left side. For movements that were scored on both limbs simultaneously, the lower score was used to compute the composite score

(Appendix J). The total score of the seven test components was added together to get a composite score of the FMS.

For each participant, the FMS, NPRS, and OSW measurements were collected at baseline and then two weeks, four weeks, and eight weeks after the initiation of treatment. At baseline, the FABQ, and PROMIS-29 also were collected. Additionally, NPRS measurements were collected at the beginning of each session, before and after each test, and any aggravation of LBP was recorded throughout the entire testing procedure.

Interventions

Participants in the SSE group were instructed in the SSEs (Appendix K), which were modeled after the SSE program designed by Hicks et al. (Hicks, Fritz, Delitto, & McGill, 2005). The SSE program targets the spinal stabilizer muscles, such as the transversus abdominus, erector spinae, lumbar multifidus, quadratus lumborum, and oblique abdominal muscles and was found to be an effective treatment for adults with LBP (Hicks et al., 2005). The SSEs consisted of four categories. The exercises in the first category were abdominal bracing exercises, which were designed primarily to target the transversus abdominus muscle. The participant performed each abdominal bracing exercise up to 30 repetitions with a target hold time of eight seconds. The SSEs in the second category were quadruped exercises, which were designed to target both the erector spinae and multifidus. The participant performed each quadruped exercise up to 30 repetitions with a target hold time of eight seconds. The SSEs

in the third category were prone-plank exercises, which were designed to primarily target the quadratus lumborum muscle. The participant performed each prone plank exercise up to 30 repetitions with a target hold time of eight seconds. Lastly, the SSEs in the fourth category were side-plank exercises, which were designed to train the oblique abdominal muscle. The participant performed each side-plank exercise up to 30 repetitions with a target hold time of eight seconds.

At the initial treatment session, participants were instructed to perform four exercises, one from each category. The exercise intensity progressed to the next level when the participant could perform the exercise with proper form and without any rest breaks for the required repetitions and hold time. Once they progressed to the next level of the exercise, they discontinued the previous level of the exercise. However, if the participant did not perform the exercise properly or did not reach a specific repetition or hold time, the participant was not allowed to progress to the next level. The progression of the SSE program and the criteria for progression are listed in Appendix K.

The GE group performed a GE program, consisting of ROM and flexibility exercises of low back and lower extremities (Appendix L). Participants were instructed to perform four exercises, one from each of the four exercise categories, at the initial treatment session. Similar to the SSE program, there were four exercise categories, including knee-to-chest, lower trunk rotation, prone press-ups, and hamstring stretch. Each participant in this group was asked to perform each exercise up to 20 times with a target hold time of 10 seconds.

The participants were instructed to perform all of the four exercises within a pain-free range. The exercise intensity progressed by increasing repetitions and hold time, and was progressed to the next level when the participant were able to perform the exercise with proper form without any rest breaks for the required repetitions and hold time.

On the first visit, all participants were instructed in the exercises at a level that they were able to perform without pain. All participants were given a compliance log (Appendix M) based on the assigned group to report their exercise compliance. In addition, all participants were given an exercise handout, which illustrated the exercises and listed the required exercise repetitions and hold time. Participants were asked to return one to two times per week for four weeks for exercise progression and to ensure that they were performing the exercises properly. The intervention frequency and duration was chosen to reflect common physical therapy practice. However, each participant was asked to perform their assigned exercise program at least five times per week, and the on-site visits were counted toward the required exercise frequency. After the four-week intervention, all participants were asked to continue their exercise program at home five times a week for another four weeks. At the week four visit, the participants were instructed on how to progress their exercises. Finally, participants who were assigned to the GE group were instructed with the SSE program at the end of eight weeks, last visit, if they so chose.

Data Analysis

All statistical analyses were performed using SPSS Statistics, Version 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequency, means, and standard deviations, were calculated for the demographic data of the participants, including age, gender, height, weight, and body mass index (BMI), the participants' characteristics (e.g., duration of pain, distribution of pain, results of physical therapy examination, FABQ scores, and PROMIS scores), and the results of outcome measures (i.e., FMS scores, NPRS scores, and OSW scores). Independent *t*-tests were used to determine if there was a difference at baseline, including demographic ratio data such as age, duration of symptoms and outcome measures. Chi-square tests were used for categorical data such as gender, onset symptoms of LBP, and distribution of pain. Three separate 2 (group) x 4 (time) repeated measure (RM) ANOVAs were used to analyze the collected data for each of the three outcome measures. Post hoc analysis was performed if there was a significant interaction. The α level was set at 0.05 for all statistical analyses.

CHAPTER IV

RESULTS

No randomized clinical trials have been conducted to assess the effectiveness of SSEs on the quality of movement using a quantitative assessment tool. The primary purpose of this study was to determine the effects of SSEs on movement performance in adults with NSLBP. Specifically, the differences in performance on the FMS were compared between patients with subacute and chronic LBP who received eight weeks of a SSE program and those who received eight weeks of a GE program at two weeks, four weeks, and eight weeks. The secondary purpose of this study was to examine whether the patients with subacute and chronic LBP receiving SSEs would have greater reductions in pain intensity and disability level at two weeks, four weeks, and eight weeks as compared to those who received a GE program. The primary outcome measures included movement performance, pain intensity, and disability level. This chapter discusses the results of the study, including characteristics of the participants and pre- and post-treatment outcome measures.

Participants

Fifty-three participants were recruited from the Dallas-Fort Worth area. A total of nine participants were excluded. One participant was excluded due to having acute LBP, one due to having neurological signs and symptoms of the lower extremities, three were older than 65 years, two had lumbar surgery, and

two were not able to come at the required testing times due to scheduling conflicts. In addition, four participants (two in the SSE group and two in the GE group) dropped out after the first visit. One of them did not respond to phone calls and text messages attempting to reschedule the appointment or did not provide the reason for discontinued participation. Another participant quit the program due to a car accident which prevented him from continuing in this study. In addition, two of the four participants left the Dallas-Fort Worth area to another state due to work. Consequently, a total of 40 participants met the inclusion criteria and completed the eight-week exercise program. Figure 1 shows a consort diagram of participants' enrollment, screening, and randomization for this study.

The characteristics of the participants and baseline outcome measurements are summarized in Table 1, including, age, gender, weight, height, BMI, onset of LBP (i.e., insidious or traumatic), duration of LBP, side of LBP, distribution of pain (LBP only, LBP and leg pain above the knee, LBP and leg pain below the knee), and physical activity level. Additionally, Table 1 lists the FABQ, PROMIS-29, NPRS, OSW, and modified FMS composite scores collected at baseline. The average age of all participants in this study was 39.9 ± 12.5 years. The sample of this study consisted of 23 men and 17 women. The participants' BMI (28.6 ± 7.7 for the SSE group, 27.5 ± 5.5 for the GE group) in both groups fell within an overweight category. In general, the participants had mild LBP with an average NPRS score of 3.5 ± 1.6. Thirty-six of the 40

participants had an insidious onset of symptoms and the LBP of the other four participants resulted from a trauma. Fourteen participants had central LBP, 13 had LBP in the right side, and the other 13 had their LBP on the left side. All participants reported CLBP (lasting longer than three months). However, only 10 of the participants (five in the SSE group, five in the GE group) reported leg pain associated with LBP. Specifically, nine (five in the SSE group, four in the GE group) of the participants complained of pain that extended below the knee, and one had pain just above the knee. Participants' physical activity level, defined as the number of minutes of activities per week, was 99.7 ± 145.1 minutes per week. The FABQ scores showed a low level of fear avoidances beliefs on work and physical activities for both groups. Six of the eight PROMIS-29 sub-domain scores were within the normal limit, but physical function and pain interference results showed mild impairments and symptoms. The independent *t*-test and chi-square analysis results showed no significant difference ($p < 0.05$) in any of the baseline characteristics, physical therapy examination results and outcome measurements between participants in the SSE group and those in the GE group (see Table 1). Therefore, the two groups were considered similar at the beginning of the study.

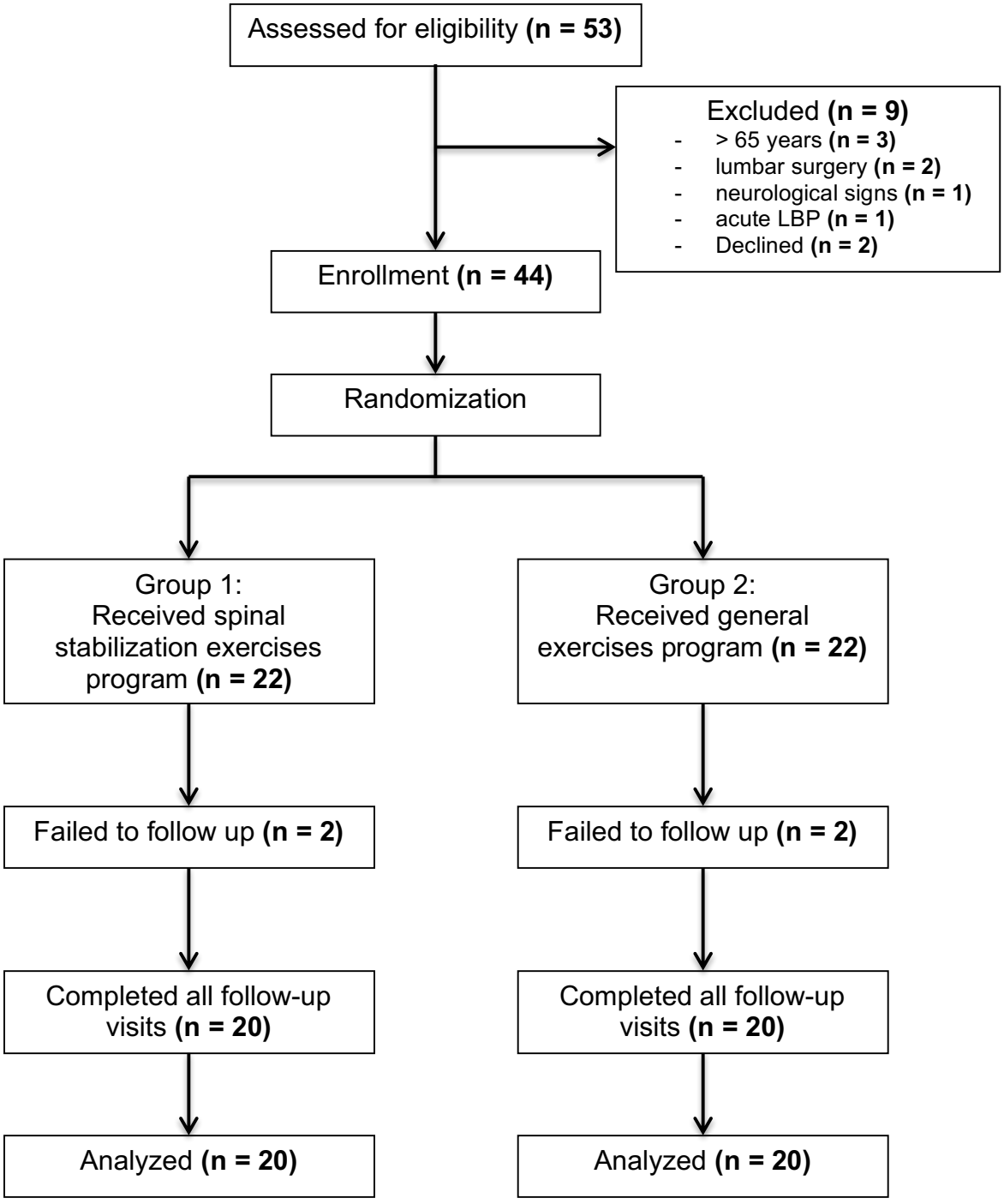

Figure 1. Consort diagram of participants' screening, enrollment, and randomization.

Table 1

Participants' Characteristics and Outcome Measurements (count or mean ± SD) at Baseline

	All participants (n = 40)	SSE Group (n = 20)	GE Group (n = 20)	*p*-value (SSE vs. GE)
Age (years)	39.9 ± 12.5	38.8 ± 11.8	41.0 ± 13.3	0.583
Gender (male/female)	23/17	13/7	10/10	0.337
Weight (kg)	79.8 ± 15.7	78.6 ± 15.6	81.1 ± 15.8	0.625
Height (cm)	169.7 ± 10.1	167.2 ± 9.8	172.3 ± 10.0	0.112
BMI	28.0 ± 6.6	28.6 ± 7.7	27.5 ± 5.5	0.612
Average pain	4.7 ± 1.8	4.5 ± 1.4	5.0 ± 2.2	0.397
LBP onset symptoms (Insidious/Traumatic)	36/4	18/2	18/2	1.000
Duration of LBP (months)	95.2 ± 87.5	78.6 ± 87.7	111.9 ± 86.3	0.234
Side of LBP(central/right/left)	14/13/13	6/7/7	8/6/6	0.803
Distribution of pain				
LBP only	30 (75%)	15 (75%)	15 (75%)	1.000
LBP + leg pain above the knee	1 (2.5%)	0	1 (5%)	
LBP + leg pain below the knee	9 (22.5%)	5 (25%)	4 (20%)	0.705
PA duration (minute/week)	99.7 ± 145.1	86.0 ± 162.9	113.5 ± 127.8	0.556
FABQ				
Work	8.4 ± 7.4	9.5 ± 6.7	7.2 ± 8.1	0.344
Physical activity	10.1 ± 6.5	10.1 ± 7.4	10.1 ± 5.6	1.000
PROMIS-29				
Physical function	43.4 ± 2.4	43.4 ± 2.4	43.4 ± 2.4	0.512
Anxiety	51.2 ± 3.1	53.7 ± 2.8	51.2 ± 3.1	0.795
Depression	49.0 ± 3.2	49.0 ± 3.2	49.0 ± 3.2	0.815
Fatigue	55.1 ± 2.4	57.0 ± 2.3	53.1 ± 2.4	0.229
Sleep disturbance	52.4 ± 3.4	52.4 ± 3.4	52.4 ± 3.4	0.695
Social roles	51.9 ± 2.2	51.9 ± 2.2	53.7 ± 2.3	0.487
Pain interference	57.1 ± 1.9	55.6 ± 1.9	57.1 ± 1.9	0.558
Average pain intensity	4.3 ± 1.8	4.1 ± 1.2	4.4 ± 2.3	0.549
Impact score	20.1 ± 6.6	19.9 ± 6.9	20.3 ± 6.5	0.852
NPRS	3.5 ± 1.6	3.4 ± 1.3	3.5 ± 1.9	0.846
OSW	18.1 ± 9.1	18.2 ± 9.1	18.1 ± 9.4	0.973
Modified FMS score	10.7 ± 3.4	10.9 ± 3.2	10.6 ± 3.8	0.788

Note: SSE = spinal stabilization exercises, GE = general exercises, BMI = body mass index, LBP = low back pain, PA = physical activity, FABQ = Fear Avoidance Beliefs Questionnaire, PROMIS-29 = Patient-Reported Outcomes Measurement Information System, NPRS = Numeric Pain Rating Scale, OSW= Modified Oswestry Low Back Pain Disability Questionnaire, FMS = Functional Movement Screen.

Physical Therapy Examination

Table 2 lists the findings of the physical examination, including ROMs of the lumbar spine and hips, presence of abnormal movement patterns (i.e., painful arc with flexion, painful arc in return from flexion, instability catch, and Gowers' sign), muscle endurance of low back (i.e., results of the Sorensen's back extensor test, right and left side-support tests, and bilateral straight-leg-raise tests), positive provocative PA stress tests to lumbar segments and sacrum, hypomobility or lack of hypomobility of PA mobility tests to lumbar segments and sacrum, and the results of the prone lumbar instability tests. Independent *t*-tests and chi-square tests showed no differences between the two groups for all of the physical examination tests ($p < 0.05$). Therefore, the groups were considered equivalent at baseline regarding these physical characteristics.

Outcome Measurements

The outcome measurements used in this study were movement performance, pain intensity, and disability level. Movement performance, pain intensity, and disability level collected at baseline, and two weeks, four weeks, and eight weeks from the start of the intervention. The means and standard deviations of all three outcome measurements at all four time points are shown in Table 3.

Table 2

Results of Physical Therapy Examination

	All participants (n = 40)	SSE Group (n = 20)	GE Group (n = 20)	*p*-value (SSE vs. GE)
Lumbar Spine ROM				
Flexion	52.9 ± 14.4°	52.8 ± 15.3°	52.9 ± 13.8°	0.983
Extension	13.4 ± 4.3°	12.9 ± 5.0°	13.9 ± 3.7°	0.496
Right side-bending	21.7 ± 6.9°	22.1 ± 7.1°	21.3 ± 6.8°	0.720
Left side-bending	20.4 ± 7.1°	21.3 ± 6.7°	19.5 ± 7.4°	0.440
Hip ROM				
Right hip flexion	76.6 ± 12.4°	76.2 ± 14.7°	77.0 ± 9.9°	0.851
Left hip flexion	71.6 ± 12.9°	70.6 ± 16.0°	72.6 ± 9.0°	0.629
Right Hip extension	10.0 ± 2.6°	9.8 ± 2.8°	10.2 ± 2.4°	0.586
Left Hip extension	9.9 ± 2.7°	9.4 ± 2.78°	10.4 ± 2.7°	0.253
Provocative movement test				
Positive painful arc with flexion	8 (20%)	4 (20%)	4 (20%)	1.000
Positive painful arc in return from flexion	14 (35%)	7 (35%)	7 (35%)	1.000
Positive instability catch	3 (7.5%)	2 (10%)	1 (5%)	0.548
Positive Gowers' sign	2 (5%)	1 (5%)	1 (5%)	1.000
Muscle endurance test				
Sorensen's test	13.5 ± 22.5 s	15.0 ± 21.2 s	11.9 ± 24.1 s	0.674
Right side-support test	23.6 ± 20.5 s	27.1 ± 20.1 s	20.1 ± 20.9 s	0.287
Left side-support test	23.0 ± 20.4 s	25.4 ± 18.0 s	20.7 ± 22.8 s	0.473
Bilateral SLR test	6 (15%)	3 (15%)	3 (15%)	1.000
PA stress test (painful)				
L1	0	0	0	
L2	2 (5%)	0	2 (10%)	0.147
L3	9 (22.5%)	3 (15%)	6 (30%)	0.256
L4	24 (60%)	11 (55%)	13 (65%)	0.519
L5	26 (65%)	14 (70%)	12 (60%)	0.507
Sacrum	13 (32.5%)	7 (35%)	6 (30%)	0.736
PA mobility test				
L1 (hypo/ Lack of hypo)	4 / 36	3 /17	1 /19	0.292
L2 (hypo/ Lack of hypo)	4 / 36	3 /17	1 /19	0.292
L3 (hypo/ Lack of hypo)	4 / 36	3 /17	1 /19	0.292
L4 (hypo/ Lack of hypo)	9 / 31	5 /15	4 /16	0.705
L5 (hypo/ Lack of hypo)	11 / 29	6 /14	5 /15	0.723
Sacral (hypo/ Lack of hypo)	9 / 31	3 /17	6 /14	0.256
Prone instability test				0.615
Negative	20 (50%)	12 (60%)	8 (40%)	
Positive	8 (20%)	3 (15%)	5 (25%)	
Could not do it	4 (10%)	2 (10%)	2 (10%)	
Not Indicated	8 (20%)	3 (15%)	5 (25%)	

Note: SSE = spinal stabilization exercises, GE = general exercises, SLR = straight leg raise, ROM = range of motion, PA = posterior-anterior, L = Lumbar spine, S = seconds Hypo = hypomobility.

Table 3

Outcome Measurements (Mean ± SD) at Baseline, and Two Weeks, Four Weeks, and Eight Weeks after Treatment was Initiated

	All participants (n = 40)	SSE Group (n = 20)	GE Group (n = 20)	*p*-value
Movement performance (mFMS score)				
Baseline	10.7 ± 3.4	10.9 ± 3.2	10.6 ± 3.8	0.788
2 weeks	12.0 ± 3.6	12.6 ± 3.4	11.3 ± 3.7	
4 weeks	13.5 ± 3.3	14.8 ± 2.5	12.1 ± 3.5	
8 weeks	14.5 ± 3.3	15.7 ± 2.7	13.2 ± 3.5	
Pain intensity (NPRS)				
Baseline	3.5 ± 1.6	3.4 ± 1.3	3.5 ± 1.9	0.846
2 weeks	2.9 ± 1.5	2.5 ± 1.1	3.2 ± 1.8	
4 weeks	1.9 ± 1.7	1.6 ± 1.1	2.2 ± 2.1	
8 weeks	2.0 ± 1.9	2.0 ± 1.9	1.9 ± 1.9	
Disability level (OSW)				
Baseline	18.1 ± 9.1	18.2 ± 9.1	18.1 ± 9.4	0.973
2 weeks	15.7 ± 9.1	15.1 ± 9.4	16.3 ± 9.1	
4 weeks	14.0 ± 9.8	12.7 ± 9.9	15.4 ± 9.6	
8 weeks	12.3 ± 10.8	12.0 ± 12.6	12.6 ± 9.1	

Note: SSE = spinal stabilization exercise, GE = general exercise, mFMS = Functional Movement Screen, NPRS = Numeric Pain Rating Scale, OSW= Modified Oswestry Low Back Pain Disability Questionnaire.

The FMS data at baseline was normally distributed. Therefore, a 2 x 4 RM ANOVA was used to analyze the differences in the modified FMS scores at baseline, two weeks, four weeks, and eight weeks between the two groups. Because both Levene's test at baseline (p = 0.341) and Mauchly's test (p = 0.302) were not significant, the assumptions for homogeneity of variance between groups and sphericity were not violated. Therefore, no corrections were made. The ANOVA result showed a significant interaction of group by time, $F(3, 114) = 3.599$, p = 0.016, indicating that there was a significant difference in movement performance between groups over eight weeks. Next, six separate 2 x 2 RM ANOVAs were used to exam the between-group differences between each two time points. Consequently, significant between-group differences were found between baseline and four weeks (p = 0.005) and between baseline and eight weeks (p = 0.026). In addition, there was a significant main effect of time. Post-hoc pair-wise comparisons were performed to examine the differences between each two time points. As a result, all participants made improvements in movement performance from baseline to two weeks (p = 0.011), from baseline to four weeks (p < 0.001), from baseline to eight weeks (p < 0.001), from two weeks to four weeks (p = 0.001), from two weeks to eight weeks (p < 0.001), and from four weeks to eight weeks (p = 0.008) (see Figure 2).

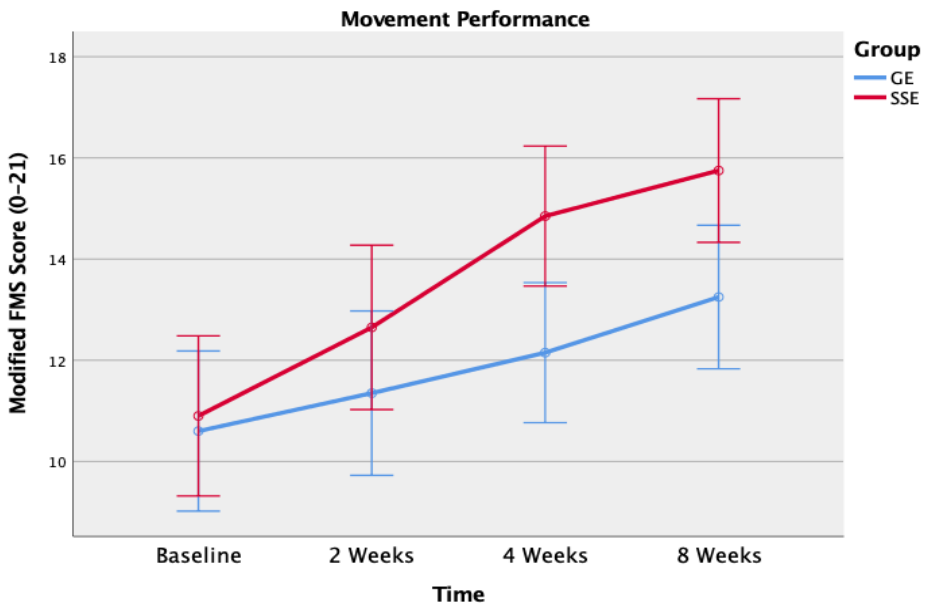

Figure 2. Movement performance using the modified Functional Movement Screen scoring system between the spinal stabilization exercise (SSE) group and the general exercise (GE) group at baseline, 2 weeks, 4 weeks, and 8 weeks.

The NPRS data at baseline was normally distributed. Therefore, a 2 x 4 RM ANOVA was used to analyze differences in the NPRS scores at baseline, two weeks, four weeks, and eight weeks between the two groups. Because both Levene's test for homogeneity of variance at baseline, (p = 0.143) and Mauchly's test for sphericity were not violated (p = 0.079), no corrections were made. The RM ANOVA showed no significant interaction of group by time F (3, 114) = 1.185, p = 0.319, indicating that there was no difference in pain intensity between groups over eight weeks. However, there was a significant main effect of time (p < 0.001). Post-hoc pair-wise comparisons were performed to examine the differences between each two time points. As a result, all participants demonstrated significant pain reduction from baseline to two weeks (p = 0.007),

from baseline to four weeks ($p < 0.001$), from baseline to eight weeks ($p < 0.001$), from two weeks to four weeks ($p < 0.001$), and from two weeks to eight weeks ($p = 0.001$), but there was no significant difference from four weeks to eight weeks ($p = 0.818$) (see Figure 3).

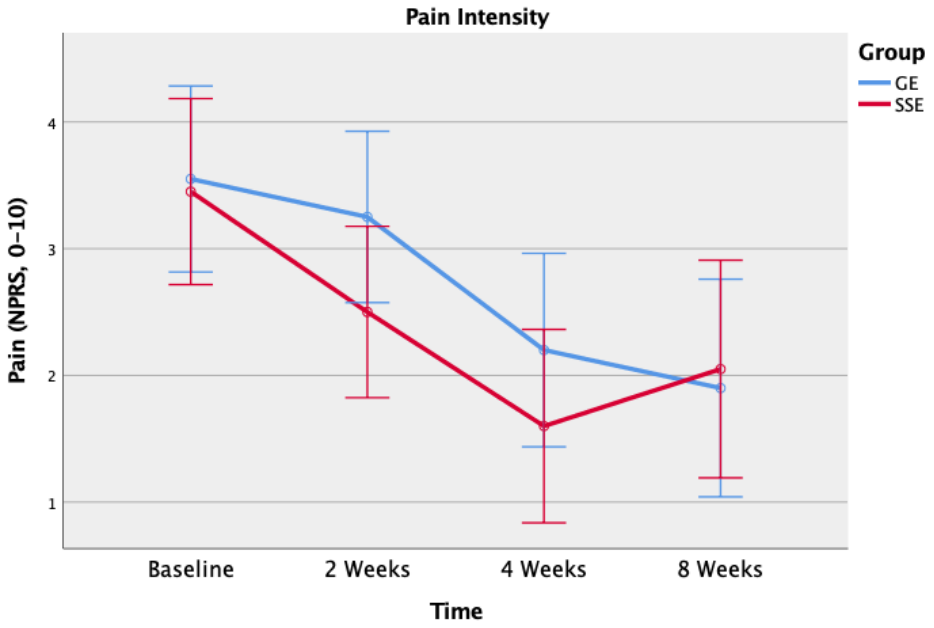

Figure 3. Pain intensity using the Numeric Pain Rating Scale (NPRS) between the spinal stabilization exercise (SSE) group and the general exercise (GE) group at baseline, 2 weeks, 4 weeks, and 8 weeks.

The OSW data at baseline was normally distributed. Therefore, a 2 x 4 RM ANOVA was used to analyze the differences in the OSW scores at baseline, two weeks, four weeks, and eight weeks between the two groups. Although Levene's test at baseline was not significant for homogeneity of variances ($p = 0.583$), Mauchly's test for sphericity was significant ($p = 0.002$). Therefore, the homogeneity assumption was not met, and the Greenhouse-Geisser statistics were reported. The RM ANOVA result showed no significant interaction of group

by time, F (3, 114) = 0.538, p = 0.605, indicating that there was no difference in disability level between groups over eight weeks. However, there was a significant main effect of time (p < 0.001). Post-hoc pair-wise comparisons were performed to examine the differences between each two time points. As a result, all participants showed significant improvement in OSW scores from baseline to two weeks (p = 0.017), from baseline to four weeks (p = 0.001), from baseline to eight weeks (p < 0.001), from two weeks to four weeks (p = 0.047), and from two weeks to eight weeks (p = 0.008), but there was no significant difference from four weeks to eight weeks (p = 0.117) (see Figure 4).

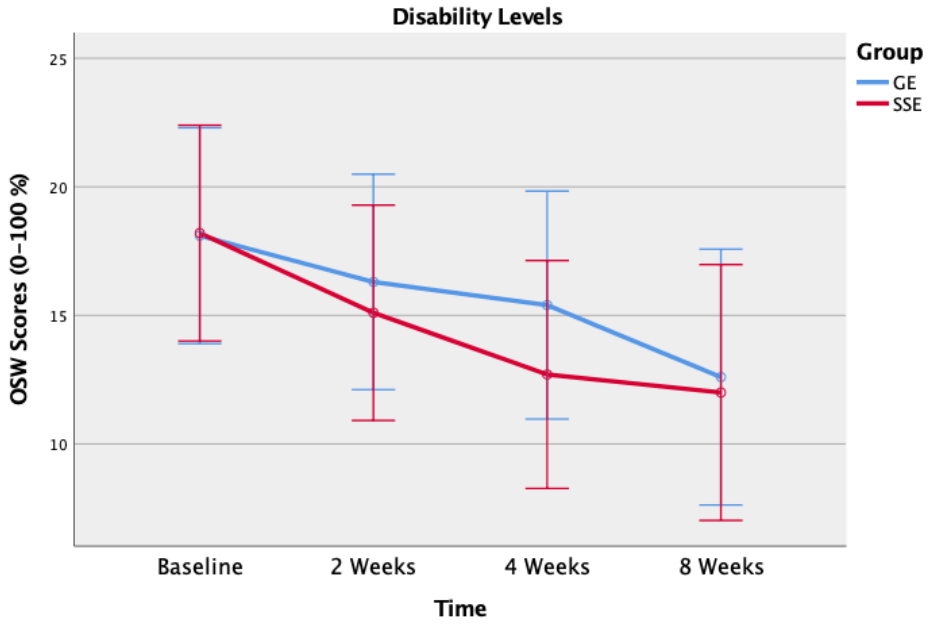

Figure 4. Disability levels using the Modified Oswestry Low Back Pain Disability Questionnaire (OSW) between the spinal stabilization exercise (SSE) group and the general exercise (GE) group at baseline, 2 weeks, 4 weeks, and 8 weeks.

Home Exercise Program Compliance

Compliance with the home exercises program (HEP) was determined by a subjective report on the participants' compliance logs. The average compliance for completing the home exercise program was calculated for the first four weeks (supervised phase), the last four weeks (unsupervised phase), and the total compliance (eight weeks) for both groups (five sessions per week). Table 4 lists HEP compliance for both groups, respectively. Independent *t*-tests were used to compare differences in HEP compliance between the two groups and paired *t*-tests used to compare differences in HEP compliance between the two phases within each group. There were no significant differences between the two groups in the supervised phase and the unsupervised phase. However, each group individually and both groups combined had significantly better exercise compliance in the supervised phase (first four weeks) than they did in the unsupervised phase (last four weeks) ($p = 0.044$ for the SSE group, $p = 0.025$ for GE group, $p = 0.002$ for both groups combined).

Table 4

Home Exercise Compliance Rates (%, Mean ± SD).

	All (n = 40)	SSE Group (n = 20)	GE Group (n = 20)	*p*-value (SSE vs. GE)
Supervised phase (0 – 4 weeks)	85.9 ± 14.8	83.7 ± 13.9	88.0 ± 15.6	0.369
Unsupervised phase (5 – 8 weeks)	76.1 ± 22.7	74.7 ± 20.4	77.5 ± 25.4	0.707
Entire study 0 – 8 weeks	81.0 ± 16.7	79.2 ± 14.8	82.7 ± 18.8	0.516
p-value (supervised vs. unsupervised)	0.002*	0.044*	0.0024*	

Note: SSE = spinal stabilization exercise, GE = general exercise.

CHAPTER V

DISCUSSION

The primary purpose of this study was to determine the effects of SSEs on movement performance in adults with NSLBP. Specifically, the differences in performance on the FMS were compared between patients with subacute and chronic LBP who received eight weeks of a SSE program and those who received eight weeks of a GE program at two weeks, four weeks, and eight weeks. The secondary purpose of this study was to examine whether the patients with subacute and chronic LBP receiving SSEs would have greater reductions in pain intensity and disability level at two weeks, four weeks, and eight weeks as compared to those who received a GE program. The primary outcome measures included movement performance, pain intensity, and disability level. This chapter presents a summary of the results and discusses the results findings, conclusion, limitations, and recommendations for future research.

Results of Hypothesis Testing

Hypothesis 1

Participants with subacute and chronic LBP who receive eight weeks of SSEs would have a significantly greater improvement in movement performance as compared to those who receive eight weeks of GEs.

The ANOVA showed a significant interaction of group by time, indicating that there was a significant difference in movement performance between the

groups over the 8 weeks. The follow-up 2 x 2 ANOVAs with repeated measures showed that there was a significant between-group difference in the FMS scores between baseline (i.e., before intervention) and four weeks as well as between baseline and eight weeks, but there was no between-group difference between baseline and two weeks. Therefore, research hypothesis 1 was accepted for the outcome measure of movement performance. The results suggest that the SSE group made a greater improvement on the movement performance than the GE group at four weeks and eight weeks after initiating treatment. However, the difference was not observed in the first two weeks of the intervention.

Hypothesis 2

All participants with subacute and chronic LBP would have significantly improved movement performance at two, four, and eight weeks after initiating treatment.

The ANOVA showed a significant main effect of time, indicating that that all participants demonstrated differences in movement performance over the 8-week study period. Specifically, movement performance significantly improved for all participants from baseline to two weeks, from two weeks to four weeks, and from four weeks to eight weeks. Therefore, research hypothesis 2 was accepted for the outcome measure of movement performance. Therefore, all participants with subacute and chronic LBP improved on their performance on the FMS during the four-week intervention phase and continuously made improvements in the following four weeks when the participants performed their exercises unsupervised.

Hypothesis 3

Participants with subacute and chronic LBP who receive eight weeks of SSEs would have a significant reduction in pain intensity and disability level as compared to those who receive eight weeks of GEs.

The ANOVA showed no significant interaction of group by time for pain intensity and disability level between groups at each time point tested (i.e., two, four, and eight weeks). Therefore, research hypothesis 3 was rejected for the outcome measures of pain intensity and disability level and the null hypothesis was accepted. These results indicate that the SSEs and GEs had equivalent positive effects on the pain intensity and disability level at two, four, and eight weeks after initiating treatment in participants with subacute and chronic LBP.

Hypothesis 4

All participants with subacute and chronic LBP would have significantly reduced pain intensity and disability level at two, four, and eight weeks after initiating treatment.

The ANOVA showed a significant main effect of time, indicating that there was a significant difference in pain intensity and disability level over the 8-week study period. Specifically, all participants demonstrated significantly reduced pain and disability from baseline to two weeks, from two weeks to four weeks, but not from four weeks to eight weeks. Therefore, research hypothesis 4 was accepted for the outcome measures of pain intensity and disability level. Therefore, all participants with subacute and chronic LBP made the most significant

improvement in pain intensity and disability in the first four weeks.

Discussion of Findings

Movement Performance

The modified FMS scores showed that participants who received SSEs had made significantly greater improvement on movement performance than those who received a GE program. The results suggest that the exercises should be specific to and target spinal stabilizers for a better quality of movement in individuals with CLBP as compared to GEs, such as ROM and flexibility exercises for the low back. There is no published evidence regarding the effectiveness of the SSE program on movement performance in patients with LBP. However, this finding is in agreement with a previously published study by Bagherian et al. (2018), who demonstrated that the SSE program enhanced functional movement patterns on healthy, pain-free collegiate athletes, particularly for those with poor movement quality (i.e., baseline original FMS score ≤ 14). In contrast to the participants in the Bagherian et al. study, the participants in this dissertation study were those with CLBP. Although the participants in this study had low disability levels, the SSEs designed in this dissertation study were at a low level of difficulty and intensity as compared to those in the Bagherian et al. study, which included high-level exercises, such as back extension and sit-up. Considering the improvement made by the participants in the SSE group, it is speculated that the dosage and progression of the SSEs were appropriate for this patient population.

The results of this dissertation study support that SSEs were effective in enhancing the spinal stabilizers, thus improving movement performance. Deficits in the spinal stabilizers is considered to be the primary cause of spinal instability leading to LBP (Jeong, Sim, Kim, Hwang-Bo, & Nam, 2015). Specifically, the TrA and LM muscles are considered to play an essential role in lumbopelvic stabilization. Impairments in activation and coordination of the TrA and LM muscles have been identified in patients with CLBP and are believed to contribute to their movement incoordination (Cho et al., 2014; Hodges & Richardson, 1996; Panjabi, 2003; Silfies et al., 2009). Therefore, strength and proper activation of these muscles are necessary for stability of the lumbar spine in order to restore proper functional movements for this patient population, as indicated by the results of this dissertation study (Chang et al., 2015; Gardner-Morse & Stokes, 1998; Haladay, Denegar, Miller, & Challis, 2015; Hodges, Richardson, & Jull, 1996; Rostami et al., 2015; Shirey et al., 2012). Furthermore, the literature supports the use of SSEs for individuals with LBP for improving neuromuscular control and endurance, retraining and strengthening deep spinal muscles, reducing pain, and enhancing proprioception related to the dysfunction (Bliss & Teeple, 2005; Grenier & McGill, 2007; Panhale et al., 2016).

The SSE program used in this dissertation study was modeled after the SSE program designed by Hicks et al. (2005). Similarly, the SSEs in this study consisted of four categories, targeting the TrA, oblique abdominus, erector spinae and LM muscles. In addition, the exercise progression used in the Hicks

et al. study was adopted. However, the SSE exercise progression was modified because of low pain intensity and potentially a higher functional level in the CLBP population as compared to the acute and subacute LBP populations in the Hick et al. study. For example, not all participants started at the first level of each exercise on the first visit. All participants were instructed in the exercises at a level that they were able to perform without pain. In addition, the frequency and duration of the SSE program was modified so that each participant was asked to perform the SSE program at least five times per week. In this dissertation study, the first four weeks were supervised PT sessions and the last four weeks were unsupervised PT sessions, whereas the participants in the Hicks et al. study were asked to attend supervised PT sessions twice weekly for eight weeks and were asked to perform the exercises at home daily. Although the SSE program in this dissertation was modified, the modification seems to be necessary to have positive effects as shown in the modified FMS scores. The results of this study also suggest that four weeks of supervised SSEs followed with four weeks of unsupervised SSEs may be sufficient when the goal of rehabilitation is to achieve optimal movement patterns.

The FMS with a modified scoring system was used to quantify the quality of movement in this dissertation study. It was necessary to modify the scoring system because the study participants were symptomatic. In a pilot study conducted by the PI and his colleagues, a group of healthy participants (n = 22) performed the FMS tests and the average of their FMS scores was 16.2 ± 2.1

using either the original or modified scoring system because the healthy participants did not have pain during the FMS testing (Alkhathami, Alshehre, Wang-Price, & Brizzolara, 2019). It is apparent that the average modified FMS score of 10.8 ± 3.5 at baseline in the participants of this dissertation study was much lower than that of the asymptomatic individuals. Consequently, a cutoff score of 12.25 was established by performing a receiver operating characteristic (ROC) analysis (Sensitivity= 0.675, Specificity = 1.000, area under curve = 0.903, $p < 0.001$). The Ko et al. (2016) study also used the FMS to examine movement performance in patients with CLBP. As described in their article, Ko et al. (2016) followed the original FMS scoring system, which gave a score of 0 if a participant felt pain during any movement task. They reported a score of 10.95 in their participants with CLBP. Accordingly, when the original scoring system was used, the participants with CLBP should have a zero score because they were symptomatic. Therefore, it is questionable if the reported FMS scores were valid in the Ko et al. study.

In this dissertation study, the SSE group demonstrated significantly more improvement than the GE group in movement performance. At four weeks, the composite FMS score of the SSE group was 14.8 points as compared to 12.1 points for the GE group. In addition, at eight weeks, the FMS composite score of the SSE group was 15.7 points as compared to 13.2 points for the GE group. Further examination of each of seven test components at baseline, week 4 and week 8 (Table 5) revealed that the SSE group appeared to have more

improvement on the rotary stability test and the trunk stability push-up test (Appendix F) than the GE group. Not surprisingly, these two test components were designed specifically to assess an individual's spinal stability, which is consistent with the goal of the SSE program (Cook et al., 2014b). These findings further support SSEs for enhancing quality of functional movements by strengthen spinal stabilizers.

Moreover, one interesting finding is that the differences in movement performance between groups occurred after four weeks of intervention. This finding implies that at least four weeks of the SSE are needed to result in a differential effect. This is consistent with other studies which found that a four-week SSE program was effective for enhancing stability and functional capabilities and for reducing pain intensity in patients with CLBP (Inani & Selkar, 2013; Salavati et al., 2016). Salavati et al. (2016) hypothesized that a four-weak SSE program could improve neuromuscular control of the spinal column, and therefore improve inter-segmental spinal stability and help reduce LBP (Salavati et al., 2016). Moreover, SSEs have been suggested to be effective for improving pain intensity and disability level for patients with CLBP (Ferreira et al., 2006).

Table 5

Changes of the modified Functional Movement Screen scores of individual test component for the spinal stabilization exercise (SSE) group and the general exercise (GE) group.

		Deep Squat	Hurdle Step	In-Line Lunge	Shoulder Mobility	ASLR	Trunk Stability Bush-up	Rotary Stability
Week 4-Baseline	SSE	+ 0.4	+ 0.8	+ 0.55	+ 0.1	+ 0.8	+ 0.55	+ 0.75
	GE	+ 0.3	+ 0.1	+ 0.45	+ 0.25	+ 0.1	+ 0.25	+ 0.1
Week 8-Baseline	SSE	+ 0.6	+ 1.1	+ 0.8	+ 0.1	+ 0.7	+ 0.7	+ 0.85
	GE	+ 0.35	+ 0.7	+ 0.25	+ 0.2	+ 0.5	+ 0.05	+ 0.6

Note: ASLR = Active Straight-Leg-Raise

Pain Intensity

The results of the ANOVAs indicated that there were no significant differences in pain reduction between SSEs and GEs over eight weeks. The pain intensity (NPRS scores) at baseline for all participants in both treatment groups was 3.5, which represents minimal pain intensity. However, although the participants in this dissertation study reported minimal pain intensity at baseline, all participants demonstrated significant pain reduction from baseline to two weeks and from two weeks to four weeks, except from four weeks to eight weeks. However, the SSE group had a slight increase in pain intensity during the last four weeks of the intervention resulting both groups' NPRS scores to be similar at the end of eight weeks. The cause of this slight increase in pain is uncertain.

At eight weeks, the SSE group had a reduction in NPRS score of 1.4 points from baseline, and the GE group had a reduction in NPRS score of 1.6

points from baseline. Neither group demonstrated a clinically meaningful change in pain intensity that exceeded the MDC or MCID for the NPRS in individuals with LBP, which is 2 points (Childs, Piva, & Fritz, 2005). Although there was no difference in pain between groups, there were differences in the modified FMS scores between groups. For individuals with CLBP who have low levels of pain and disability, the NPRS may not be a sufficient outcome measure to examine treatment effects. Instead, a high functional level test, such as the FMS, may be required to detect different treatment effects.

Disability Level

Similar to the result of the NPRS scores, the results of ANOVAs indicated that there were no significant differences in disability reduction between the SSE program and the GE program over eight weeks. This result implies that both exercise interventions had an equivalent effect on functional improvement and disability reduction. The disability level at baseline for participants in both treatment groups was low (OSW score = 18.1 ± 9.1). Despite the participants in this dissertation study reporting minimal disability level at baseline, all participants demonstrated significant improvement in disability level, from baseline to two weeks and from two weeks to four weeks, but not from four weeks to eight weeks. However, neither group demonstrated a clinically meaningful change in their disability level that exceeded the MDC for the OSW in individuals with LBP, which is 10.5 points (Davidson & Keating, 2002). However, even though there were no significant differences between both groups, the

reduction (6.2 points) in OSW scores of the SSE group exceeded the MCID, which is 6 points, whereas the reduction (5.5 points) in OSW scores of the GE group did not (Fritz & Irrgang, 2001).

The minimal pain intensity and disability levels at baseline could be the reason for not finding significant differences between groups. However, the pain level was low enough that the participants could complete the FMS tests without obvious restrictions due to pain. In addition, the improvement in disability level was consistent with an improvement in movement performance as measured by the FMS. Given that all of the participants in this dissertation study had CLBP, we believe that these improvements are meaningful even though they are not clinically significant.

The results of this dissertation study are in agreement with the findings of a systematic review with a meta-analysis published by Smith et al. (2014) which showed that the SSEs have very minimal benefit in pain and disability level reduction in the short term (less than three months). However, this was not statistically significant when compared with other types of exercise for adults with non-specific LBP (Smith, Littlewood, & May, 2014). In contrast, Brizzolara's study (2018) showed that SSEs are beneficial in pain reduction and improve disability (Brizzolara, Wang-Price, Roddey, & Medley, 2018). In addition, SSEs were found to be more effective than GEs in decreasing pain and improving physical function in patients with LBP (Wang et al., 2012). Furthermore, the results of the Akhtar et al. (2017) study demonstrated that the effect of SSEs was greater than routine

exercises regarding reduction in pain in patients with chronic NSLBP (Akhtar et al., 2017). As discussed earlier, variations in the level of pain intensity and disability in the previous studies could be one of the causes of showing the disagreement in the results among studies.

Limitations of the Study

There were several limitations in this dissertation study. As discussed earlier, the participants in this dissertation study had mild pain intensity with an average of 3.5 on the NPRS. In addition, the participants in both groups of this study had an average disability level of 18.1 on the OSW, representing a minimal disability level. Therefore, the results of this study only can be generalized to those individuals with CLBP with low pain intensity and mild disability levels. However, participants with a moderate or moderate-to-high level of pain may not be able to complete or perform the FMS tests or SSE program. Furthermore, this study has been conducted on participants between 18 and 65 years old. Therefore, this study cannot be generalized for the population over 65 years old. The other limitation is that the participants were not restricted from other physical activities although participants were advised not to engage in any activity that may increase their LBP. However, the randomization procedure should have minimized this limitation. Lastly, medication use was not controlled in this dissertation study in order to reflect to the current clinical practice collected at baseline. However, at each follow-up visit, all participants were asked if they had taken any medication because of their low back pain.

Conclusion

The findings of this dissertation study suggest that SSEs are more effective in enhancing movement performance than GEs over a period of eight weeks in individuals with CLBP. In addition, all participants in both groups demonstrated a significant reduction in pain intensity and disability level while attending supervised PT sessions with the investigators for the first four weeks of the study. However, these significant improvements seemed to be diminished during the unsupervised PT sessions for the last four weeks when the participants stopped meeting regularly with the investigators. Moreover, this study demonstrated that supervised SSE sessions seemed to maximize the benefits of this treatment including improving the quality of movement and reducing the aberrant movement that are associated with CLBP. In addition, the modified FMS scoring system was found to be a useful tool for adults with LBP, allowing clinicians to quantify the quality of movement as well as identifying restrictions and limitations to movement patterns with minimal time and financial costs. Identification of such factors may allow therapists to address movement impairments in their plan of care. It is recommended that therapists emphasize the importance of exercise compliance in order to maintain the benefits achieved from the treatment program for the long term as well as to reduce the likelihood of future recurrences of LBP.

Recommendations for Future Research

In this dissertation study, all participants in the unsupervised phase did not attain clinical improvement in their pain intensity and disability level. Future studies should examine the effects of eight-week supervised treatments (e.g., SSEs) in order to achieve better outcomes and to maximize the benefits of the treatment. In addition, it is recommended that future studies should examine the effectiveness of SSEs on movement performance of individuals who have moderate and higher pain intensity of LBP and disability level. Furthermore, longer-term follow-ups are recommended for future studies to examine the effects of physical therapy interventions on movement performance on patients with CLBP.

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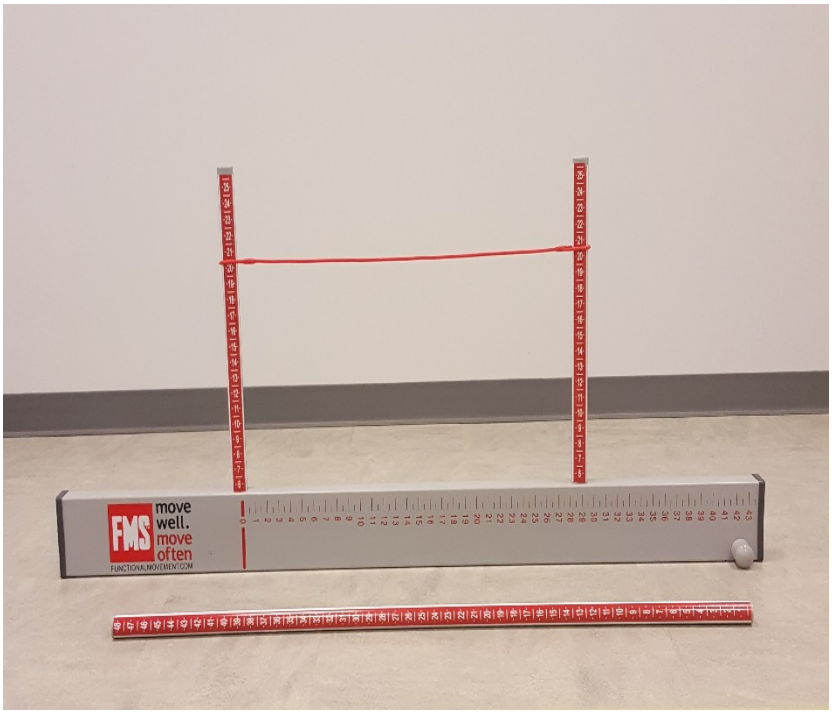
APPENDIX A

Functional Movement Screen™ Kit



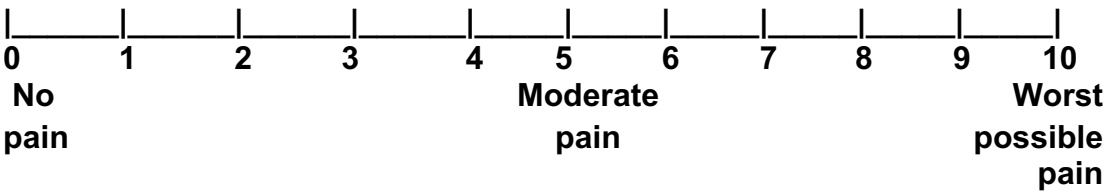
Functional Movement Screen™ Kit

APPENDIX B

Numeric Pain Rating Scale

ID#: _____

Date: _____



APPENDIX C

Modified Oswestry Low Back Pain Disability Questionnaire

ID#: _____

Date: _____

Modified Oswestry Low Back Pain Disability Questionnaire

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

Personal Care (Washing, Dressing, etc.)
☐ 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, wash with difficulty and 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 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 walking any distance.
☐ Pain prevents me walking more than 1 mile.
☐ Pain prevents me walking more than ½ mile.
☐ Pain prevents me walking more than ¼ mile.
☐ I can only walk using crutches or a cane.
☐ I am in bed most of the time and have to crawl to the toilet.

Sitting
☐ I can it in any chair as long as I like.
☐ I can only sit in my favorite chair as long as I like.
☐ Pain prevents me sitting more than 1 hour.
☐ Pain prevents me from sitting more than ½ hour.
☐ Pain prevents me from sitting more than 10 minutes.
☐ Pain prevents me from sitting at all.

Standing
☐ I can stand as long as I want without increased pain.
☐ I can stand as long as I want but increases my pain.
☐ Pain prevents me from standing for more than 1 hour.
☐ Pain prevents me from standing for more than ½ 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 pain medication, I sleep less than 6 hours.
☐ Even when I take pain medication, I sleep less than 4 hours.
☐ Even when I take pain 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, etc.).
☐ Pain prevents me from 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.
☐ Pain restricts travel over 2 hours.
☐ Pain restricts travel over 1 hour.
☐ Pain restricts my travel to short necessary journeys under ½ hour.
☐ Pain prevents all travel except for visits to the doctor/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 (ex. 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/homemaking chores.

Appendix D

Fear-Avoidance Beliefs Questionnaire (FABQ)

ID#: _____

Date: _____

Fear-Avoidance Beliefs Questionnaire (FABQ)
Waddell et al (1993) Pain, 52 (1993) 157 - 168

Here are some of the things which other patients have told us about their pain. For each statement please circle any number from 0 to 6 to say how much physical activities such as bending, lifting, walking or driving affect or would affect *your* back pain.

	Completely disagree			Unsure			Completely agree
1. My pain was caused by physical activity.	0	1	2	3	4	5	6
2. Physical activity makes my pain worse.	0	1	2	3	4	5	6
3. Physical activity might harm my back.	0	1	2	3	4	5	6
4. I should not do physical activities which (might) make my pain worse.	0	1	2	3	4	5	6
5. I cannot do physical activities which (might) make my pain worse.	0	1	2	3	4	5	6

The following statements are about how your normal work affects or would affect your back pain

	Completely disagree			Unsure			Completely agree
6. My pain was caused by my work or by an accident at work.	0	1	2	3	4	5	6
7. My work aggravated my pain.	0	1	2	3	4	5	6
8. I have a claim for compensation for my pain.	0	1	2	3	4	5	6
9. My work is too heavy for me.	0	1	2	3	4	5	6
10. My work makes or would make my pain worse.	0	1	2	3	4	5	6
11. My work might harm my back.	0	1	2	3	4	5	6
12. I should not do my normal work with my present pain.	0	1	2	3	4	5	6
13. I cannot do my normal work with my present pain.	0	1	2	3	4	5	6
14. I cannot do my normal work till my pain is treated.	0	1	2	3	4	5	6
15. I do not think that I will be back to my normal work within 3 months.	0	1	2	3	4	5	6
16. I do not think that I will ever be able to go back to that work.	0	1	2	3	4	5	6

Scoring
Scale 1: fear-avoidance beliefs about work – items 6, 7, 9, 10, 11, 12, 15.
Scale 2: fear-avoidance beliefs about physical activity – items 2, 3, 4, 5.

Source: Gordon Waddell, Mary Newton, Iain Henderson, Douglas Somerville and Chris J. Main, A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability, *Pain*, 52 (1993) 157 – 168, 166.

APPENDIX E

Patient-Reported Outcomes Measurement Information System (PROMIS-29)

PROMIS–29 Profile v2.0

Please respond to each question or statement by marking one box per row.

	Physical Function	**Without any difficulty**	**With a little difficulty**	**With some difficulty**	**With much difficulty**	**Unable to do**
PFA11 1	Are you able to do chores such as vacuuming or yard work?	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
PFA21 2	Are you able to go up and down stairs at a normal pace?	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
PFA23 3	Are you able to go for a walk of at least 15 minutes?	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
PFA53 4	Are you able to run errands and shop?	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
	Anxiety **In the past 7 days…**	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
EDANX01 5	I felt fearful	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDANX40 6	I found it hard to focus on anything other than my anxiety	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDANX41 7	My worries overwhelmed me	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDANX53 8	I felt uneasy	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Depression **In the past 7 days...**	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
EDDEP04 9	I felt worthless	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDDEP06 10	I felt helpless	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDDEP29 11	I felt depressed	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
EDDEP41 12	I felt hopeless	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Fatigue **During the past 7 days…**	**Not at all**	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
HI7 13	I feel fatigued	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
AN3 14	I have trouble starting things because I am tired	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

PROMIS–29 Profile v2.0

	Fatigue **In the past 7 days…**	**Not at all**	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
FATEXP41 15	How run-down did you feel on average? ...	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
FATEXP40 16	How fatigued were you on average?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Sleep Disturbance **In the past 7 days…**	**Very poor**	**Poor**	**Fair**	**Good**	**Very good**
Sleep109 17	My sleep quality was.....	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
	In the past 7 days…	**Not at all**	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
Sleep116 18	My sleep was refreshing.....	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
Sleep20 19	I had a problem with my sleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Sleep44 20	I had difficulty falling asleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Ability to Participate in Social Roles and Activities	**Never**	**Rarely**	**Sometimes**	**Usually**	**Always**
SRPPER11_CaPS 21	I have trouble doing all of my regular leisure activities with others.....	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
SRPPER18_CaPS 22	I have trouble doing all of the family activities that I want to do	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
SRPPER23_CaPS 23	I have trouble doing all of my usual work (include work at home)	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
SRPPER46_CaPS 24	I have trouble doing all of the activities with friends that I want to do	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
	Pain Interference **In the past 7 days…**	**Not at all**	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
PAININ9 25	How much did pain interfere with your day to day activities?.....	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PAININ22 26	How much did pain interfere with work around the home?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PAININ31 27	How much did pain interfere with your ability to participate in social activities?.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PAININ34 28	How much did pain interfere with your household chores?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

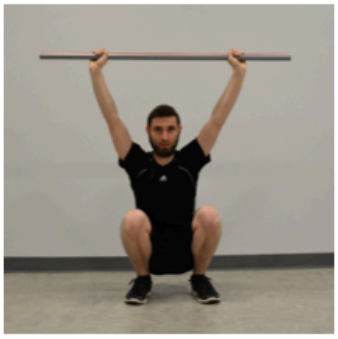
PROMIS–29 Profile v2.0

Pain Intensity
In the past 7 days…

Global07 29	How would you rate your pain on average?.....	☐ 0 **No pain**	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	☐ 10 **Worst imaginable pain**

Appendix F

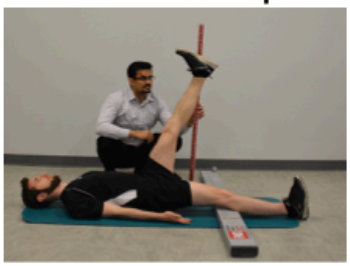
Functional Movement Screen™



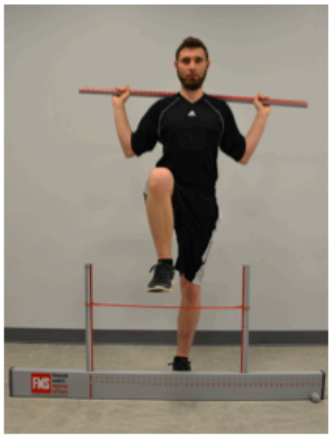
Deep Squat
(Frontal View)

Deep Squat
(Sagittal View)

Trunk Push-Up

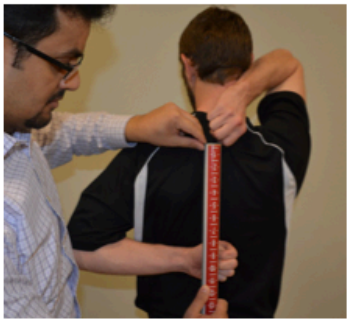


Active Straight Leg Raise

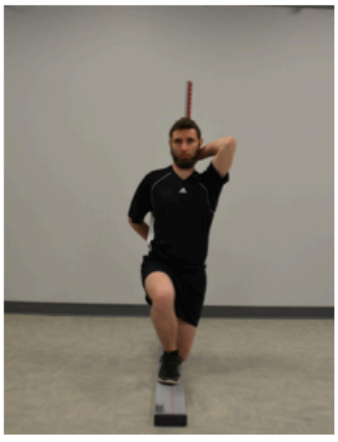


Hurdle Step
(Frontal View)

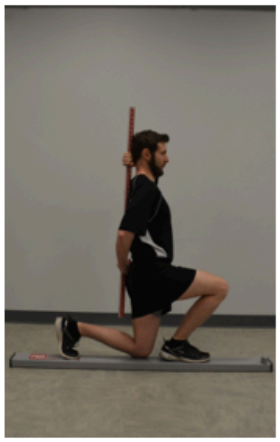
Hurdle Step
(Sagittal View)



Shoulder Mobility



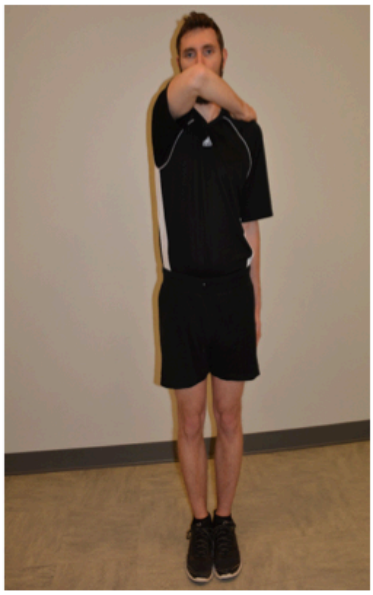
In-line lunge
(Frontal View)



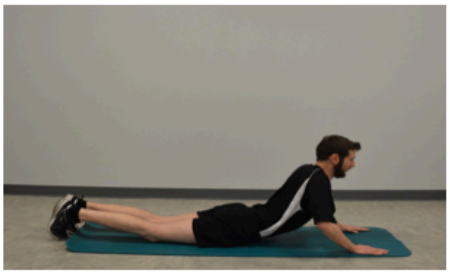
In-line lunge
(Sagittal View)

Rotary Stability (Extended Position)

Rotary Stability (Flexed Position)



Impingement-clearing test



Press-up clearing test

Posterior-rocking clearing test

APPENDIX G

Intake Form

ID#: _____

Intake Form

Name: _____ Sex: _____
Age:_____

Ht: _____ Wt: _____ Occupation:_____ Hand Dominance: _____

Medical History: *please check if you have ever had*:

- □ Arthritis
- □ Broken bones/fractures of legs
- □ Osteoporosis
- □ Blood disorders
- □ Circulation/vascular problems
- □ Heart problems
- □ High blood pressure disease
- □ Kidney problems
- □ Diabetes/high blood sugar
- □ Currently pregnant
- □ Stroke
- □ Multiple Sclerosis
- □ Muscular Dystrophy
- □ Parkinson Disease
- □ Seizures/epilepsy
- □ Thyroid problems
- □ Cancer
- □ Repeated Infections
- □ Low blood sugar/hypoglycemia
- □ Taking anti-coagulant (blood thinner)
- □ Skin diseases
- □ Depression
- □ Head Injury
- □ Ulcers/stomach problems
- □ Lung problems
- □ Infectious
- □ Other

Others_____

Low Back Pain History

1. Have you ever had low back pain in the past? □Yes □No

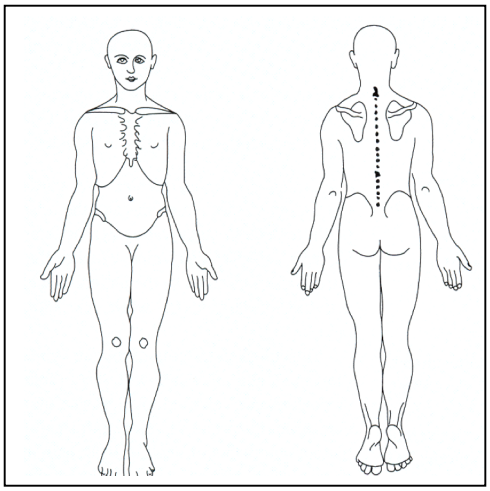
Is yes, please describe frequency and duration of the episode:

_____

_____

Please answer the following question if you currently have low back pain:

2. Where is the exact location of you low back pain?
Please mark on the following body diagrams:



3. How long have you had low back pain?

_____years _____months _____weeks

4. Onset of low back pain: Gradual or Trauma (circle one)

If there is a trauma, please describe:

_____

_____

_____

5. Please describe your low back pain by circling all that apply:

Stiffness Shooting Throbbing Numbness Tingling

Deep ache Sharp Superficial Deep Other:

_____

6. On a scale of 0 to 10, 0 being no pain, 10 being unbearable pain, please rate your pain level

Now _____

Worst in the past week _____

Least in the past week _____

7. Please list anything that makes your low back pain WORSE

_____

8. Please list anything that makes your low back pain BETTER

_____

9. Describe any previous treatment you have received for your low back pain:

_____

_____

10. Have you ever had low back surgery? □Yes □No

If yes, please describe and include dates:

_____

Month/Year_____

_____

Month/Year_____

11. Please list all prescription medications you are currently taking:

_____

_____

12. Please list any nonprescription medications you are taking:

_____

_____

Activity Level:

Do you currently exercise? □ Yes □ No:

If yes, how many days per week?

_____

On average, how many minutes per day?

_____

Please describe the types of exercise that you perform.

_____

_____

Describe your daily activity.

□ Sedentary (spend most of the day sitting)

□ Lightly Active (spend a good part of the day on your feet)

□ Active (spend a good part of the day doing some physical activity)

□ Very Active (spend most of the day doing heavy physical activity)

APPENDIX H

Neurological Screening Sheet

ID#: _____

Date: _____

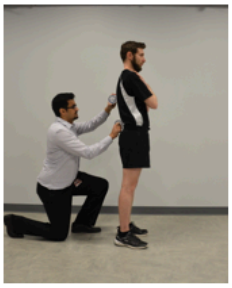
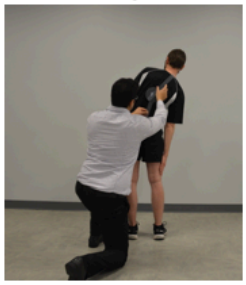
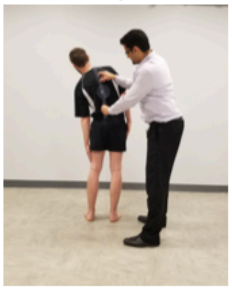
Neurological Screen				Note
1	Dermatomes (L1-S2):	Intact	Impaired	
2	Myotomes (L1-S2):	Intact	Impaired	
Reflexes				
3	Knee jerk (L2-4):	Intact	Impaired	
4	Post. tibialis (L4):	Intact	Impaired	
5	Peroneus (L5-S1):	Intact	Impaired	
6	Ankle jerk (S1-2):	Intact	Impaired	
7	Babinski:	Negative	Positive	
8	Clonus:	Negative	Positive	

APPENDIX I

Physical Examination

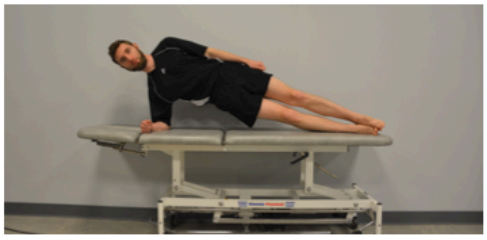
1- Active range of motion (ROM) Measurement of the Lumbar Spine

Flexion ROM **Extension ROM** **Right side-bending ROM** **Left side-bending ROM**

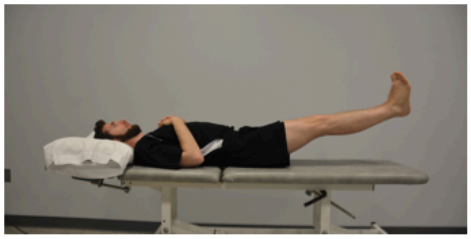
2- Straight Leg Raise (SLR) ROM

3- Side Support Test

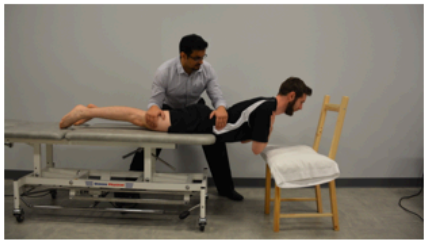


4- Hip Extension

5- Active Bilateral SLR Test



6- Extensor Endurance Test



7- Lumbar Segmental Testing for Mobility

9- Prone Instability Test

APPENDIX J:

Functional Movement Screen Test Scoring Sheet

Functional Movement Screen Test Score (Order:_____)

ID#: _____

Date: _____

Sport/Activity Reference: _____

Hand dominance: RIGHT LEFT Hand measure_____

Leg dominance: RIGHT LEFT Leg measure_____ NPRS: _____/10

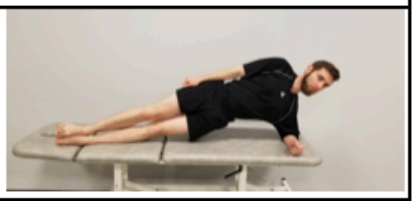
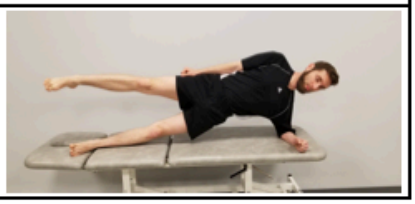
TEST	RAW SCORE			ORIGINAL SCORE	LBP LEVEL	MODIFIED SCORE		COMMENTS		
Deep squat					/10					
Hurdle step R					/10					
Hurdle step L					/10					
In-line lunge R					/10					
In-line lunge L					/10					
Sh. mobility R					/10					
Sh. mobility L					/10					
Active Imp. R (clearing test)	-ve			+ve	/10	-ve	+ve			
Active Imp. L (clearing test)	-ve			+ve	/10	-ve	+ve			
ASLR R					/10					
ASLR L					/10					
Trunk push-up					/10					
Extension (clearing test)	-ve			+ve	/10	-ve	+ve			
Rot. stability R					/10					
Rot. stability L					/10					
Passive flexion (clearing test)	-ve			+ve	/10	-ve	+ve			
TOTAL										

APPENDIX K

Spinal Stabilization Exercises with Progression Criteria (Adapted from Hicks et al., 2005)

Each participant performed one exercise from each of the following 4 categories: abdominal bracing, quadruped, prone plank, and side plank exercises.

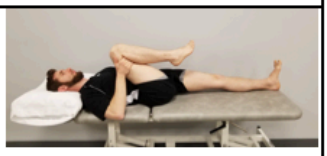
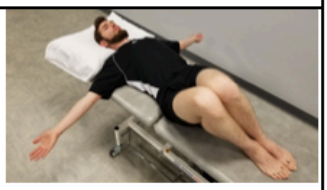
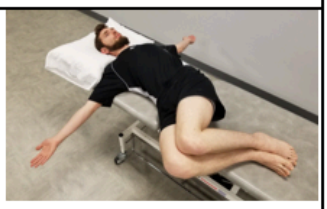
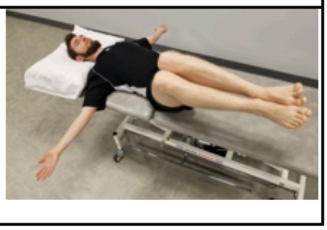
Exercise	Progression (A → B → C)	Duration	Figure
1. Abdominal Bracing Exercises	A. Bracing with heel slides	15 repetitions per leg with 4 seconds hold	
	B. Bracing with leg lifts	15 repetitions per leg with 4 seconds hold	
	C. Bracing with bridging	30 repetitions with 8 seconds hold	
2. Quadruped Exercises	A. Quadruped arm lifts with bracing	15 repetitions per arm with 8 seconds hold	
	B. Quadruped leg lifts with bracing	15 repetitions per leg with 8 seconds hold	
	C. Quadruped alternate arm and leg lifts with bracing	15 repetitions per arm and leg with 8 seconds hold	

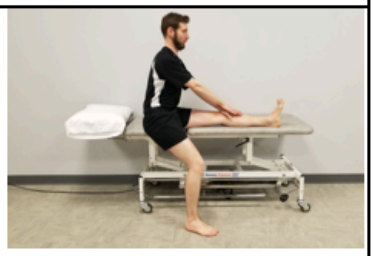
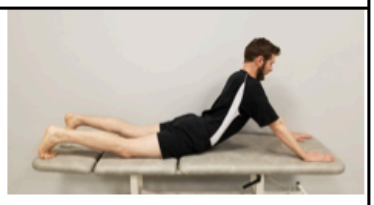
3. Prone Plank Exercises	A. Knee plank	30 repetitions with 8 seconds hold	
	B. Prone plank	30 repetitions with 8 seconds hold	
	C. Prone plank with leg lifts	15 repetitions per leg with 8 seconds hold	
4. Side Plank Exercises	A. Side plank with knees flexed	15 repetitions for each side with 8 seconds hold	
	B. Side plank with knees extended	15 repetitions for each side with 8 seconds hold	
	C. Side plank with leg lifts	15 repetitions for each side with 8 seconds hold	

APPENDIX L

General Exercise Program with Criteria of Progression

Each participant performed one exercise from each of the following 4 categories: knee to chest exercise, lower trunk rotation, prone press-ups, and Hamstring Stretch exercises.

Exercise	Progression (A → B → C)	Duration	Figure
1. Knee to Chest Exercise	A. Single knee to chest exercise with pain free	10 repetitions per leg with 10 seconds hold	
	B. Single knee to chest exercise to end range	10 repetitions per leg with 10 seconds hold	
	C. Double knees to chest exercise	20 repetitions with 10 seconds hold	
2. Lower Trunk Rotation	A. Lower trunk rotation with pain free	10 repetitions for each side with 10 seconds hold	
	B. Lower trunk rotation to end range	10 repetitions for each side with 10 seconds hold	
	C. Lower trunk rotation with legs lift	10 repetitions for each side with 10 seconds hold	

3. Hamstring Stretch	A. Hamstring stretch with pain free	10 repetitions per leg with 10 seconds hold	
	B. Hamstring stretch with pain free to end range	10 repetitions per leg with 10 seconds hold	
	C. Seated Hamstring Stretch	10 repetitions per leg with 10 seconds hold	
4. Prone Press-Ups	A. Prone on elbow	20 repetitions with 10 seconds hold	
	B. Prone press-ups with pain free	20 repetitions with 10 seconds hold	
	C. Prone press-ups to end range	20 repetitions with 10 seconds hold	

APPENDIX M

Compliance log

Compliance log (SSE)

- Please put "✓" or "x" in each box if you complete the assigned exercise without a rest break and with proper form.
- Please do the assigned exercises at least 5 times a week for each week.

	Date	1. Abdominal Bracing Exercises			2. Quadruped Exercises			3. Prone Plank Exercises			4. Side Plank Exercises			Initials	Comments
		1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C		
Week 1															
Day 1															
Day 2															
Day 3															
Day 4															
Day 5															
Day 6															
Day 7															
Week 2															
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Day 4															
Day 5															
Day 6															
Day 7															
Week 3															
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Day 5															
Day 6															
Day 7															
Week 4															
Day 1															
Day 2															
Day 3															
Day 4															
Day 5															
Day 6															
Day 7															

	Date	1. Abdominal Bracing Exercises			2. Quadruped Exercises			3. Prone Plank Exercises			4. Side Plank Exercises			Initials	Comments
		1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C		
Week 5															
Day 1															
Day 2															
Day 3															
Day 4															
Day 5															
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Day 6															
Day 7															
Week 8															
Day 1															
Day 2															
Day 3															
Day 4															
Day 5															
Day 6															
Day 7															

Compliance log (GE)

- Please put "✓" or "x" in each box if you complete the assigned exercise for 10 times.
- Please do the assigned exercises at least 5 times a week for each week.

	Date	1. Knee to Chest Exercise			2. Lower Trunk Rotation			3. Hamstring Stretch			4. Prone Press-Ups			Initials	Comments
		1 A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C		
Week 1															
Day 1															
Day 2															
Day 3															
Day 4															
Day 5															
Day 6															
Day 7															
Week 2															
Day 1															
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Day 6															
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Week 4															
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Day 2															
Day 3															
Day 4															
Day 5															
Day 6															
Day 7															

	Date	1. Knee to Chest Exercise			2. Lower Trunk Rotation			3. Hamstring Stretch			4. Prone Press-Ups			Initials	Comments
		1 A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C		
Week 5															
Day 1															
Day 2															
Day 3															
Day 4															
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