EFFECTIVENESS OF SPINAL STABILIZATION EXERCISES FOR LOW BACK PAIN IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS

A DISSERTATION

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Karina Zapata entitled "Effectiveness of Spinal Stabilization Exercises for Low Back Pain in Adolescents with Idiopathic Scoliosis." I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Physical Therapy.

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DEDICATION

To my other half, José René Zapata:
I really did this to find you.

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ABSTRACT

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EFFECTIVENESS OF SPINAL STABILIZATION EXERCISES FOR LOW BACK PAIN IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS

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Background: The purpose of this study was to investigate the effectiveness of spinal stabilization exercises in reducing pain intensity and disability and improving disability, quality-of-life (QOL), back muscle endurance, and perceived changes in participants with low back pain (LBP) and adolescent idiopathic scoliosis (AIS).

Methods: Participants were randomized into either a supervised PT group or unsupervised home exercise program (HEP) group. Thirty participants (15 in each group) completed the study. The supervised group received weekly supervised PT for 8 weeks. The unsupervised group received a one-time treatment and an 8-week HEP on DVD. Both groups received the same standardized spinal stabilization exercise program. Exercise progression was determined by the treating PTs for the supervised group and by the participants/caregivers for the unsupervised group. The following outcome measures were collected before and after 8 weeks: the Numeric Pain Rating Scale (NPRS) for pain intensity, the Revised Oswestry Back Pain Disability Questionnaire (OSW) for disability, the Scoliosis Research Society-22 Health-Related Quality-of-Life

Questionnaire (SRS-22) for QOL, the prone-double-leg-raise (PDLR) test for back muscle endurance, and the Global Rating of Change (GROC) for participants' perceived changes. Four 2X2 ANOVAs with repeated measures were used to analyze the NPRS, OSW, SRS-22, and PDLR data. A Mann-Whitney U test was used to analyze the GROC scores.

Results: The ANOVA results revealed a significant interaction for the NPRS (p = .01), but not for the PDLS, OSW, and SRS-22 scores. Further, post-hoc analysis revealed significant between-group and within-group differences in the NPRS (p < .01), showing that the supervised group had significantly greater reductions in pain intensity than the unsupervised group. The ANOVA results also showed that all participants, regardless of group, improved in all outcome measures after 8 weeks (p < .001). Both groups had improved GROC scores after 8 weeks of intervention, but no significant difference was found between groups.

Conclusions: This study indicates that supervised PT is superior to an unsupervised HEP in reducing pain intensity in AIS and LBP. Spinal stabilization exercises may provide clinicians with an evidence-based treatment option for adolescents with idiopathic scoliosis with LBP.

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CHAPTER I

INTRODUCTION

Idiopathic scoliosis (IS) is a structural curve of the spine that has an undetermined cause (Weinstein, Dolan, Cheng, Danielsson, & Morcuende, 2008). Adolescent Idiopathic Scoliosis (AIS) is the most common type of scoliosis and develops in adolescents before skeletal maturity ("Scoliosis," 2008, p. 265). Adolescent Idiopathic Scoliosis is diagnosed only after other causes of scoliosis have been ruled out (Weinstein et al., 2008). One to three percent of the population reportedly has AIS (Weinstein et al., 2008).

The latest evidence suggests that the majority of adolescents with idiopathic scoliosis (IS) develop low back pain (LBP). Sato et al. (2011) assessed a large number of adolescents (*n* = 43,630), revealing significantly more back pain in adolescents with IS compared to adolescents without IS (controls). Twenty-eight percent of adolescents with IS reported currently having back pain compared to 12% of controls. Furthermore, adolescents with IS reported a 59% lifetime prevalence of back pain compared to 33% of controls. The scoliosis group also encountered more severe pain of longer duration with more frequent recurrences compared to controls. In addition, authors of a multi-center prospective study of 1,433 adolescents with IS found that 78% of patients reported back pain before posterior spinal fusion (Landman, Oswald, Sanders, Diab, & Members of the

Spinal Deformity Study Group, 2011). Although back pain was reduced to 64% at 1 and 2 years post-operatively, the use of analgesics for back pain remained at almost 30% (Landman et al., 2011). In addition to increased health care utilization, adolescents with recurrent back pain are absent from school more often, are more limited in participating in physical activities, and have a reduced quality-of-life (QOL) (Jones, Stratton, Reilly, & Unnithan, 2004).

Researchers also have examined the relationship between physical fitness, physical activity, and back pain in 9,413 adolescents (Andersen, Wedderkopp, & Leboeuf-Yde, 2006). Physical fitness measures included vertical jump height, back extensor endurance, sit-and-reach test, and maximal oxygen uptake. These authors found that the presence of back pain was associated with low isometric muscle endurance of the back extensors, and that the absence of back pain was associated with high isometric muscle endurance of the back extensors. No other physical fitness measures or self-reported physical activity factors were associated with LBP. Although causal statements cannot be made about poor muscle endurance and LBP, this association suggests that a treatment focusing on back muscle endurance may be beneficial for adolescents with LBP.

A systematic review by Jeffries, Milanese, and Grimmer-Somers (2007) reported a high prevalence of LBP during the transition from adolescence to adulthood, suggesting a relationship between adolescent LBP and adult LBP. In addition, Jones, Stratton, Reilly, and Unnithan (2007) found that an individual with a previous history of

LBP was at risk of developing LBP in the future. Several risk factors have been associated with a future episode of LBP, including spine asymmetry, lumbar spine extension endurance, high levels of physical activity, part-time work, and psychosocial difficulties (Hill & Keating, 2010). Therefore, researchers recommended that properly treating LBP during adolescence may prevent recurrent episodes into adulthood (Hestbaek, Leboeauf-Yde, Kyvik, & Manniche, 2006).

Minimal research addresses physical therapy (PT) interventions for adults who have scoliosis with LBP. Exercises have been mentioned, but no specific interventions have been described. Rather, the focus in research has been on surgical and more invasive treatment options (Aebi, 2005). Since degeneration at the spine typically accompanies adult scoliosis (Aebi, 2005), PT interventions for adults with scoliosis may not be appropriate for adolescents with IS. No published studies have investigated the effectiveness of PT interventions for patients with AIS with LBP.

Currently, two common PT practices are used for managing adolescents with IS who have LBP: (a) supervised PT and (b) a one-time treatment with no follow-up. No studies have examined which of these two approaches is superior. Spinal stabilization exercises are routinely included regardless of the type of PT practice (i.e. supervised PT or one-time treatment). Spinal stabilization exercises designed to activate the deep abdominal and back extensor muscles have been shown to prevent recurrent episodes of LBP in the adult population (Cairns, Foster, & Wright, 2006; Hicks, Fritz, Delitto, & McGill; Hides & Jull, 2001). Authors of a long-term follow-up randomized control trial

revealed that adult patients were more than two times less likely to have LBP 3 years after spinal stabilization exercises compared to a control group who did not receive spinal stabilization exercises (Hides, Jull, & Richardson, 2001). Based on these findings, a standardized spinal stabilization program has been recommended for adults with LBP (Hicks et al., 2005). However, spinal stabilization exercises for LBP in adolescents with IS may not have the same effect on this patient population.

Statement of the Problem

Although LBP is prevalent in AIS, no studies have evaluated the effectiveness of the most common PT intervention, spinal stabilization exercises, for managing LBP in this population. Spinal stabilization exercises may be of particular importance in adolescents with IS due to possible reduced spinal stability from structural deformity. While spinal stabilization exercises are effective in treating adults who have LBP, we did not know if spinal stabilization exercises were effective in AIS. Given the high prevalence of LBP in AIS and limited evidence of conservative interventions, exploring the effectiveness of spinal stabilization exercises was warranted.

Purpose of the Study

The primary purpose of the study was to investigate the effectiveness of spinal stabilization exercises in participants with AIS and LBP. Specifically, the purpose was to investigate whether or not 8 weeks of weekly supervised PT compared to 8 weeks of an unsupervised home exercise program (HEP), would reduce pain intensity and disability and improve QOL and back muscle endurance. Participants' overall perceived changes

were also examined after 8 weeks of treatment. Spinal stabilization exercises are commonly provided for LBP in AIS, but their effectiveness is unknown. This study also provides information regarding the optimum frequency of visits for patients with AIS and LBP.

Research Questions

The following research questions were addressed in this study:

1. Would there be differences in pain intensity, disability, QOL, and back muscle endurance between participants with AIS and LBP who receive 8 weeks of weekly supervised PT compared to those who receive 8 weeks of an unsupervised HEP?
2. Would there be improved pain intensity, disability, QOL, and back muscle endurance in participants with AIS and LBP, regardless of group, after 8 weeks of intervention?
3. Would there be a difference in perceived changes between participants with AIS and LBP who receive 8 weeks of weekly supervised PT compared to those who receive 8 weeks of an unsupervised HEP?

Hypotheses

Research Hypotheses

The hypotheses of the study were as follows:

1. Participants with AIS and LBP who receive 8 weeks of weekly supervised PT would have significantly improved pain intensity, disability, QOL, and back muscle endurance following the intervention compared to those who receive 8 weeks of an unsupervised HEP.

2. Participants with AIS and LBP, regardless of group, would have significantly improved pain intensity, disability, QOL, and back muscle endurance after 8 weeks of intervention.
3. Participants with AIS and LBP who receive 8 weeks of weekly supervised PT would demonstrate significantly improved perceived changes compared to those who receive 8 weeks of an unsupervised HEP.

Null Hypotheses

The null hypotheses of this study were as follows:

1. There would be no differences in pain intensity, disability, QOL, and back muscle endurance following the intervention between participants with AIS and LBP who receive 8 weeks of weekly supervised PT and those who receive 8 weeks of an unsupervised HEP.
2. Participants with AIS and LBP, regardless of group, would demonstrate no improved pain intensity, disability, QOL, and back muscle endurance after 8 weeks of intervention.
3. There would be no significant differences in perceived changes between participants with AIS and LBP who receive 8 weeks of weekly supervised PT and those who receive 8 weeks of an unsupervised HEP.

Operational Definitions

The definitions used for this study included the following:

- Spinal stabilization exercises: Spinal stabilization exercises are a series of exercises designed to target the spinal stabilizers, such as the transversus abdominis, erector spinae/multifidus, quadratus lumborum, and oblique abdominals (Hicks et al., 2005).
- Exercise compliance: The number of exercise sessions completed out of 28 possible exercise sessions.
- Low back pain intensity: LBP intensity is determined using a subjective report of the participant's perceived pain localized to the lumbar spine on the Numeric Pain Rating Scale (NPRS).
- Disability: The level of disability associated with LBP was determined using the Revised Oswestry Back Pain Disability Questionnaire (OSW).
- Quality-of-life: QOL is a subjective report of the participant's perceived physical and psychosocial health associated with the participant's LBP and AIS as measured by the Scoliosis Research Society-22 Health-Related QOL Questionnaire (SRS-22).
- Back muscle endurance: Back muscle endurance is determined by the participant's performance of the prone-double-leg-raise test.
- Overall perceived change: Overall perceived change is a subjective report of perceived change of LBP due to PT treatment as measured by the GROC.
- Scoliosis: A lateral curvature of the spine measuring at least 10° on a radiograph using the Cobb method (Weinstein et al., 2008).

- Adolescent Idiopathic Scoliosis: Scoliosis of unknown origin with age of onset from 10 to 16 (Weinstein et al., 2008).

Assumptions

Assumptions of this study included the following:

- Participants would rate their LBP intensity that best reflected their perception of LBP.
- Participants would give maximal effort with the back muscle endurance test.
- Participants would understand the OSW and SRS-22 questionnaires and reply honestly.
- Participants and caregivers would report the home exercise diary honestly.

Limitations

Potential limitations of the study included the following:

- A placebo effect of treatment attendance may have occurred in the supervised PT group. However, we minimized this effect by providing a DVD to the unsupervised HEP group.
- Participants with larger scoliotic curves may have demonstrated worse LBP. However, we randomized the participants into two groups and limited the inclusion criteria to curves that were not severe enough (10° to 45°) to qualify for surgery.
- Participants with different scoliotic curve types may have demonstrated differences in LBP severity. However, we randomized the participants into two groups and examined subgroups if differences were found.

- Participants may have asked their caregivers for help in interpreting the OSW or SRS-22, which may have biased results of the OSW or SRS-22. However, we chose the OSW since this revised version replaced the question about sex life and was considered reliable and sensitive to change in adults with LBP. Also, the SRS-22 had been validated in the adolescent population.
- Participants treated at Texas Scottish Rite Hospital for Children (TSRHC) may not have been representative of adolescents with IS with LBP which may limit the generalizability of the study. However, TSRHC treats all children with orthopedic conditions throughout the state of Texas regardless of families' ability to pay.

Significance of the Study

Since the majority of adolescents with IS develop LBP (Sato et al., 2011), LBP is a major public health concern. Adolescents with back pain have increased health care utilization, use of analgesics, school absences, and physical activity limitations, as well as a reduced QOL (Jones et al., 2004). Properly treating LBP during adolescence may reduce health care costs, promote full participation in school, and enable physical activity.

Should the outcomes of this study favor 8 weeks of weekly supervised PT, then the appropriate duration and frequency of PT could be recommended. If no differences in outcomes are found between the two PT approaches (i.e. 8 weeks of weekly supervised PT versus an unsupervised HEP), the optimal choice of treatment would be 8 weeks of an unsupervised HEP as part of a one-time visit, since it is more cost-effective

and less burdensome for the family. In addition, the results of the study may contribute to the body of literature in an attempt to eventually develop clinical guidelines for treating LBP in the AIS population.

CHAPTER II

REVIEW OF THE LITERATURE

The primary purpose of the study was to investigate the effectiveness of an unsupervised home exercise program (HEP) in participants with adolescent idiopathic scoliosis (AIS) who had low back pain (LBP). Specifically, the purpose was to investigate whether or not 8 weeks of weekly supervised physical therapy (PT) compared to 8 weeks of an unsupervised HEP, would have superior reductions in pain intensity and disability and improvements in quality-of-life (QOL) and back muscle endurance. The main literature related to AIS is explored first, including clinical features and treatment outcomes. Next, an overview of back pain is provided with a focus on the pediatric population. Instruments used to measure back pain are discussed before outcome measures related to the low back. Finally, various PT treatments related to back pain in adolescents are described. Due to the lack of research regarding spinal stabilization exercises for LBP in AIS, a further contribution to the body of literature is needed. Although spinal stabilization exercises are considered common practice in PT, the effectiveness of this treatment has not been validated in adolescents.

Adolescent Idiopathic Scoliosis (AIS)

Scoliosis

Scoliosis is a three-dimensional deformity in with a lateral and rotated curvature of the spine measuring at least 10° on an x-ray (Weinstein et al., 2008). Scoliosis is observed clinically by the following signs: uneven shoulders, pelvis, or waistline, a prominent scapula or thorax, or trunk lean. The Adams forward bending test is frequently used in school screenings or in primary care physician offices to screen for scoliosis ("Scoliosis," 2008, pp. 269-270). Standing behind the patient, the examiner asks an individual to bend forward at the hips while keeping the knees straight until the spine is horizontal to the floor. The examiner evaluates whether one side of the spine appears higher at any level of the spine. If an inequality exists, the examiner assesses the amount of trunk rotation noted during forward bending, usually with a scoliometer. The examiner places the scoliometer at the apex of the noted rotational deformity perpendicular to the long axis of the body. The examiner refers an individual to a medical doctor when the angle of trunk rotation measures at least seven degrees ("Scoliosis," 2008, p. 270).

Scoliosis is most often classified as idiopathic, congenital, or neuromuscular. Subtypes of idiopathic scoliosis (IS) include infantile (age of onset 0 to 2), juvenile (age of onset 3 to 9), and AIS (age of onset 10 to 16) ("Scoliosis," 2008, p. 265; Weinstein et al., 2008). AIS is the most common type of scoliosis affecting one to three percent of children (Weinstein et al., 2008). The majority of curves do not progress enough to

require serious interventions such as bracing or surgery, as the prevalence of curves measuring greater than 20° is low, 0.3 to 0.5%. However, as the curve magnitude increases, girls are affected more profoundly than boys, requiring intervention at a ratio of 7:1 ("Scoliosis," 2008, p. 266). AIS develops during puberty in children from 10 years old until skeletal maturity is achieved. Despite extensive research about AIS, its cause remains unknown with numerous factors likely involved, including central neurologic dysfunction, connective tissue abnormalities, and genetic factors (Weinstein et al., 2008).

Scoliotic curves can be classified in various ways. Curves are generally described by the anatomic location of their curve pattern, the main ones being thoracic, thoracolumbar, lumbar, or double (thoracic and lumbar) curves (Weinsten, 1999). The King classification system identifies five curve types of IS, considering the location of the curve apex and curve flexibility which is determined by bending radiographs. A bending radiograph is obtained from an anterior-to-posterior view with the patient supine and actively bending maximally to both sides. In 1997, Lenke introduced a more complex classification with 42 IS curve types ("Scoliosis," 2008, pp. 289-290). Although the Lenke classification system is more complex, it is popular among surgeons because it helps determine which vertebral levels should be included in a surgical fusion ("Scoliosis," 2008, p. 290).

Curve progression is most affected by skeletal and sexual immaturity, as indicated by age at diagnosis, bone age (Risser sign and triradiate cartilage status),

menarche, and peak growth (Sanders et al., 2006). The Risser sign is a radiographic measurement taken from a routine scoliosis radiograph ("Scoliosis," 2008, p. 267). The Risser grading system is based on the ossification of the iliac apophysis, which is divided into four quadrants. A child's' skeletal maturity is rated on a scale of 0 (no ossification) to 5 (fused ossified apophysis), which correlates with remaining spinal growth ("Scoliosis," 2008, p. 267). Patients who are Risser 0 and 1 are growing rapidly and at greatest risk for curve progression ("Scoliosis," 2008, p. 268). The triradiate cartilage closure is another radiographic index of maturity and typically closes before Risser 1 and menarche ("Scoliosis," 2008, p. 268). The triradiate cartilage refers to the Y-shaped growth plate that separates the ilium, ischium, and pubis until ossification ("Lower Extremity Injuries," 2008, pp. 2573-2574).

The Cobb method is used to measure curve magnitude and to monitor curve progression in the clinic. The Cobb angle is determined on radiograph by measuring the angle formed at the intersection of two perpendicular lines drawn at the end-vertebrae. The end-vertebrae, or top and bottom of the curve, have the greatest amount of tilt. To account for measurement error, a curve must increase at least five degrees before it is considered a true change and to have progressed (Weinstein et al., 2008).

The standard medical management for AIS in the United States includes observation, bracing, and surgery. Observation is indicated in curves measuring less than 25° if patients are skeletally immature, and in curves less than 45° if patients have achieved skeletal maturity. Bracing is recommended in curves ranging from 25° to 40°

among patients who are still growing with the goal of preventing curve progression and avoiding surgery. Surgery is indicated in curves greater than 45° with the goal to correct the curve. In other countries (mostly European countries), physical therapy (PT) consisting of scoliosis-specific exercises is utilized to reduce curve progression, to reduce brace prescription, and to enhance brace wear (Fusco et al., 2011). In the United States, PT is not commonly utilized due to a lack of evidence supporting the concept that exercise alters the natural history of scoliosis (Mordecai & Dabke, 2012; "Scoliosis," 2008, p. 287).

Observation is the standard medical management of AIS with mild curves in the United States. The frequency of follow-up examinations depends on the patient's maturity and curve size ("Scoliosis," 2008, p. 278). Prognostic factors for curve progression included skeletal immaturity (premenarchy and Risser 0), larger curves (greater than 30°), younger age (below 12 years old), and curves with a thoracic component (Bunnell, 1986). Therefore, a skeletally immature adolescent with a curve approaching 25° may be monitored every 3 months, as opposed to a more skeletally mature adolescent who may be monitored every 6 months ("Scoliosis," 2008, p. 278).

Curve patterns also influence progression; thoracic and double curves are more progressive than thoracolumbar curves, and lumbar curves are the least likely to progress. In curves greater than 50°, thoracic curves progress about one degree per year (Weinstein, 1999). Further, reduced pulmonary function is often observed in adolescents with idiopathic scoliosis (IS) with large curves, especially thoracic curves

over 50°. A lower pulmonary function includes a lower vital capacity and shortness of breath, but rarely cardiopulmonary compromise. Increased rates in mortality occur in curves greater than 100° (Weinstein, Dolan, Peterson, Spratt, Spoonamore, & Ponseti, 2003).

The efficacy of bracing in reducing curve progression in AIS remains controversial, because studies have reported both favorable and unfavorable results. Goldberg, Dowling, Hall, and Emans (1993) found no significant differences in curve progression between 32 untreated girls with AIS in Dublin and 32 brace-treated girls with AIS in Boston matched by curve size, age, and skeletal immaturity at diagnosis. Goldberg, Moore, Fogarty, and Dowling (2001) compared their surgery rates of untreated patients with AIS to an active bracing center, finding no statistically different surgical rates for AIS. However, Katz, Herring, Browne, Kelly, and Birch (2010) demonstrated findings from a landmark study, indicating that bracing is effective in preventing curve progression in AIS. Katz et al. utilized brace sensors to monitor brace wear compliance and curve progression in 100 adolescents with IS. Adolescents were either prescribed 16 or 23 hours of brace wear, depending on the surgeon's discretion. The treating surgeons were blinded to brace wear data. When brace treatment was complete, the authors examined the relationship between the amount of brace wear and curve progression. An inverse correlation between amount of brace wear and curve progression was found. In addition, the most skeletally immature adolescents appeared at highest risk of progression. Successful outcomes, or curve progression less than 6°,

were found in 82% of adolescents who wore their brace more than 12 hours a day. In contrast, only 31% of adolescents who wore their brace less than 7 hours a day had successful outcomes. Finally, Katz et al. found that the more adolescents wore their brace, the less likely was the need for surgery.

Surgery is generally recommended for severe curves and is a widely accepted form of treatment. Larger curves tend to progress over time, especially curves greater than 45° (Weinstein 1999; Weinstein et al., 2003). The current literature is rather focused on comparing surgical approaches, the extent of fusion, and the instrumentation used (Weinstein et al., 2008). Minimal research compares surgery to non-operative treatment (Weinstein, 1999). Dickson, Mirkovic, Noble, Nalty, and Erwin (1995) compared the two groups, finding that the surgically treated group reported significantly improved pain, self-image, and ability to perform functional activities than the group who declined surgery. However, the two groups only included a small group of adults who had declined surgery (n = 30) and took place only an average of 5 years after surgery.

Clinical Features of AIS

Clinical features of AIS include back pain during adolescence and in adulthood, as well as decreased health-related quality-of-life (QOL). Authors of recent studies indicate a stronger relationship between AIS and back pain than previously believed. As part of a multi-center prospective study of 1,433 adolescents with IS, Landman, Oswald, Sanders, Diab, and Members of the Spinal Deformity Study Group (2011) found that 78% of

patients reported back pain pre-operatively in contrast to surgeons' report of 44%, suggesting that surgeons underestimated the prevalence of pain in their patients. Landman et al. also found that complaints of back pain were reduced to 64% at 1 and 2 years after surgery, although almost 30% of the subjects reported using analgesics for back pain both before and after surgery. In addition, patients were more likely to report back pain if they were older, were overweight, or had larger proximal thoracic curves.

A retrospective chart review conducted by Ramirez, Johnston, and Browne (1997) at Texas Scottish Rite Hospital for Children (TSRHC) also assessed the prevalence of back pain in the AIS population. Ramirez et al. reported that 560 (23%) of 2,442 patients reported current back pain. The majority (392 patients) was observed for scoliosis, performed exercises, and took medication for their back pain. The rest (168 patients) were braced or had surgery. At the latest follow-up visit an average of 3 years later, only 53% (208 patients) of patients observed for scoliosis had no more back pain while 69% (116 patients) who were braced or had surgery were free of back pain. The investigators hypothesize that back pain is relieved when a curve is stabilized due to altered spinal biomechanics from the scoliotic deformity. Ramirez et al. also found that the following factors were significantly associated with patients having back pain: age greater than 15 years, skeletal maturity (Risser sign at least two), post-menarchal status, and a history of injury. In contrast, the following factors had no association with back pain: gender, family history of scoliosis, limb length discrepancy, magnitude or type of curve, or spinal alignment. However, spinal alignment approached significance (p = .052)

and was recorded if a shift lateral to the gluteal cleft relative to a plumb line dropped vertically from the seventh cervical vertebra was greater than one centimeter. Interestingly, out of the 560 patients that reported to have back pain, only 48 (9%) had a pathology, mostly spondylolysis or spondylolisthesis.

A similar prevalence of LBP in AIS also was found outside of the United States. Sato et al. (2011) involved 43,630 students in Japan and found significantly more back pain in adolescents with IS compared to adolescents without IS (controls) by prevalence, location, and severity. Adolescents with IS reported a 28% current prevalence of back pain compared to 12% of controls, and a 59% lifetime prevalence compared to 33% of controls. Adolescents in the scoliosis group experienced more severe pain of longer duration with more frequent recurrences compared to controls. Adolescents with IS reported significantly more pain in the upper middle and right back compared to controls, suggesting a relationship between pain and right rib hump deformity.

In addition to LBP, reduced QOL and body image are also common in adolescents with IS. Pain and body image may be related. In the study by Landman et al. (2011) which evaluated adolescents with IS with LBP pre- and post-operatively, patients who perceived themselves as more deformed had a greater desire to change their appearance and had less reduction in pain after surgery. Results of a systematic review (Tones, Moss, & Polly, 2006) concluded that adolescents with IS demonstrated worse health-related QOL, psychosocial functioning, and body image compared to their peers, especially during treatment for AIS. In this systematic review, psychological distress also

was found in adolescents with IS who had pre-existing psychological conditions and challenging social and family situations. Therefore, psychological therapy was offered as an option to target current and future psychosocial issues. This systematic review also found that disturbed body images in adolescents with IS relating to their appearance may be worse than patients who were diagnosed with a chronic illness in childhood or adulthood. A worse body image was associated with brace wear, as opposed to an improved body image after surgery. Body image and physical exercise in AIS also was explored by Dekel, Tenenbaum, & Kudar (1996). Dekel et al. (1996) evaluated the body images and physical activity levels of 286 adolescents (140 with IS, 146 without spinal deformity) using questionnaires and self-reports of physical activity beyond school time. Adolescents with IS rated their body image lower than adolescents without spinal deformities, $F(1, 264) = 53.51$, $p < .000$. Further, adolescents with IS demonstrated a positive association between body image and physical activity. Specifically, adolescents with IS who engaged in physical activity at least three times a week were found to have an improved body image.

Back pain is more common among adults who received no treatment for AIS than in the general population (Weinstein et al., 2003). However, little research has been conducted to examine the effects of PT interventions for adults with scoliosis with back pain. Several types of adult scoliosis have been described, including progressive IS, referring to adults who had AIS. If progressive IS is accompanied by secondary degeneration or imbalance, it is considered a different type of scoliosis. Adults with

progressive IS also can present differently depending on whether they were treated surgically (Aebi, 2005). Although the most frequent clinical problem of adult scoliosis is back pain, patients present with a variety of symptoms due to various etiologies and the possibility of radicular symptoms (Aebi, 2005). Surgery is more readily explored in addition to medication, bracing, root blocks, and facet joint injections. Although therapeutic interventions such as muscle exercises, swimming, and traction have been recommended for adults with progressive IS (Aebi, 2005), the effectiveness of these interventions has not been investigated.

The effects of back pain on function and health are less clear in adults who had AIS. In a long-term prospective study (Weinstein et al., 2003), back pain did not necessarily lead to more disability or decreased ability to perform activities of daily living. However, adults with scoliosis did report restrictions such as buying clothes, decreased physical ability, and self-consciousness. No relationship was found between development of osteoarthritis and curve severity. Psychosocial sequelae, such as decreased self-esteem, were associated with AIS, but clinical depression was not (Weinstein et al., 2003).

Long-term outcomes have been evaluated among adults treated non-operatively and with surgery for AIS. Haefeli, Elfering, Kilian, Min, and Boos (2006) investigated non-operative outcomes among patients with AIS after at least 10 years. Patients with curves larger than 45° reported significantly more pain than patients with smaller curves. No significant differences were found in pain, disability, and health-related QOL between

those treated by bracing and those without bracing. A systematic review on health-related QOL and psychosocial concerns among adults with AIS by Tones, Moss, and Polly (2006) investigated treatment outcomes in studies with over 20 years of follow-up. Tones et al. found that previous bracing or surgery did not influence health-related QOL; however, they suggested that patients treated by bracing may report less satisfaction from treatment, and patients treated by surgery may have worse physical functioning compared to patients without scoliosis. Further, Daniellson and Nachemson (2003a, 2003b) described that patients with scoliosis treated with both bracing and surgery took more sick leave due to back problems than patients without scoliosis. Though pyschosocial concerns were not as evident in adults as in adolescents, adults who had AIS still reported limited participation in social activities due to self-consciousness and fear of injury. Body image also was found to be lower in adults with scoliosis than patients without scoliosis.

Decreased spinal mobility and muscle strength were also observed in adults who had AIS. Daniellson, Romberg, and Nachemson (2006) published a case-control study in which patients with AIS who were followed for over 20 years were compared to healthy adults without spinal deformities. Spinal mobility and muscle strength were examined between the two groups: adults treated for AIS by either bracing or surgery, and age- and sex-matched healthy adults without spinal deformity (controls). Patients treated by either bracing or surgery had decreased lumbar spinal mobility and endurance compared to the control group. Daniellson et al. also found that patients with decreased

spinal mobility treated by bracing or surgery exhibited more back pain than controls. However, the investigators could not answer whether reduced muscle endurance resulted from scoliotic deformity, treatment, or chronic back problems.

Low Back Pain

Low Back Pain in Adults

LBP is epidemic worldwide, and almost every individual experiences LBP at some point in their lifetime (Costa-Black, Loisel, Anema, & Pranksy, 2010). Back pain is the most common type of pain reported, with one in four adult Americans reporting LBP within the past 3 months (Deyo, Mirza, & Martin, 2002). Almost all adults will recover from LBP. However, recurrences are also common. LBP is commonly differentiated as specific or non-specific, with non-specific LBP associated with an unknown origin. Over 90% of individuals with LBP have non-specific LBP (Koes, van Tulder, & Thomas, 2006). A variety of classification systems have been used by different health care providers to label non-specific LBP, but they are of questionable reliability and validity (Koes et al., 2006). One widely agreed upon classification system of non-specific LBP by Koes, van Tulder & Thomas (2006) defines types of LBP by the duration of symptoms. Koes et al. defined acute LBP as lasting less than 6 weeks, sub-acute LBP lasting between 6 weeks and 3 months, and chronic LBP lasting longer than 3 months.

An increasing number of individuals with LBP do not recover and develop chronic LBP (Freburger et al., 2009). Authors of a population-based study in North Carolina demonstrated a significantly increased prevalence in chronic LBP from 4% in 1992 to

10% in 2006, using the same definitions to describe LBP during both 1992 and 2006 (Freburger et al., 2009). Increases in LBP prevalence were noted across all demographic categories, including age, gender, and ethnicity. Additionally, more individuals sought medical care during the past year in 2006 (84%) than in 1992 (73%). Increases in health care services have been attributed to an increase in chronic LBP cases.

In a clinical review which summarized systematic reviews, Koes et al. (2006) found several individual, psychosocial, and occupational factors that are associated with the development and chronicity of LBP in adults. Four individual risk factors were identified for the development of back pain: weak abdominal and back muscles, age, physical fitness, and smoking. However, individual risk factors found to influence the chronicity of LBP included obesity, little education, and high levels of pain and disability. Job dissatisfaction, unavailability of light duty upon return to work, and lifting three quarters of the day were the occupational factors for developing chronic LBP. Lastly, several psychosocial factors were associated with development of chronic LBP, including distress, depressive mood, and somatization.

Although we have speculated that exercises would relieve LBP, currently no exercise guidelines exist (Koes et al., 2006). However, a Cochrane systematic review found a moderate quality of evidence to indicate that exercise programs prevents recurrences of LBP in adults (Choi, Verbeek, Tam, & Jiang, 2010). Exercise therapy also has been found to be slightly effective in reducing pain and improving function in adults with chronic LBP (Hayden, van Tulder, Malmivaara, & Koes, 2005). A recent meta-

analysis found that specific motor control exercises (i.e. spinal stabilization exercises) reduce pain and disability in adults with chronic and recurrent low back pain (Boestrom, Rasmussen-Barr, & Grooten, 2013).

Low Back Pain in Pediatrics

The reported lifetime prevalence of LBP in children between ages 7 to 18 varies from 7% to 72% in a systematic review by Hill and Keating (2009). This excessively wide range is the result of the use of varying definitions for LBP and data collection methods. Children are most prone to develop LBP during periods of rapid growth, which occurs for boys at 12.5 ± 2 years old and for girls 2 years earlier. Hill and Keating (2009) also documented a 1% lifetime prevalence of LBP in children 7 years old. This very low prevalence gradually increases to 17% at 12 years of age, and a sharp increase occurs after 12 years of age until 15 years of age when the prevalence reaches a plateau at 53%. A leveling off occurs in the late teens when LBP prevalence approaches that of adults at almost 60%. Additionally, adolescents with a previous history of LBP are at risk of developing LBP in the future (Harreby, et al., 1999; Jones & Macfarlane, 2005). Authors of a systematic review on the epidemiology of LBP suggest a relationship between adolescent and adult LBP (Jeffries, Milanese, & Grimmer-Somers, 2007).

Little information exists on the prevalence of chronic LBP among adolescents, as authors typically describe lifetime prevalence of LBP (Hill & Keating, 2009). Some studies have evaluated point prevalence, while others include 1 year prevalence. Although chronic LBP typically lasts longer than 3 months, chronic LBP has not been clearly

defined in the adolescent population, making comparisons difficult. Harreby et al. (1999) from Denmark examined the severity of chronic LBP in 1,389 adolescents 13 to 16 years old. Moderate to severe recurrent or continuous LBP was found in 19.4% of children, with significant risk factors including daily smoking, female gender, and jobs requiring heavy lifting more than 5 hours a week. Adolescents with severe LBP demonstrated increased use of analgesics and health care utilization, and reduced QOL. Jones, Stratton, Reilly, and Unnithan (2004) from England investigated the prevalence and consequence of recurrent LBP in 500 adolescents 10 to 16 years old. Recurrent LBP was defined as regular LBP classified by repeated acute episodes and was found in 13.1% of adolescents, with the prevalence increasing significantly by age. Unlike Harreby et al., Jones et al. did not find a significant difference in recurrent LBP between boys and girls. Nevertheless, Jones et al. found that adolescents with recurrent LBP were absent from school more often, visited a health care professional more frequently, and were limited by participation in physical activities.

Due to the high prevalence of LBP among children and increased likelihood of future LBP, a systematic review by Hill and Keating (2010) investigated risk factors for a first episode of LBP in children. LBP has been attributed to genetics, psychological issues, and physical activity, but risk factors have not been validated in independent investigations. Five prospective studies met the inclusion criteria with 47 risk factors identified for a first-time occurrence of LBP in children. Nine of these 47 risk factors demonstrated a significant correlation with a future episode of LBP, but a follow-up

study confirming these factors has not been completed. These nine factors were: spine asymmetry, lumbar spine extension endurance, the ratio of lumbar flexion mobility to lumbar extension endurance, the ratio of lumbar extension mobility to lumbar extension endurance, the ratio of lumbar flexion and extension mobility to extension endurance, high levels of physical activity, part-time work, abdominal pain, and psychosocial difficulties. Due to difficulty in undertaking studies predictive of LBP, Hill and Keating suggested evaluating intervention studies instead.

Physical activity can have a curvilinear relationship with LBP, with both low and high levels of physical activity increasing the risk of LBP (Fritz & Clifford, 2010). However, the effect of high levels of physical activity on disability and pain is unclear. Fritz and Clifford (2010) investigated the effect of sports participation on clinical outcomes of PT among 12- to 17-year-old adolescents with LBP. They found that adolescent patients who were involved in sports underwent PT for a longer period of time, but had less improvement in disability compared with adolescents who were not involved in sports. However, the disability and pain levels in the adolescents with LBP were similar to those in adults with LBP.

Decreased back muscle endurance is another main factor associated with LBP, according to Andersen, Wedderkopp, and Leboeuf-Yde (2006a). Andersen et al. investigated the association between physical fitness and LBP in 9,413 adolescents 17 years old. Physical fitness measures included functional leg extensor strength, back extensor endurance, flexibility, and aerobic fitness. The results revealed that back pain

was associated with low isometric back extensor muscle endurance and the absence of back pain was associated with high back muscle endurance. No other physical fitness measures or self-reported physical activity factors were associated with LBP. Although causal statements cannot be made about muscle weakness and LBP, the association between back extensor weakness and LBP suggests that spinal stabilization programs may be used to treat and prevent future episodes of LBP, as they increase muscle endurance in both healthy individuals and those with LBP (Andersen et al., 2006a).

Outcome Measures for Back Pain

A systematic review exploring outcome measurements used in LBP studies by Kamper, Stanton, Williams, Maher, and Hush (2011) demonstrated no consistent measures to describe LBP recovery. Many studies used pain, disability, or function, or a combination of the two to describe LBP recovery as an outcome measure. Other studies mentioned in the systematic review used self-rating scales, physical performance, or return to work. This section describes instruments used as outcome measurements applicable to adolescents with LBP.

Function Measurements

The patient-specific functional scale (PSFS) (see Appendix A) is a patient-specific questionnaire used to assess functional limitations in patients with orthopaedic conditions, including LBP. Patients are asked to identify up to three important activities that they are unable to do or having difficulty performing because of their back pain (Hall, Maher, Latimer, Ferreira, and Costa, 2011). Patients score the activity on a scale of

0 (unable to perform the activity) to 10 (able to perform the activity at pre-injury level). Scores are summed and averaged, resulting in a total score out of 10. The PSFS has been found to be reliable (Stratford, Gill, Westaway, and Binkley, 1995) and valid, especially for patients with low levels of activity limitations (Hall et al., 2011). The PSFS has been found to have a MCID of 2 from the average score of three activities in adults with chronic LBP (Maughan & Lewis, 2010). We are unaware of the use of this scale in the adolescent population.

Pain Intensity Measurements

Pain intensity self-rating scales widely used are the Visual Analog Scale (VAS), faces pain scales, and the Numerical Pain Rating Scale (NPRS). The VAS quantifies the intensity of pain on a continuum from 0 (no pain at all) to 10 (worst pain ever). Although variations of the VAS exist (LaMontagne, Hepworth, Cohen, & Salisbury, 2003), a common version that has been used to examine adolescents with LBP associated with AIS includes anchors at the endpoints of a 10 centimeter horizontal line. Adolescents are asked to mark their pain intensity on a 10 centimeter line, with verbal descriptors at 0 (no pain) and 10 (worst pain ever) (Williamson & Hoggard, 2005). The VAS is considered a ratio scale since it has a zero point (Sherman, Eisen, Burwinkle, & Varni, 2006). The VAS is reliable and valid in children as young as 5 years old (Sherman et al., 2006). The minimal clinically significant difference for the VAS ranges from a 1 to 2 centimeter change (von Baeyer, 2009).

Faces scales are considered simpler to use and less abstract than the VAS or numerical scales (Tomlinson, von Baeyer, Stinson, & Sung, 2010). They are typically utilized in younger children (ages 4 to 12). The Faces Pain Scale-Revised includes six faces on a horizontal line using the 0 to 10 pain rating scale (in intervals of 2). A series of facial expressions accompanies each point, with a happy face at the 0 anchor endpoint and a sad face at the 10 endpoint (Tomlinson et al., 2010). During administration of the FPS-R, children are asked to choose a face that reflects their pain intensity. Results of a systematic review of faces pain scales in children recommended the FPS-R for research purposes due to its utility and psychometric features (Tomlinson et al., 2010).

The NPRS is another scale that is used to measure pain intensity. Children are asked to rate their pain in whole numbers from 0 (no pain) to 10 (worst imaginable pain). The NPRS is the most widely used self-reported pain scale in pediatric hospitals (Connelly & Neville, 2010) and has been recommended in children at least 8 years old (von Baeyer, 2009). The NPRS is also referred to as the verbal numeric scale (Bailey, Daoust, Doyon-Trottier, Dauphin-Pierre, & Gravel, 2010) and the numerical rating scale (Connelly & Neville, 2010). The NPRS is considered to be reliable, valid, and to have good sensitivity in pediatrics (Williamson & Hoggard, 2005). When evaluating the content validity in children, the NPRS has been found to correlate with the VAS from .89 to .93 (Bailey et al., 2010; von Baeyer et al., 2009) and with the FPS-R at .87 (von Baeyer et al., 2009). The test-retest reliability of the NPRS has been found to have 95% limits of agreement of -0.9 and 1.2 (Bailey et al., 2010). The NPRS is advantageous for

researchers who wish to follow-up with a child over the phone, since the scale can be verbally presented and does not require physical materials.

Connelly and Neville (2010) compared the responsiveness of three pain scales: VAS, FPS-R, and NPRS. Children ages 9 to 18 were followed for their pain level over 3 days after a surgical procedure. The NPRS results had consistently higher ratings compared to those of VAS and FPS-R, suggesting that the NPRS may be less responsive than the other scales, although the clinical significance is unknown. On the contrary, von Baeyer (2009) compared the NPRS to the VAS and FPS-R and found the NPRS to be functionally equivalent except for in very mild pain (rated less than 1 out of 10). The NPRS has been used in previous PT studies examining adolescents with LBP (Clifford & Fritz, 2003; Fritz & Clifford, 2010). The minimum clinically important difference (MCID) for the NPRS has been found to be 2 in adults with LBP (Childs, Piva, & Fritz, 2005; Kamper et al., 2011) and 1 in children with acute pain (Bailey et al., 2010). Treatment success also has been described as 30-50% decreased pain (von Baeyer, 2009). Therefore, a 50% success rate could be from 10/10 to 5/10, or from 2/10 to 1/10 on the NPRS (von Baeyer, 2009).

Disability Measurements

The Revised Oswestry Back Pain Disability Questionnaire (OSW) is a region-specific disability scale used for individuals with LBP (see Appendix B). It is a 10 question scale addressing different aspects of function. Each question is scored on a scale of 0 to 5, with 5 indicating the highest level of disability. The total score ranges from 0 to 50.

The total score may be divided by the total possible score (50 if all questions are completed) and multiplied by 100 to yield a percentage score; 0 percent is equivalent to no disability and 100 percent is equivalent to a great deal of disability (Maughan & Lewis, 2010). The Revised OSW is adapted from the original Oswestry Low Back Pain Disability Questionnaire that replaces the sex life item with an item regarding fluctuations in pain intensity. The OSW is considered reliable and sensitive to change (Hudson-Cook, Tomes-Nicholson, & Breen, 1989). Another modified version of the Oswestry Low Back Pain Disability Questionnaire replaces the sex life item with or an item regarding employment and home-making (Fritz & Irrgang, 2001). This modified version is reliable (ICC = .90) and valid (Fritz & Irrgang, 2001). The modified version has a MCID of 6 points (Fritz & Irrgang, 2001) and minimal detectable change of 10.5 points (Davidson & Keating, 2002). The modified version also has been used to define a successful outcome if there was at least a 50% improvement in the score (Fritz & Clifford, 2010). The modified version was used in adolescents with LBP by Clifford & Fritz (2003), but a low correlation between the modified version and pain scores was found, indicating that the modified version may not be an appropriate outcome measure to measure disability in adolescents. Clifford & Fritz further elaborated that the questions in the modified version may not apply to the functional difficulties of adolescents with LBP. To date, the modified version has not been validated in adolescents.

Quality-of-life Measurements

The Short Form-36 (SF-36) is a general health questionnaire that can compare across health care organizations in a uniform and accurate way (Bartie, Lonstein, & Winter, 2009). It is commonly used as a health-related QOL questionnaire as it is not specific to any age, disease, or treatment group (Helenius, Remes, Lamberg, Schlenzka, & Poussa, 2008). The SF-36 consists of 36 questions in eight domains with scores ranging from 0 to 100 and higher scores reflecting a better health status. The eight domains include physical function, role physical, bodily pain, general health, vitality, social function, role emotion, and mental health. Two summary measures describe the overall physical and mental health (Lai, Asher, & Burton, 2006). The SF-36 has a copyrighted scoring algorithm that must be annually purchased for each research study. The SF-36 takes about ten minutes to complete (Davidson & Keating, 2002). In addition, the SF-36 has been validated for ages 18 years old and above but not in adolescents.

The Scoliosis Research Society-22 Health-Related Quality-of-Life Questionnaire (SRS-22) is the most commonly used health-related QOL instrument in AIS, was developed by the SRS, and is commonly utilized in individuals after surgery (see Appendix C). The SRS-22 is a disease-specific questionnaire that may be more relevant to the health issues of individuals with IS than a generalized health questionnaire such as the SF-36 (Asher, Min, Lai, Burton, & Manner, 2003). It consists of 22 questions in five domains which include pain (five questions), self-image (five questions), function (five questions), mental health (five questions), and management satisfaction/dissatisfaction

(two questions). The mental health domain was adapted with written permission from the SF-36. Each item is scored from 1 (worst) to 5 (best); higher scores indicate a better health-related QOL. The first four domains have a total sum score that ranges from 5 to 25, and the management satisfaction/dissatisfaction domain has a total sum score that ranges from 2 to 10. The maximum total score of the first four domains is 100, and the total score of all five domains is 110. The SRS-22 can be scored in various ways. The first method of scoring is to divide the total score for each domain by the total possible score to yield an average score for each domain. The second method of scoring the SRS-22 is to either sum or average the first four domains to yield either a sub-total sum or sub-total average score. The third method of scoring the SRS-22 is to either sum or average all five domains to yield either a total sum or total average score. Unlike the SF-36, the SRS-22 is free and easy to score by hand. It is user-friendly, taking only 2 to 3 minutes to complete (Parent, Hill, Mahood, Moreau, Raso, & Lou, 2009). The SRS-22 is internally consistent, reliable, and valid, correlating with the SF-36 and the OSW (r = .87)(Bridwell et al., 2005; Lai et. al., 2006; Parent et al., 2009). When comparing scores between individuals pre- and post-operatively, the SRS-22 has a MCID of 0.20 for the pain domain, 0.98 for self-image, and 0.08 for function (n = 387) (Carreon, Sanders, Diab, Sucato, Sturm, & Glassman, 2010).

The MCID for the total SRS-22 score, mental health, and management satisfaction/dissatisfaction could not be determined since no anchors exist to serve as a

comparison (Carreon et al., 2010). Another study (*n* = 91) that excluded the two questions on management satisfaction/dissatisfaction showed a MCID of 6.8 for the SRS-22 sub-total sum score (possible score ranges from 22 to 100), 0.5 for the SRS-22 sub-total average score (average score out of 20 questions), 0.6 for pain, 0.8 for function, 0.5 for self-image, and 0.4 for mental health using the distribution-based method (Bago, Pérez-Grueso, Francisco, Les, Hernández, & Pellisé, 2009). When using the anchor-based method, Bago et al. (2009), found a MCID of 13.1 for the sub-total sum score, 0.6 for the sub-total average score, 0.6 for pain, 0.3 for function, 1.3 for self-image, and 0.3 for mental health.

Measurement for Participants' Perceived Changes

The global rating of change (GROC) is a scale that assesses individuals' overall perceived change, usually to determine the effect of an intervention or to report on the progress of a condition (Kamper, Maher, & Mackay, 2009). Individuals rate their perceived change or improvement on a Likert scale that can range from 3 to 101 points (Kamper et al., 2009). Kamper et al. (2009) recommended an 11-point scale ranging from -5 (very much worse) to 0 (unchanged) to 5 (completely recovered). The GROC is reliable and valid, and is quick and simple to measure (Kamper et al., 2009). The 11-point GROC has a MCID of 2 points (Kamper et al., 2009). However, the GROC has not been used in the adolescent population.

Impairment Measurements for Back Pain

Measurement for Spinal Stability

Though standard measurements for spinal stability do not exist (Kane & Bell, 2009), spinal stability is generally described as the ability of the deep spinal muscles to stabilize the individual vertebra and its adjacent vertebrae. Three components must function properly to achieve spinal stability: the vertebral column to provide intrinsic stability, the spinal muscles to provide dynamic stability, and the neural control unit to coordinate the muscle response for stability requirements (Panjabi, 2003). Adult patients who may benefit from spinal stabilization exercises due to spinal instability often present with the following clinical characteristics: recurrent LBP, regular manipulation with short-term relief, trauma, pregnancy, oral contraceptive use, and positive responses to spinal immobilization (Fritz et al., 2007).

Several clinical tests have been developed to evaluate lumbar spine instability, including lumbar flexion range of motion (ROM), the segmental intervertebral motion test (i.e. prone lumbar posterior-anterior stress test), and the prone instability test. Fritz, Piva, and Childs (2005) evaluated the relationship between these three clinical tests and radiographic lumbar instability in adults with LBP. The authors found that individuals with ≥ 53° of lumbar flexion or a lack of hypomobility with the segmental intervertebral motion test had a 4.3 positive likelihood ratio (95% *CI*: 1.8, 10.6) for predicting radiographic instability. The presence of both findings increased the probability of instability from 50% to 93%. However, the prone instability test did not

show any predictive value for lumbar instability. For the first test, lumbar flexion ROM, the authors collected lumbar flexion ROM measures according to the methods described by Waddell et al., (1992). With the individual lying prone, the examiner marks the midlines of S2 and T12-L1. Next, the individual stands relaxed with the arms by the side. The examiner records the individual's position in standing at S2 and T12-L1 with a single inclinometer. The examiner then instructs the individual to bend as far forward as possible while keeping the knees straight before making recordings at T12-L1 and S2 again. Lumbar flexion is calculated by subtracting the pelvic flexion at S2 from total lumbar flexion at T12-L1. The second clinical test that measures spinal instability is the lumbar segmental intervertebral motion test. The individual lies prone while the examiner produces a posterior to anterior force with the hypothenar eminence at the spinous processes. Each lumbar segment is judged as normal, hypermobile, or hypomobile. The third test previously mentioned, the prone instability test, is performed with the individual prone and feet resting on the floor. The examiner performs the segmental intervertebral motion test and records pain provocation. The individual is then asked to lift the legs off the floor, and the examiner performs the segmental intervertebral motion test again at the painful segment. A positive test is recorded when pain is present with the feet resting on the floor but alleviated with the feet off the floor. We are unaware of any studies which utilized the above mentioned lumbar instability tests in the adolescent population.

In addition to the above-mentioned clinical tests, assessment of the ability to activate or contract deep spinal muscles (e.g. transversus abdominus and lumbar multifidus) has been used to indirectly determine spinal stability. Palpation is a simple and quick method to assess muscle contraction in the clinical setting. Two common procedures activate the transversus abdominis: the abdominal draw-in maneuver and abdominal bracing. The abdominal draw-in maneuver is performed with an individual in prone or supine hooklying. The transversus abdominis can be palpated medial and distal to the anterior superior iliac spines. The examiner's thumbs or middle three fingers sink gently but deeply into the abdomen. The individual is instructed to do the following: take a relaxed breath in and out, hold the breath out, and then draw-in your lower abdomen without moving your spine (Koppenhaver et al., 2009). The examiner should feel a drawing in of the lower abdomen with gentle deep tension under the fingers (Hides, Scott, Jull, & Richardson, 2000). The procedure for abdominal bracing is aimed at co-contraction of the global abdominal muscles with the individual in supine hooklying (Hides et al., 2000). The examiner's thumbs or middle three fingers sink into the abdomen, as in the abdominal draw-in maneuver, as the individual is instructed to brace as if punched in the stomach (Bressel, Willardson, Thompson, & Fontana, 2009). The examiner will feel a bulging under the fingers (Hides et al., 2000). The lumbar multifidus can be palpated with the individual in prone. The examiner places the index finger and thumb of one hand, or thumbs, index or middle fingers of both hands adjacent to the lumbar spinous process. The examiner's fingers sink gently but deeply into the

multifidus. The examiner instructs the individual to gently swell out the muscles under the examiner's fingers without moving the spine or pelvis; hold the contraction while breathing normally (Richardson et al., 2004). The examiner gently releases pressure at the multifidus as the individual contracts so that the contraction is not inhibited. The examiner feels for differences between sides and vertebral levels (Richardson et al., 2004).

The Pressure Biofeedback Unit (PBU) (Stabilizer, Chattanooga Group Inc., Hixson, TN) is a clinical instrument designed to quantify contraction of deep spinal muscles, specifically the ability to perform the abdominal draw-in maneuver. The PBU is a simple pressure transducer with a three-chamber air-filled pressure bag, catheter, and sphygmomanometer gauge (see Appendix D) (Lima et al., 2012). The PBU can show whether local or global anterior abdominal wall muscles are recruited during the abdominal draw-in maneuver. To measure the ability to perform an abdominal draw-in maneuver, the examiner positions the individual in prone with the PBU under the abdomen with the navel in the center of the pad. The pressure pad is inflated to 70 mm Hg. The examiner palpates the abdomen and gives the same instructions as the abdominal draw-in maneuver. The examiner observes the dial of the PBU, observes the individual's pelvis and trunk for extraneous movements, and continues to palpate the abdominal wall. An optimal test performance reduces the pressure of the unit 4 to 10 mm Hg for 10 seconds without spinal or pelvic movement and without abdominal bulging (Richardson et al., 2004). Pressure changes indicate the capability of the

transversus abdominis to contract into its shortened range independently of other abdominal muscles (Richardson et al., 2004).

In the past decade, researchers have used ultrasound imaging to visualize and quantify the size and behavior of deep spinal stabilizing muscles (Stokes, Hides, Elliott, Kiesel, & Hodges, 2007). Ultrasound imaging is non-invasive as compared to intra-muscular fine-wire electromyography, and is cheaper as compared to magnetic resonance imaging. In addition, muscle size and thickness measurements on ultrasound images have been shown to be reliable in quantifying muscle morphological changes during contraction of the deep spinal stabilizing muscles, specifically the lumbar multifidus and transversus abdominis (Koppenhaver, Hebert, Fritz, Parent, Teyhen, & Magel, 2009; Stokes et al., 2007). Adults with chronic LBP have a reduced ability to contract the lumbar multifidus, which can be improved with ultrasound imaging (Stokes et al., 2007). Ultrasound imaging has been found to be valid and reliable in adults, especially when averaging muscle thickness values measured by an experienced examiner (Hebert, Koppenhaver, Parent, & Fritz, 2009).

Little literature is available regarding measurements for spinal stability in children. The ability to perform six functional exercises has been suggested to indicate spinal stability in children with development coordination disorder (Kane & Bell, 2009). These exercises included sit-ups, push-ups, plank, hip bridge, four-point arm/leg lift, and single-leg stance. However, these exercises were not specific to the lumbar spine nor isolated the deep spinal stabilizing muscles.

Measurement for Muscle Endurance

Back muscle endurance in individuals with LBP is commonly assessed by the Sorensen test. The Sorensen test is often used for examining the treatment effects before and after rehabilitation programs (Demoulin, Vanderthommen, Duysens, & Crielaard, 2006). In a prone position with the upper body unsupported, the examiner records the amount of time that an individual can hold a horizontal position. Several variations of the test exist. The original test describes the arms folded across the chest, the upper iliac crests aligned at the edge of a table, and the legs fixed by three straps across the pelvis, knees, and ankles. A typical stopping point for the test is when the individual deviates more than 10° from neutral as measured by a hand-held inclinometer (O'Sullivan, Smith, Beales, & Straker, 2011). The maximum recorded time is 4 minutes. The Sorensen test is safe, has good discriminative validity, and is reliable, although motivation may be a confounding factor (Demoulin et al., 2006). It has been used in adolescents with and without LBP (Andersen, Wedderkopp, & Leboeuf-Yde, 2006b; Dejanovic, Harvey, & McGill, 2012; O'Sullivan et al., 2011; Sjölie & Ljunggren, 2001). Dejovanic, Harvey, & McGill (2012) reported normative mean and percentile data in 753 Serbian children by gender and age (7 to 14 years old). In adolescents with chronic LBP, the amount of time the position can be held is significantly decreased (Andersen et al., 2006b). The Sorensen test has been used in adults who had AIS (Danielsson, Romberg, & Nachemson, 2006) and a modified version in adolescents with AIS (Ahlqwist, Hagman, Kjellby-Wendt, & Beckung, 2008). The modified version of the

Sorensen test in adolescents with AIS was performed on an inclined bench with instruction to hold the position for a maximum of 180 seconds (Ahlqwist et al., 2008).

The prone-double-leg-raise (PDLR) test is another common back muscle endurance test used in the clinic (see Appendix F). From a prone lying position with the hands folded underneath the forehead and arms perpendicular to the body, the examiner asks an individual to raise both legs straight back until the knees clear the support surface. The examiner slides one hand under the knee to record the time in seconds the individual is able to maintain knee clearance (Arab, Salavati, Ebrahimi, & Mousavi, 2007). The PDLR test is reliable and valid (McIntosh, Wilson, Affieck, & Hall, 1998). Also, normative percentile data has been published in seconds by 25th, 50th, and 75th percentiles categorized by age (19 to greater than 60 years) and gender (McIntosh et al., 1998). Arab, Salavati, Ebrahimi, & Mousavi (2007) examined the diagnostic accuracy of five trunk muscle endurance tests, including the PDLR test and the Sorensen test. They evaluated 200 adults with and without LBP by gender and obtained average hold time in seconds for each test by gender. Arab et al. found that the PDLR test had the best sensitivity (men 96%, women 100%), specificity (men 100%, women 92%), and predictive value (positive predictive value: 100% men, 93% women; negative predictive value: 96% men, 100% women) compared to the other tests, including the Sorensen test. Some researchers consider the PDLR test to be a better test for the LBP population; it targets the endurance of the lower back muscle extensors, such as the multifidus, while the Sorensen test targets hip extensor muscle endurance (Arab et al., 2007;

McIntosh et al., 1998). Another practical advantage of the PDLR test is that it is easier to administer than the Sorensen test which requires either an inclined bench or the lower body stabilized. However, the PDLR test has not been used in the adolescent population.

Treatment for LBP in Adolescents

Overview

Researchers performing systematic reviews on the effectiveness of exercises for treating non-specific LBP have not included studies on children or adolescents (Hayden, Tulder, Malmivaara, & Koes, 2005; Kosseim, Rein, & McShane, 2008). Researchers of one recent Cochrane systematic review found that exercises were slightly effective in decreasing LBP and improving function in adults with chronic LBP (Hayden et al., 2005). Researchers of another recent Cochrane systematic review revealed moderate evidence that exercise prevents recurrences of back pain, but optimal treatment types are unclear (Choi, Verbeek, Tam, & Jiang, 2010). Treatment recommendations for adults with LBP do not necessarily apply to children with LBP (Fritz & Clifford, 2010). Therefore, PT treatment recommendations for nonspecific LBP in pediatrics are needed.

We conducted a pilot study at TSRHC to survey the standard of care provided by physical therapists for treatment of children with IS. One component of the study examined the care for a subgroup of adolescents with IS who had LBP. Eighteen surveys were distributed to orthopaedic surgeons representing major pediatric facilities across the United States (*n* = 16) and internationally (*n* = 2) in January 2011. All 18 orthopaedic surgeons responded to the survey. The primary aim of this survey (see Appendix G) was

to determine the orthopaedic surgeons' reasons for referring adolescents with IS to PT. Almost all (14 out of 15) orthopaedic surgeons referred an unbraced child with scoliosis and back pain to PT. The most common referral reasons were to improve posture and trunk or core muscle strengthening. The results of the survey indicate that referring orthopaedic surgeons recommend spinal stabilization exercises as the optimal PT treatment for managing AIS with back pain. Although surgeons recognize the importance of spinal stabilization exercises, no study has shown the effectiveness of spinal stabilization exercises on adolescents with IS who have back pain. Therefore, the treatment effect of common PT practice (spinal stabilization exercises) should be validated.

Generalized Exercises

Authors of two randomized control trials investigating generalized exercise programs for adolescents with LBP reported decreased back pain compared to a control group of no intervention (Fanucchi, Stewart, Jordaan, & Becker, 2009; Jones et al., 2007). However, all of these trials were school-based studies using group sessions. The authors of the first randomized control trial (Jones et al., 2007) examined the effect of aerobic exercises in 54 adolescents with recurrent nonspecific LBP. The outcome measures included pain intensity, disability, muscle flexibility, and trunk muscle endurance. This study consisted of an 8-week exercise program; each session lasted 30 minutes and occurred twice a week. Adolescents were encouraged to do a home

exercise program with the goal of alleviating pain. All adolescents attended at least 12 out of 16 sessions. Although the exercise group was found to have decreased pain intensity, the adolescents in this group did not demonstrate a significant decrease in pain frequency at three times a week. The authors also discussed disability measures including absence from school and physical activity. No significant differences were found regarding school absences, although most kids in both groups did not miss school due to LBP. Improvements in the exercise group were found in the number of times kids did not participate in physical activity due to LBP. Physical activity was considered another measure of disability since it is a normal activity of daily living for children, both voluntary activity (like play) and compulsory activity (like physical education) (Jones et al., 2007).

The authors of the second school-based randomized control trial also compared the effects of an exercise program in adolescents with LBP to a control group (Fanucchi et al., 2009). Outcome measures included pain intensity, lumbar stability, flexibility, neural mobility, proprioception, and QOL. This study also consisted of an 8-week exercise program in 72 adolescents who had LBP within the past 3 months. Each session lasted about forty-five minutes and occurred weekly. The program began with 10 to 15 minutes of education, including explanations about exercise rationale, core musculature, correct posture, and spinal alignment. A home exercise program was given with self-reports of daily compliance recorded. Authors of this study included a 3 month follow-up to understand if improvements remained, unlike the previously mentioned

study. The authors noted improved flexibility in some major muscle groups, but not in lumbar stability which was measured by the active-straight-leg-raise test. The exercise group had decreased back pain intensity and prevalence post-intervention and at 3 months follow-up compared to the control group. However, no significant differences were found in QOL scores (measured by the Mental Health Inventory-5) post-intervention and at 3 months follow-up.

Spinal Stability Exercises

Specific spinal stabilization exercises are common treatments in managing LBP with a focus on retraining the deep spinal muscles to control movement. Training of the abdominal muscles, specifically the transversus abdominis, has been suggested to achieve spinal stability (Grenier & McGill, 2007). Two abdominal activation strategies, the abdominal draw-in maneuver and abdominal bracing are commonly used, but debate exists as to whether individuals should be instructed to perform the abdominal draw-in maneuver or abdominal bracing. The abdominal draw-in maneuver attempts to activate only the transversus abdominis, and abdominal bracing attempts to activate the entire abdominal girdle. In a study where authors used different mechanical loading conditions during the abdominal draw-in maneuver and abdominal bracing, abdominal bracing was shown to provide significantly better spinal stability in both simulation and in vivo data (Grenier & McGill, 2007).

As discussed earlier, specific spinal stabilization exercises prevent recurrent episodes of LBP in the adult population (Cairns, Foster, & Wright, 2006; Hides et al.,

2001). In particular, a long-term follow-up randomized control trial by Hides, Jull, and Richardson (2001) revealed that adults 3 years after spinal stabilization exercises were more than 2 times less likely to have LBP compared to a control group. Although spinal stabilization exercises are recommended by researchers for adolescents with LBP (Clifford & Fritz, 2003; Sjölie & Ljunggren, 2001), the effectiveness of a specific spinal stabilization program has not been studied in adolescents with IS who have LBP.

Postural Education

Postural education may prevent LBP in adults and children (Cardon, De Clercq, & De Bourdeaudhuij, 2002; Heymans, van Tulder, Esmail, Bombardier, & Koes, 2004; Kosseim et al., 2008). In a systematic review, Steele, Dawson, and Hiller (2006) evaluated the effectiveness of school-based spinal health interventions aimed at improving knowledge, changing behaviors, and decreasing pain. Steele et al. revealed that spinal health interventions increased knowledge about the spine/spinal care and decrease spinal pain, but changes in behavior varied. Cardon, De Clercq, and De Bourdeaudhuij (2002) found decreased pain and improved spinal care behavior after 6 weeks of specific postural education at 1-year follow-up. After the systematic review from 2006 was published, Vidal et al. (2011) also investigated the effects of behavioral changes related to LBP after postural education in 137 children ages 10 to 12. The intervention consisted of 6 weekly group sessions in a school-based setting. Four theoretical sessions covered human anatomy and physiology, LBP basics and risk factors, exercise promotion, ergonomics, and schoolbags. Two theoretical sessions

covered postural analysis, carrying objects, balance, breathing and relaxation. Vidal et al. found that healthy habits were significantly better in the intervention group than the control group post-intervention and at 3 months of follow-up. The investigators postulate that learned spinal care behavior changes may prevent LBP.

A randomized control trial by Ahlqwist, Hagman, Kjellby-Wendt, and Beckung (2008) evaluated the effects of two treatment approaches of back exercises and back education on 45 adolescents (ages 12-18) with LBP (greater than 2/10 on the VAS). Group 1 received individualized PT, and Group 2 did not receive individualized PT. Both groups were given a standardized back exercise program and back education. The program lasted 12 weeks. Group 1 received weekly PT and a twice a week home exercise program. Group 2 carried out the home exercise program three times a week. Exercises were designed to improve conditioning, mobility, strength, and coordination. Both groups demonstrated significant improvements in perceived health, mobility, and trunk muscle endurance, as well as decreased pain intensity. Group 1 had significantly improved physical function and pain duration. Ahlqwist et al. concluded the improvement in Group 1 may have been from the increased attention received. However, Group 2 still received follow-up after 1 week, halfway through the treatment program, and post-intervention, so this group was not a true control group.

Summary

This literature review gives an overview of the research related to AIS and back pain in adolescents. Various methods of measuring back pain in adolescents, outcome

measures for LBP, physical impairments relating to back pain in adolescents, and treatments for back pain in adolescents have been discussed. Minimal studies have investigated the effect of exercises to improve LBP in adolescents without AIS. No study has examined the effectiveness of exercises, including spinal stabilization exercises, for LBP in adolescents with IS.

CHAPTER III

METHODS

The purpose of the study was to investigate the effectiveness of spinal stabilization exercises in participants with adolescent idiopathic scoliosis (AIS) and low back pain (LBP). Specifically, this study evaluated whether 8 weeks of weekly supervised PT compared to 8 weeks of an unsupervised home exercise program (HEP), would have equivalent improvements in pain reduction, disability reduction, quality-of-life (QOL), and back muscle endurance. The primary hypothesis was that participants who received 8 weeks of weekly supervised PT would have improved pain, disability, QOL and back muscle endurance, compared to participants who received 8 weeks of an unsupervised HEP. The research design, sources of data, outcome measures, data collection, and data analysis are discussed in this chapter.

Research Design

This study was a mixed-design randomized clinical trial to compare two physical therapy (PT) interventions (weekly supervised PT and unsupervised HEP). The two independent variables were: (a) intervention with two levels (supervised PT and unsupervised HEP), and (b) time with two levels (before and after the 8-week intervention period). The intervention variable was a between-group factor and the time variable was a within-group factor. The primary dependent variables were: (a) pain

intensity, measured by the Numeric Pain Rating Scale, (b) disability, measured by the Revised Oswestry Back Pain Disability Questionnaire, (c) QOL, measured by the Scoliosis Research Society-22 Health-Related QOL Questionnaire, and (d), back muscle endurance, measured by the prone-double-leg-raise test. One additional dependent variable, overall perceived change as measured by the Global Rating of Change (GROC), was collected.

Participants

Thirty-two participants with AIS and LBP were recruited from all scoliosis clinics at Texas Scottish Rite Hospital for Children (TSRHC) in Dallas, TX. Scoliosis is the most frequent diagnosis seen at this pediatric orthopaedic hospital, and seven physicians at the hospital hold scoliosis clinics on a weekly basis. Physical therapists see one to two patients with AIS and LBP during each clinic. A power analysis using G* Power (Buchner, Erdfelder, & Faul, 1997), *F*-test ANOVA with repeated measures, was performed to estimate the sample size. With an effect size of .25 (medium), α at .05, correlation among repeated measures of .60, a total sample size of 28 was needed to achieve a power of .80. Allowing for 10% attrition, the total sample size was 32 participants (16 in the weekly supervised PT group, 16 in the unsupervised HEP group).

Participants met the following inclusion criteria: girls or boys ages 10 – 17 with AIS, primary curve angles 10° to 45°, and LBP rated at least 2 on the Numeric Pain Rating Scale (NPRS). The exclusion criteria included underlying spinal pathology (including a spondylolytic lesion or tumor), current treatment for AIS (including brace wear) or for

LBP, back pain located beyond the lumbar spine, and back pain more than a week ago. Participants must have had primary curve angles at least 10° to meet the definition of scoliosis. Participants with curves greater than 45° are typically candidates for surgery, so they would be less likely to respond well to conservative intervention.

All participants were given an incentive of $60 at the end of the study for their participation. Participants in the supervised group received an additional $150 at the end of the study as compensation for the additional required time and travel expense for the 8 weekly PT visits.

After obtaining informed assent from both participants and legal guardians, the following demographic data of each participant was collected: age, gender, ethnicity, Risser sign, height, weight, body mass index, curve pattern classification (thoracic, double thoracic, double, thoracolumbar, or lumbar), curve magnitude (Cobb angle), physical activity level (hours per week), back pain duration, back pain frequency (number of days the past week), and the patient-specific functional scale (PSFS). Curve magnitude was measured by the Cobb method. The referring physician determined the Cobb angle on radiograph, which is where two perpendicular lines drawn at the end-vertebrae intersect.

In addition, two clinical tests were performed and collected to evaluate lumbar spine instability, including lumbar flexion range of motion (ROM) and the absence of hypomobility with the segmental intervertebral motion test. The first test, lumbar flexion ROM, was collected according to Waddell et al., (1992). With the participant in

prone, the investigator performing outcome measures marked the midlines of the participant in prone at S2 and T12-L1. Next, with the participant standing relaxed with the arms by the side, the investigator recorded S2 and T12-L1 with a single inclinometer (see Appendix E). The participant then bent as far forward as possible while keeping the knees straight, and the investigator made recordings at T12-L1 and S2 again. Lumbar flexion was calculated by subtracting S2 from T12-L1. For the second test, the lumbar segmental intervertebral motion test, the investigator produced a posterior to anterior force with the hypothenar eminence at the spinous processes with the participant in prone. Each lumbar segment was recorded as normal, hypermobile, or hypomobile.

Instruments

Numeric Pain Rating Scale (NPRS)

The NPRS was used to determine the level of pain intensity in the low back that was perceived by the participant. The NPRS was chosen instead of the Visual Analog Scale (VAS) or the Faces Pain Rating Scale – Revised (FPS-R), because it allowed for long-term follow-up over the phone. The VAS and FPS-R require a child's presence which contributes to difficulty in obtaining follow-up data. The NPRS was measured on an 11-point scale with 0 being no pain and 10 being the worst imaginable pain. The NPRS has been shown to be reliable and valid in children (Williamson & Hoggart, 2005). The minimum clinically important difference (MCID) of the NPRS was found to be one in children (Bailey et al., 2010). In addition, researchers have used the NPRS in adolescents

with LBP, and the average pain level was 4.4 ± 2.7 (Clifford & Fritz, 2003; Fritz & Clifford, 2010).

Revised Oswestry Back Pain Disability Questionnaire (OSW)

The revised OSW (Appendix B) was used to determine the participant's disability level due to LBP. The revised OSW was selected because it was designed specifically for the low back region and is easy to complete. The revised OSW consists of only 10 questions which address different aspects of function. Each question is scored from 0 to 5, with 5 indicating the highest level of disability. The total score ranges from 0 to 50, with higher scores indicating more disability. The revised version most appropriate to adolescents was chosen because the question about sex life from the original version was replaced with a question asking about pain intensity fluctuations. The revised OSW is considered reliable and sensitive to change (Hudson-Cook, Tomes-Nicholson, & Breen, 1989), but has no reported MCID. A modified version replaces the sex life question with a question about homemaking and employment (Fritz & Irrgang, 2001). The modified version was not considered applicable to this study since adolescents may not have employment or homemaking duties. However, the modified version has been found to have a MCID of 6 points (Fritz & Irrgang, 2001). In addition, a successful outcome is defined as at least a 50% improvement in the modified version score in adults with LBP (Fritz & Clifford, 2010). The modified version has been used in adolescents with LBP (Clifford & Fritz, 2003), but has not been validated in adolescents.

Scoliosis Research Society-22 Health-Related Quality-of-Life Questionnaire (SRS-22)

The SRS-22 (see Appendix C) was used to measure QOL in this study. Although it is not specific to individuals with LBP, the SRS-22 was selected because it is specific to the AIS population (Asher et al., 2003; Parent et al., 2009). Unlike the OSW, the SRS-22 has been validated in adolescents. The SRS-22 consists of 22 questions, each worth 5 points. Higher scores indicate better QOL. Each question or domain score ranges from 1 to 5. The SRS-22 includes five domains: pain (five questions), self-image (five questions), function (five questions), mental health (five questions), and management satisfaction/dissatisfaction (two questions). Therefore, the first four domains have a total sum score that ranges from 5 to 25, and the management satisfaction/dissatisfaction domain has a total sum score that ranges from 2 to 10. The maximum total score of the first four domains is 100 (sub-total score), and the total score of all five domains is 110. Only the first four domains were used for statistical analysis in this study, since the two questions on satisfaction/dissatisfaction may have been unclear to participants before PT had begun. The MCID is 0.5 for the average sub-total score, 0.6 for pain, 0.8 for function, 0.5 for image, and 0.4 for mental health (Bago et al., 2009).

Stop Watch

A stop watch was used to time the prone-double-leg-raise (PDLR) test to evaluate isometric back muscle endurance to the nearest tenth of a second (see

Appendix F). The PDLR test is easier to administer clinically than the Sorensen test, since it is does not require an inclined bench or the lower body stabilized. The PDLR test was stopped when the participant was no longer able to maintain knee clearance from a prone lying position (Arab et al., 2007). The PDLR test is reliable and valid in adults (McIntosh et al., 1998), and also has better sensitivity (men 96%, women 100%), specificity (men 100%, women 92%), and predictive values (positive predictive value: 100% men, 93% women; negative predictive value: 96% men, 100% women) compared to the Sorensen test (Arab et al., 2007). Normative percentile data for this test has been published in seconds by 25th, 50th, and 75th percentiles categorized by age (19 years to greater than 60 years) and gender (McIntosh et al., 1998). Also, average hold time in seconds has been reported in adults by gender and whether participants had LBP (Arab et al., 2007). No data specific to adolescents has been found in the literature for the PDLR test.

Global Rating of Change Scale (GROC)

The GROC is a common scale that assesses participants' overall perceived changes, usually to determine the effect of an intervention or to report on the progress of a condition (Kamper et al., 2009). Participants were asked to rate their perceived change of LBP due to PT treatment on a scale ranging from -5 (very much worse) to 0 (unchanged) to 5 (completely recovered) (Kamper et al., 2009). The GROC is reliable, valid and is quick and simple to measure (Kamper et al., 2009). The 11-point scale has a MCID of 2 points (Kamper et al., 2009). The GROC is not frequently used to study the

adolescent population; therefore, no specific GROC data such as reliability or validity has been found in adolescents.

Patient-Specific Functional Scale (PSFS)

The PSFS is a patient-specific questionnaire used to assess functional limitations in patients with orthopaedic conditions, including LBP. Participants were asked to identify up to three important activities that they were unable to do or had difficulty performing, because of their back pain (Hall et al., 2011). Next, participants scored each activity on a scale of 0 (unable to perform the activity) to 10 (able to perform the activity at pre-injury level). Scores were summed and averaged, resulting in a total score out of 10. The PSFS has been shown to be reliable (Stratford et al., 1995) and valid, especially for patients with low levels of activity limitations (Hall et al., 2011). The PSFS has a MCID of 2 (Maughan & Lewis, 2010). We are unaware of the use of this scale in the adolescent population.

Investigators

Four staff physical therapists at TSRHC participated in consenting participants and collecting data. Two physical therapists served as intervention therapists. Investigator #1 supervised most exercise sessions. Investigator #1 is the principal investigator (PI) of this study, has 5 years of experience at TSRHC. The PI also was responsible for designing the standardized core stabilization exercise program. Both the PI and Investigator #2 instructed participants in the standardized spinal stabilization exercise program. Prior to data collection, Investigator #2 was trained in the

intervention protocol by Investigator #1. Investigator #2 has worked at TSRHC for one year and covers numerous scoliosis clinics at TSRHC as well.

Investigators #3-4 performed initial and follow-up outcome measures and were blinded to group assignment. Prior to data collection, Investigators #3-4 were trained in standardized verbal instructions and protocol by Investigator #1. Investigator #3 has been practicing as a physical therapist at TSRHC for 10 years and has assisted with previous research projects at TSRHC. Investigator #3 is the lead physical therapist at TSRHC, a board certified Pediatric Clinical Specialist, and Certified Orthopedic Manual Therapist. Investigator #4 assisted when Investigator #3 was not available. Investigator #4 has worked at TSRHC for two years and also covers numerous scoliosis clinics.

Procedures

This research proposal was approved by the Institutional Review Board at TSRHC (see Appendix H), at University of Texas Southwestern Medical Center (see Appendix I), and Texas Woman's University (see Appendix J). However, all data collection occurred at TSRHC. All participants with AIS who were referred to PT at TSRHC for LBP and met the inclusion criteria were invited to participate in the study. All participants in the study were randomly assigned to a supervised PT group or an unsupervised HEP group by an independent research assistant who drew an equal number of group assignments from a hat (16 for each group). When a participant did not return for follow-up or dropped out, Investigator #2 returned the participant's group number to the hat, thus making that number available for a newly-recruited participant, ensuring that the number of

participants in each group remained at 16. When participants and their legal guardians agreed to participate in the study, the PI obtained their assent on the first visit. After a participant was assented, one intervention physical therapist initiated the spinal stabilization exercise program. On the first visit and after 8 weeks of intervention, the four primary outcome measures (NPRS, OSW, SRS-22, PDLR test scores) were collected by Investigators #3-4 who were blinded to the group assignment. After 8 weeks of intervention, the GROC was collected as well. The spinal stabilization exercise program (see Appendix K) given to all participants was modified from Hicks et al., (2005). The original spinal stabilization exercise program was found to be an effective treatment in adults with LBP and was designed to target the spinal stabilizers, such as the transversus abdominis, erector spinae/multifidus, quadratus lumborum, and oblique abdominals (Hicks et al., 2005). The exercise program used in this study was modified by the principal investigator and her colleagues based on their clinical experience, so that the exercise program was more appropriate for the adolescent population. The exercises were designed to be challenging, fun, and recognizable to promote motivation and adherence to the treatment regimen. Exercises progressed from basic to more advanced as exercise performance improved. Each exercise incorporated abdominal bracing. The PI believed that adolescents would respond better to the instruction “brace your stomach for a punch” to activate the transversus abdominis, rather than the traditional instruction “draw in your lower abdomen.” Therefore, “brace your stomach for a punch” was used for this study. Palpation was used to monitor muscle contractions since it is

simple, especially in various exercise positions. Proper techniques of abdominal bracing include normal breathing, no phasic erratic contractions, and no recruitment of accessory muscles.

Participants were instructed to perform four exercises total, one from each of the four exercise categories. Participants only moved on to the next level of the exercise once they were able to perform the exercise with proper form without any rest breaks for 100 seconds or repetitions. Once they progressed to the next level of the exercise, they discontinued the previous level of the exercise.

The spinal stabilization exercises in the first category focused on isolating the transversus abdominis. As the levels advanced in difficulty, the intensity of the exercises increased as participants were asked to move their extremities while continuing to contract their transversus abdominis (i.e. abdominal bracing). The spinal stabilization exercises in the second category focused on isolating the transversus abdominis during functional activities, such as sitting, standing and standing-up. The spinal stabilization exercises in the third category were designed to train both the multifidus and erector spinae. The advanced levels of the exercises required extremity movements while maintaining the spine in neutral. Maintaining the spine in the neutral and pain-free position ensured engagement of the transversus abdominis muscle. The spinal stabilization exercises in the fourth category incorporated global core musculature in various plank positions. Participants were informed that the goal was more than just completing the exercise progression. The ultimate challenge was to tighten their

stomach muscles continuously throughout the day, especially during positions that have caused LBP.

Participants in the unsupervised HEP group were given a one-time instruction in the spinal stabilization program and were asked to continue performing the exercises at home for 8 weeks. A DVD of the standardized spinal stabilization exercises was provided for participants to follow at home (see Appendix L). Participants were instructed to progress to the next exercise once they could perform the previous exercise with proper form without taking a rest break. Participants were instructed in how to self-evaluate proper technique by determining whether they could tighten their abdominal muscles while breathing normally, maintain a continuous and steady muscle contraction, and keep their shoulders and ribs relaxed with exercises.

Participants in the supervised PT group attended one 30-minute supervised PT session per week for 8 weeks. The PI or investigator #2 would treat the same participant for all 8 weeks. Participants performed the same spinal stabilization program given to the unsupervised HEP group. Participants performed their HEP on the day of supervised PT, completing 100 seconds or repetitions of each of the four exercises. The exercise progression was determined by the treating physical therapist, based on the participant's performance. If participants had increased LBP during the exercise session, no other forms of PT were added. Rather, participants were instructed to stop the exercise and were offered a modification of the exercise that was not painful. After 8 weeks, participants were offered the same DVD of standardized spinal stabilization

exercises that was provided for participants in the unsupervised HEP group (see Appendix L).

Participants in both groups were asked to complete their exercises for 20 minutes at least 5 days a week for the first 2 weeks, and at least 3 days a week after 2 weeks for 8 weeks. The frequency of exercises decreased after 2 weeks because we expected neuromuscular changes. For participants in the supervised PT group, the weekly supervised PT session of the same spinal stabilization exercises counted toward one day of exercise. All participants reported their exercise compliance in a diary which was signed by their guardians (see Appendix M). All participants were also given an exercise handout.

Data Analysis

IBM SPSS Statistics 19 Software (IBM Corp., Amronk, New York) was used to perform statistical analysis for all collected data. Means and standard deviations were calculated for outcome measures (the NPRS, OSW, SRS-22 sub-total score, back muscle endurance, and GROC scores) and participant characteristics (age, body mass index, curve magnitude, duration and frequency of symptoms, physical activity level, lumbar flexion range-of-motion, and PSFS). Descriptive statistics were calculated for the demographic data of all participants, including gender, ethnicity, Risser sign, curve pattern classification, and the prone intervertebral motion test.

Independent *t*-tests were used to analyze the baseline data of the four dependent variables for the primary research question (NPRS, OSW, SRS-22 sub-total,

and PDLR scores) to verify that there was no difference between the two groups before the PT intervention ($p < .05$). Four separate 2x2 ANOVAs with repeated measures were used to analyze the NPRS score, OSW score, SRS-22 score and PDLR score. The alpha was set at .05 for each of the ANOVAs. When a significant interaction was found, pair-wise comparisons were performed. A Mann-Whitney U test was used to analyze the GROC scores after 8 weeks of the PT intervention between the two groups, with the alpha set at .05. An independent *t*-test was used for post-hoc analysis to analyze PSFS scores for between-group differences. A Bonferroni adjustment was done to prevent type I error, with the alpha set at .01.

CHAPTER IV

RESULTS

The effectiveness of spinal stabilization exercises has not been investigated in adolescent idiopathic scoliosis (AIS) and low back pain (LBP). The purpose of this study was to compare the results of 8 weeks of weekly supervised physical therapy (PT) to 8 weeks of an unsupervised home exercise program (HEP). The primary outcome measures included pain intensity, disability, quality-of-life (QOL), and back muscle endurance. The secondary outcome measure was participants' perceived changes after 8 weeks of treatment. This chapter discusses characteristics of the participants and pre- and post- treatment outcome measures.

Participants

Forty-one participants with AIS and LBP were recruited from Texas Scottish Rite Hospital for Children (TSRHC). Thirty participants (15 in the supervised PT group, 15 in the unsupervised HEP group) completed the 8-week exercise program and post-treatment assessment. Eleven participants, two in the supervised PT group and nine in the unsupervised HEP group, did not complete the post-treatment assessment and represent a 27% drop-out rate (12% in the supervised PT group and 38% in the unsupervised HEP group). The most common reason given for refusing to participate was that participants lived too far away. The two participants in the supervised PT group

did not return for their second visit and did not return phone calls attempting to reschedule the appointment. Nine participants in the unsupervised HEP group did not show for their post-treatment assessment and did not respond to telephone calls. The three participants who answered the phone stated that they had not been doing their exercises. They declined to return despite encouragement to attend a post-treatment assessment and collect their monetary incentive. A consort diagram (Figure 1) illustrates the details of participant flow.

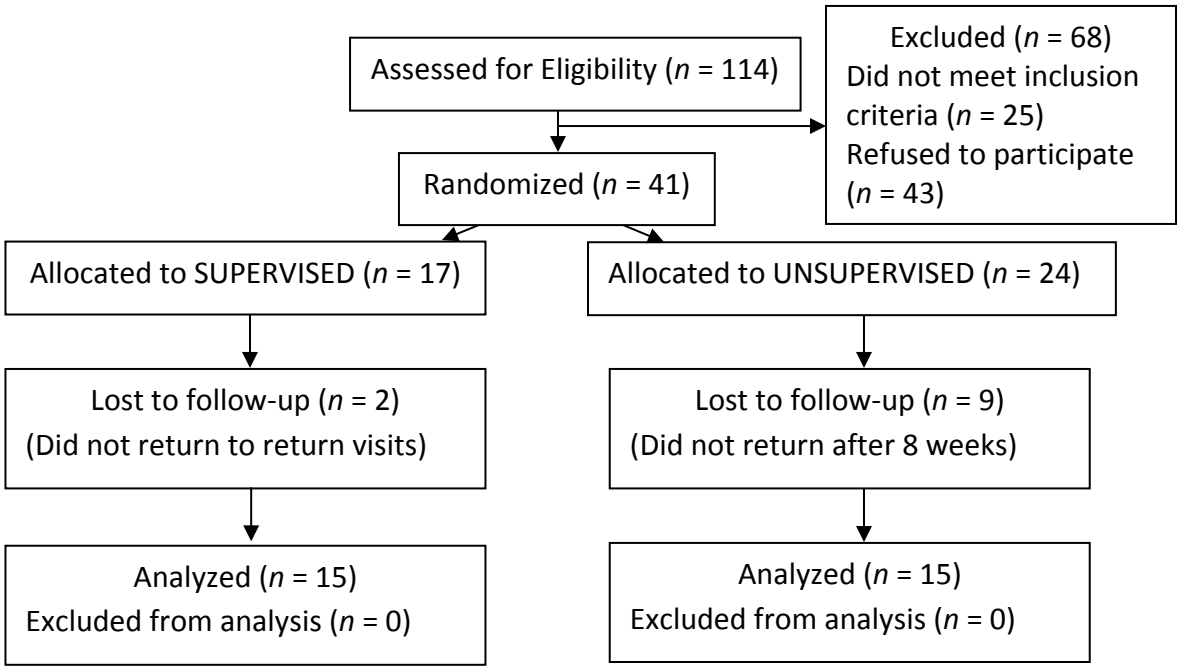

Figure 1. Consort diagram of participant flow.

The 30 participants who completed the post-treatment assessment consisted of 26 girls and 4 boys with a mean age of 15.1 years. Most participants had chronic LBP, averaging 505 days of LBP. Specifically, twenty-two participants reported LBP lasting longer than 3 months. Participants' physical activity level, defined as the number of

hours of organized leisure time per week, was 2.8 hours per week. Baseline participant characteristics can be found in Table 1.

Table 1

Participant Characteristics (M ± SD) at Baseline

	All (*n* = 30)	Unsupervised Group (*n* = 15)	Supervised Group (*n* = 15)
Age (yrs)	15.1 ± 2.0	15.8 ± 2.0	14.3 ± 2.0
Gender	26 girls 4 boys	14 girls 1 boy	12 girls 3 boys
Ethnicity	17 Caucasian 8 Hispanic 4 African American 1 American Indian	9 Caucasian 3 Hispanic 2 African American 1 American Indian	8 Caucasian 5 Hispanic 2 African American
Body Mass Index (kg/m^2)	22.0 ± 4.6	20.9 ± 4.6	23.0 ± 4.6
Physical Activity (hrs/wk)	2.6 ± 3.1	3.0 ± 3.5	2.2 ± 2.7
Risser Grade	3.3 ± 1.7	3.6 ± 1.5	2.9 ± 1.9
Curve Magnitude	25.3 ± 9.3°	21.9 ± 8.3°	28.7 ± 10.4°
Curve Type	6 Thoracic 14 Double 5 Thoracolumbar 5 Lumbar	4 Thoracic 6 Double 3 Thoracolumbar 2 Lumbar	2 Thoracic 8 Double 2 Thoracolumbar 3 Lumbar
Duration of LBP			
Days	526 ± 443	600 ± 509	452 ± 376
Days in the past wk	5.1 ± 2.0	5.3 ± 2.1	4.9 ± 1.9
Pain intensity (NPRS)			
Worst, past wk	6.9 ± 1.4	6.8 ± 1.4	7.0 ± 1.4
Average, past wk	5.4 ± 1.4	5.4 ± 1.3	5.3 ± 1.5
Current	2.7 ± 2.6	2.4 ± 2.4	3.0 ± 2.7

Note. LBP=Low Back Pain. NPRS=Numeric Pain Rating Scale.

Lumbar spine instability tests were performed including lumbar flexion range of motion (ROM) and segmental intervertebral motion to assess for a lack of hypomobility.

Fritz, Piva, and Childs (2005) found that adults with ≥ 53° of lumbar flexion and a lack of hypomobility with the segmental intervertebral motion test had a 93% probability of radiographic instability. Results of the lumbar spine instability tests are listed in Table 2. The majority of participants (29 out of 30) demonstrated lumbar spine instability according to Fritz, Piva, and Childs (2005).

Table 2

Lumbar Spine Instability Tests

	All (*n* = 30)	Unsupervised Group (*n* = 15)	Supervised Group (*n* = 15)
Lumbar flexion	60.1 ± 13.3°	60.9 ± 13.2°	59.3 ± 13.4°
Lack of hypomobility	29	15	14

Compliance with the spinal stabilization exercises was determined by examining participants' exercise logs. When participants did not submit exercise logs, participants were asked to estimate compliance by verbal reports. Table 3 lists exercise compliance by group. An independent *t*-test revealed statistically significant differences in exercise compliance between the two groups ($t = 3.68$, $p = .002$). That is, the supervised group performed their exercises significantly more often (i.e. better exercise compliance) than the unsupervised group.

Table 3

Exercise Compliance of Supervised and Unsupervised Groups

	Unsupervised Group (*n* = 15)	Supervised Group (*n* = 15)
Submitted logs	71% (*n* = 8)	98% (*n* = 8)
Verbal reports	57% (*n* = 7)	91% (*n* = 7)
Combined	64%	95%

Participants in the unsupervised group were asked how often they viewed the DVD. The majority of the participants (*n* = 13) reported not viewing the DVD at all. The most common reason given for not viewing the DVD was that the participants already had written instruction in the exercise program. Two participants reported viewing the DVD an average of three times total.

Functional Limitations

The patient-specific functional scale (PSFS) was used to assess functional limitations. In particular, participants were asked to identify up to three important activities that they had difficulty performing because of their back pain. Each activity was scored on a scale of 0 (unable to perform the activity) to 10 (able to perform the activity at pre-injury level) (Hall et al., 2011). An independent *t*-test revealed no statistically significant difference in the pre-treatment PSFS scores between the two groups ($t = 1.11$, $p = .28$). That is, the supervised PT and unsupervised HEP groups had similar functional limitations before spinal stabilization exercises. The average PSFS scores are reported in Table 4. The higher PSFS scores indicate improved functional

limitations post-treatment compared to pre-treatment. An independent *t*-test of changes in PSFS scores (average post-treatment scores minus average pre-treatment scores) was used to test for statistical differences between groups. An alpha level of .01 was used for this post-hoc statistical analysis, since an alpha level of .05 was divided by 5 outcome measures (the PSFS and the 4 other outcome measures) after a Bonferroni justification was performed to prevent type I error. The independent *t*-test revealed no between-group differences in PSFS scores ($t = 2.40$, $p = .025$), indicating that the supervised group did not demonstrate statistically significant improved functional limitations compared to the unsupervised HEP group.

Table 4

Average Patient-Specific Functional Scale Scores (M ± SD) Pre- and Post- Treatment

	Pre-Treatment	Post-Treatment	Mean Change
All (*n* = 30)	4.1 ± 1.1	7.1 ± 1.7	3.0 ± 1.9*
Supervised (*n* = 15)	4.3 ± 1.0	8.1 ± 1.4	3.9 ± 1.5*
Unsupervised (*n* = 15)	3.9 ± 1.2	6.0 ± 1.9	2.2 ± 2.3*

Note. * indicates minimum clinical important difference.

The supervised group's PSFS scores had improvements that exceeded the MCID of 2.0, found in adults with chronic LBP (Maughan & Lewis, 2010). The supervised PT group improved on average by 3.8, whereas the unsupervised HEP group improved by 1.9 on average.

Pain Intensity

Pain intensity of the low back was assessed using the Numeric Pain Rating Scale (NPRS). Specifically, participants were asked to report their average pain during the past

week on a scale of 0 (no pain) to 10 (worst imaginable pain). The mean and standard deviation values for the pre- and post-treatment pain intensity scores are shown in Table 5. The lower pain intensity scores indicate reduced pain intensity post-treatment compared to pre-treatment. All participants in the supervised group reported reduction in pain intensity, and three participants in the unsupervised group reported no reduction in pain intensity. An independent *t*-test between groups pre-treatment revealed that pain intensity scores were not statistically significant (t = -.07, p = .95). That is, the supervised PT and unsupervised HEP groups had similar low back pain intensity before spinal stabilization exercises. A 2X2 ANOVA with repeated measures at an alpha level of .05 was used to test for pain intensity differences. The assumed homogeneity of variance (HOV) was not violated, based on Levene's test, with p = .61. Sphericity was not violated, based on Mauchly's test of sphericity, with p = 1.00. The ANOVA result revealed a significant group by time interaction, $F(1, 28) = 8.38$, p = .01. Post-hoc paired *t*-tests to evaluate within-group differences indicated significant improvements in both the unsupervised group (t = 3.41, p = .004) and supervised group (t = 10.02, $p < .001$) after 8 weeks of intervention. Post-hoc independent *t*-tests to evaluate between-group differences indicated significant improvements in the supervised group compared to the unsupervised group (t = 2.94, p = .007) after 8 weeks of intervention. In addition, the ANOVA result of main effect revealed that all participants, regardless of group, had reduced pain after 8 weeks of treatment, $F(1, 28) = 79.0$, $p < .001$.

Table 5

Average Pain Scores (M ± SD) Pre- and Post- Treatment

	Pre-Treatment	Post-Treatment
All (*n* = 30)	5.4 ± 1.4	2.4 ± 1.8*
Supervised (*n* = 15)	5.3 ± 1.5	1.5 ± 1.8*
Unsupervised (*n* = 15)	5.4 ± 1.3	3.4 ± 1.8*

Note. * indicates minimum important clinical difference.

As the results indicated, both groups' pain intensity was reduced. Further, the improvements exceeded a minimum clinical important difference (MCID), which is 2.0 in adults with LBP (Childs et al., 2005; Kamper et al., 2011) and 1.0 in children with acute pain (Bailey et al., 2010). The supervised PT group had pain reduction on average by 3.8, and the unsupervised HEP group had pain reduction on average by 2.0. Since treatment success also has been described as 30-50% of pain decrease (von Baeyer, 2009), the spinal stabilization exercises may be regarded as successful to reduce pain in AIS with LBP regardless of the frequency of the treatments (8 weeks of weekly supervision versus an unsupervised HEP). The supervised PT group had a 73% success rate and unsupervised HEP group a 35% success rate.

Disability

The participants' disability level related to LBP was measured using the Revised Oswestry Back Pain Disability Questionnaire (OSW). The total score, ranging from 0 to 50, was calculated by dividing the participant's score by the total possible score. A higher score means a higher level of disability associated with LBP. The mean and standard deviation values for the pre- and post-treatment OSW scores are shown in

Table 6. An independent *t*-test between groups pre-treatment revealed that OSW scores were not statistically significant (t = -.44, p = .67). That is, the supervised PT and unsupervised HEP groups had similar disability levels before spinal stabilization exercises. A 2X2 ANOVA with repeated measures at an alpha level of .05 was used to test for OSW differences. The assumed HOV was not violated, based on Levene's test, with p = .11. Sphericity was not violated, based on Mauchly's test of sphericity, with p = 1.00. The ANOVA result showed no significant group by time interaction, $F(1, 28) = 2.48$, p = .13, indicating that the supervised PT group did not demonstrate statistically significant reduced disability compared to the unsupervised HEP group after 8 weeks of spinal stabilization exercises. However, the ANOVA result of main effect revealed that all participants, regardless of group, had reduced disability after 8 weeks of treatment, $F(1, 28) = 67.0$, $p < .001$.

Table 6

Average Revised Oswestry Back Pain Disability Questionnaire Scores (M ± SD) Pre- and Post- Treatment

	Pre-Treatment	Post-Treatment
All (n = 30)	17.1 ± 6.6	8.4 ± 6.7*
Supervised (n = 15)	16.5 ± 7.5	6.2 ± 6.9*
Unsupervised (n = 15)	17.6 ± 5.7	10.6 ± 6.5*

Note. * indicates minimum clinical important difference.

However, as shown in the descriptive data, both groups had reduced disability which exceeded the MCID of the modified version (6.0 points) in adults with LBP (Fritz & Irrgang, 2001). The supervised PT group had reduced disability on average by 10.3

points, and the unsupervised HEP group improved by 7.0 points on average. Since treatment success also has been described as a minimum 50% improvement in the score of the modified version (Fritz & Clifford, 2010), the spinal stabilization exercises may be regarded as successful to reduce disability level in AIS with LBP regardless of the frequency of the treatments (8 weeks of weekly supervision versus an unsupervised HEP). The supervised PT group had a 63% success rate and unsupervised HEP group a 43% success rate.

Given that the ANOVA result of interaction effect was not significant and $p = .13$, a post-hoc power analysis was performed with a power of .90, a medium effect size of .29, and α at .05. A total sample size of 34 would be needed to potentially obtain a significant interaction. Therefore, we plan to continue with data collection until we achieve two more participants in each group.

Quality-of-Life

The SRS-22 was used to measure QOL. Specifically, participants completed a questionnaire consisting of 22 questions worth 5 points each. Higher scores indicate better QOL. Each question or domain score ranges from 1 to 5. The SRS-22 includes five domains: pain (five questions), self-image (five questions), function (five questions), mental health (five questions), and management satisfaction/dissatisfaction (two questions). The mean and standard deviation values for the pre- and post-treatment SRS-22 scores are shown in Table 7. The sub-total scores of the first four domains were used for statistical analysis in this study, since the two questions on management

satisfaction/dissatisfaction in the last domain were unclear since PT treatment had not yet begun. An independent *t*-test between groups pre-treatment revealed that SRS-22 sub-total scores were not statistically significant ($t = -.54$, $p = .59$). In other words, the supervised PT and unsupervised HEP groups had similar QOL before spinal stabilization exercises. A 2X2 ANOVA with repeated measures at an alpha level of .05 was used to test for SRS-22 sub-total differences. The assumed HOV was not violated, based on Levene's test, with $p = .68$. Sphericity was not violated, based on Mauchly's test of sphericity, with $p = 1.00$. The ANOVA result revealed no significant group by time interaction, $F(1, 28) = .16$, $p = .69$. Therefore, the supervised PT group did not demonstrate statistically significant improvement compared to the unsupervised HEP group after 8 weeks of spinal stabilization exercises. However, the ANOVA result of main effect revealed that all participants, regardless of group, had improved QOL after 8 weeks of treatment, $F(1, 28) = 42.5$, $p < .001$.

Table 7

Average SRS-22 Scores (M ± SD) Pre- and Post- Treatment

	Pre-Treatment	Post-Treatment
Total Score		
Supervised (*n* = 15)	3.6 ± 0.3	4.1 ± 0.5
Unsupervised (*n* = 15)	3.7 ± 0.4	3.9 ± 0.8
Sub-total Score		
Supervised (*n* = 15)	3.6 ± 0.3	4.1 ± 0.5*
Unsupervised (*n* = 15)	3.7 ± 0.4	4.1 ± 0.5
Pain domain		
Supervised (*n* = 15)	3.4 ± 0.6	4.1 ± 0.6*
Unsupervised (*n* = 15)	3.2 ± 0.5	3.8 ± 0.8*
Self-image domain		
Supervised (*n* = 15)	3.2 ± 0.6	3.9 ± 0.6*
Unsupervised (*n* = 15)	3.6 ± 0.7	4.0 ± 0.6
Function domain		
Supervised (*n* = 15)	4.0 ± 0.5	4.3 ± 0.7
Unsupervised (*n* = 15)	4.0 ± 0.7	4.4 ± 0.6
Mental Health domain		
Supervised (*n* = 15)	3.6 ± 0.5	4.0 ± 0.8*
Unsupervised (*n* = 15)	3.7 ± 0.4	4.2 ± 0.6*
Management Satisfaction/Dissatisfaction domain		
Supervised (*n* = 15)	3.4 ± 0.8	4.5 ± 0.7
Unsupervised (*n* = 15)	3.7 ± 0.9	4.1 ± 0.9

Note. * indicates minimum clinical important difference.

The supervised PT group made improvements that exceeded the MCID of 0.5 for the average sub-total score, whereas the unsupervised group did not (Bago et al., 2009). The supervised PT group's sub-total score improved on average by 0.5, and the unsupervised HEP group only improved by 0.4 on average. Both groups had improvements that exceeded the MCID of 0.6 for the pain domain score (Bago et al., 2009). The supervised PT group's pain domain score improved on average by 0.7, while

the unsupervised HEP group improved by 0.6 on average. For the self-image domain score, the supervised PT group improved on average by 0.7, which exceeded the MCID of 0.5 (Bago et al., 2009). However, the unsupervised HEP group only improved by 0.4 on average. Both groups did not have improvements that exceeded the MCID of 0.8 for the function domain score (Bago et al., 2009). The supervised PT group's function domain score improved on average by 0.3, and the unsupervised HEP group improved by 0.4 on average. Both groups had improvements that exceeded the MCID of 0.4 for the mental health domain score (Bago et al., 2009). The supervised PT group's mental health score improved on average by 0.4, while the unsupervised HEP group improved on average by 0.5. Since Bago et al. (2009) excluded the two questions on management satisfaction/dissatisfaction, the MCID of this domain and of the total score were not calculated.

Back Muscle Endurance

Back muscle endurance was assessed using the prone-double-leg-raise (PDLR) test. Specifically, participants were timed as to how long they could maintain knee clearance in the prone position. The mean and standard deviation values for the pre- and post-treatment PDLR test scores are shown in Table 8. The higher PDLR test scores indicate greater back muscle endurance post-treatment compared to pre-treatment. An independent *t*-test between groups pre-treatment revealed that PDLR scores were not statistically significant ($t = -1.2$, $p = .23$). In other words, the supervised PT and unsupervised HEP groups had similar isometric back muscle endurance before spinal

stabilization exercises. A 2X2 ANOVA with repeated measures at an alpha level of .05 was used to test for back muscle endurance. The assumed HOV was not violated, based on Levene's test, with $p = .39$. Sphericity was not violated, based on Mauchly's test of sphericity, with $p = 1.00$. The ANOVA result revealed no significant group by time interaction, $F(1, 28) = .99$, $p = .33$. Therefore, the supervised PT group did not demonstrate statistically significant improvement on back muscle endurance compared to the unsupervised HEP group after 8 weeks of spinal stabilization exercises. However, the ANOVA result of main effect revealed that all participants, regardless of group, had improved back muscle endurance after 8 weeks of treatment, $F(1, 28) = 25.0$, $p < .001$.

Table 8

Average Prone-Double-Leg-Raise Test Scores (M ± SD) Pre- and Post- Treatment (s)

	Pre-Treatment	Post-Treatment
All (n = 30)	46.6 ± 29.2	84.3 ± 49.3
Supervised (n = 15)	40.1 ± 32.1	85.3 ± 40.7
Unsupervised (n = 15)	53.1 ± 26.2	83.3 ± 57.9

Participants' Perceived Changes

Participants' overall perceived changes were evaluated by the global rating of change (GROC). Specifically, participants were asked to rate their perceived change of LBP due to the 8-week PT treatment on an 11-point scale ranging from -5 (very much worse) to 0 (unchanged) to 5 (completely recovered) (Kamper et al., 2009). The average

GROC score was 3.7 ± 1.0 in the supervised PT group, and was 2.4 ± 2.2 in the unsupervised HEP group. The Mann-Whitney U test statistic at an alpha level of .05 revealed that the differences in the GROC scores between groups were not significant (p = .10), indicating that the supervised PT group did not demonstrate statistically significant improvement compared to the unsupervised HEP group after spinal stabilization exercises. However, the GROC scores in both groups exceeded the MCID of 2.0 (Kamper et al., 2009).

Summary

Thirty participants with AIS (15 in the supervised PT group and 15 in the unsupervised HEP group) completed the post-treatment assessment after 8 weeks of spinal stabilization exercises for LBP. The primary outcome measures included pain intensity, disability, QOL, and back muscle endurance. The secondary outcome measure included participants' perceived changes.

Both groups were similar in all outcome measurements before starting treatment, and improved in all outcome measures after treatment. The results revealed statistically significant differences between the two groups in pain intensity as measured by the NPRS, with the supervised PT group demonstrating greater pain reduction than the unsupervised HEP group.

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effectiveness of an 8-week spinal stabilization exercise program in participants with adolescent idiopathic scoliosis (AIS) and low back pain (LBP). A weekly supervised physical therapy (PT) group was compared to an unsupervised home exercise program (HEP) group. The primary hypothesis was that participants in the weekly supervised group would demonstrate reduced pain and disability and improved quality-of-life (QOL) and back muscle endurance, compared to participants in the unsupervised HEP group. This chapter presents a summary and discussion of the findings, conclusion, limitations, and recommendations for future research.

Summary of Findings

Research Question 1

The first research question was, "Would there be differences in pain intensity, disability, QOL, and back muscle endurance between participants with AIS and LBP who receive 8 weeks of weekly supervised PT compared to those who receive 8 weeks of an unsupervised HEP?" The null hypothesis and resulting decision are presented. The null hypothesis was that no differences would exist in pain intensity, disability, QOL, and back muscle endurance following the intervention between participants with AIS and

LBP who receive 8 weeks of weekly supervised PT and those who receive 8 weeks of an unsupervised HEP.

The null hypothesis is rejected for the outcome measure of pain intensity as measured by the Numeric Pain Rating Scale (NPRS) scores. The ANOVA result revealed a significant group by time interaction in the NPRS scores. Post-hoc analysis indicated significant within-group differences and between-group differences. These results suggest that both groups had significant pain reduction after 8 weeks of spinal stabilization exercises, but the supervised PT group demonstrated greater pain reduction as compared to the unsupervised HEP group.

However, the null hypothesis is accepted for the other three outcomes: disability, QOL, and back muscle endurance. The ANOVA results revealed no significant group by time interactions for disability as measured by the Revised Oswestry Back Pain Disability Questionnaire (OSW), QOL as measured by the Scoliosis Research Society-22 Health-Related QOL Questionnaire (SRS-22), and back muscle endurance as measured by the prone-double-leg-raise (PDLR) test. These findings indicate no group differences in disability, QOL, and back muscle endurance after 8 weeks of spinal stabilization exercises.

Research Question 2

The second research question was, “Would there be improved pain intensity, disability, QOL, and back muscle endurance in participants with AIS and LBP, regardless of group, after 8 weeks of intervention?” The null hypothesis was that participants with

AIS and LBP, regardless of group, would demonstrate no improved pain intensity, disability, QOL, and back muscle endurance after 8 weeks of intervention.

The null hypothesis is rejected for all outcome measures. The ANOVA results revealed a significant main effect of time in the NPRS, OSW, SRS-22, and PDLR scores. These findings indicate that all participants, regardless of group, demonstrated improved pain intensity, disability, QOL, and back muscle endurance after 8 weeks of intervention.

Research Question 3

The third research question was, "Would there be a difference in perceived changes between participants with AIS and LBP who receive 8 weeks of weekly supervised PT compared to those who receive 8 weeks of an unsupervised HEP?" The null hypothesis was that there would be no significant differences in perceived changes between participants with AIS and LBP who receive 8 weeks of weekly supervised PT and those who receive 8 weeks of an unsupervised HEP.

The null hypothesis is accepted. The Mann-Whitney U test statistics at an alpha level of .05 revealed that the between-group difference for the global rating of change (GROC) was not significant. This finding indicates that the weekly supervised PT group did not demonstrate statistically significant perceived improvement compared to the unsupervised HEP group after 8 weeks of spinal stabilization exercises.

Discussion of Findings

Pain Intensity

Our results indicate that 8 weeks of weekly supervised PT is superior in reducing pain compared to 8 weeks of an unsupervised HEP in participants with LBP and AIS. Our study is unique in numerous regards. First, our study appears to be the first study investigating the effectiveness of PT interventions on pain intensity reductions for adolescents with LBP and idiopathic scoliosis (IS). Second, the broader examination of the effectiveness of various interventions in the treatment of children and adolescents with LBP is a relative new area of inquiry, and findings have been mixed. Three separate randomized control trials by Ahlqwist et al. (2008), Fanucchi et al. (2009), and Jones et al. (2007) have explored the effectiveness of the treatment of LBP in adolescents. Researchers led by Fanucchi and Jones found significant between-group differences in pain intensity reduction, but Ahlqwist's research team did not. Although all three studies included stabilization exercises of some sort, the interventions varied, including combinations of back education (Ahlqwist et al. 2008; Fanucchi et al. 2009), general physical conditioning (Ahlqwist et al. 2008; Jones et al. 2007), and manual therapy (Ahlqwist et al. 2008). Furthermore, authors did not provide detailed aspects of the treatment such as intensity, duration and magnitude as noted in a meta-analysis by Calvo-Muñoz, Gómez-Conesa, & Sánchez-Meca (2013). None of these studies involving a more generalized population of adolescents with LBP without spinal deformity focused their intervention on spinal stabilization exercises as in our study.

Finally, several other methodological differences illustrate the contribution of our study and may explain in part the mixed findings. Fanucchi et al. (2009) and Jones et al. (2007) had true control groups of no intervention, so their results of superior pain intensity reduction in the exercise groups are expected. The studies by Fanucchi et al. and Jones et al. also differed from our study, since they had a different treatment setting. Fanucchi et al. and Jones et al. were school-based studies using group sessions, as opposed to our study that was a community-based study using supervised and individualized PT. In contrast to our study, Ahlqwist et al. (2008) did not find superior pain intensity reduction in an individualized PT group compared to a self-training group. However, Ahlqwist et al. found superior pain duration reduction and physical function in the individualized PT group. The study by Ahlqwist et al. was similar to our study in that the treatment setting of Ahlqwist et al. was also a community-based study using individualized PT. However, the self-training group of Ahlqwist et al. differed from the unsupervised HEP group of our study, since the self-training group in Ahlqwist et al. received in-person follow-up after 1 week and a telephone follow-up halfway through the treatment. In contrast, the unsupervised group of our study only received in-person follow-up after 8 weeks, similar as to the care typically provided in our setting. The increased attention given to the individualized PT group by Ahlqwist et al. may have improved exercise compliance and results of pain intensity reduction compared to the self-training group. In addition, Ahlqwist et al. provided a variety of exercises for conditioning, mobility, strength, and coordination, including spinal stabilization

exercises. Because the exercise program by Ahlqwist et al. was so diverse, the most significant aspect of the training program which contributed to their findings cannot be discerned. Given our findings, we speculate that spinal stabilization exercises may be the key factor in reducing pain intensity and duration. For example, participants in our study commonly reported LBP with prolonged sitting. Abdominal bracing in sitting was one exercise provided in our study, with the ultimate goal of teaching participants to incorporate abdominal bracing throughout the day while sitting at home or school. The focus of PT should be on activity-specific spinal stabilization exercises designed to reduce activity-specific pain. Generalized exercises may not be sufficient to reduce LBP, since some of the participants with LBP in our study already participated in organized sports and met physical activity recommendations. Furthermore, our participants quickly learned the spinal stabilization exercises. Although teaching adolescents abdominal bracing with the cue "brace your stomach for a punch" incorporates violent language, we observed participants readily responding to this cue with the correct muscle activation. As soon as adolescents learned the technique, we did not mention punching anymore. We rather cued them to "tighten your stomach," which is not correct anatomically, but was understood by the adolescents.

Our study further contributes to the understanding of optimal PT treatment duration and frequency for adolescent LBP, despite methodological differences among the randomized controlled trials. Significant pain reduction was found after 8 weeks of PT intervention in our study. The duration of 8 weeks of exercise intervention is similar

to the treatment duration in the studies by Fanucchi et al. (2009) and Jones et al. (2007), whereas the treatment duration was 12 weeks in the study by Ahlqwist et al. (2008). In our study, each exercise session lasted 30 minutes. Our treatment time was similar to the study by Jones et al., while each PT session was 45 minutes in the study by Fanucchi et al. Further, participants in the supervised PT group of our study were seen weekly, which was similar to the treatment frequency of Ahlqwist et al. and Fanucchi et al. The PT treatment frequency in the study by Jones et al. was twice a week. Like these three studies, the exercises in our study were prescribed at least three times a week. Weekly PT for a duration of 8 to 12 weeks appears to be sufficient in treating adolescents with LBP with or without AIS. The exercise intervention frequency of three times a week appears to be the optimal exercise dosage for adolescents with LBP with or without IS.

Our study also furthers the body of literature on the optimal number of PT exercises that should be provided to adolescents. The total number of exercises participants in the three previously described studies performed during PT sessions and for their HEP is unclear, but our study provided only four exercises at a time. Reducing the HEP to as few exercises as possible may promote exercise compliance similar to the effect reported among older adults (Henry, Rosemond, & Eckert, 1999; Campbell et al., 2001). In addition, we recommend increasing the repetitions to promote adequate exercise intensity, mass practice and carryover into daily life. Our study used 100 second or repetition holds for each exercise, which is much higher than that used in an adult study by Hicks et al. (2005). We noticed that participants achieved 100 second or

repetition hold times during their weekly supervised PT visit when they had not achieved such times at home. By performing their exercises for a physical therapist, participants in the weekly supervised PT group may have had increased motivation to challenge themselves to achieve 100-second or 100-repetition hold times compared to the unsupervised HEP group.

Interestingly, the three studies described above and our study all found pain reduction with exercises, but different methods were used to determine pain intensity. We used the NPRS. However, a 10-point pain scale was used in the study by Jones et al. (2007), and the Visual Analog Scale was used in the studies by Ahlqwist et al. (2008) and Fanucchi et al. (2009). In our study, the initial average pain intensity was reported at 5.4, similar to the reported initial pain intensities in those three studies, ranging from 4.0 to 6.5 (Ahlqwist et al., 2008; Fanucchi et al., 2009; Jones et al., 2007). Pain intensity reduction in the supervised PT group of our study was also similar (3.8 point decrease) to pain reduction found in individual PT group (3.6 point decrease) of Ahlqwist et al. and at least one point more than the two exercise groups (2.7 to 2.8 point decreases) of Fanucchi et al. and Jones et al. Superior pain intensity reductions in our study and in the study by Ahlqwist et al. may be due to individualized PT sessions in contrast to the group sessions of Fanucchi et al. and Jones et al.

The results of our study may indicate that the NPRS is a sensitive tool for detecting reductions in LBP in patients with AIS. The NPRS has good sensitivity in children (Williamson & Hoggard, 2005) and can be further applied to the particular

subgroup of patients with LBP and AIS. The NPRS also has been used in retrospective studies evaluating adolescents with LBP (Clifford & Fritz, 2003; Fritz & Clifford, 2010). In our study, both groups (supervised PT and unsupervised HEP) improved by a minimum clinical important difference (MCID), which is 2 in adults with LBP (Childs et al., 2005; Kamper et al., 2011) and 1 in children with acute pain (Bailey et al., 2010). Although both groups were given spinal stabilization exercises, the supervised PT group benefited from individualized, regular follow-up and better exercise compliance compared to the unsupervised group. The greater pain reduction in the supervised group may have been due to both an increased attention and better exercise compliance.

Disability

The results of our study indicate no between-group differences in the OSW scores after 8 weeks. However, since the *p*-value approached significance at $p = .13$, this outcome measure requires further exploration. Although the revised OSW has not been validated in adolescents, the tenth question from the original and modified versions were not appropriate for this age group. The revised OSW replaces the original version's question about sex life and the modified version's question about homemaking and employment with a question asking about pain intensity fluctuations. A drawback of the revised version's question about pain intensity fluctuations is that the underlying construct of the question is changed. Furthermore, patients may confuse impairment with disability (Fairbank & Pynsent, 2000).

Another version of the OSW may be appropriate for adolescents. Clifford changed the tenth question to ask about employment or school activities, including sports and recreation activities, thus retaining the intended construct (Clifford, 2003). However, Clifford's version of the OSW has not been published beyond the dissertation, so we did not use it in our study. Clifford took steps to investigate the validation of her version of the OSW in adolescents. However, future studies are warranted, especially in the AIS and LBP population.

Quality-of-Life

The results of our study found no differences in QOL improvement between groups after 8 weeks. The SRS-22 has been validated in adolescents with IS, but is not specific for adolescents with LBP. Therefore, this outcome measure may not be sensitive to detect QOL changes in adolescents with both IS and LBP. We found that participants had difficulty understanding some of the SRS-22 questions, for example, question number 10, "Which of the following best describes the appearance of your trunk; defined as the human body except for the head and extremities?" Although this question defined the trunk as part of the question, participants still did not know what was meant and asked either their guardian or the investigator who measured the outcomes. Also, the last two SRS-22 questions on management satisfaction or dissatisfaction were unclear to the participants, since PT management of the LBP had not begun yet. Since the SRS-22 had validity concerns in our study, a different

questionnaire specific to AIS may need to be developed, especially for younger adolescents whose vocabularies are limited.

The SRS-22 is highly correlated with the original version of the OSW (r = .87) in adults with scoliosis (Bridwell et al., 2005). The concurrent validity for function was determined by comparing the 5 function SRS-22 questions (function domain) to the 10 function questions of the original OSW (Bridwell et al., 2005). Our study's findings do not seem to agree with that of Bridwell et al. (2005) in that our results seem to indicate that the SRS-22 does not measure the same way as the OSW. Participants in our study scored the highest in the SRS-22 function domain pre-treatment (4.0 out of 5.0 indicating good function), and on average, they did not demonstrate improvements that met a MCID. Mean OSW scores, in contrast, were low at pre-treatment (17.1 out of 50) indicating worse function, and on average, the participants' demonstrated improvements that met a MCID. We speculate that the OSW is better than the function domain of the SRS-22 at revealing functional limitations in adolescents with IS and LBP.

The SRS-22 was most helpful in identifying participants with psychosocial concerns. Participants who did not have reduced pain intensity reported lower than average self-image or mental health scores on the SRS-22. Out of the four participants who reported self-image or mental health scores averaging less than three out of five, three participants had less than 3-point reductions on the NPRS. Follow-up with those participants with low self-image or mental health scores may be helpful to better understand the psychosocial components of LBP in adolescents with IS. For example, a

psychologist or psychiatrist could intervene in an attempt to modify psychosocial factors which may be influencing LBP intensity.

Back Muscle Endurance

The results of our study found no differences in back muscle endurance improvements between groups after 8 weeks. This finding may be due in part to large standard deviations reflecting the variability in performance, which may be due to personal factors like motivation, pain tolerance, and competitiveness (Demoulin et al., 2006). In adults 19 to 29 years old, the 50th percentile hold time for the PDLR was reported at 88 seconds for males and 74 seconds for females (McIntosh et al., 1998). Adolescents in our study averaged a similar hold time of 86 seconds post-treatment. However, the PDLR test does not appear to be useful for adolescents given their higher than expected performance variability. A better outcome measure may be a test targeting the activation of the deep abdominal or back extensor musculature. The effectiveness of spinal stabilization exercises on the deep abdominals or back extensors for participants with AIS and LBP may be better quantified with a pressure biofeedback unit or rehabilitative ultrasound imaging. Alternatively, simple palpation to evaluate whether a contraction can be held for 100 seconds in supine hooklying may be sufficient. Finally, movement dysfunction tests of the lumbar spine described by Luomajoki, Kool, Bruin, and Airaksinen (2010) may better characterize changes in movement control due to improved spinal stability with daily activities than the PDLR test.

Participants' Perceived Changes

The results of our study found no differences in participants' perceived changes between groups after 8 weeks. However, the *p* value approached significance at .10, with the supervised group approaching statistically significant improvement compared to the unsupervised group. The GROC score ranges from -5 to 5, whereas the PSFS and NPRS range from 0 to 10. Given that the GROC is administered verbally in conjunction with the PSFS and NPRS, the GROC's different end-points may be confusing to adolescents. Therefore, instruction for GROC administration may need to be changed for adolescents to eliminate rating errors due to scale confusion. Simply using two-step questioning may eliminate errors. First, adolescents can be asked if they feel better, worse or no change after the intervention. Depending on whether adolescents feel better or worse, they can then be asked to rate their improvement or worsening on a scale of 1 to 5.

Functional Limitations

The patient-specific functional scale (PSFS) was used to evaluate functional limitations. Although not included as an outcome measure, we performed a post-hoc statistical analysis because improvements were seen in the PSFS scores for both groups. However, the post-hoc *t*-test results indicate no between-group differences in the PSFS scores after 8 weeks. However, the *p*-value approached significance at .025, with .01 indicating significance. In addition, both groups improved by a MCID of 2 (Maughan & Lewis, 2010). Authors of another randomized control trial also evaluated improvements

in functional limitations in adolescents with LBP but without scoliosis (Ahlqwist et al., 2008). Ahlqwist et al. (2008) evaluated the effectiveness of individualized PT compared to a self-training group. Although they did not administer the PSFS, they used the Roland and Morris Disability Questionnaire, a reliable and valid outcome measure of physical function. Contrary to the findings of our study, Ahlqwist et al. found significantly improved functional limitations in the group receiving individualized PT compared to the self-training group.

Although the PSFS was not included as an outcome measure in our study, we think that the PSFS may be sensitive to activity limitations in adolescents with LBP, since adolescents have the opportunity to describe meaningful activities that are difficult for them. Common activities mentioned included sitting throughout a class period and running. Questionnaires like the OSW and SRS-22 may include questions that are not pertinent to adolescents. Although the PSFS is valid in adults (Hall et al., 2011), the PSFS has not been validated in adolescents. Validation of this scale and determination of a MCID in adolescents with LBP is recommended.

The PSFS may be confusing to adolescents if it is administered in conjunction with the NPRS. The absence of pain and activity limitations are on opposite ends of the 11-point scale, where 0 is “no pain” on the NPRS, while 0 is “unable to perform the activity” on the PSFS. Therefore, instructions will need to be very specific to adolescents when administering the PSFS in future studies. Or, the PSFS should be administered at a different time than the NPRS.

Participant Characteristics

Almost all participants in our study had chronic LBP, with an average duration of almost one and a half years. This finding suggests that their back pain may not necessarily improve regardless of time. In addition, the chronicity of their pain may produce central nervous system changes involving pain perception, which exercise may or may not alter (Fanucchi et al, 2009; Jones et al, 2007). Although weekly supervised PT may be preferable to one-time treatment to manage LBP according to our study, adolescents with LBP are rarely referred to community-based physical therapists (Clifford & Fritz, 2003). Factors for low referral rates may be that few adolescents seek medical care for LBP and a general belief that back pain during growth is normal (Clifford & Fritz, 2003).

The majority of participants in our study also had lumbar spine instability using the criteria reported in a previous study: more than or equal to 53° of lumbar flexion and a lack of hypomobility with segmental intervertebral motion testing (Fritz et al., 2005). Participants in both groups averaged about 60° of lumbar flexion, which is a risk factor for radiographic instability in adults (Fritz et al., 2005). The relatively high values of lumbar flexion indicate that adolescents with LBP may benefit from lumbar stability, not lumbar mobility treatment. However, no normative data has been published for lumbar flexion range of motion in adolescents 10 to 17 years old. Lumbar flexion is generally greater in younger ages, so this study's lumbar flexion findings may rather be indicative of normal range of motion values. Also, almost all participants (29 out of 30)

had a lack of hypomobility with segmental intervertebral motion testing. These results also indicate that lumbar stability may be of particular importance. Also, adolescents may have less hypomobile segments than adults, so the segmental intervertebral motion test may not be the most ideal test for lumbar instability in adolescents. Future studies should compare lumbar spine instability tests in adolescents with true radiographic lumbar instability to evaluate whether tests in adults are valid for tests in adolescents.

Over four times as many participants in the unsupervised group were lost to follow-up (*n* = 9) compared to the supervised group (*n* = 2). The high attrition rate in the unsupervised group may indicate that participants were not fully compliant with the HEP and therefore did not wish to return. Based on clinical experience, older adolescents tend to have lower adherence to instructions by a PT or caregiver than younger adolescents (10 to 12 years old).

The participants in the unsupervised group who returned for follow-up were significantly less compliant in performing their exercises than in the supervised group (64% versus 95%, respectively). This finding is not surprising given the lack of contact and accountability in the unsupervised group despite the exercise DVD. In contrast, participants in the supervised group counted their weekly PT session as part of their exercise compliance and received regular encouragement to do their exercises.

Surprisingly, participants in the unsupervised group rarely viewed the provided DVD. We had believed that a DVD would be superior to a sheet of paper with written

instruction due to adolescents' preference for technology. However, most adolescents reported that the written instructions were sufficient in familiarizing themselves with the exercises and that they already knew many of the spinal stabilization exercises before the study. Nevertheless, the adolescents in the unsupervised group may not have performed the exercises correctly and did not advance themselves on the exercise program correctly. For example, participants in the supervised group were noted to arch their back or not clear their shoulders off the floor for some of the exercises. Future consideration may be given to alternative technology to promote exercise compliance, for example a link that could be accessed from their cell phone or reminder applications for cell phones.

Limitations

This study only included participants within a certain proximity to Texas Scottish Rite Hospital for Children (TSRHC). Although TSRHC treats children throughout the state of Texas, participants needed to be willing to attend physical therapy sessions on a weekly basis for 8 weeks. Therefore, participants in this study may not be representative of adolescents with IS and LBP which may limit the generalizability of the study.

Participants in the supervised group may have improved partly due to a placebo effect of treatment attendance. Although we attempted to minimize this effect by providing a DVD to the unsupervised group, participants in the unsupervised group did not benefit from the increased accountability and attention received by the supervised group.

Conclusion

The findings of this study suggest that spinal stabilization exercises for LBP are effective in adolescents with IS. Weekly supervised PT is more effective in reducing back pain than an unsupervised HEP in participants with AIS and LBP after 8 weeks. Although participants in both groups improved, participants in the supervised PT group had significantly greater reductions in pain intensity compared to the unsupervised group. Both groups demonstrated similar reductions in disability and improvements in QOL, back muscle endurance, and participants' perceived changes.

We recommend that clinicians provide weekly supervised spinal stabilization exercises for patients with AIS and LBP whose primary concern is pain intensity. We recommend an unsupervised spinal stabilization HEP for adolescents whose primary concern is back muscle endurance or QOL. Adolescents with disability concerns may need to be treated on a case-by-case basis, depending on whether they have activity-specific LBP which may respond better to regular follow-up. Also, if participants and caregivers are concerned that exercise compliance may be an issue, we recommend more regular follow-up due to the significantly higher rate of attrition in the unsupervised group compared to the supervised group.

Recommendations for Future Study

Further study is recommended in patients with AIS and LBP. Although participants in our study demonstrated reduced pain with spinal stabilization exercises, how they would respond to other forms of intervention is unclear. For example,

scoliosis-specific exercises like the Schroth method or Barcelona Scoliosis Physical Therapy School are also worth exploring. Since our study found no between-group differences in QOL, we can evaluate whether curve-specific exercises that teach patients with AIS how to hold themselves in a straighter posture result in superior QOL improvements as measured by a self-image questionnaire. Since our study found no between-group differences in disability, another intervention option is to evaluate and treat movement dysfunctions at the lumbar spine that may result in superior reductions in disability. In addition, long-term follow-up studies are needed to evaluate the long-term effectiveness of spinal stabilization exercises in patients with AIS and LBP. Further research should continue to evaluate treatment outcomes at least 6 months after initiating treatment, since our study only has treatment outcomes immediately following treatment.

Normative data and valid questionnaires are needed for adolescents. Normative values of lumbar range of motion in adolescents would provide a better understanding of the likelihood of spinal instability in patients with AIS and LBP. Validating the PSFS and the OSW or Clifford's version of the OSW in adolescents would provide a better understanding of pertinent functional limitations and disability. In addition, a QOL outcome measure other than the SRS-22 should be developed for patients with AIS.

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APPENDIX A

Patient-Specific Functional Scale

The Patient-Specific Functional Scale

This useful questionnaire can be used to quantify activity limitation and measure functional outcome for patients with any orthopaedic condition.

Clinician to read and fill in below: Complete at the end of the history and prior to physical examination.

Initial Assessment:

I am going to ask you to identify up to three important activities that you are unable to do or are having difficulty with as a result of your _____ problem. Today, are there any activities that you are unable to do or having difficulty with because of your _____ problem? (Clinician: show scale to patient and have the patient rate each activity).

Follow-up Assessments:

When I assessed you on (state previous assessment date), you told me that you had difficulty with (read all activities from list at a time). Today, do you still have difficulty with: (read and have patient score each item in the list)?

Patient-specific activity scoring scheme (Point to one number):

0 1 2 3 4 5 6 7 8 9 10

Unable to perform activity

Able to perform activity at the same level as before injury or problem

(Date and Score)

Activity	Initial					
1.						
2.						
3.						
4.						
5.						
Additional						
Additional						

Total score = sum of the activity scores/number of activities
Minimum detectable change (90%CI) for average score = 2 points
Minimum detectable change (90%CI) for single activity score = 3 points

PSFS developed by: Stratford, P., Gill, C., Westaway, M., & Binkley, J. (1995). Assessing disability and change on individual patients: a report of a patient specific measure. Physiotherapy Canada, 47, 258-263.

APPENDIX B

Revised Oswestry Back Pain Disability Questionnaire

Revised Oswestry Back Pain Disability Questionnaire

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

Pain Intensity

0 The pain comes and goes and is very mild.
1 The pain is mild and does not vary much.
2 The pain comes and goes and is moderate.
3 The pain is moderate and does not vary much.
4 The pain comes and goes and is severe.
5 The pain is severe and does not vary much

Personal Care (eg, Washing, Dressing)

0 I would not have to change my way of washing or dressing in order to avoid pain.
1 I do not normally change my way of washing or dressing even though it causes some pain.
2 Washing and dressing increases the pain, but I manage not to change the way of doing it.
3 Washing and dressing increases the pain and I find it necessary to change my way of doing it.
4 Because of the pain, I am unable to do some washing and dressing without help.
5 Because of the pain, I am unable to do any washing or dressing without help.

Lifting

0 I can lift heavy weights without extra pain.
1 I can lift heavy weights, but it gives me extra pain.
2 Pain prevents me from lifting heavy weights off the floor.
3 Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned-eg, on a table.
4 Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
5 I can only lift very light weights, at the most.

Walking

0 Pain does not prevent me from walking any distance.
1 Pain prevents me from walking more than 1 mile.
2 Pain prevents me from walking more than 1/2 mile.
3 Pain prevents me from walking more than 1/4 mile.
4 I can only walk using a stick or crutches.
5 I am in bed most of the time and have to crawl to the toilet.

Sitting

0 I can sit in any chair as long as I like without pain.
1 I can only sit in my favorite chair as long as I like.
2 Pain prevents me from sitting for more than 1 hour.
3 Pain prevents me from sitting for more than 1/2 hour.
4 Pain prevents me from sitting for more than 10 minutes.
5 Pain prevents me from sitting at all.

OTHER COMMENTS:

_____

Standing

0 I can stand as long as I want without pain.
1 I have some pain when standing, but it does not increase with time.
2 I cannot stand for longer than 1 hour without increasing pain.
3 I cannot stand for longer than 1/2 hour without increasing pain.
4 I cannot stand for longer than 10 minutes without increasing pain.
5 Pain prevents me from standing at all.

Sleeping

0 I get no pain in bed.
1 I get pain in bed, but it does not prevent me from sleeping well.
2 Because of pain, my normal night's sleep is reduced by less than one quarter.
3 Because of pain, my normal night's sleep is reduced by less than one-half.
4 Because of pain, my normal night's sleep is reduced by less than three-quarters.
5 Pain prevents me from sleeping at all.

Social Life

0 My social life is normal and gives me no pain.
1 My social life is normal, but it increases the degree of my pain.
2 Pain has no significant effect on my social life apart from limiting my more energetic interests, eg, dancing, etc.
3 Pain restricts my social life and I do not go out very often.
4 Pain has restricted my social life to my home.
5 I have hardly any social life because of my pain.

Traveling

0 I get no pain while traveling.
1 I get some pain while traveling but none of my usual forms of travel make it any worse.
2 I get some pain while traveling but it does not compel me to seek alternative forms of travel.
3 I get extra pain while traveling which compels me to seek alternative forms of travel.
4 Pain restricts all forms of travel.
5 Pain prevents all forms of travel except that done lying down.

Changing Degree of Pain

0 My pain is rapidly getting better.
1 My pain fluctuates, but overall is definitely getting better.
2 My pain seems to be getting better, but improvement is slow at present.
3 My pain is neither getting better nor worse.
4 My pain is gradually worsening.
5 My pain is rapidly worsening.

With Permission from: Hudson-Cook N, Tomes-Nicholson K, Breen AC. A Revised Oswestry Back Disability Questionnaire. Manchester Univ Press, 1989.

APPENDIX C

Scoliosis Research Society-22 Health-Related Quality-of-Life Questionnaire

SRS-22r Patient Questionnaire

INSTRUCTIONS: We are carefully evaluating the condition of your back and it is **IMPORTANT THAT YOU ANSWER EACH OF THESE QUESTIONS YOURSELF.** Please **CIRCLE THE ONE BEST ANSWER TO EACH QUESTION.**

1. Which of the following best describes the amount of pain you have experienced during the past 6 months?
    1. Severe
    2. Moderate to severe
    3. Moderate
    4. Mild
    5. None
2. Which one of the following best describes the amount of pain you have experienced over the last month?
    1. Severe
    2. Moderate to severe
    3. Moderate
    4. Mild
    5. None
3. During the past 6 months have you been a very nervous person?
    1. Severe
    2. Moderate to severe
    3. Moderate
    4. Mild
    5. None
4. If you had to spend the rest of your life with your back shape as it is right now, how would you feel about it?
    1. Very unhappy
    2. Somewhat unhappy
    3. Neither happy nor unhappy
    4. Somewhat happy
    5. Very happy
5. What is your current level of activity?
    1. Bedridden
    2. Primarily no activity
    3. Light labor and light sports
    4. Moderate labor and moderate sports
    5. Full activities without restriction
6. How do you look in clothes?
    1. Very bad
    2. Bad
    3. Fair
    4. Good
    5. Very good
7. In the past 6 months have you felt so down in the dumps that nothing could cheer you up?
    1. Very often
    2. Often
    3. Sometimes
    4. Rarely
    5. Never
8. Do you experience back pain when at rest?
    1. Very often
    2. Often
    3. Sometimes
    4. Rarely
    5. Never
9. What is your current level of work/school activity?
    1. 0% normal
    2. 25% normal
    3. 50% normal
    4. 75% normal
    5. 100% normal
10. Which of the following best describes the appearance of your

trunk; defined as the human body except for the head and extremities?

1. Very poor
2. Poor
3. Fair
4. Good
5. Very good

11. Which one of the following best describes your pain medication use for back pain?
    1. Narcotics daily
    2. Narcotics weekly or less (e.g., Tylenol III, Lorcet, Percocet)
    3. Non-narcotics daily
    4. Non-narcotics weekly or less (e.g., Aspirin, Tylenol, Ibuprofen)
    5. None
12. Does your back limit your ability to do things around the house?
    1. Very often
    2. Often
    3. Sometimes
    4. Rarely
    5. Never
13. Have you felt calm and peaceful during the past 6 months?
    1. None of the time
    2. A little of the time
    3. Some of the time
    4. Most of the time
    5. All of the time
14. Do you feel that your back condition affects your personal relationships?
    1. Severely
    2. Moderately
    3. Mildly
    4. Slightly
    5. None
15. Are you and/or your family experiencing financial difficulties because of your back?
    1. Severely
    2. Moderately
    3. Mildly
    4. Slightly
    5. None
16. In the past 6 months have you felt down hearted and blue?
    1. Very often
    2. Often
    3. Sometimes
    4. Rarely
    5. Never
17. In the last 3 months have you taken any days off of work, including household work, or school because of back pain?
    1. 4 or more days
    2. 3 days
    3. 2 days
    4. 1 day
    5. 0 days
18. Does your back condition limit your going out with friends/family?
    1. Very often
    2. Often
    3. Sometimes
    4. Rarely
    5. Never
19. Do you feel attractive with your current back condition?
    1. No, not at all
    2. No, not very much
    3. Neither attractive nor unattractive
    4. Yes, somewhat
    5. Yes, very
20. Have you been a happy person during the past 6 months?
    1. None of the time
    2. A little of the time
    3. Some of the time

4. Most of the time
5. All of the time

21. Are you satisfied with the results of your back management?
    1. Very unsatisfied
    2. Unsatisfied
    3. Neither satisfied nor unsatisfied
    4. Satisfied
    5. Very satisfied
22. Would you have the same management again if you had the same condition?
    1. Definitely not
    2. Probably not
    3. Not sure
    4. Probably yes
    5. Definitely yes

Thank you for completing this questionnaire. Please comment if you wish.

SRS-22r Patient Questionnaire/Score Sheet

DOMAIN	**Sum of Responses**	**# Questions Answered (Possible)**	**Mean Score**
	A	**B**	**A / B**
Function (5, 9, 12, 15, 18)	___	___ (5)	___
Pain (1, 2, 8, 11, 17)	___	___ (5)	___
Self-image (4, 6, 10, 14, 19)	___	___ (5)	___
Mental health (3, 7, 13, 16, 20)	___	___ (5)	___
SUB TOTAL		___ (20)	___
Satisfaction/Dissatisfaction			___
with management (21, 22)	___	___ (2)	___
TOTAL	___	___ (22)	___

APPENDIX D

Pressure Biofeedback Unit (Stabilizer, Chattanooga Group In., Hixson, TN)


STABILIZER

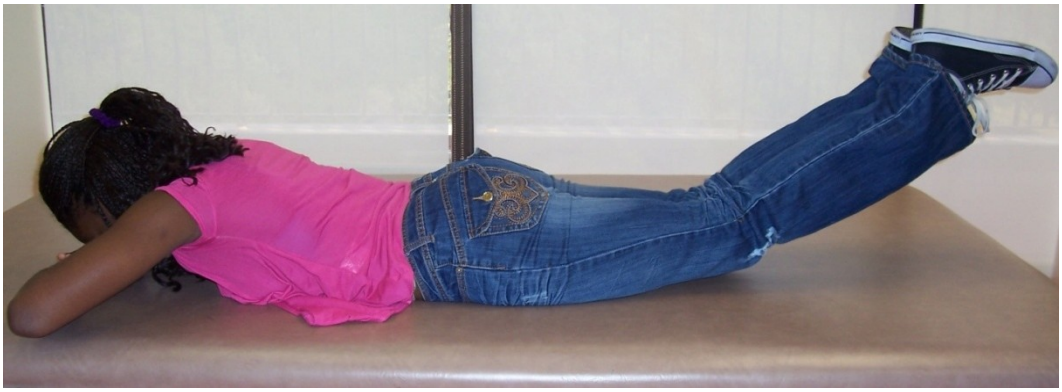
APPENDIX E

Inclinometer (Clinical Goniometer, MIE Medical Research Ltd., Leeds, U.K.)


MIE
medical research ltd
CE
0120
UK Pat 8401841

APPENDIX F

Prone-double-leg-raise Test



APPENDIX G
Survey

To understand the role of physical therapists treating adolescents with idiopathic scoliosis, please complete the following survey by checking the appropriate options. Return indicates consent.

Conservative Treatment <u>without</u> Bracing

1. Do you refer an unbraced child/adolescent with scoliosis to physical therapy (PT)? ☐ *Yes* / ☐ *No*
   - A. If yes, check the curve severity/severities that apply: ☐ *mild (10-24°),* ☐ *moderate (25-45°),* ☐ *severe (≥46°)*?
   - B. If yes, check all the goal(s) that apply for PT:
     - ☐ *to improve back or hamstring ROM/flexibility,*
     - ☐ *to improve quality of life,*
     - ☐ *to improve posture,*
     - ☐ *to improve trunk or core strength*
     - ☐ *to reduce curve progression*
     - ☐ *to prepare for bracing,*
     - ☐ *to prepare for casting,*
     - ☐ *to prepare for surgery,*
     - ☐ *to prepare for traction*
     - ☐ *other*_____
   - C. If no referral to PT, do you recommend home exercises for an unbraced child? ☐ *Yes* / ☐ *No*
2. Do you refer an unbraced child/adolescent with scoliosis AND back pain to PT? ☐ *Yes* / ☐ *No*
3. Do you initiate traction for a child/adolescent with scoliosis? ☐ *Yes* / ☐ *No*
   - A. If yes, do you refer the child receiving traction to PT? ☐ *Yes* / ☐ *No*
4. Do you initiate casting for a child/adolescent with scoliosis? ☐ *Yes* / ☐ *No*
   - A. If yes, do you refer the child receiving casting to PT? ☐ *Yes* / ☐ *No*

Conservative Treatment <u>with</u> Bracing

5. Do you refer a braced child/adolescent with scoliosis to PT? ☐ *Yes* / ☐ *No*
   - A. If yes, check the curve severity/severities that apply: ☐ *mild (10-24°),* ☐ *moderate (25-50°),* ☐ *severe (≥51°)*?
   - B. If yes, check all the goal(s) that apply for PT:
     - ☐ *to improve back or hamstring ROM/flexibility,*
     - ☐ *to improve quality of life,*
     - ☐ *to improve posture,*
     - ☐ *to improve trunk or core strength*
     - ☐ *to improve brace wear compliance,*
     - ☐ *to reduce curve progression,*
     - ☐ *to reduce pain or discomfort*
     - ☐ *other*_____
   - C. If no referral to PT, do you recommend home exercises for a braced child? ☐ *Yes* / ☐ *No*

Post-Operative Treatment

6. In the hospital following scoliosis surgery, do you refer a child/adolescent to PT before discharge? ☐ *Yes* / ☐ *No*
   - A. If yes, check all the goal(s) that apply for PT:
     - ☐ *gait training,* ☐ *to improve posture,* ☐ *to improve respiratory function,*
     - ☐ *transfer training,* ☐ *to improve ROM/flexibility,* ☐ *to improve trunk/core strength,*
     - ☐ *other*_____
   - B. If no, does nursing mobilize the child/adolescent post-operatively? ☐ *Yes* / ☐ *No*

7. Once at home following scoliosis surgery, do you refer a child/adolescent to PT? ☐ *Yes* / ☐ *No*
   - A. If yes, check when you want PT to start (counting from the surgery date)?
     - ☐ *0-5 wks,* ☐ *6-11 wks,* ☐ *12-17 wks,* ☐ *≥18 wks,* ☐ *other*_____
   - B. If yes, check all the goal(s) that apply for PT:
     - ☐ *to improve posture,* ☐ *to improve ROM/flexibility,* ☐ *to prepare for return to athletics,*
     - ☐ *to improve quality of life,* ☐ *to improve respiratory function,* ☐ *to improve trunk/core strength,*
   - C. If no PT referral, do you recommend home exercises after scoliosis surgery? ☐ *Yes* / ☐ *No*

Surgeon Characteristics

8. Do you practice in the US? ☐ *Yes* / ☐ *No*
9. Are you currently practicing as a surgeon? ☐ *Yes* / ☐ *No* How many years in surgical practice? _____ *years*
10. What is your gender? ☐ *Male* / ☐ *Female*
11. Do children/adolescents with scoliosis make up a significant (> 30%) segment of your practice? ☐ *Yes* / ☐ *No*
12. In your opinion, what is the primary role of physical therapists treating children/adolescents with scoliosis?

For questions, contact:
Karina Kunder, PT, DPT
Therapy Services, Texas Scottish Rite Hospital for Children
2222 Welborn Street; Dallas, TX 75219
Phone: 214-559-7790, E-mail: karina.kunder@tsrh.org.

Thank you for your time.

APPENDIX H

IRB Approval Letter from Texas Scottish Rite Hospital for Children

MEMO

August 30, 2011

Karina Kunder
Physical Therapy

RE: Investigation Project: Research Project Number: 1059
Spinal Stabilization Exercises for Low Back Pain in Adolescents with Idiopathic Scoliosis

---

I am pleased to report that the Research Advisory Panel has recommended that your proposal be approved as submitted. This memo is to notify you that I have accepted their recommendation and that I approve your going on to the next step in the approval process.

Your next step will be the internal approval of Informed Consent forms, which should be forwarded to me for review and approval. After the Consent Forms have been approved, you may submit the required documents to the UTSW IRB for their approval. If you need any assistance, please contact me at 214-559-7765.

Authorization To Proceed with your proposal will be granted when I have received copies of all UTSW approval letters and the associated documents. If you are unsure of which approvals are needed, please do not hesitate to contact me.

Sincerely,

Jeremy Howell
Administrative Director of Research

cc: Cindy Daniel

APPENDIX I

IRB Approval Letter from University of Texas Southwestern Medical Center

UT SOUTHWESTERN MEDICAL CENTER eIRB System

From: Ahamed Idris
Institutional Review Board Chairperson
IRB - 8843

To: Karina Kunder , Cindy Daniel

Date: November 8, 2011

Re: Study Approval

IRB Number: STU 092011-073

Title: Spinal stabilization exercises for low back pain in adolescents

Documents: Protocol, English and Spanish Consent Forms and HIPAA Authorizations

The UT Southwestern Institutional Review Board (IRB) reviewed the above-referenced research study via an expedited review procedure on October 26, 2011 in accordance with 45 CFR 46.110(a)-(b)(1). Having met all applicable requirements, the research study is approved for a period of 12 months. The approval period for this research study begins on November 8, 2011 and lasts until October 25, 2012.

The research study cannot continue beyond the approval period without continuing review and approval by the IRB. In order to avoid a lapse in IRB approval, the Principal Investigator must apply for continuing review of the protocol and related documents before the expiration date. A reminder will be sent to you approximately 90 days prior to expiration of research study approval.

The approved number of subjects to be enrolled is 32. The IRB considers a subject to be enrolled once s/he signs a Consent Form. If additional subjects are needed, you must first obtain permission from the IRB to increase the sample size.

If you have any questions related to this approval letter or about IRB policies and procedures, please telephone the IRB Office at 214-648-3060.

APPENDIX J

IRB Approval Letter from Texas Woman's University

TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

February 28, 2012

Ms. Karina Kunder
School of Physical Therapy
Dallas - Presbyterian

Dear Ms. Kunder:

Re: Effectiveness of Spinal Stabilization Exercises for Low Back Pain in Adolescents with Idiopathic Scoliosis (Protocol #: 16896)

Your application to the IRB was reviewed and approved on 1/30/2012. This approval is valid for one (1) year. The study may not continue after the approval period without additional IRB review and approval for continuation. It is your responsibility to assure that this study is not conducted beyond the expiration date.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

A final report must be submitted to the IRB at the conclusion of the study. If using a consent form, copies of the signed informed consent are to be submitted with the final report before the study file can be closed.

The Institutional Review Board is pleased to acknowledge your sense of responsibility for ethical research. If you have any questions concerning this review, please contact me at (214) 706-2461 or email SLin@twu.edu.

Sincerely,

Suh-Jen Lin

Dr. Suh-Jen Lin, Chair
Institutional Review Board - Dallas

cc. Dr. Venita Lovelace-Chandler, School of Physical Therapy - Dallas
Dr. Sharon Wang, School of Physical Therapy - Dallas

APPENDIX K

Spinal Stabilization Exercises Modified from Hicks et al., (2005)

Primary Muscle Group	Exercise	Criteria for progression
Tranversus abdominis	Abdominal bracing	100 s
	Bracing 100	100 repetitions
	Bracing with bicycle	100 repetitions: 50 at each leg
	Bracing with single leg bridge	100 repetitions: 50 at each leg
Transversus abdominis	Bracing in sitting or standing	100 s
(functional positions)	Bracing with deep squat	100 repetitions
	Bracing with standing row	100 repetitions
	Bracing with step ups	100 repetitions: 50 at each side
Multifidus	Quadruped arm lifts with bracing	100 repetitions: 50 at each arm
	Quadruped leg lifts with bracing	100 repetitions: 50 at each leg
	Quadruped alternate arm & leg lifts	100 repetitions: 50 at each leg
	with bracing	
	Superman	100 s
Global core	Prone plank on elbows	100 s
	Side plank on elbow, arm raised	100 s total: 50 at each side
	Alternating prone and side plank	100 planks total

APPENDIX L

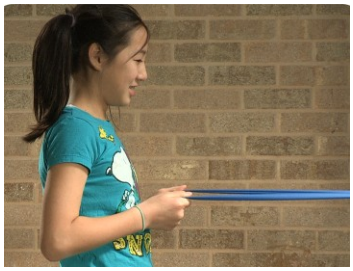
Spinal Stabilization Home Exercise Program DVD Script

VISUAL	AUDIO
How To Manage Low Back Pain	
1. Spinal stabilization exercises	
	The best support you can give your back is building strong and flexible supporting muscles. Even if you are strong in general, you may not be isolating your inner stomach muscles which stabilize your spine.
Show a model of inner unit muscles (the transversus abdominis and multifidus). Add outer unit muscles (quadratus lumborum, internal oblique, external oblique, and erector spinae). No labels.	The supporting muscles of your back consist of an inner and outer unit. The inner unit consists of deep abdominal and spinal muscles that attach directly to your back. They create a corset or brace around your back, and when working properly, stabilize and protect the bones and tissue of your back. The outer muscles provide global back stability. You will first learn how to isolate and train your inner unit before incorporating the outer unit of supporting muscles.
Show all exercises categorized into four groups: Group 1: 1. Abdominal bracing 2. Bracing 100 3. Bracing with bicycle 4. Bracing with bridging	The following spinal stabilization exercise program targets the muscles that stabilize your back. These exercises have been found to be an effective treatment for low back pain. They progress from basic to more advanced as your exercise performance improves. There are four groups of exercises which target your inner and outer units. You will perform four exercises total, one from each of the four groups of exercises. Count to 100 for each exercise. Your exercises will take a maximum of 20 minutes to complete. For the first 2

VISUAL	AUDIO
Group 2: 1. Bracing in standing or sitting 2. Bracing with deep squat 3. Bracing with standing row 4. Bracing with step ups Group 3: 1. Quadruped arm lifts with bracing 2. Quadruped leg lifts with bracing 3. Quadruped alternate arm and leg lifts with bracing 4. Superman Group 4: 1. Prone plank on elbows 2. Side plank on elbow, arms raised 3. Alternating prone and side plank Highlight the first exercise in each group. Person will demonstrate each exercise, following the narrator's instructions. Show a boxer tightening his stomach muscles before being punched.	weeks, you will do four exercises at least five times a week. After 2 weeks, you will decrease the exercise frequency to at least 3 days a week. By then, you should notice significant improvement in your pain and in your ability to perform the exercises. You will begin with the first exercise from each of the four groups. You will only move on to the next exercise once you are able to perform the exercise with proper form for 100 seconds or repetitions. Once you progress to a more advanced exercise, you will not do the exercise that came before it. Each exercise incorporates abdominal bracing, where you tighten your stomach muscles, as if you are bracing for a punch: although I'm sure no one would ever dare to punch you in the stomach! You will know when you are maintaining proper technique when you can tighten or brace your stomach muscles while breathing in and out. You should also be able to maintain a continuous, steady muscle contraction while performing your exercises. The goal is more than just completing the exercise progression. The ultimate challenge is to tighten your stomach muscles continuously throughout the day, especially during positions that have caused you back pain. A strong, tight core will protect your back and decrease your pain.
Group 1 Show & Label the Transversus Abdominis	The first group of exercises teaches you how to target the muscle of your inner unit.
1. Abdominal bracing	The first exercise group teaches you how to isolate the muscle of your inner unit.

VISUAL	AUDIO
 Person demonstrates examples of incorrect technique.	Lie on your back with your knees bent. Place your middle fingers just inside your pelvic bones. Breathe normally, in and out. As you breathe out, tighten your stomach muscles as if you are bracing for a punch. You should feel a light, deep tension under your fingers. Continue to breathe normally while holding the contraction for 100 seconds. Do not hold your breath when tightening your stomach. Do not lose the contraction at your stomach while you are breathing. For example, you should not feel the tension under your fingers disappear. Do not contract muscles of your body that should otherwise be relaxed. For example, do not raise your upper shoulders as you try to contract your inner abdominals. When you can do this exercise without back pain and with proper technique (like breathing normally, holding a constant strong contraction, and keeping your shoulders and ribs relaxed), you can progress to the second exercise in this group.
2. Bracing 100	This second exercise, Bracing 100, is popular in pilates.
	Keep your low back pressed down against the floor. Lift and bend your knees and hips to 90 degrees. Brace your stomach. Lift your shoulder blades off the floor. Lift and straighten your arms to your side, extending through your fingertips. Move your arms up and down 100 times. Once you can do this for 100 repetitions without stopping, you are ready for the next exercise.
3. Bracing with bicycle	The third exercise incorporates abdominal bracing with a bicycle movement at your arms and legs.

VISUAL	AUDIO
	Lie on your back with your knees and hips lifted and bent to 90 degrees. Fold your hands behind your head. Brace your abdominals. Lift your head and shoulders up off the floor. Bring your right elbow towards your left knee and your left knee towards your right elbow as you simultaneously straighten your right leg. Repeat and alternate sides, like you are pedaling a bike. Keep your lower back pressed down against the floor. Do not to pull your head forward with your hands. Once you can do this 100 times without stopping, which amounts to 50 times with each leg, you are ready to progress to the next exercise.
4. Bracing with bridging	The final exercise in this first group of exercises is called alternating single leg bridges.
	Lie on your back with your knees bent and feet flat on the floor. Tighten your stomach muscles and slowly lift your hips off the floor. Next, lift and straighten your right leg off the floor while keeping your left leg bent and your hips level. Keeping your hips in the air, repeat with the left leg, alternating sides. The goal is to be able to complete 100 repetitions, that is 50 repetitions with each side.
Group 2	The second group of exercises teaches you how to target the muscle of your inner unit as you go about your daily activities.
1. Bracing in standing or sitting	You will either or stand or sit for the first exercise in the second group depending on what causes you the most pain. If you get pain after standing for long periods of time, you will stand for this exercise. If you get pain after sitting for long periods of time, sit for this exercise.

VISUAL	AUDIO
	When standing, stand upright with your arms relaxed by your side. Tighten your stomach muscles as if you are bracing for a punch. While breathing normally, hold for 100 seconds. In sitting, sit at the edge of a chair with your feet flat on the floor and your arms relaxed by your side. Tighten your stomach muscles as if you are bracing for a punch. While breathing normally, hold for 100 seconds.
2. Bracing with deep squat	The second exercise progresses to bracing your stomach in a standing position while you do a deep squat.
	Stand with your feet shoulder width apart. Brace your abdominals. Bend your knees and squat down until your knees are bent to almost 90 degrees, or as if you will sit down into a chair. Be sure to keep your knees over your ankles. Once you are able to perform this exercise 100 times, you are ready to move on to the next exercise in this group.
3. Bracing with standing row	The third exercise is called Bracing with Standing Row.
	Attach your theraband to a door knob at waist height. Tighten your stomach muscles while pulling the theraband back with your hand. Be sure to keep your head and back straight. Remember to keep those abdominal muscles contracted like you are bracing for a punch. Repeat this exercise for a total of 100 repetitions.
4. Bracing with step ups	The final exercise in this second group incorporates abdominal bracing while marching up and down a step.

VISUAL	AUDIO
	Stand in front of a normal sized step, or stool, or thick book. Tighten your stomach muscles. In one continuous motion, step up onto the step with one leg while lifting and bending your opposite hip before you bring it back down to the floor in a marching fashion. Repeat and perform 100 alternating repetitions, which amount to 50 at each side. "Step up with the right, lift up with the left, down with the left, down with the right."
Group 3 Show and label the multifidus (inner unit) and erector spinae (outer unit)	The second exercise group targets both the inner unit and outer unit muscles.
1. Quadruped arm lifts with bracing	The first exercise in the third exercise group starts on all fours, or in quadruped, before your lift your arms.
	Start on all fours in a comfortable position. Do not arch your neck. Be sure to keep your back flat. Tighten your stomach muscles as if you are bracing for a punch. Lift and straighten your right arm, keeping your hips level. Repeat with the other arm. Perform 100 alternating repetitions, 50 at each arm. Once you can do this exercise properly, progress to the second exercise.
2. Quadruped leg lifts with bracing	The second exercise now focuses on moving your legs instead of your arms while you brace your stomach.
	Start again on all fours. Tighten your stomach muscles. Lift your right leg back, keeping your hips level. Repeat with the other leg. Perform 100 alternating repetitions, 50 at each leg.
3. Quadruped alternate arm and leg lifts with bracing	The third exercise in this exercise group consists of lifting your opposite arm and leg at the same time.

VISUAL	AUDIO
	On all fours with your stomach muscles tight, lift and straighten your right arm and left leg, keeping your hips level. Repeat with the opposite arm and leg. Perform 100 alternating repetitions, 50 at each leg.
4. Superman	The fourth and final exercise in the third group of exercises, is called superman, since you look like you are flying through the sky like superman.
	Lie on your stomach with your arms stretched out in front of you. Brace your stomach muscles as you lift your arms and legs a few inches up off the floor. Hold this position for 100 seconds, keeping your elbows and knees off the floor. Your back will be arched and your neck should be relaxed.
Group 4 Show and label the quadratus lumborum, internal oblique, and external oblique	The fourth and final exercise group targets muscle groups of the outer unit.
1. Prone plank on elbows	The first exercise in the fourth group is called the prone plank and is a popular core strengthening exercise.
	Start by lying on your stomach with your elbows bent and placed under your shoulders and with your toes touching the floor. Tighten your abdominal muscles like you are bracing for a punch. Lift your body off the ground by placing your weight through your forearms and toes. Your body should make a straight line from your toes to your head. Do not arch your back. Breathe normally as you hold this position. Once you are able to hold this for 100 seconds, you are ready to move onto the next exercise.
2. Side plank on elbow, arms raised	For the second exercise, you perform a plank on your side.

VISUAL	AUDIO
	Begin on your right side with your knees straight. Tighten your stomach muscles like you are bracing for a punch. Lift your body off the ground by placing your weight through your forearm and the side of your foot. Your body should make a straight line from your toes to your head. Straighten your left arm and point it up towards the ceiling. Breathe normally as you hold this position. Once you are able to hold this for 50 seconds at each side for a total of 100 seconds, you are ready to move onto the last exercise.
3. Alternating prone and side plank	The last exercise combines the first two plank exercises.
	First, perform a plank on elbows, then move to a right side plank with your arm raised, then back to plank on elbows, and then to a left side plank with your arm raised. Each plank performed counts as one. Repeat until you are able to complete 100 planks total.

APPENDIX M

Home Exercise Diary

Exercise Diary

Please check which of 4 exercises are completed 100 times without a rest break with proper form.

	1. Abdominal Bracing				2. Bracing in a Functional Position				3. Quadruped				4. Plank			Initials
	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	
	Brace	100	Bicycle	Bridge	Stand/Sit	Squat	Row	Step up	Arm lift	Leg lift	Both lift	Superman	Prone	2 Sides	Alternate	
For the first 2 weeks, do exercises at least 5 times a week.																
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 4																
Day 5																
Day 6																
Day 7																
Now, do exercises at least 3 days a week.																
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