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Emily R. Silva
Utah State University

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Clinical Assessment of Adolescent Idiopathic Scoliosis Pre- and Post-Surgical Intervention in a
Division I Female College Gymnast: A Case Study

By

Emily R Silva

A plan B paper submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

HEALTH AND HUMAN MOVEMENT

Approved:

Dennis Dolny, PhD
Major Professor

Trek Lyons, MD
Committee Member

Lori Olsen, PT
Committee Member

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Abstract

Adolescent idiopathic scoliosis is defined as a lateral and rotational curvature of the spine with an unknown origin. Scoliosis is diagnosed based on age of onset and clinical presentation. Physicians measure curve severity by Cobb's angle, which is marked on an x-ray. Participation in sports, which require compressive and tensile forces on the spine increase risk of back-related injury, including scoliosis or the progression of scoliosis. Sports such as gymnastics have been shown to increase back pain; although, studies have found some participation in gymnastic activities helps in strengthening skeletal musculature and respiratory musculature, which benefits patients diagnosed with scoliosis. The purpose of this research is to explore the clinical assessment of adolescent idiopathic scoliosis pre- and post surgical intervention in a division I female college gymnast. The patient in this study is a 21-year-old female gymnast that was clinically diagnosed with adolescent idiopathic scoliosis at 20 years of age. The patient has competed in gymnastics since the age of six and currently underwent spinal fusion surgery to correct a scoliotic curve of 81 degrees that was creating breathing difficulties. Pulmonary function testing, joint range of motion measurements, and muscular power were clinically assessed one week prior to spinal fusion surgery and one year following curvature correction. Results expressed overall improvement in parameters tested along with reduction of pre-surgical symptoms, which were caused by the severe spinal curvature.

Introduction

Since 1972 female participation in sport has increased. Currently female athletes make up 1/3 of US College and Olympic athletes (d'Hemecourt, Micheli, & Gerbino, 2002). With this increase in sport participation comes increase risk of injury. Overall incidence of back injury in sports is estimated to be between 10-15%. Females showed an increase in orthopedic doctor visits when compared to their male counterparts. Among the various causes of back pain, scoliosis is a predominant concern in the female athlete (d'Hemecourt et al. 2002). Over the years of research completed in respect of scoliosis there have been many factors which have been found to contribute to the etiology of spinal deformity and injury. Factors, as explained by d'Hemecourt et al. (2002) and Lowe, Edgar, Chir, Margulies, Miller, Raso, & Reinker (2000), include sport specific mechanics, skeletal muscle abnormalities, and biomechanical factors. Participation in noncontact sports showed an increase in low back pain in female college athletes. Sports often bring an increased risk of injury. Back injuries specifically tend to be sport specific, especially in gymnastics, figure skating, and dance. These sports emphasize extremes in spinal motion; therefore, creating a greater risk of spinal injuries and abnormal curve development (d'Hemecourt et al. 2002). Sports such as gymnastics have been shown to increase risk of back injury due to compressive and tensile forces that are placed on the spine. Such forces as described by d'Hemecourt et al. (2002) could be an etiology of back pain pertaining to scoliosis.

Scoliosis is classified based on age of onset and clinical presentation. The three age onsets are infantile, juvenile, and adolescent idiopathic. For the purpose of this paper the focus will be placed on adolescent idiopathic scoliosis (AIS). Age of onset is between 10 years of age and skeletal maturity (d'Hemecourt et al. 2002 & Greiner 2002). AIS is defined as lateral and

rotational spinal curvature of unknown origin (Greiner 2002 & Lowe et al. 2000). Other than a general complaint of back pain, physical abnormalities are typically the primary cause of doctor visits. Early years of detection came from school-based screening which began in the 1970's and currently spans 26 states. A study completed in 1996 by the US Preventative Services Task Force Report showed few children were actually referred to a physician. The American Academy of Pediatrics recommend screening be done at physician visits. A physical exam can be useful; however subjective, the use of radiographic decision-making will prove to be more helpful in the diagnosis and prognosis of AIS (Greiner 2002 & Hawes 2006). Once diagnosed importance is placed on efforts to aid progression. Greiner (2002)

explained curves would progress 10-15 degrees over a lifetime when the curve measures 40-50 degrees at skeletal maturity.

However, if a curve measures greater than 50 degrees at skeletal maturity the progression can be 1-2 degrees per year. Clinical measurements of scoliosis are obtained using the Cobb method to determine the degree of scoliosis (Figure 1). Along with degree of curve scoliosis is categorized based on location of apex vertebrae. The apex vertebra is the middle vertebrae found

between the proximal and distal most tilted vertebrae. The five

types of curves are thoracic, lumbar, thoracolumbar, cervical, or double major. A double major curve refers to two curves in different spinal regions (i.e. thoracic and lumbar) creating a major and minor curve as well as primary and secondary curve (Greiner 2002).

Typical treatment options for patients with AIS consist of observation, bracing, physical therapy, and surgical intervention. Treatment differs based on curve severity and age of onset.

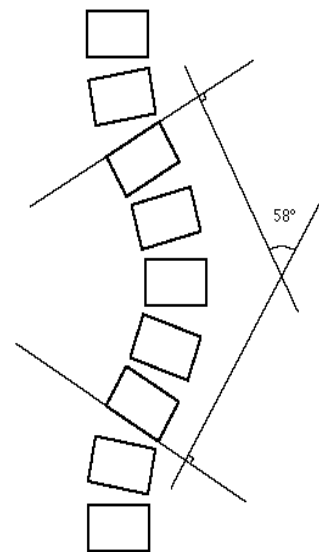


Figure 1. Example of Cobb Angle measurement

Patients diagnosed with AIS and a curve less than 10-15 degrees do not require active treatment; a curve between 25-45 degrees is considered moderate and requires treatment such as bracing and/or therapy. Severe curves measuring greater than 45 degrees will require surgery, which usually consist of rod placement and bone grafts. Over the past 20 years there have been shifts in treatment. In a study conducted by Negrini (2008) it was mentioned that in today's medical community the tendency to operate on scoliosis patients is happening sooner and by using more advanced surgical techniques. At increased curvatures patients likely will experience residual effects such as pulmonary dysfunction and some cardiorespiratory changes. Spinal fusion surgery is required not only at a certain degree but also if previous treatments have failed or AIS causes symptoms.

Surgery & Pulmonary Function

Treatment of scoliosis changes depending on risk of curve progression, severity of curve, and current symptoms causing change to activities of daily living. Observation and possible physical therapy is accepted for scoliotic curves < 25 degrees with the goal of preventing curve progression. Physical therapy and bracing commonly is required for curves between 25-45 degrees along with observation of the attending physician. Lastly, the recommended treatment for curves > 45 degrees is spinal fusion surgery. Spinal fusion surgery has been used to treat scoliosis for more than 100 years (Hawes & O'Brien 2008). The goal of conservative scoliosis treatments is to prevent progression while maintaining quality of life. In cases of scoliosis where the curve has exceeded 45 degrees typically there will be a reduction in quality of life as well as causing other anatomical, physiological, and psychological adaptations, which are sometimes fatal. Adaptations in which surgeons aim to correct are respiratory defects, pain, and psychological distress. Pulmonary function is affected by the anatomical alteration of the rib

age, which impairs the mechanical function of the chest wall. Shneerson & Edgar (1979) discuss baselines for determining pulmonary function, which examine forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and peak expiratory flow rate (PEFR). Curves exceeding 70 degrees are a concern to physicians due to the accelerated progression and decreased mechanical function of the chest wall (Hawes & O'Brien 2008). In order to improve pulmonary function, pain, and psychological distress the Scoliosis Research Society (www.srs.org) states two primary goals of spinal fusion surgery. The two goals are as follows; to prevent spine deformity progression and to diminish spinal deformity. Current surgery uses metal implants, which attach to the spine, connect a single rod or two rods, and fuse to the bone. The rods are used to correct the curvature and maintain the correction overtime (www.srs.org). The fusion surgery can be completed anteriorly; performed through the front of the spine, or posteriorly; performed though the back of the spine. Like other types of surgery there are advantages and disadvantages to both procedures; however, posterior approach is the most common. When considering surgical treatment one should be aware of the impacts of the spine fusion surgery on spinal deformity. By correcting the spinal curvature there is typically an increase in spinal longitudinal length (Watanabe, Hosogane, Kawakami, Tsuji, Toyama, Chiba, & Matsumoto, 2012). Rhee, Bridwell, Won, Lenke, Chotigavanichaya, & Hanson (2002) suggested that the change in spinal length could be correlated to degree of curve correction by spinal fusion surgery. The results of the study conducted by Rhee et al. (2002) noted there was a significant increase in spinal longitudinal length, which correlated to the correction of spinal curvature when the patient received posterior spinal fusion (PSF). A recent study completed by Watanabe et al. (2012) also reported a significant increase in spinal longitudinal length following spinal fusion surgery. An average increase for anterior spinal fusion is 16.6 ± 7.7 mm and

posterior spinal fusion increased an average of 32.4 ± 10.8 mm. Greater increases in spinal length are not only determined by surgical procedure but also by type of instrumentation used. Jefferson, Weisz, Turner-Smith, Harris, & Houghton (1988) found the use of Harrington instrumentation showed the greatest change in pre- and post-operative Cobb angle measurements. Other than the cosmetic effects of scoliosis symptoms such as impaired pulmonary function and quality of life have been known to transpire from a diagnosis of idiopathic scoliosis. Secondary symptoms to the deformity of the spine can occur regardless of age at diagnosis. Spinal deformity associated with scoliosis alters the mechanics of the chest wall, which leads to decreased chest expansion during inspiration. With regards to impaired pulmonary function there has been a reduction of maximal inspiration/ vital capacity (VC) and decreased total lung capacity. Oxygenated arterial blood can also be decreased due to these physiological changes adapting from scoliosis. VC measurements in particular show a significant inverse correlation between degrees of thoracic spinal curvature. Meaning the greater the curve the lower the VC (Hawes, 2006). Decreased VC does not typically occur in scoliosis patients that only exhibit a lumbar curve deformity. Some scoliosis patients are asymptomatic regarding pulmonary function and others reveal shortness of breath, recurrent respiratory infections, and decreased participation in activities requiring cardiovascular endurance (Hawes, 2006). An extensive review of literature performed by Hawes (2006) discovered that by improving chest symmetry, by way of surgical intervention, allows a gradual improvement in pulmonary function over time. Corrections achieved by surgery continue to improve following surgical intervention. Shneerson & Edgar (1979) found increases of 9.1-15.9% in FVC, FEV₁, and PEF_R following surgical treatment of scoliosis. Although when values were adjusted for change in patient height the results did not yield significance. Wood, Schendel, Dekutoski,

Boachie-Adjei, & Heithoff (1996) mentioned respiratory changes continue improving up to two years following spinal fusion surgery to correct scoliosis. Modern surgical treatments aim to correct more than spinal curvature alone. Sagittal alignment, rib prominence, vertebral rotation, and chest asymmetry have become additional aims to surgical intervention in scoliosis patients (Hawes 2006 & 2008, Jefferson et al. 1988, Rhee et al. 2002, & Watanabe et al. 2012). Proper alignment of the sagittal plane is important to the long-term health of the spine. In respect to surgical outcomes for sagittal plane alignment it has been shown either method of surgical instrumentation (anterior or posterior) is acceptable in creating optimal sagittal plane profiles (Rhee et al. 2002).

Scoliosis & Exercise

Due to asymmetry caused by scoliosis it is assumed physical activity is to be avoided in patients with idiopathic scoliosis. However, it has been shown that regular aerobic training in scoliosis patients can improve some symptoms caused by spinal deformity (Athanasopoulos, Paxinos, Tsafantakis, Zachariou, & Chatziconstantinou, 1999). In a study forty females diagnosed with scoliosis were put through an eight-week training program. The researchers found positive adaptations to aerobic training in scoliotic patients. Through training scoliotic patients strengthened respiratory muscles as well as skeletal musculature. The training protocol also reduced the feeling of “breathlessness” along with increased ability to perform aerobic work. These improvements could offer long-term advantages to aerobic training and short-term adaptations. Overall, Athanasopoulos et al. (1999) found approximately 50% improvement in capacity to perform aerobic work. This could indicate that patients whom suffer from scoliosis could participate in physical activity, including sports. Prior research has focused on intense physical activity and the detrimental effects on the musculoskeletal system. However, regular

and moderate participation in physical activity and sports does not prove detrimental to growth or overall health in the musculoskeletal system in scoliosis patients (Meyer, Cammarata, Haumont, Deviterne, Gauchard, Leheup, Lascombes, & Perrin, 2006). The qualitative study completed by Meyer et al. (2006) explored the prevalence of participation in physical activity of scoliotic patients. The researchers found most patients participate in physical and sport activities with the majority of them practicing gymnastics rather than traditional sports, such as volleyball and basketball, which involve keeping the spine straight. A secondary measurement of joint flexibility was obtained and is noted that the participants whom practiced gymnastics exhibited increased joint laxity when compared to control subjects. Meyer et al. (2006) stated in conclusion that low intensity participation in gymnastics cannot increase the progression of idiopathic scoliosis. Practice of gymnastics, regularly, reinforces deep musculature of the spine; therefore, aiding proprioception and musculoskeletal development. With the prevalence of scoliosis patients participating in gymnastics Meyer, Haumont, Gauchard, Leheup, Lascombes, & Perrin (2008) wanted to explore the possibility of correlation between curve type and the practice of physical activity. Results showed patients with a double major curve (DMC) to prefer participating in more physical and sport activities. Furthermore, patients with a double major curve practiced more gymnastics than patients with a single major curve. Meyer et al. (2008) suggested the DMC patients took part in gymnastics due to a better symmetry in the spinal musculature and structure generated by the two curves. Gymnastics activity increases the need for balance control; therefore, requiring symmetry of the spinal musculature. Although, overall idiopathic scoliosis can be associated with postural control disorders that were not a restriction in the study conducted by Meyer et al. (2008).

Balance

Early research discovered positive correlations between extent of equilibrium disturbance and degree of curve, rate of progression and skeletal immaturity. Slight postural sway is a normal phenomenon with upright equilibrium; however, in patients with idiopathic scoliosis postural sway is increased, specifically when visual input is affected. Furthermore, it was shown by Sahlstrand, Örtengren, & Nachemson (1978) that left convex patients had a more pronounced reaction than right convex patients when studying postural sway. Although, not all research supports the theory that due to spinal deformity scoliosis patients will experience disequilibrium. Proprioception is taxed when visual cues are eliminated creating added difficulty for scoliotic patients due to the spinal deformity. A displacement of Center of Pressure (COP) is a measure of body neuromuscular demand in order to maintain stability while standing. Dalleau, Damavandi, Leroyer, Verkindt, Rivard, & Allard (2011) explained that type and location of the spinal deformity will effect balance control. Following the study completed by Sahlstrand et al. (1978) nearly 30 years later Gauchard, Lascombes, Kuhnast, & Perrin (2001) stated scoliosis patients with a DMC are more stable than patients with only a lumbar curve. Dalleau et al. (2011) explained a trend of Center of Mass (COM) offsets in scoliotic patients and increased balance instability.

The purpose of this paper is to clinically assess adolescent idiopathic scoliosis pre- and post-surgical intervention on joint flexibility/range of motion (ROM), muscular power, and pulmonary function in a division I female college gymnast.

Methods

The patient in this study is a 21-year-old female, height 159.4 cm, weight 63.5 kg, and a menstrual cycle beginning at age 15. The patient began gymnastics at the age of two and began competing at age six. Signs of scoliosis began at age 10 with a noticeable increase in severity by age 13. Throughout adolescent development the patient was capable of performing high-level competitive gymnastics and received an athletic scholarship to a Division I university. After sustaining a dislocated patella to the left knee at the beginning of the first season of competition, which required lateral release surgery in January 2011. Following the completion of collegiate competition in 2012 and complaints of respiratory difficulties the patient received a clinical assessment of the current scoliotic condition, which presented a 77-degree concave curve and a 49-degree convex curve. Prior to spinal fusion surgery the patient was 153.7 cm tall and weighed 61.2 kg. Cobb angle measurements on the day of surgery were concave curve 81 degrees and convex curve 49 degrees of the thoracic spine. Symptoms before surgical intervention included, difficulty breathing described as “pinching” during inhalation, lower back and hip pain, and shoulder/scapula muscular tightness and discomfort. The day after surgery the patient was assisted in sitting up and standing. The patient was placed in a Boston brace for stability and instructed to begin standing and short duration walking for the first three months following surgery. At three months the patient could begin walking as tolerated naturally or on a treadmill. Between three and six months the patient was cleared to begin light jogging, bike, and elliptical and the use of the Boston brace was discontinued. At six months the patient began physical therapy where the focus of rehabilitation was placed on core strengthening and stability. Instruction from the attending surgeon regarding physical therapy included no bending, twisting, lifting, and walking as much as desired. At the time physical therapy began the patient did not

perform any core exercises. The patient did not report pain throughout the course of physical therapy. The exercises chosen for the patient focused on neutral spine and core strengthening. The patient performed conditioning, core, balance, and general strengthening exercises during physical therapy (Table 1). Primary focus of physical therapy was core strengthening with exercises targeting core static stability and dynamic stability. Near the conclusion of therapy the patient progressed to some rotational core exercises such as wood chops with a FreeMotion weight machine. The exercise program was designed in a way that the patient could continue to progress independently following discharge from physical therapy. One year following posterior spinal fusion surgery the patient was cleared for full activity with restrictions placed on specific sport participation. The patient is no longer capable to participate in gymnastics or other sports which demand high impact to the spine.

Focus	Exercises	
Conditioning	4-way Treadmill, elliptical, stepper	
Core	<i>Static stability:</i> planks – side and forward, bridges – double leg and single leg	<i>Dynamic stability:</i> swiss ball exercises – superman, back extensions, bridges, hamstring curls, TRX - lunges, hamstring curls, mountain climbers
Balance	Bosu squats, vew do balance board, SL balance with airex pad	
General Strengthening	Multiplanar lunges, squatting progression, 4-way hip machine, monster walks	

Table 1 Examples of exercises competed during physical therapy.

For the purpose of this study the patient was tested for muscular strength and joint flexibility. The muscular strength was assessed using the muscle lab version 8 software. The patient was asked to complete seven exercises. Each exercise was performed three times. The average of the three trials was used to describe the data. The seven exercises were chosen to best estimate overall muscular strength. The exercises are as follows; chest press, bicep curl, lat pull down, reverse crunch, sit-up, leg press, and hamstring curl. A FreeMotion weight machine was

used to perform all exercises. For each exercise the Muscle Lab V8 was used to assist in determining the appropriate weight. The patient performed the desired task until they reached a steady state. The patient was then instructed to perform the three repetitions at maximal effort.

The researcher utilized a goniometer to measure joint range of motion (ROM) of the patient. Joints, which were measured, consisted of the shoulder and hip flexion and extension. The patient was measured bilaterally three times actively and passively. All measurements were obtained through a starting point in anatomical position. For shoulder flexion the patient was lying supine on a treatment table to better stabilize the scapula thus isolating the shoulder joint. Shoulder extension was performed with the patient lying prone on a treatment table to isolate the shoulder joint by restricting the motion of the torso. Hip flexion and extension were performed in the same manner, flexion being carried out with the patient supine and extension carried out with the patient prone on a treatment table to stabilize the pelvis. The main researcher performed passive ROM measurements with assistance from a certified athletic trainer. The average measurement of both AROM and PROM will be used to obtain the most accurate range of motion measurement for each joint.

Pulmonary function testing carried out with the KoKo® Trek Classic PC-Based Spirometer provided baseline measurements of respiratory function prior to spinal fusion surgery. Parameters measured were as follows; expiratory: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC , forced expiratory volume in three seconds (FEV_3), FEV_3/FVC , forced expiratory flow within 25-75% of total flow of expiration (FEF 25-75%), peak expiratory flow rate (PEFR), and Expiration Time. The researcher in this study applied a three-liter syringe for calibration, which fit the criteria for calibration as explained in the technical specifications of the device. Setting the barometric pressure and age, height, and

weight, which differed between testing days, standardized the KoKo® Trek Classic PC-Based Spirometer (nSpire Health, 2010).

Information regarding patient demographics, surgery, and rehabilitation was acquired through an extensive patient history and surgical notes provided by the patient.

Results

The patient underwent posterior spinal fusion surgery from T2-L2 and posterior spinal instrumentation from T2-L2 to correct the spinal curvature on December 12, 2012. Following surgery the patient was in a Boston brace for three months, which was molded to the patient specifications. During the first three months the patient was instructed to walk as much as possible, slowly increasing duration. The three to six month mark the patient discontinued the Boston brace and began light jogging, bike, and elliptical exercise. At six months the patient began physical therapy, which incorporated jogging and light weight lifting. The focus of physical therapy was core strengthening and neutral spine exercises with functional progression. One year following surgery the patient is released by surgeon to participate in activities within the patient's comfort zone, excluding impact sports and gymnastics. The patient has a two-year follow-up appointment with the surgeon to reassess the spine following surgical intervention of metal rod spinal fusion. Appendix A shows an x-ray of the spine pre- and post-spinal fusion surgery. Post surgical Cobb angle measurement was a 20-degree thoracic curve. Symptoms after surgical intervention include; neck aches where the metal rods start, low back pain during standing for long periods of time, and burning/itching throughout back due to nerve disruption during surgery.

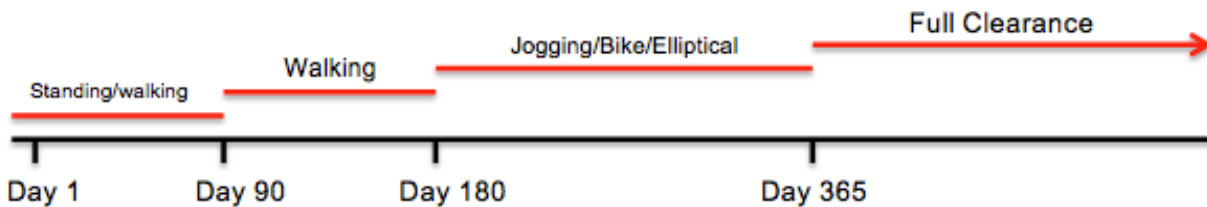


Figure 2 Activity restrictions set by attending physician following posterior spinal fusion surgery

Shoulder flexion ROM, is shown in Table 2, for both right and left sides. Inability to measure ROM for shoulder flexion pre-surgery resulted in the most noteworthy changes. Curvature of the spine resulted in scapulohumeral dysfunction with premature scapular motion, therefore diminishing true isolation of shoulder flexion. With the correction of the spinal deformity, through surgical intervention, true isolation of the shoulder joint as obtained for ROM measurements. Following surgery ROM measurements are within normal limits.

	Pre-R	Pre-L	Post-R	Post-L
AROM	N/A	N/A	175°	175°
PROM	N/A	N/A	170°	182°

Table 2 Shoulder flexion range of motion post surgery for left and right side.

Shoulder extension ROM, shown in Figure 3, exhibits decreased ROM in active range of motion (AROM) and passive range of motion (PROM) respectively for both right and left sides. PROM measurements saw a greater decrease following surgery when compared to AROM measurements. During pre-surgical measurements for AROM the patient exhibited shoulder abduction when attempting to transition into shoulder extension therefore, the patient was instructed by the researcher to stop motion when there was no longer a true isolation of shoulder extension. For PROM the researcher restricted the abduction of the shoulder by stabilizing the scapula. Thus creating a more stable scapula resulting in isolation of shoulder extension. Stabilization was necessary due to the abnormal positioning of the scapula, which is a result of the spinal deformity caused by scoliosis. Spinal fusion surgery resulted in AROM measurements for the right and left shoulder to decrease by 7 degrees. PROM measurements had a greater

decrease in ROM following the surgery with the right shoulder decreasing by 18 degrees and left decreasing 36 degrees. Straightening of the spine is most likely the cause of the decrease in range of motion; however, the ROM measurements for active and passive ROM following surgery are within normal limits.

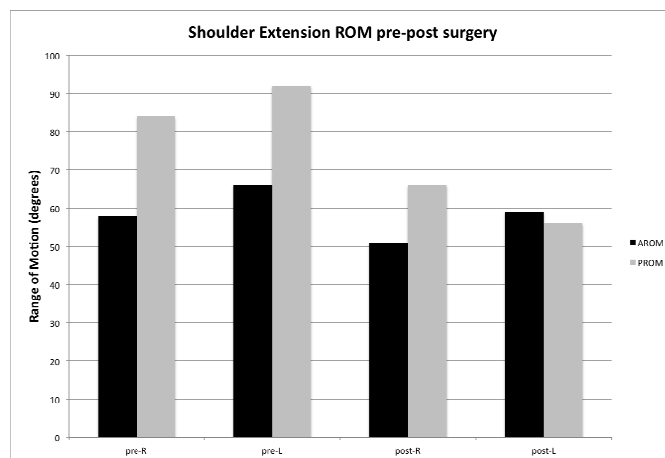


Figure 3 Shoulder extension range of motion pre and post surgery for right and left sides.

Hip flexion ROM, represented in Table 3, shows a decrease in ROM on the right side following surgery whereas the left side only shows minor change. This is likely due to lack of effect scoliosis had on the patient’s anterior musculature. The decrease in ROM of the right hip could be subsequent to the straightening of the spine creating improved anatomical position.

	Pre-R	Pre-L	Post-R	Post-L
AROM	121°	108°	112°	102°
PROM	163°	155°	147°	151°

Table 3 Hip flexion range of motion pre and post surgery for right and left side

Hip extension ROM, shown in Figure 4, exhibits increased ROM measures passively exceeding active measurements. Overall AROM measurements decreased following surgery, the greatest decrease occurring on the right side with an 8-degree loss in ROM, actively. Passively the patient’s ROM measurements exhibited an increase of 5 degrees on the right and 6 degrees

on the left for hip extension respectively. Corrected rotational alignment of the pelvis in the frontal plane is a plausible cause of decreased AROM.

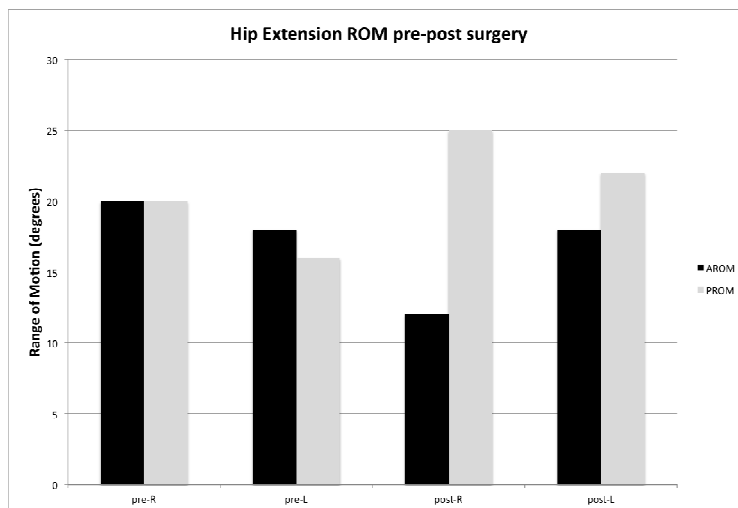


Figure 4 Hip extension range of motion pre and post surgery for right and left side

Muscle power lab results exhibited an increase in muscular power across the majority of exercises, which were separated by side of the body (Figure 5 & 6). Chest press saw the greatest increase in muscular power output on the right side by 24.5 watts. Exercises, which require bilateral activation of skeletal muscles, saw a decrease in muscular power due to the fusion of the spine through surgery. The greatest decrease in muscular power is seen when the patient performed a sit-up. The straightening of the spine caused the inability to flex the trunk at the vertebral level showing a decrease of 17.9 watts (Table 4).

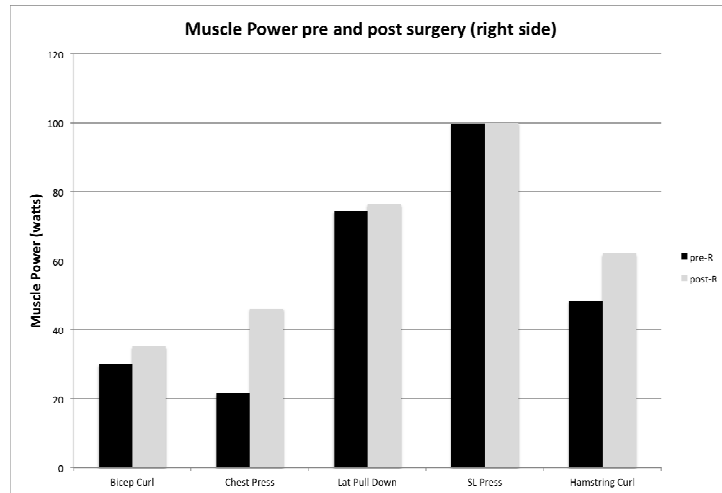


Figure 5 Muscle power pre and post surgery for right side only

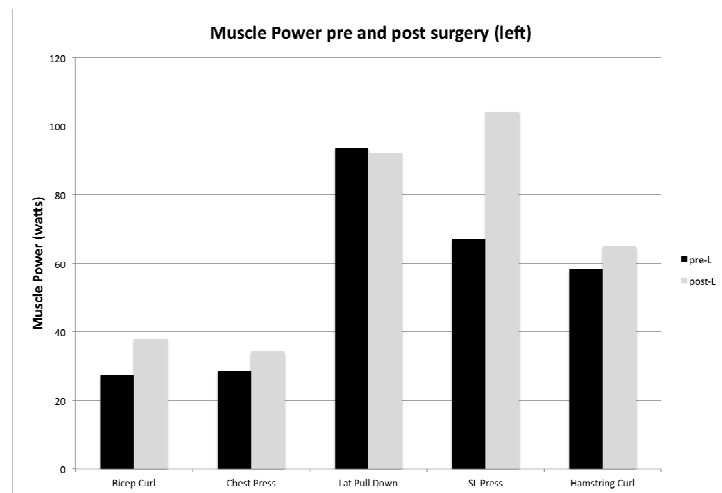


Figure 6 Muscle power pre and post surgery left side only

	Reverse Crunch	Sit-up
Pre-op	6.9	19.6
Post-op	4.3	1.7

Table 4 Muscle power pre- and post- operative, measured bilaterally.

Pulmonary function test reveal an increase of overall pulmonary function following spinal fusion surgery. The standard error for the KoKo® Trek Classic PC-Based Spirometer is $\leq \pm 3\%$ in accuracy and reproducibility $\leq \pm 0.5\%$. Predicted values for parameters tested differed due to change in age of the patient before and after surgery. Forced vital capacity (FVC) increased by 0.25 liters (L) following spinal fusion surgery. When compared to predicted normative values it is an increase of 92%. FEV₁ also increased following surgical intervention

by 0.28 L, which is 94% of predicted normative values (Table 5). Decrease in rib cage rotation resulted in the appropriate space for the lungs to be capable of filling to maximal capacity.

Without pulmonary restriction the patient was able to achieve a steady flow of air throughout the test. By correcting the position of the rib cage to an anatomically neutral position the patient was capable of maintaining a steady flow during expiration over time, which is shown in an increase of forced expiratory flow 25-75% (FEF 25-75%) by 0.38 L/s and 95% of predicted normative values. Figures 7 and 8 are physical demonstrations of the pulmonary function test results pre- and post surgery.

*Normative values	FVC (L)	FEV ₁ (L)	FEV ₁ /FVC (L)	FEF 25-75% (L/s)
Pre-op Best	3.46	3.00	0.87	3.49
Post-op Best	(3.41)* 3.71	(3.08)* 3.28	(0.91)* 0.89	(4.05)* 3.87

Table 5 Pre- and post-operative Best values based on age, height, and weight for Pulmonary Function using the KoKo® Trek Classic PC-Based Spirometer.

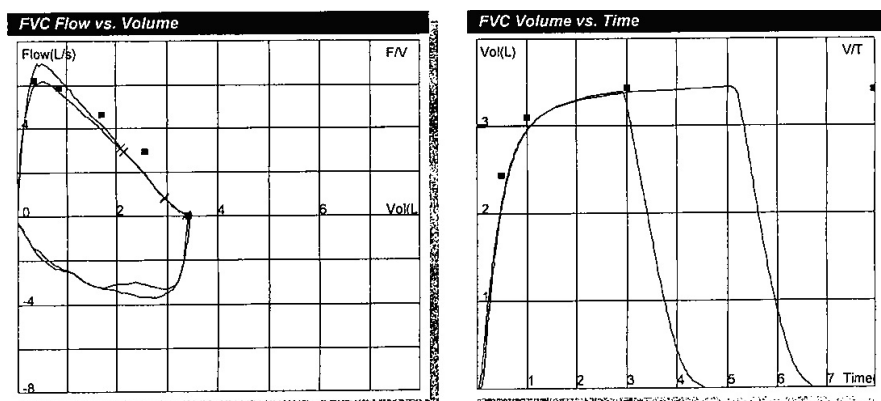


Figure 7 Pre-surgical pulmonary function test results.

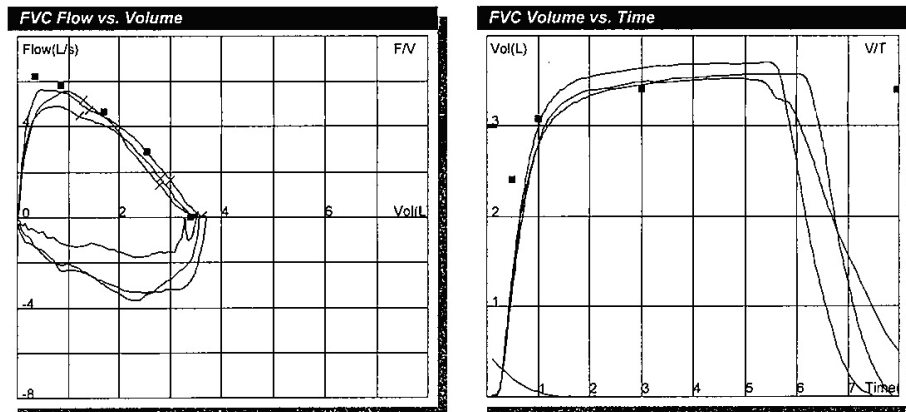


Figure 8 Post surgical pulmonary function test results.

Discussion

Following current surgical practices described by the Scoliosis Research Society spinal fusion surgery aims to prevent the progression of the curve and diminish spinal deformity. Spinal curvatures exceeding 45 degrees can become detrimental to patients and therefore require surgical intervention to correct the problems, which can be caused from a severe curve. In this patient the extent of the thoracic curve measured approximately 80 degrees with a sizable rib hump and rib cage rotation. The rotation of the rib cage from deformity in the thoracic spine caused depleted pulmonary function, which made the patient a candidate for spinal fusion surgery having already met the degree of curve criteria. Following spinal fusion surgery the patient did increase pulmonary function; however, like previous research the results were not significant. Hawes (2006) and Shneerson & Edgar (1979) suggested that pulmonary function continues to change in the years following surgical intervention. However, there is minimal current research examining the longevity of pulmonary function changes in scoliosis patients, which receive spinal fusion surgery. Although significance has not been found in pulmonary function changes it can be argued that the psychological benefits could play a role in making it “easier” to breathe. It should be noted that the patients’ participation in competitive gymnastics

could be a factor in the integrity of the respiratory musculature, prior to surgery. This could result in abnormal pulmonary function test results if compared to a patient that is not diagnosed with scoliosis.

Meyer et al. (2006) uncovered that participation in gymnastics for patients with scoliosis had a positive effect on symptoms of the deformity; however, the study also mentioned the duration and intensity for the practices were shorter and at a lower intensity than the patient in this study performed. This patient participated in high intensity gymnastics practices since beginning her competitive career at age six, which is cause for speculation regarding her post skeletal maturity curve progression. Research has not confirmed that intense practices of sports, which place increased force on the spine, actually escalate progression of the curve deformity. There has been speculation such practices could be detrimental to the health of the spine; however, the patient in this study seemed to have benefited from participation in gymnastics even at the increased intensity and duration with respect to muscular strength and endurance. Such practices allowed the patient to condition cardiovascular, pulmonary, and skeletal musculature creating a stronger and more stable structure. Well-conditioned musculature coupled with superior cardiovascular health beginning at a young age could be an important factor in the longevity of the lack in progression of the scoliosis. Patients exhibiting severe scoliosis typically progress at a rate of 1-2 degrees per year creating the need for surgery to become necessary at an earlier age (Greiner 2002). However, the patient in this study prolonged surgery with, what could be argued, superior musculature surrounding the spine acting as an anatomical brace. Traditionally, curve progression does not manifest after skeletal maturity is reached although in this patient spinal curvature increased by 17 degrees once the attending physician reported skeletal maturity. Therefore, a question remains as to why curve progression

continued subsequent to skeletal maturity. Earlier research exposed possible causes of scoliosis being hormonal and/or nutritional. Concurrent with reaching skeletal maturity the patient experienced life changes, which could have altered the hormonal balance, such as beginning college, moving away from home, living with new people, and starting a division I college gymnastics program. Such life changes could have also affected the patient's nutritional habits. The possible hormonal and nutritional changes coupled with the compressive loads of participation in division I college gymnastics could have been detrimental to bone health, specifically bone mineral density, which is typically attained between the ages of 20 and 30 (d'Hemecourt et al. 2002). With a possible decrease in bone mineral density from changes in hormonal balances and nutrition the possibility of late stage progression of the scoliotic curve becomes more relevant. These factors should be studied more closely with possible links to the progression of scoliosis as a general diagnosis and practical cause of adult onset scoliosis.

Although the patient was cleared to participate in a high level of competitive sport, surgery became inevitable. Curve progression exceeded a degree in which the attending physician was uncomfortable allowing the patient to continue gymnastics and the patient reported difficulties breathing during activity and at rest. Prior to surgery there was a highly noticeable rib hump and spinal deformity, which set the patient apart from the normal population. While collecting ROM measurements and muscular power output there was noticeable difference in strength and ROM when comparing the right and left side of the body as a result of the spinal deformity. Following surgery there is a minimal curve as well as an absence of physical deformity upon observation. Previous research explained an increase in spinal longitudinal length following spinal fusion surgery, for this patient there was an increase of 57 mm to spinal longitudinal length. When compared to previous research the patient in this

study showed a greater increase in spinal longitudinal length by approximately 24.6 mm. The correction of spinal deformity resulted in more equal ROM and muscular power when comparing right and left sides of the body. Muscular power deficit seen in the sit-up exercise post surgical intervention is likely related to a biomechanical disadvantage and abdominal musculature weakening. Having received posterior spinal fusion the erector spinae muscles had to remodel and other posterior chain muscles were required to adapt to the straighter spine. Muscular adaptations have been studied and researchers found adaptations continue to occur following spinal fusion surgery up to two years (Hawes et al. 2006).

Current research focuses on pre-surgical measurements and symptoms; therefore there is a lack of post-surgical measurements and symptoms for comparison with the patient in this study. Future research should focus on changes which occur following spinal fusion surgery including functional attributes like, muscular strength and power, longevity of pulmonary function, and range of motion symmetry. Although researchers have not been able to find a cause for adolescent idiopathic scoliosis, efforts should continue to explore the possibilities, which might lead to the understanding that the diagnosis is multifactorial but will remain idiopathic in nature.

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Appendix A



X-ray Pre-Surgery; Cobb angle 77 degrees



X-ray Post Surgery; Cobb angle 20 degrees