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The comparison of cross sectional area and parasagittal dimension measurements of the multifidus muscles in collegiate athletes identified on the basis of gender, body morphology, history of back pain, and rotational nature of sport

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by

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Declaration of Originality

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

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Abstract

This collaborative study used diagnostic ultrasound to identify the cross sectional area (CSA) and parasagittal dimension (PSD) of the multifidus muscle in helping allied health professionals learn more about the relationship between low back injuries and this muscle's measurement in collegiate athletes. Bilateral ultrasound measurements (L3-L5) were taken from 91 collegiate athletes who participate in men's and women's non-contact sports, volleyball, track/field, swimming, softball/baseball. This exploratory study looked at participant history of low back pain (LBP), gender, height, sport mechanics, and presence of one-sided sports.

Researchers used independent t-tests to identify athletes with LBP showed muscular atrophy occurred at L5 according to CSA and PSD measurements. Taller athletes (males $\geq$ 180.3cm and females $\geq$ 175.3cm) were found to have greater CSA and PSD measurements of the multifidus muscle than shorter athletes. Male CSA and PSD measurements were found to be greater than in females. CSA and PSD measurements were also greater in rotational athletes' at all lumbar segments except PSDL4L. ANOVA was used to identify the relationship between one-sided dominant sport athletes and non-dominant sport athletes CSA and PSD measurements. CSA measurements in rotational athletes were all greater than non-rotational athletes and PSD were greater at L3L and L4R. In one-sided dominant sports, research indicated greater CSA measurements at L5 and L4 and PSD measurements at L3 on the left only. A Least Significant Difference Post Hoc Test was also used to identify baseball/softball athletes being statistically significantly greater in CSA measurements than all sports when comparing groups. Volleyball athletes also had measurements greater than track athletes.

This study used diagnostic ultrasound to discover differences in CSA and PSD measurements. Measuring the multifidus muscle may be a great strategy to assist allied health professionals with diagnosis of superficial soft tissue injuries, and assist with treatment and prevention of low back injuries. CSA and PSD measurements can help identify abnormalities within the stabilizing multifidus muscle and allow the allied health professionals to create strategies to strengthen and reduce potential LBP. These findings might change how allied health professionals are diagnosing, treating, and rehabilitating low back injuries.

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List of Abbreviations

CSAL5R	Cross sectional area measurement taken at level L5 on the right side
CSAL5L	Cross sectional area measurement taken at level L5 on the left side
CSAL5SYM	Cross sectional area measurements taken on both sides of the spine at L5 and compared right minus left
CSAL4R	Cross sectional area measurement taken at level L4 on the right side
CSAL4L	Cross sectional area measurement taken at level L4 on the left side
CSAL4SYM	Cross sectional area measurements taken on both sides of the spine at L4 and compared right minus left
CSAL3R	Cross sectional area measurement taken at level L3 on the right side 3.
CSAL3L	Cross sectional area measurement taken at level L3 on the left side
CSAL3SYM	Cross sectional area measurements taken on both sides of the spine at L3 and compared right minus left
PSDL5R	Parasagittal dimension measurement taken at level L5 on the right side
PSDL5L	Parasagittal dimension measurement taken at level L5 on the left side
PSDL5SYM	Parasagittal dimension measurements taken on both sides of the spine at L5 and compared right minus left
PSDL4R	Parasagittal dimension measurement taken at level L4 on the right side
PSDL4L	Parasagittal dimension measurement taken at level L4 on the left side
PSDL4SYM	Parasagittal dimension measurements taken on both sides of the spine at L4 and compared right minus left
PSDL3R	Parasagittal dimension measurement taken at level L3 on the right side

PSDL3L	Parasagittal dimension measurement taken at level L3 on the left side
PSDL3SYM	Parasagittal dimension measurements taken on both sides of the spine at L3 and compared right minus left

Chapter One: Introduction

Background of the Problem

The topic of this research study was an area of the body that seems to be understudied by allied health professions, namely, the inter-relationships of cross sectional area (CSA) and parasagittal dimension (PSD) measurements of the multifidus muscle within the collegiate athlete population who experience low back pain. This particular study focused on the bilateral lumbar multifidus measurements and the relationship of these measurements to low back pain (LBP) in intercollegiate athletes who participate in men's and women's swimming, men's and women's track and field/cross-country, men's and women's volleyball, women's fast-pitch softball, and men's baseball. A scarcity of research exists concerning gender difference, variance within non-contact sports, and differences between linear and rotational movement sports.

Research has been conducted extensively on the topic of back pain as a consequence of sports involvement (Greene, Cholewecki, Galloway, Nguyen, & Radebold, 2001; Vela, Haladay, & Denegar, 2011). There are few articles relating to the low back and particular sports, even less related to specific sports and the multifidus muscle. Competitive athletics and "elite-level" training programs are promoted at very young ages. These athletes travel all over the world competing with no medical staff on hand for injuries or prescreening practices to prevent injuries. Consequently, athletic injuries that are both acute and chronic are a much more commonplace occurrence. Having an effective screening and monitoring process for measuring the multifidus muscles may present a significant preventative modality for back pain because muscle size seems to be related to LBP. A specific exercise program could be developed to increase the size of this muscle and surrounding muscles to help prevent potential injuries.

The multifidus muscle is emerging as an engaging research area. Researchers believe LBP can be identified by the malfunction or reduction in size or function of the multifidus muscle (Hodges, Holm, Hansson, & Holm, 2006; Van, Hides, & Richardson, 2006; Wallwork, Stanton, Freke, & Hides, 2008). Even though the multifidus muscle group runs from the sacrum to cervical vertebra number 4 (C4), each individual branch of the multifidus runs 2-4 segments of the spine (Kendall, McCreary, Provance, Rodgers, & Romani, 2005; Tortora, & Derrickson, 2009). Others stated this muscles runs to C2 (Hansen et al., 2006; Watkins, 1996). Segments are defined as individual vertebra. Frymoyer and Cats-Baril (1991) indicated between 60 and 90% of people will experience LBP in their lifetime. Some problems are congenital, and others develop with age and activity. The activity itself is not always the cause of pain. Each vertebra has a synergetic relationship with the next and when there is a malfunction with one segment, the vertebra above and below adjust and help support the vulnerable area, causing more stress on the healthy units. Those occasional “tweaks” or “micro-traumas” in the back compound over time to create serious problems as an athlete ages. Treating the lower back for pain is historically well documented; however, as athletic skill and technological innovations increase, a focus on prevention of injury and treatment efficacy should also simultaneously be a part of the knowledge base.

The specific use of ultrasound to identify the CSA and PSD of the multifidus muscle is a fairly new concept. However, research dating back to 1974, suggests ultrasound has been used for rehabilitative purposes, and assists with identification of function during training of the lumbar multifidus muscle (Herbert, Heiss, & Basso, 2008; Hides, Stanton, McMahon, Sims, & Richardson, 2008). Individuals can see the muscle contracting on the ultrasound screen when performing exercises. This feedback is an effective way to educate the individual how that particular muscle functions. Prevention of injury or identifying the potential of injury prompted these studies. Prevention is just one area allied health professionals specialize in with their careers. The CSA or PSD normative data has not been promoted as a way to identify potential injuries.

For the past 22 years, I have been a certified athletic trainer. For the past 11 years, I have been employed by Lindenwood University (LU) as an athletic trainer and an educator. As an athletic trainer, one of my primary responsibilities is injury prevention. I have treated numerous back injuries, some corrected with no return of pain and some athletes have returned with the same complaints the next year. I also taught a *back school* (proper body mechanics to protect the back from injury) while working in the clinical setting. The back has always been one of my favorite areas to treat. Approximately three years ago, LU collaborated with a local chiropractic school, Logan College of Chiropractic (Logan), to treat LU athletes' injuries. The supervised chiropractic students come from Logan once a week to see athletes that LU athletic trainers have already evaluated and treated, but may benefit from chiropractic treatments to aid in their recovery. The athletic trainer makes an appointment with the chiropractor and supplies the original evaluation. This collaboration has been working well for the chiropractic students, athletic trainers, and athletes.

Logan has minimal sports teams, so its director of sports medicine approached me about collaborative studies. Due to my interest in the spine and the limited research on the multifidus muscles in specific sports and athletes, we were able to find a suitable topic for both Logan and LU. Logan has the scientific equipment and LU has the athletes.

Statement of the Problem

In the field of allied health, advancing knowledge in the subject of spine strength is a significant need of inquiry. The spine is critical in movements of both upper and lower extremities. Spinal stability is the base behind all movement. Athletic trainers, exercise scientists, physical therapists, chiropractors, nurses, and doctors all need to understand the function and importance of the multifidus muscle and its stabilizing ability with movements. Previous research has not been conclusive regarding what happens to this muscle once there is a back injury.

Despite the numerous studies on LBP in athletes, little empirical research exists on the CSA and PSD measurements of the lumbar multifidus muscle. Identifying non-symmetrical CSA and PSD measurements may help allied health professionals reduce the number of chronic back injuries, possibly identify and/or predict potential future injury, reduce the astronomical cost of care for low back pain, and keep individuals and athletes active for longer periods of time. There are no definitive answers presently on the extent to which height or gender influence the size of the CSA or PSD. There are also no known CSA or PDS studies that compare rotational and non-rotational athletes as subjects.

Purpose of the Study

The purpose of this study is to compare the relationship of CSA and PSD measurements by history of injury, body morphology, gender, and biomechanical nature of sport.

Hypotheses

Hypothesis #1. Subjects with no history of LBP will have symmetrical CSA measurements.

Hypothesis #2. Subjects with no history of LBP will have symmetrical PSD measurements.

Hypothesis #3. CSA and PSD measurements will be greater in taller athletes (males ≥180.3cm and females ≥175.3cm).

Hypothesis #4. CSA and PSD measurements will be greater in male athletes.

Hypothesis #5. Rotational athletes will have greater CSA measurements compared to non-rotational athletes.

Hypothesis #6. Rotational athletes will have greater PSD measurements compared to non-rotational athletes.

Hypothesis #7. One-sided dominant sport athletes (e.g. volleyball, baseball, and softball) will have higher CSA measurements compared to non-dominant sided sport athletes (e.g., swimming and track).

Hypothesis #8. One-sided dominant sport athletes (e.g. volleyball, baseball, and softball) will have higher PSD measurements compared to non-dominant sided sport athletes (e.g., swimming and track).

Importance of the Study

Back injuries keep athletes out of the game and individuals out of work. There is mental stress associated with lack of work and play, and a huge financial stress on the budget and insurance companies as a consequence of injury. Identifying the potential cause of an occasional twinge of pain or constant pain will allow individuals to lead better lives, both physically and mentally. Humans may feel an emotional drain if they are told to just deal with back pain. A study on adolescent low back pain identified 50% improvement on a disability questionnaire as being successful (Fritz & Clifford, 2010).

Athletic trainers, team physicians, physical therapists, nutritionists, sports psychologists, and chiropractors work with injured athletes on a daily basis. At LU, the sports medicine team consists of an orthopedic surgeon and family practice physician from the area, athletic trainers, and chiropractors from Logan. With appropriate teamwork, LU has created well-rounded, choreographed treatment plans for the athletes. The chiropractors focus on the segmental components of treatment while the physicians and athletic trainers focus on the global components. Together, they encompass a finely tuned machine of talented and skilled allied health professionals.

Prevention of injury is a strong focus in athletics. Logan has provided equipment, staff, and chiropractic students to assist with this study. Fairly recent non-invasive technology is being used to diagnose tissue damage below the skin. This technique is called diagnostic ultrasound. In this study, Logan provided a portable ultrasound machine to measure tissue size of the lumbar multifidus muscle.

Lindenwood University is known in the U.S. Midwest for having a large collegiate athletic program. This research study used athletes from four non-contact teams, both males and females, as subjects. Cross country and track athletes were considered the non-rotational sports subjects while baseball, softball, volleyball, and swimming athletes were considered the rotational sports subjects for this study.

Definition of Terms

Acute back pain – pain in the low back that has continued for one month or less (Kiesel, Underwood, Mattacola, Nitz, & Malone, 2007)

Annulus fibrosus – the outer portion of the disk (Cailliet, 1988)

Asymptomatic – without symptoms(Asymptomatic,1982)

Atrophy – wasting away of muscle tissue (Prentice, 2011a)

Bilateral – on both sides (Tortora & Derrickson, 2009)

Brachial Plexus – C5 – T1 nerves that produce movement and sensation to the upper extremities (Watkins, 1996)

Cervical pain – pain between the base of the skull and above the shoulders

Cervical vertebrae – the first seven vertebra of the spine. Each one is named by the section of the spine followed by the number of vertebra from the top of that unit (e.g., the fourth vertebra of the cervical unit is called C4) (Tortora & Derrickson, 2009)

Chronic back pain – pain in the low back that continues after 12 weeks (Kiesel, Underwood et al., 2007)

Cross sectional area (CSA) – a diagnostic ultrasound measurement taken of the circumference of the multifidus muscle. The ultrasound machine will calculate the CSA of the muscle from the circumference measurement. The CSA is measured using the following structures as landmarks: superficially, the thoracolumbar fascia; laterally, the fascial plane between multifidus and erector spinae; anteriorly, the lamina and articular processes of the lumbar vertebrae; medially, the spinous process of the lumbar vertebrae. The CSA can provide an estimation of the force-producing capacity of the muscle as well as the level of activation (Whittaker et al., 2007).

Denervation – a condition where the nerve is no longer attached to a muscle (Hodges et al., 2006)

Diagnostic Ultrasound – ultrasound imaging used as a form of biofeedback to identify muscle performance during rehabilitation, also known as rehabilitative ultrasound imaging (RUSI) (Hides, Richardson, Jull, & Davies, 1995)

Dermatome – area of the skin innervated by afferent nerves (Prentice, 2011b)

Electromyograph – a machine that picks up electrical impulses from muscles. It can be imbedded deep into a muscle or superficially on top of the skin. As a muscle contracts, it registers the impulse (MacDonald, Moseley, & Hodges, 2009).

Histochemical – chemical changes which occur at the cellular level (Histochemical, 1982)

Hypermobility – an extreme movement in the joint (Arnheim & Prentice, 2002)

Hypertonicity – an increase in tone within a muscle (Starkey & Johnson, 2006)

Innervation – location where the nerve and muscle connect (Innervation, 1982)

Ipsilateral pain – on the same side of the body (Tortora & Derrickson, 2009)

Kyphosis – an increase in the posterior curvature of the spine in the thoracic unit (Cuppett & Walsh, 2005)

Lordosis – an anterior increase in curvature of the spine in the lumbar unit (Kendall et al., 2005)

Low back – located below the last rib and above the upper buttocks

Low back pain – pain located below the last rib and above the upper buttocks

Lumbar vertebrae – five vertebrae below the 12th thoracic spine. Each one is named by the section of the spine followed by the number of vertebra from the top of that unit (e.g., the fourth vertebra of the lumbar unit is called L4) (Hansen & Lambert, 2005)

Multifidus – a muscle located nearest the spine controlling erection of the spine and stabilization during movements of the spine and extremities, and assisting in all other spinal movements (Kendall et al., 2005)

Myotome – efferent nerves which provide movement (Prentice, 2011b)

Nociceptor – a nerve that receives painful stimuli (Watkins, 1996)

Non-rotational athletes – athletes who participate in sports that do not require consistent rotation of the spine (e.g., track, cross-country, and cycling)

Parasagittal dimension (PSD) – a diagnostic ultrasound measurement taken of the multifidus muscle from the superficial landmark of the thoracolumbar fascia to the deep landmark of the lumbar facet joints. This measurement is a thickness measurement of the lumbar multifidus muscle in the sagittal anatomical plane (Hebert, Koppenhaver, Parent, & Fritz, 2009)

Proprioceptive receptors – receptors which receive information about position and movement in space (Lephart & Fu, 2000)

Reflex inhibition – "the reduction in alpha motor neuron excitability as a result of afferent input from joint structures" (Hodges et al., 2006, p. 2931)

Rehabilitative ultrasound imaging (RUSI) – ultrasound imaging used as a form of biofeedback to identify muscle performance during rehabilitation, also known as diagnostic ultrasound (Hides et al., 1995)

Rotational athletes – athletes who participate in sports which require consistent rotation of the spine. This would classify most athletes (e.g., baseball, softball, swimming, and volleyball)

Scheuermann's kyphosis – an increase in the posterior curvature of the spine in the thoracic unit found in adolescents (Cuppett & Walsh, 2005)

Thoracic Pain – pain between the cervical and lumbar units

Thoracic vertebrae – 12 vertebrae below the cervical unit. Each one is named by the section of the spine followed by the number of vertebra from the top of that unit (e.g., the fourth vertebra of the thoracic unit is called T4) (Arnheim & Prentice, 2002).

Transverse plane – a reference to a plane of the body that divides the body into upper and lower halves (Tortora & Derrickson, 2009)

Potential Limitations of the Study

Pain can be devastating. However, the body can adapt to the pain and can develop a pain threshold. Being able to rate pain (the way each individual interprets pain) is one limitation of this study. Athletes' self-perception of pain is unpredictable because the athlete's experience with previous injuries to other parts of their body or their back can change the thought process of how they feel the pain, therefore changing the pain threshold.

Because of space and usage of rooms, all of the equipment used for this study needed to be portable. Goniometers and petrometers, measuring devices used in range of motion, are easily portable. The ultrasound unit used was also portable. Vertically stacked yard sticks were used for measuring height. Supervised chiropractic students from Logan were used to perform orthopedic special tests related to the neurological system at each station. These students were in their last or second to last tri-semester, and worked in a supervised clinical setting when not in the classroom. Another potential limitation of the study involves measurement error in using the above listed measuring tools. However, every effort was taken to ensure consistent and accurate measuring techniques.

Due to the exploratory nature of this study, it is accepted that a limitation exists on account of a small sample size. Specifically, there are very few sports which are considered to be purely linear. In this study, rotational athletes significantly outnumbered athletes involved in linear sports.

High school and collegiate athletes are exposed to different training techniques, programs, and philosophies concerning strength and conditioning. It is unclear at this point whether the sport alone accounts for differences in muscle measurements or whether it is influenced by quality and quantity of strength and conditioning programs. At the collegiate level, many strength and conditioning programs are dependent upon the coaches' experience and training philosophy.

Delimitations

It is assumed that non-contact sports are less likely to sustain significant external trauma due to the nature of the competitive environment. Traditional strength and conditioning programs for contact sports are more likely to emphasize exercises that build spinal stability to counteract external forces. Non-rotational athletes have very little contact in their sport and tend to not participate in contact activity. The number of non-rotational sports is very limited in collegiate athletics. Swimmers who compete in breast stroke and butterfly will train using rotational strokes during practice so isolation of non-rotational sports is difficult.

Assumptions

Four major assumptions outline the foundation for this study. First, it is assumed that the chiropractic students have appropriate training in performing special tests and the sonographer, the person performing ultrasound measurement, has years of experience. Second, it is assumed that self-reports of pain and medical history by athletes is consistent and honest. Third, it is assumed that rotational sports athletes and non-rotational sports athletes are fundamentally different regarding CSA and PSD measurements. Finally, it is assumed that body morphology and gender will impact the measurements of the multifidus muscle.

Summary

The use of diagnostic ultrasound can assist in identifying indicators of potential LBP, and assists allied health professionals in prevention and treatment of athletic injuries. Allied health professionals use their verbal, visual, and manual skills to identify global deficiencies within joints during evaluations. With the use of diagnostic ultrasound, allied health professionals will be able to identify segmental deficiencies or potential problems not identified through normal evaluations. The goal of this study is to identify specific segmental instabilities due to muscle deficiency and/or size of the multifidus muscle in the lumbar unit.

Chapter Two: Review of Literature

Overview

In the field of allied health, advancing knowledge of LBP in collegiate athletes creates a significant need of inquiry. The low back is defined as being below the 12th rib and above the top of the buttocks. The low back area, along with the abdominal muscle function, is critical in movements of both the core and upper and lower extremities. Core strength and stability is the basis behind all movement. In order for the limbs to move, the spine needs to be stabilized and that stability mainly originates from the function of the multifidus muscle. One study indicated "elite athletes with low back pain exhibit specific deficits in a muscle that is known to play a key role in segmental stability of the lumbar spine" (Hides et al., 2008, p. 106).

Athletic trainers, exercise scientists, physical therapists, chiropractors, nurses, and doctors all need to understand the function and importance of the multifidus muscle along with its stabilizing abilities for human movements. The review of literature explores the most current knowledge within the scientific world regarding function of the multifidus muscle, LBP, and how it affects athletes. Diagnostic ultrasound is used within this study, and other studies, to greater understand complications of back pain.

Research is not conclusive regarding what happens to the multifidus muscle once there is a low back injury. Evidence indicates that the lumbar multifidus shows a reduction of muscle size within the first 24 hours of injury (Hodges et al., 2006) and the multifidus may not recover completely even though back pain symptoms are resolved (MacDonald et al., 2009). Most low back injuries occur at the L4-5 junction of the spine according to Brennan, Shafat, Mac Donncha, and Vekins (2007b). Symptoms normally subside within the first four weeks of the initial injury (Hides, Jull, & Richardson, 2001). The Herbert et al. (2008) study identified that between 50% and 86% of people with LBP have a recurrent episode within a year of their initial injury.

In a 2007 study by Brennan et al. (2007b), 188 collegiate students were surveyed in physically active studies (e.g., Equine Science, Physical Education, and Exercise Science) to ascertain knowledge regarding back pain and options for treatments. Of those 188 students surveyed, 61 reported back pains within the last 12 months. Seventy seven percent reported recurrent LBP, and 14% surveyed commented that their back pain was ongoing or constant. Their most common site of pain was at L4-L5 at 39%. Even though 43% received no medical care for their condition, common coping strategies consisted of low back and core exercises, prescription medications, rest, and stretching. Five percent of these individuals took more than six months off of physical activity while 36% lost up to a month of activity. Only 8% stated feeling they were healed with no recurrence while 48% reported healed but recurrent injuries within the 12 months. There were no statements on how many of these students were also athletes participating in collegiate sports, but a number of them participate in physical activity. Even though these individuals are young and active, this indicates back education and coping skills are limited (Brennan et al., 2007b). In the Danish population, ages 20-71, their coping skills were also to seek medical assistance and decrease activity (Leboeuf-Yde, Fejer, Nielsen, Kyvik, & Hartvigsen, 2011). Genetics, environment, and exposure to risk factors as well as personal training for extended hours need to be taken into consideration when looking at careers that might be related to LBP (Brennan et al., 2007b). Educators, specifically physical education teachers, are at larger risk of LBP (Brennan et al., 2007b).

This lack of education can relate to the large cost of health care. In a 1991 study, Frymoyer and Cats-Beril (1991) indicated that society views back pain as just a part of life, and individuals just deal with the pain until they are unable to deal with the intensity. The researchers also concluded “the population had always assumed back pain was a normal part of life” (Frymoyer & Cats-Beril, 1991, p. 263).

Anatomy

The spine has characteristics that allow individuals to withstand heavy loads, provides stability while using the limbs, and protects the spinal cord and nerve roots (Panjabi, 1992). It is important to clarify the anatomical structure of the spine because quite often people confuse the erector spinae muscles with the deep muscles, both of which assist with stability and erection of the spine. The first group, superficially, is the erector spinae group which consists of the iliocostal, longissimus, and spinalis muscles (Cailliet, 1988). All three muscles utilize the same origin of the T11 through L5, iliac crest, sacral spine, sacrum, and sacroiliac ligament, and run parallel to the spine until it inserts at C4 (iliocostal), T1 (spinalis), and occipital (longissimus) (Cailliet, 1988). The deeper fibers, also known as the transverse spinae muscles, consist of the semispinalis, multifidus, and rotatores, running superficial to deep. The semispinalis spans three to five segments, multifidus two to four segments, and rotatores only span one segment at a time (Cailliet, 1988; Kendall et al., 2005). These three muscles are closest to the vertebrae and are said to have the most stabilizing effect on the spine (White & Panjabi, 1978). The transverse abdominis is also a deep muscle that plays a significant role in stabilization of the spine and core. This muscle is the deepest of the abdominal muscles and runs in the transverse plane with the waistband. The other abdominal muscles, rectus abdominis, internal oblique, and external oblique assist with core strength but will not be discussed in this research. Many studies include the transverse abdominis when discussing the multifidus muscle and their role in stability of the spine (Hides et al., 2001; Hides et al, 2008; Kiesel, Underwood et al., 2007; Springer, Mielcarek, Nesfield, & Teyhen, 2006; Stone, 1999).

The spine consists of five units of individual segments that work together to create movement. The cervical unit, or neck, consists of seven vertebrae and emphasize movements of flexion and extension, followed by axial rotation and then lateral flexion. The thoracic spine consists of 12 vertebrae and the lumbar has five. Researchers agree that the main function of the thoracic spine is rotation and lateral flexion followed by flexion and extension, and the lumbar spine has the greatest movement in flexion and extension followed by lateral bending and rotation (Alexander, 1976; White & Panjabi, 1978). The sacrum and coccyx are the last two units and they are fused together. The 24 vertebrae in the cervical, thoracic, and lumbar can act both independently and together. The independent moving vertebrae, specifically the lumbar, and its deep stabilizing muscle, the multifidus, is the focus of this study. The lumbar sits on the sacrum and coccyx and the multifidus originates from the sacrum, along with the other deep muscles.

Panjabi (1992) described the spine as having three components which work together to create stability. The passive musculoskeletal subsystem consists of the bones, ligaments, and joint capsules and does not produce movements, while the active musculoskeletal subsystem consists of muscles and their tendons, producing force for movement to occur. The third subsystem is found inside ligaments, tendons, muscles, and neural control centers; therefore, it is called the neural control subsystem. The neural control center receives information to facilitate stability so the active subsystem can create forces to achieve stability. Each subsystem has its own function, but together they create stability of the spine so humans can create the motions of the spine and the extremities (Panjabi, 1992).

Multifidus. This study focused on the multifidus muscle and its function, or lack thereof, after an injury. The multifidus muscle is a strong stabilizer of the individual segments of the spine, extends the spine and assists with lateral flexion (Kolber & Beekhuizen, 2007). This muscle also opposes force to the opposite side during rotation (Hansen et al., 2006; Stokes, Rankin, & Newham, 2005). The multifidus means “with many branches” (Ward et al., 2009) and runs from the sacrum to C2 (Hansen et al., 2006; Watkins, 1996). The many branches come from the three origins: laminar fibers, basal fibers, and common tendon fibers (Dutton, 2002). The laminar fibers originate from the inferior-posterior edge of the lamina, the basal fibers from the base of the spinous process, and the common tendon originates from the inferior tip of the spinous process of each vertebra (Dutton, 2002). Each spinal unit (cervical, thoracic, and lumbar) has different characteristics of the multifidus muscle, but in the lumbar, there are five separate branches which emerge from one origin (Hansen et al., 2006; Hides, Stokes, Saide, Jull, & Cooper, 1994).

Both Type I and Type II fibers can be found in the all muscles but more Type I fibers can be found in the multifidus because of its function. Type I fibers are slow twitch fibers that have characteristics of needing oxygen to function, slow to fatigue, and hold long contraction times, and Type II are fast to fatigue, fast to contract, and require little to no oxygen for function (Matějke, Zůchová, Koudela, & Pavelka, 2006). Norris

(2000) added that Type I fibers are typically found closest to the joint, build tension slowly, are short muscles, and are considered to be stabilizers. Type II fibers are able to respond to sudden movements or loads whereas Type I fibers are used more for maintaining posture (Matějke et al., 2006; Norris, 2000). Type I fibers are also the quickest to atrophy when injured (Norris, 2000).

The multifidus creates movement bilaterally and unilaterally. During unilateral motion, it assists with lateral flexion and rotation, both times functioning as a segmental stabilizer. Dutton (2002) stated “the multifidus is active in nearly all antigravity activities and appears to contribute to the stability of the lumbar spine by compressing the vertebra together” (p. 280). The multifidus accounts for more than two-thirds of the stability during human movements (Wilke, Wolf, Claes, Arand, & Wiesend, 1995). In fact, the multifidus is a major stabilizer for all functions of the spine. It even stabilizes the spine during shoulder and hip movements. In extension, it assists with producing greater lordosis.

In an ideal erect posture, the spine sits on its base, the sacrum. The muscles of the spine do not function when standing still in proper posture. What holds humans in the upright position is the balance between the ligaments and muscle tone (Cailliet, 1988). The only muscle group that actually “works” during standing is the gastrocnemius-soleus muscle group in the lower legs. During flexion of the spine, each lumbar vertebra moves only 8-10°, producing approximately 45° range of motion, with the lumbar unit moving from lordosis to kyphosis (Cailliet, 1988).

Ironically enough, the disks that cause many people so much pain actually are aneural, or without a nerve, on the inside layers according to Cailliet (1988). Many people walking around right now probably have disk injuries and have no idea. Only the extreme outer layer of the 12 layers in the annulus fibrosus has a nerve that can receive stimuli, and only sensory stimulation (Hodges et al., 2006; Calliet, 1988). The pain that occurs is attributable to the disk pushing on the supporting ligaments or the nerve root, causing nociceptor receptors to be activated (Calliet, 1988).

Pain can produce other ‘normal functions’ of the tissue to malfunction. Muscles create hypertonicity, an increase in nerve activation within the muscle causing continuous contraction and miscommunication of proprioceptors. Hypertonicity found in a muscle tells allied health professionals that something has been injured in the immediate area. This can be examined by palpation of the muscle. Proprioception receptors misinterpret signals about spatial awareness. These receptors can be found in “spinal ligaments, facet joints, intervertebral discs, and paraspinal muscles” (Silfies, Cholewicki, Reeves, & Greene, 2007, Background section, para. 1). Break down in proprioception communication in any joint or muscle can lead to many injuries, not just in the spine, but in the whole body. Proprioception receptors in the spine assist in stability. When proprioception is compromised, compensation occurs in the muscles and tendons causing muscle spasms, fatigue and potentially injury (Panjabi, 1992). Silfies et al. (2007) reported on Newcomer, Laskowski, Yu, Johnson and An’s 2001 study that proprioception errors were greater in the subjects with LBP in flexion and extension injuries. Silfies et al. (2007) concluded that position sense was not related to LBP in collegiate athletes, suggesting that an increase in age and a drop in fitness levels may play a role in LBP. Proprioception measurements were also taken in the transverse plane while athletes commonly use all planes during athletic movements (Silfies et al., 2007).

Numerous studies have concluded that even though pain has diminished or completely resolved itself, there are still deficits to the CSA of the multifidus muscle (Brennan et al., 2007b; Hides et al., 1995; Hides et al., 2008). Fifteen to 86% of individuals reinjure their backs within the first year after the initial injury (Brennan et al., 2007b; Herbert et al., 2008) and about 35% will need to have some form of intervention (Wasiak, Kim, & Pransky, 2006). Silfies et al. (2007) concluded that once an injury occurs to the low back, athletes have a three times greater risk of injury in the future. Others believe re-injury could be caused by either poor physical training or pain-avoiding mechanisms (Dehner et al., 2009).

Lower Back Pain

There is little research data as to the true cost of LBP to society at this point. Most published data has taken totals from one year and predicted what will happen in 10 or 15 years. The most useful information was collected from the Eastman Kodak plant in Rochester, NY (Frymoyer & Cats-Baril, 1991). Statistics from the American Academy of Orthopeadic Surgeons (1984) showed the total cost of low back disorders in 1984 (Frymoyer & Cats-Baril, 1991). Back then, $15,872,760,000 was spent on low back disorder in the U.S. This cost was broken down to $12,922,740,000 in direct costs and $2,950,000,000 in indirect costs. Direct costs consist of drugs, hospital fees, emergency room, physician costs, and related goods and services. Indirect costs consist of loss in wages. Frymoyer and Cats-Baril (1991) projected that most direct and indirect disability costs, around 75%, would be dedicated to temporary or permanent disabilities of the low back, estimating $24,336,153,000 would be spent on back pain in direct costs alone in 1990. Most increases would be due to an increase in technology, population growth, visits to specialists (chiropractors, neurologists), and inflation. Their study suggested the biggest challenge in the future is prevention and optimum management of LBP. Cailliet (1988) reported that 30% of surgeries fail to relieve pain, and after five years, 10% have failed to relieve pain.

In a study that looked at 44 states, researchers identified the mean cost per workers' compensation for back injury, per case, was $6,807 and a median cost of $391 in 1986 (Webster & Snook, 1990). Back injuries were classified as areas of the sacrum, coccyx, low back, disc, and trunk. It was estimated that the cost to the United States for back injuries alone would be $11.1 billion. Medical costs averaged out to be about one-third of the cost and indemnity took the rest (Webster & Snook, 1990). Statistics from Workers' Compensation Agencies, the Bureau of Labor Statistics Data System, and 30 states in the US were evaluated to identify the direct costs of workers' compensation claims (Haddad, 1987). One physician was given seven years of workers' compensation cases to evaluate for "residual impairment" (Haddad, 1987, p. 767). This came to a total of 2,932 individual cases. At the end of this study, 30 of the 44 states paid $1.9 billion in workers' compensation and medical treatments. In cases that resulted in no disability, the average treatment of these 1,706 cases lasted nearly two years. In over 2,000 of these 2,932 cases, there were three or more physicians working on just one workers' compensation case, with a mean of 4.3 physicians per case. This number did not include therapists and testing personnel. In this seven year study, 91% of workers were not back to work. The researcher contributed this to cases not being resolved and representation for litigation. In interviews of open workers' compensation cases, their reasoning for not working was, "I am on disability" and "I was injured at work"—the most frequent responses (Haddad, 1987, p. 768). Research conducted in 1981 concluded that over 500 million dollars was spent on x-rays alone and most were unnecessary (Scavone, Latshaw, & Rohrer, 1981).

In a 2006 study pertaining to workers' compensation in the state of New Hampshire, back injury costs and days off work were compared to recurrence of care only, recurrence of work disability only, recurrence of care and work disability, and no recurrence (Wasiak et al., 2006). Recurrence of care is defined as having 45 days between treatments and recurrence of work disability as "resumption of payments for total work disability after a minimum of a 3-day break in indemnity payments, implying a temporary return to work" (Wasiak et al., 2006, p. 220). New Hampshire statistics were used because the state requires all workman compensation claims to be reported. The data selection was related to low back, sacrum, coccyx, and multiple trunk injuries. The Wasiak et al. (2006) study concluded that there was a mean of 10 days taken off work for employees with no recurrence, a mean of 26 days off for recurrence of care only, 52 days for recurrence of work disability only, and a mean of 141 days off taken when recurrence of care and work disability were combined. Although the cost for recurrence of care and work disability used more days off during this three-year study, 58% of the overall medical cost was comparable to values for recurrence of care individuals. In this study, there were 91.7% reported injuries of strains, 7.1% were contusions, 1.1% were sprains, and 0.1% were inflammation. There was no indication of whether or not there were temporary or permanent disabilities (Wasiak et al., 2006). In a 2007 study using physically active collegiate students, 77% had recurrent back pain and 57% received treatment for their injury (Brennan et al., 2007b).

Low back pain occurs in about 85% of individuals through their lifespan (Kulig et al., 2007). Causes for LBP consist of decreased functioning muscles in the back, decreased neurological function, compensation of muscle movement (MacDonald et al., 2009), reflex inhibition (Stokes & Young, 1984), and improper proprioceptive communication (Panjabi, 1992). The multifidus muscle reduces function after an injury to the low back (Hides et al., 2008). The transverse abdominis shows marked reduction as well (Hides et al., 1994; Springer et al., 2006).

It is not uncommon for people who have had back pain to have recurrent pain. In a study by Hides et al. (2001), it recognized the recurrence rate of back pain more prevalent within the first year than two to three years later. Their study consisted of 39 first-episode patients who were split into two groups. The control group was asked to return to daily activities and the second group was given exercise for the lumbar multifidus muscle. Subjects who were instructed to resume normal daily activity had a recurrence rate of 84% within the first year. Those who were given exercises showed a marked decrease in recurrence of only 30% (Hides et al., 2001). In the non-athletic population, back pain is evident and usually begins at the mean age of 30 and gets significantly worse 15 to 30 years later (Brennan et al., 2007b; Frymoyer & Cats-Baril, 1991). Permanent disabilities related to back injuries “exceeds the population growth and virtually all other chronic health conditions” (Frymoyer & Cats-Baril, 1991, p. 265).

Treatment of low back pain varies among allied health professionals. It is common to treat the back globally (as a whole) when dealing with an acute injury, but segmental correction is not emphasized once it gets beyond the acute injury. Global treatment of the low back consists of range of motion, pain control, and core strengthening (Dutton, 2002; Prentice, 2011b). The goal of segmental correction would be to gain stability in the back (Hides et al., 2001; MacDonald et al., 2009). Like anything else, once a strong base is provided, the other sections work more effectively. Many researchers have discovered that at four weeks post injury most symptoms and disabilities (loss of range of motion) have resolved in 90% of their subjects, but have also confirmed significant decreases in the CSA of the multifidus muscle at the same time (Hides et al., 2001; Hides et al., 2008; MacDonald et al., 2009). Other studies have found a decrease in multifidus size on the ipsilateral side in acute unilateral LBP (Hides et al., 1995; Hides et al., 1994). It has been documented that one quarter of the people with LBP continue to have pain beyond 12 weeks (Grotle et al., 2005). Walkers and runners sought treatments by physicians (30%), chiropractors (23%),66% used medications with more than half using OTC, and 61% used exercises and stretching out of 539 surveys (Woolf & Glaser, 2004).

In a 2008 study by Hides et al., there were significant differences between the CSA of the lumbar multifidus muscle found in elite male cricketers with and without LBP at L5 after segmental stabilization exercises. There was an 8.3% difference between the smallest side and the largest side ($p < .05$) with LBP, prior to any intervention (treatment). After intervention, there was only a 1.4% difference between the two sides of L5. To make sure exercises were performed correctly, real-time ultrasound imagery (RUSI) was used to identify contractions of the muscles during exercises. In cricketers without back pain there was only a 0.8% difference in CSA size at L5 prior to intervention and then 0.05% difference after intervention. At L2, L3, and L4 there was no significant difference between the CSA in relation to the intervention used with these athletes (Hides et al., 2008).

Activities reported among collegiate athlete's LBP were with team sports, lifting, individual sports, contact within sports, strength and fitness training, and horse riding activities, in order of significance (Brennan et al., 2007b). Low back pain can be classified as general mobility issues (Panjabi, 1992) or segmental deficiencies (Hicks, Fritz, Delitto, & Mishock, 2003) producing pain between the last rib and the upper buttocks. In a 1999 article by Verni et al., swimmers contribute their LBP to poor fitness and technique, and also found exhaustion as being a contributing factor to pain late in the season; supporting Adams 'U-shaped' curve theory. Adams 'U-shaped' curve theory states that extreme physical activity and sedentary life styles are more likely to have back pain than someone with moderate activity. Brennan et al. (2007b) disagreed with Adams 'U-shaped' curve theory because they felt it may be more of an effect, rather than a cause of LBP, but did find tendencies relating long hours of training and specific movements in the lumbar region to be an issue with LBP. Brennan et al. (2007b) concluded that young skilled and educated populations were more prone to injury; but once an injury occurs, their educations on treatment options were limited. During this study, 25% of the 188 participants were participating in team sports and 20% were participating in individual sports, and refer to these as a contributing factor.

Long term effects of back injury show performance drops as well as loss of training time. For some, giving up their sport due to back pain is a possibility. Dehner et al. (2009) found that 15% of the elite rowers had stopped participating due to back pain.

Even after a back injury, evidence shows that low activity levels do not help in injury recovery (Brennan et al., 2007b; Hides et al., 2001).

Having an injury to the multifidus, and it being a stabilizer of the spine, increases the occurrence of back pain by reducing the general stability of the spine and potentially creating muscle atrophy, delayed activation, and/or lack of volitional control (Dehner et al., 2009; Kiesel et al., 2007). Macrae and Wright (1969) realized that trunk mobility is in linear and angular motions, identifying that all movements are effected by spinal stability (Kulig et al., 2007). This study observed differences of manual segmental motion by comparing posterior to anterior force and palpation of spinous processes during flexion-extension of the trunk. Researchers evaluated movement through real time interactive MRI on the lumbar vertebrae while their subject did prone press-ups and the examiners applied manual posterior-anterior (PA) pressure to the vertebrae. When applying PA force, Kulig et al. (2007) found greater mobility at L2-L3 segment with subjects with LBP. The least amount of motion was found in L4-L5 for both symptomatic and asymptomatic subjects. During a prone press-up, L4-L5 segments showed the most movement and L1-L2 showed the least amount of motion in symptomatic subjects. Results show that 40% of symptomatic subjects have hypermobility at one or more segments during PA pressure and 26.7% in prone press-up. This study confirms findings from Dvorak, Panjabi, Novotny, Chang, and Grob (1991) that subjects with LBP have hypermobility at spinal segments (Kulig et al., 2007).

Using ultrasound, Kiesel et al. (2007) found that thickness changes in the lumbar multifidus varied at levels and sides of the spine during arm-lifting tasks in subjects with LBP. Also indicated was that the multifidus responds differently in LBP subjects with loads applied to their limbs. Duration of symptoms does affect the thickness changes within the muscle. This study, along with Hides et al. (1994) found that individuals with chronic LBP shows greater deficit in transverse abdominis and multifidus muscle thicknesses. In chronic LBP, there are more changes in the CSA at the L4 and/or L5 compared to other segments of the spine (Kader, Wardlaw, & Smith, 2000). Single segment CSA measurements have shown to be reduced as quickly as 24 hours of the initial injury (Hodges et al., 2006). Identified changes within the muscle include decreased cross sectional area (Hodges et al., 2006), and reduced Type I and II fiber size (Matějke et al., 2006; Hodges et al., 2006). Hodges et al. (2006) proposed muscle atrophy is due to disuse and denervation while Matějke et al. (2006) and Hides et al. (1994) excluded disuse due to localized changes. Matějke et al. (2006) also have identified Type II fibers significantly decrease after injury, but not Type I fibers. This opposes what Norris (2000) found. According to Hodges et al. (2006), if the short fibers of the multifidus show greater density prior to injury, this may explain localized atrophy.

Findings state that the short segments of the multifidus muscle in healthy individuals activate earlier than the long segments of the multifidus muscle, according to electromyography (EMG) readings (MacDonald et al., 2009). Comparing the healthy group to the individuals who were injured, the EMG shows the healthy group activated their multifidus muscle prior to those with a back injury in both arm flexion and extension. Those with ipsilateral pain, EMG activity shows back muscle activity in shoulder flexion earlier than shoulder extension (MacDonald et al., 2009). Control and size of the multifidus muscle can reduce the recurrence of injury (Herbert et al., 2008). Also comparing healthy to injured subjects, the CSA side-to-side difference (right to left) on healthy individuals was an average of 3%, and 31% in injured individuals with pain on one side of the spine (Hides et al., 1994).

Denervation on the other hand is common in disc herniation and nerve root compression, and shows localized effects of the short-angled fibers (Hodges et al., 2006). Within days of the onset of symptoms there is nearly a 30% reduction in CSA of the multifidus that cannot be explained as of yet, “however, it is uncertain whether denervation-related changes explain the changes in acute LBP and the rate at which they occur” (Hodges et al., 2006, p. 2926). When it is localized to one single vertebra, Hodges et al. (2006) believed atrophy is caused by either deep fiber inhibition or Type I fibers distribution. If the nerve root were affected then all fibers across the segments related to that one nerve root would also have atrophy. Other suggestions for atrophy are histochemical changes due to nerve root compression (Macintosh & Bogduk, 1991) and interruption of electromyography indicating denervation (Haig, Weiner, Tew, Quint, & Yamakawa, 2002). Other cellular changes consisted of “enlargement of adipose cells, myofibril clustering, and reduced muscle water and lactate concentration” (Hodges et al., 2006, pp. 2928-2929).

Research is unclear to whether segmental changes occurred prior or after LBP (Hodges et al., 2006). After injury, intracellular changes could cause atrophy (Macintosh & Bogduk, 1991) and atrophy normally occurs at the level above the painful segment (Hides et al., 1994). Bogduk, Macintosh, and Pearcy (1992) hypothesized that atrophy occurred by default. The function of the multifidus is to stabilize by compression of the joint during movement, but once injured, the multifidus does not contract and the more superficial muscles labor in attempt to stabilize the spine. Stokes and Young (1984) hypothesized atrophy might be due to a reduction of mechanical stimuli once an injury occurs. "The multifidus muscle shows focal impairments in size, timing, amplitude, and co-activation with the abdominal muscles" (p. 262) reported Herbert et al., (2008), increasing susceptibility to reinjury.

Diagnostic Ultrasound

"There is emerging research evidence supporting the use of ultrasound imaging as a non-invasive tool to assess deep muscle function" (Kiesel et al., 2007, p. 597). Ikai and Fukunaga (1968) were the first to document ultrasound imaging used to measure muscular cross sectional area in 1968. Ultrasound imaging can be used to identify muscle performance during rehabilitation which is called rehabilitative ultrasound imaging (RUSI) (Herbert et al., 2008) or real time ultrasound imaging (Hides et al., 1995). During rehabilitation exercises, therapists and patients look for immediate feedback of thickness changes while contracting the transverse abdominis and multifidus muscles (Kiesel et al., 2007). Ultrasound can also be used to diagnose injuries of superficial tissues (also called diagnostic ultrasound).

Allied health professionals can use RUSI for rehabilitation and diagnostic purposes, but for this study, ultrasound is being used to measure the CSA and the PSD. Cross sectional area measures the axial plane using the spinous process and lamina as bony landmarks medially and anteriorly, and the fascial boarder of the multifidus muscle group laterally and posteriorly. Parasagittal dimension is measured by sagittal images measuring from the thoracolumbar fascia (subcutaneous tissue) to the bony acoustical landmark of the inferior articular processes of the lumbar vertebrae. In unpublished research, ultrasound and magnetic resonance imaging (MRI) were compared identifying no significant difference in the CSA measurements of the multifidus muscle (Hides et al., 1994). Other studies also validated ultrasound measurement of the cross sectional area against MRI's (Hides et al., 1995; Hides et al., 1994). Researchers have demonstrated reliability of ultrasound measurements of both transverse abdominis and multifidus muscles (Brennan, Gill, Buscema, & Kiesel, 2007a; Hides et al., 1994; Stokes, et al., 2005; Teyhen, Childs, Flynn, & Boyles, 2005).

Cross Sectional Area

Many studies have found the most significant difference of CSA measurements at L5. Hides et al. (2008) found cricketers with LBP had the most significant difference at 8.3% at L5 compared to the cricketers with no back pain at 0.8% difference. When looking at the results of Hides et al. (1995), they have found the CSA to be 24.03% ± 8.67% differences at L5 on 34 of 39 subjects. In a 1994 study, researchers found 26 patients with acute unilateral pain having 33±7% difference in CSA and patients 15 days out or more had 25±8% difference compared to the other side, only two had less than 20% difference (Hides et al., 1994). This 1994 study led to the conclusion that there are greater differences in CSA measurements with acute back pain. In their control group, an asymptomatic group, there were four subjects with greater than 10% difference in CSA measurement. Upon evaluation of results, the researchers suggested that either the patients with greater than 15 days of pain may have atrophy to the asymptomatic side or an increase in size of the symptomatic size (Hides et al., 1994). It has been proven that the lumbar multifidus muscle is normally triangular in shape, but once injured, the shape changes to more of a round shape (Stokes et al., 2005). Hides et al. (1994) believed the shape change is due to muscle spasm, but no evidence proves this at this time.

According to Hodges et al. (2006), a study on injured animals found the CSA on the side of the lesion was localized, and showed reduction in size of the CSA by 17%. Measurements taken of "piggies" on day three and six post injury identified no changes within the structure, except the immediate changes found in days one through three, no differences in the CSA of different levels, or on the contralateral side. This study found CSA changes being isolated to a single segment after disc injury and a different distribution following denervation. The researchers warned that even though "piggies" and humans are similar biomechanically, muscle responses may differ between the two. Species also differ in response to denervation (Hodges et al., 2006).

During activities, the intramuscular pressure (IMP) builds during each contraction. Pressure in the multifidus muscle can read above 105mm Hg (Konno, Kikuchi, & Nagaosa, 1994). Resting IMP is 20-50mmHg (Dehner et al., 2009). Factors that influence IMP are capillary blood flow and muscle function. This great increase and repetition of IMP can lead to chronic functional compartment syndrome (CFCS), therefore causing back pain. Chronic functional compartment syndrome signs and symptoms consist of "pressure increase in tissue, drop in tissue oxygenation, and resulting loss of muscle function" (Dehner et al., 2009, p. 573).

Injection of saline into the facet of the pig's vertebrae evoked a reduction of afferent input from somatic structures, supporting the hypothesis that the observed changes in the CSA were due to disuse (Hodges et al., 2006). Water content was reduced over multiple segments and was bilateral after disc injury, which does not explain the segmental cross-sectional changes (Hodges et al., 2006). Acute episodes of LBP do not always resolve spontaneously and are commonly present when retested four weeks post symptoms (Hides et al., 1995).

Parasagittal Dimension

Parasagittal dimension images are taken in the same fashion as CSA images, but this time the ultrasound transducer is positioned in the sagittal direction. In this image, the researcher can identify L3, L4, and L5 at the same time. Most ultrasound machines will have a caliper within the software to measure the transcutaneous tissues (Kiesel, Uhl, Underwood, Rodd, & Nitz, 2007). Parasagittal measurements, also known as linear measurements, can identify muscle size changes during contractions or movements of the extremities. This particular study was able to identify between 19% and 34% change in the lumbar multifidus during no loads put on the extremity and heavy loads on the extremity, respectively (Kiesel, Uhl et al., 2007). Other studies have not been able to identify such changes to this degree (Hodges, Pengel, Herbert, & Gandevia, 2003).

Stokes et al. (2005) believed that parasagittal measurements might be more accurate than CSA measurements when researching area. To increase reliability, it is recommended to take the average of three caliper measurements. If only two measurements are used, it reduces standard error measurement (SEM) by 25% and then nearly 50% for only one measurement (Koppenhaver, Parent, Teyhen, Herbert, & Fritz, 2009). It has also been suggested that when measuring the transverse abdominis from the anterior surface of the body, ultrasound imaging is not as effective for rehabilitative exercises (Koppenhaver et al., 2009).

Morphological Indicators

There are numerous differences between males and females when it comes to pain. A three-year follow-up study was performed with 50 boys and 48 girls. This study identified that girl athletes had greater range of motion (ROM) in the lumbar spine than nonathletic girls and non-athletes had greater lordosis (Kujala, Taimela, Oksanen, & Salminen, 1997). In a study of over 11,000 Finnish adolescents, 8%, ages 12-18, have LBP (Vikat et al., 2000). Low back pain was more common in girls than boys. The number of individuals complaining of either shoulder or neck pain, or LBP increased as age increased, at least doubling by the age of 18. This study also discovered a correlation between shoulder or neck pain and LBP amongst Finnish adolescents. If there was pain in the shoulder or neck, these individuals were more likely to also complain about LBP (Vikat et al., 2000). Frymoyer and Cats-Baril (1991) identified a 1988 study that males will be hospitalized more for back surgery than females and females complain of more sciatica pain than males. Stokes et al. (2005) identified that males have a larger multifidus muscle than females, and that in a study on biomechanics of the spine in 1984, the researchers found that when lifting, females used shear forces when lifting and males used compression forces (Bejjani, Gross, & Pugh, 1984). This might explain why women complain more of back pain.

Silfies et al. (2007) showed 12 of 31 collegiate athletes who had a second injury to their back had characteristics of being taller and heavier. A study in 2005 also showed similar characteristics to those with recurring low back injuries (Cholewicki et al., 2005). Spinal mobility and LBP have yet to be correlated due to age-related changes, experimental methodology, and structural spine heterogeneity (Kulig et al., 2007).

Researchers in other studies stated that morphological indicators (height, weight, and gender) have no statistical significance with LBP (Brennan et al., 2007b; Hides et al., 2008). Hides et al. (2008) added activity level of their athletes, body mass, and age to the list of indicators that have no statistical significance to LBP. Another study found no significant differences with gender, age, height, or body mass (Stokes et al., 2005). There is limited data on one-sided dominant sports and back injuries. In a study of transverse abdominis thickness and hand dominance, they found no significance between the two (Springer et al., 2006).

Sports

During sports, there are many angles, or planes, that athletes use at one time. Athletes do not think about the forces being put on their body during sports when jumping, twisting, and landing. Rotation sports consist of softball, baseball, tennis, and golf, and extension sports consist of volleyball and swimming events of breast stroke and butterfly. Volleyball, gymnastics, and tennis have a greater number of low back injuries due to the rotation and extension occurring at the same time (Alexander, 1976). Muscle differences in rotational sports were an area of suggested study by Springer et al. (2006), but no other studies were found discussing rotational sports.

According to Watkins (1998), most injuries to athletes occur during practice. Only 6% occur during competition while nearly 80% during practice (Watkins, 1998). Diagnosis of lumbar injuries in the athlete population consists of 6% acute injury, 12% overuse, and 29% pre-existing (Watkins, 1998), but during the initial evaluation of injury, the correct diagnosis is accurate only 2% of the time (Nachemson & Spitzer, 1987). The percentage rises to 15% when pain lasts for six weeks, and 30% after three months of pain (Nachemson & Spitzer, 1987).

It is not uncommon to find only a few studies comparing the lumbar multifidus muscle and one specific sport, but there continues to be more interest. In a radiological study of athletes, there were over half of the athletic population with some form of lumbar abnormality (Hellstrom, Jacobsson, Sward, & Peterson, 1990). A study in Norway focused on high school skiing athletes and reported 36% of the students had LBP before even entering high school (Bergstrøm, Brandseth, Fretheim, Tvilde, & Ekeland, 2004). Thirty to 45% of collegiate athletes who participate in “activities involving high load on the lumbar region” (Okada et al., 2007. p. 692) experience LBP. Radiological examinations of collegiate wrestlers showed 66% had some lumbar changes within their spine (Iwai, Nakazato, Irie, Fujimoto, & Nakajima, 2004). In a cross-sectional study of 439 adolescents, ages 12 and 13, athletes and non-athletes who participate in one or more sports reported nearly the same percentage of spine pain, 40% and 39% respectively (Mogensen, Gausel, Wedderkopp, Kjaer, & Leboeuf-Yde, 2007). In this same study, the number of sports and hours spent participating was also insignificant.

Looking at statistics of running sports, 13% of runners who participate in aerobics were less likely to have a history of LBP, and 33% walkers were less likely (Woolf & Glaser, 2004). Back pain is linked to runners who have excessive lordosis and pronation (flat feet) or one leg shorter than the other (Alexander, 1976). On the other hand, walkers who lift weights regularly were more likely to report LBP (Woolf & Glaser, 2004). In a study on biomechanics of the breaststroke, high school freshmen who were evaluated and 25 of 184 subjects complained of low back pain (Colman, Persyn, & Winters, 2000).

Most subjects complaining of LBP had differences in hyperextension of the lumbar spine and improper hip rotation, thus producing less effective forces to project them through the water. This study used an interactive computer-aided instruction (CAI) program for evaluation of their breaststroke (Colman et al., 2000). Swimmers who compete in the butterfly commonly have Scheurmann's kyphosis due to repetition of hyperflexion and hyperextension of the spine (Alexander, 1976). Kyphosis of the thoracic spine adds stress to the lumbar spine as it tries to stabilize the thoracic spine during movements. In addition, movements that combine flexion, extension and rotation are more prevalent to have LBP (Bergstrøm et al., 2004).

Treatment of the low back should be thorough and complete, but athletes want to get back on the court or field so many come back too soon because the pain is gone, but the muscles have not necessarily recovered. According to MacDonald et al. (2009) the multifidus may take longer to recover. In a comparison study of adolescent athletes and non-athletes (mean age 15.40 ± 1.44), athletes had more outpatient physical therapy appointments over a longer period of time, and had significantly less changes in their disability questionnaire (Fritz & Clifford, 2010). Athletes were also more prone to receive magnetic resistance imaging (MRI) than the non-athlete who received x-rays (Fritz & Clifford, 2010). Many studies indicate that adolescents with back injuries will have recurrent episodes when they are older (Brattberg, 2004; Harreby, Neergaard, Hesselsoe, & Kjer, 1995; Mogensen et al., 2007).

Summary

Low back trauma is a costly injury to individuals, society, and playing time in athletics. Up to 86% of individuals will suffer from back pain in their lifetime (Hodges et al., 2006) and nearly as many will also reinjure their back (Kulig et al., 2007), many within the first year after their first episode of pain. Most individuals will injure their back around the mean age of 30 and then progressively get worse between the ages of 45-60 (Brennan et al., 2007b; Frymoyer & Cats-Baril, 1991). With so many injured backs, it cost the United States nearly $16 billion in 1984, combining direct and indirect costs (Frymoyer & Cats-Baril, 1991) and 11.1 billion in 1986 in just direct costs (Webster & Snook, 1990). The average cost for a workers' compensation claim in 44 states is $6,807; and, it is calculated that they are off work for nearly two straight years (Webster & Snook, 1990).

One of many causes of LBP can be malfunction of the lumbar multifidus muscle. The multifidus might be a small muscle in the back, but it does a lot of work to keep the body upright and moving. Segmental stability is the main function of the multifidus, followed by rotation of the spine. Researchers do not think atrophy of this muscle is due to disuse because the changes occur segmentally, not globally (Hides et al., 1994; Matějke et al., 2006), however the reason for the change is still unknown. When low back pain occurs, the multifidus decreases in size within the first 24 hours, by nearly 30%, in CSA measurements according to Hodges et al. (2006). Stokes and Young (1984) hypothesized that reflex inhibition caused LBP. Panjabi (1992) thought it was miscommunication of proprioceptors, and Macintosh and Bogduk (1991) believed intracellular changes caused atrophy which led to LBP. Others hypothesized disuse of muscles, changes in neurological function, and muscle compensation (MacDonald et al., 2009).

Diagnostic ultrasounds are used to identify injuries to muscles, including the multifidus. Ultrasounds have identified that there are significant differences of CSA at L5 (Hides et al., 1995; Hides et al., 2008; Hides et al., 1994). Researchers found ultrasound to be statistically accurate compare to MRI's (Hides et al., 1995; Hides et al., 1994). Parasagittal dimensions are measured as well. Stokes et al. (2005) found this measurement to be even more accurate that CSA.

Morphological indicators such as height, weight, and gender have not been identified as statistically significant in predicting LBP (Brennan et al., 2007b; Hides et al., 2008). Others have identified height and weight as factors in recurrent injuries (Silfies et al., 2007). The focus of this study is on the CSA and PSD measurements in the lumbar multifidus muscle in reference to symmetry, morphology, rotation sports, and one-sided dominant sports.

Chapter Three: Methodology

Overview

The intent of this study was to examine collegiate athletes who have and who have not had low back pain, and relating their complaints of LBP to measurements of CSA and PSD to demographics such as height, gender, sport biomechanics, and one-sided dominant sports. This self-designed study built upon existing research and provided further information on how allied health professionals can treat LBP injuries and chronic pain. Lindenwood University's Institutional Review Board (IRB) approved this research prior to the initiation of data collection and completion of the study (Appendix A).

Statement of the Problem

Current technology utilizing diagnostic ultrasound can enable the researchers to visually survey the inner lying muscle, the multifidus. Determining the size and asymmetry of the muscle will allow allied health providers to identify the likelihood of chronic injury and potentially aid in the prevention of LBP by giving exercises to increase the size of this muscle. While working with select groups of collegiate athletes, the purpose of this study is to compare the relationships of CSA and PSD measurements of the multifidus muscle to variables, such as history of injury, body morphology, gender, and biomechanical nature of sport.

Subjects

In this study, researchers selected four non-contact collegiate sports, men's and women's swimming, men's and women's cross country and track, men's and women's volleyball, women's fast pitch softball, and men's baseball. Baseball and softball are combined as one sport. Athlete's ages ranged were from 18 to 25, with a mean of 19.9 years. Ninety-one athletes volunteered for this study. Table 1 illustrates the sport and gender of the athletes who participated in the study. Due to the similar nature of baseball and softball, they were combined as one for purposes of analysis. Exclusions for this research study consisted of any athlete who might be pregnant and individuals who had previous surgery on their spine.

Table 1

Number of Participants per Sport

Sport	Males	Females
Swimming	4	4
Track	10	7
Baseball/Softball	33	14
Volleyball	9	10
Totals	56	35

Sampling Procedure

Athletes were asked by their coach to attend a meeting regarding the research. The coaches were specifically asked to tell their athletes that participation was strictly voluntary to attend this meeting. Coaches were not allowed to attend. During the meeting, students were introduced to the purpose of this research and asked for their volunteer participation. Question and answer time was granted.

All subjects in attendance at this meeting were asked to sign in (Appendix B), and identify their name and contact information. This allowed researchers to get in touch with the volunteer subjects at a later date to gather statistical information. All subjects were given three forms at the initial orientation meeting—one form was Lindenwood University's Liability Waiver (Appendix C). If the athletes wanted to participate, they filled in the information needed, signed it, and filled out the next form. If they declined to participate in this study, they were instructed to put an 'X' through the liability waiver and no information was gathered on either of the remaining form. The second was the Informed Consent (Appendix D). This form identified exactly what procedures were going to occur during data collection. If the athletes agreed to participate in the study, they read, signed and dated the form.

The last form was the Participant Questionnaire (Appendix E). This form asked questions about age; gender; sporting history; injury history to their back; pain to the cervical, thoracic and lumbar spine; current history of the shoulder and hip; and types of treatments sought for those conditions and medications presently being taken for any of the listed injuries or conditions. The information was written in black or blue ink. The purpose of this form was to find athletes who might be excluded from this research, obtain important injury history, and assist with morphological knowledge. All forms were collected, whether or not the athlete agreed to participate in the study.

On the top of the Participant Questionnaire was a Universal Identification (UI) number. The UI number was already on the form prior to attending this meeting. This UI number was written on the sign-in sheet next to their name when the forms were distributed. The UI number was used to keep identification anonymous. This information was kept secure in the lead researcher's office under lock and key.

Research Setting

On the day of data collection, the locker room or classroom at LU, or the classroom at the pool were used to conduct this research. There were five stations set up for each athlete. Station 1 was check in. Station 2 and 3 were shoulder and hip evaluation, respectively. Station 4 was the spine evaluation, and Station 5 was the diagnostic ultrasound. After the ultrasound was completed, the athlete was thanked for their participation and then permitted to leave. All athletes were participating on their designated teams so all pre-participation physicals for sports participation were completed prior to their initial start date of practices. These physicals were stored in the athletic training rooms on LU's campus. Through SportsWare (a software program), a list of athletes, per team, was obtained to identify if a physical was on file before any data collection was obtained.

At check-in, the participants were given their previous Participant Questionnaire, with UI number, from the first meeting. The athlete reviewed this to make sure there were no changes in the injury descriptions or dates noted on the form. If changes were made on this form, a red pen was used to note any changes made by the athlete. The participants were then checked for height. The subject was then instructed to go to the second station for shoulder assessment and given an evaluation form (Appendix F). In the upper right corner, their UI number, taken from the Participant Questionnaire, was written in red.

In Station 2, shoulder strength, special tests, and neurological indications were tested including reflexes. Station 3 was set up for evaluation of the hip. Here subjects were tested for their hip strength, reflexes and special tests. Spine evaluation was performed in Station 4. Cervical, thoracic, and lumbar ranges of motion were assessed as well as each individual myotome and dermatome for cervical and lumbar areas. Special testing for neurological indications was also evaluated to identify any acute or chronic injuries to the spine or its nerves. Station 5 was where subjects received a diagnostic ultrasound of their lumbar multifidus muscle.

Research Design

The research design for this study was exploratory. The intent was to gather data in a previously un-researched area of exercise physiology. The allied health professionals have recently stumbled on the idea of using real time ultrasound imaging (RUSI) to assist with not only rehabilitation exercises, but now also diagnostic use of injuries or deficits to subcutaneous tissues. For this study, ultrasound was specifically used to measure CSA and PSD of the lumbar multifidus muscle at L3, L4, and L5 levels on both sides of the spine.

Instrumentation

All five screening stations performed non-invasive testing. Station 1, check-in, measured height using stacked yard sticks against the wall and athletes reviewed their Participant Questionnaire information. To measure their height, the athletes were barefoot and put their back to the wall where the stacked yardsticks were located. A clipboard on the top of each subject's head identified his or her mark on the yard stick. Each yard stick measured 92 cm. The height measurement was written down on the Participant Questionnaire.

The athlete was then given the Evaluation form for Stations 2-4. Senior Intern chiropractic students performed all tests and measurements, under direct supervision of a resident chiropractor from Logan at Stations 2, 3, and 4. Stations 2 and 3 measured strength in flexion, extension, internal rotation, external rotation, adduction, and abduction of the shoulder and hip joints, respectively, following standardized Manual Muscle Testing (MMT) guidelines. Station 2 also tested the athletes for Thoracic Outlet Syndrome and deep tendon reflexes of the upper extremity. Thoracic outlet syndrome is a condition that reduces the effectiveness of the nerves and blood vessels in the neck region causing numbness, tingling, and diminished strength in the arms and hands. Station 3 tested the athletes for neurological injuries related to the hip and lower extremity deep tendon reflexes. A list of the shoulder and hip tests and their references are located in Appendix G. All these tests were performed to indicate any significant conditions which might skew the test results. No significant finds were identified by the chiropractic students.

Station 4 consisted of examination of the spine consisting of ROM, strength, and special testing. Sensory and motor neurons were also tested in this station. The researchers used The Petrometer’s System (Primary & Extremity Total Range of Motion Movement, patent #5,758,658, model #BV-933), also known as an Inclinometer, to measure ROM of the cervical, thoracic and lumbar spine. To measure cervical ROM, one petrometer was placed on top of the head with the yellow arrow in line with the red open arrow. The other petrometer was placed over C7, also with the yellow arrow lined up with the red open arrow. As the athlete moved into cervical flexion, chin to chest, the yellow arrows moved. The difference between the two numbers given at the end ROM gives the examiner the cervical ROM for flexion. Cervical extension was done the same way, except the athlete was asked to bring his or her head backwards, into extension or looking towards the ceiling. To measure thoracic and lumbar flexion or extension ROM, the same procedure was performed by the examiner, but the petrometers were placed at T1 and T12, and L1 and L5, respectively. Athletes were asked to move in their given range of motions. These tests were all performed in the sitting position. Range of motion measurements were written on their evaluation forms.

To measure lateral flexion, the examiner used the same landmarks as flexion and extension in each cervical, thoracic and lumbar region. To measure cervical lateral flexion, the athlete was asked to move his or her ear to the one shoulder. Again, the yellow arrows were lined up with the red hollow arrow. Measurements are taken from both petrometers and the difference was calculated. Measurements were taken on both right and left sides. To measure thoracic and lumbar rotation, one petrometer is placed on top of the head and the other is placed at either T12 or L5, depending upon which spinal unit is being measured. Each time the athlete was asked to laterally flex, bringing his or her hand from the side down towards the lateral knee. The differences were taken from each petrometer for the total ROM for the thoracic and lumbar lateral flexion.

When working with lateral rotation, the petrometers were set with the red solid arrow on the red hollow arrow. One petrometer was placed on top of the head and the other petrometer was placed on C7 for cervical lateral rotation. The athlete was asked to laterally rotate to one direction, looking over his or her shoulder. Again, once the numbers were determined, the difference was taken between the two. The same was repeated on the other side. To identify thoracic and lumbar lateral rotation, one petrometer was placed on the top of the head, and the other was placed at T12 for the thoracic ROM or L5 for lumbar ROM. Measurement differences were taken from the red solid arrow. All measurements were performed on each side and documented on the evaluation form. According to Kendall et al. (2005), normative data for spinal range of motion is identified on Table 2.

Table 2

Spinal Range of Motion Normative Data

Norms for Spinal Range of Motion	Cervical	Thoracic	Lumbar
Flexion	50	35-50	60
Extension	60	0	25
Rotation	80	25-35	45
Lateral Flexion	45	20-40	25

Note. From Kendall et al., 2005.

Neurological sensory exam, known as dermatomes, were evaluated from C2-T1 through L1-S1. To check the sensory nerves, the examiner asked the athlete to close his or her eyes and applying pressure to the skin using a brush, a pin, or nothing at all. The athlete was asked to distinguish between them. The areas and nerves covered are listed in Table 3.

Table 3

Dermatomes Tested

Dermatome	Area of the body
C4	Lower cervical area and superior shoulder
C5	Lateral upper arm
C6	Lateral forearm and thumb
C7	Palmar surface of hand
C8	Medial surface of palmar surface of hand
T1	Medial side of forearm and elbow
L1	Lateral to medial upper thigh
L2	Middle thigh, lateral and medial
L3	Lower thigh, lateral and medial
L4	Medial foot and lower leg
L5	Anterior foot
S1	Lateral foot and lower leg

Note. From Hoppenfeld (1976).

The neurological motor exam, myotome testing, consisted of holding specific resisted positions for 5 seconds. Cervical vertebra 5, C5, tests the deltoid muscle by resisting shoulder abduction at 90° with the elbow bent at 90°. The athlete holds the position while the examiner applies downward pressure over the lower humerus bone for 5 seconds (Prentice, 2011b). The biceps were tested at complete flexion of the elbow and also at end ROM of wrist extension to test C6 motor neuron. Downward resistance was applied to the forearm when in elbow flexion while the stabilizing hand was placed on the anterior shoulder. To test wrist extension, the elbow was flexed at 90° and the wrist put into extreme extension. Resistance was applied to the posterior hand, trying to move the wrist into flexion (Anderson, Parr, & Hall, 2009).

Triceps and finger extension was tested to check neurological function of C7. The athletes were asked to bend their elbow at 90° at their side and push downward as the examiner pushed upward. The examiner stabilizes at the elbow. Finger extension was performed by extending the fingers and keeping them there while the examiner pushes the fingers into flexion (Daniels & Worthingham, 2007). The next test was finger flexion which tests C8. The athlete was asked to make a half-fist so the examiner can get her fingers under the athlete's fingers. The athlete was instructed to hold that position while the examiner tries to straighten or extend the fingers (Dutton, 2002). To test T1, finger adduction, the athlete was asked to spread the fingers out and the examiner put her fingers between the athlete's fingers, as if they were holding hands. The examiner asked the athlete to squeeze his or her fingers together for 5 seconds. All of these results were written down on the athlete's evaluation form (Anderson et al., 2009).

The neurological motor exam for the lower extremity consisted of L1-S1. To test for L1, L2, and L3, the athlete's hip flexion muscles were tested in a sitting position with legs over the edge of the table. The athlete was asked to lift the leg off the table and hold it there for 5 seconds while the examiner applied downward pressure (Dutton, 2002).

While in this same position, the examiner tested L2, L3, and L4. The athlete was then asked to extend the lower leg outward and hold it there for 5 seconds while the examiner applied pressure to the tibia bone, trying to push it backwards. The stabilizing hand was placed on the lower thigh (Hoppenfeld, 1976). Tibialis anterior (L4) was tested next by placing the examiner's hand on the top of the foot and asking the athlete to pull the ankle upward towards the knee cap and hold for 5 seconds (Daniels & Worthingham, 2007). The examiner asked the athlete to do the exact same thing, but this time with the great toe to test L5. The examiner applied downward pressure on the great toe for 5 seconds (Prentice, 2011b). The last exam in this sitting position was ankle eversion, testing S1. Here the athlete was asked to move the bottom of the foot outward while the examiner resisted and tried to push the foot medially for 5 seconds (Anderson et al., 2009).

The athlete was then asked to move into the prone position for one examination. The athlete was asked to extend the legs on the table and then lift one leg off the table while the examiner pushed down on the leg towards the table for 5 seconds. This tested S1, hip extension (Daniels & Worthingham, 2007). For the last two tests, the athlete needed to be side lying to test gluteus medius (L5) and hip adduction (L2, L3, and L4). The athlete was asked to lift the top leg about 10 inches off the other table and then rotate the leg posterior to test the gluteus medius. The athlete was asked to hold this position for 5 seconds while the examiner applied downward pressure towards the table with one hand and stabilized the hip with the other hand (Hoppenfeld, 1976). To test for hip adduction the athlete was asked to bend the top leg and place the foot in front of the opposite hip in front. The athlete was asked to lift the lower leg off the table about 3 inches, keeping the leg straight, and hold it there while the examiner applied downward pressure for 5 seconds (Anderson et al., 2009).

Special testing for the cervical unit was achieved in the sitting position with legs over the edge of the table. Jackson's Compression Test was performed when the athlete slightly laterally flexed his or her head and a downward pressure was applied by the examiner (Evans, 2002). If no pain, the Spurling's Test was performed by repositioning the head to neutral and delivering a blow to the uppermost portion of the head with the soft part of the fist. Numbness, tingling or pain down the arm was indicative of neurological compression, or pain on the spine was conducive to facet joint involvement (Prentice, 2011b). Foraminal Compression Test was performed with downward compression from the top of the head and then repeated with the head rotated to each side. A positive test indicates narrowing of the foraminal but pain down the arms will indicate a nerve root compression (Dutton, 2002).

During the Valsalva Maneuver, the athlete was asked to bear down as if defecating. This increases intrathecal pressure, pressure within the spine, and can cause pain in the shoulders or radiating down the arms if positive (Konin, Kikuchi, & Nagaosa, 2006). This would indicate a vertebral disk injury. Dejerine's Triad Testrequires the athlete cough, sneeze, and bear down. Pain in the shoulders or pain radiating down the arms identifies Dejerine's Triad Test as positive also (Watkins, 1996). Maximal Foraminal Compression Test was performed with the athlete rotating his or her head over the shoulder and then moving the head into extension. Pain or radiating pain on the side that the movement was occurring, indicates nerve compression or apophyseal joint pathology (injury where two segments attach in the spine). Pain on the opposing side indicates muscular or ligamentous strains (Evans, 2002).

Depressing the shoulder, while laterally flexing the head to the opposite side, was called the Shoulder Depression Test (Shultz, Houglum, & Perrin, 2005). Pain penetrating down the arm that was depressed may indicate thoracic outlet syndrome and pain on the opposite side may indicate foraminal closing, disc injury, or facet problems. Cervical Distraction Test was performed when the examiner lifts the head away from the spine while in a sitting position. If radiating pain decreases, either a disc injury was indicated or there was closure of the foraminal space (Watkins, 1996). Jackson's Compression Test was performed with the examiners fingers interlocked and applied to the crown of the athlete's head. The athlete rotated the head to one direction and the examiner applied downward pressure to the athlete's head (Evans, 2002). The same was repeated on the opposite side. Pain radiating down the arm or in the shoulder indicates nerve root compression.

Diagnostic ultrasound of the low back was performed in Station 5. Diagnostic ultrasound was a portable unit that researchers from Logan brought with them. A broadband curvilinear 2 to 5 MHz probe was used on a GE Logiq e ultrasound machine (GE Healthcare, Milwaukee, WI). The procedure used is similar to Kiesel, Uhl et al. (2007) and Koppenhaver et al. (2009), but no pillow was used under the pelvis and no measurements were taken in the muscle contracted state. The athlete was asked to lay prone on a treatment table. The shirt was lifted to bare just the lumbar vertebrae and if necessary, the shorts were moved just below L5. Ultrasonic gel was applied to the skin overlying the lumbar area. The probe was placed in the transverse anatomical plane and was maneuvered inferiorly until the bony acoustical landmarks of the sacrum were identified. Once identified, the probe was maneuvered in a superior direction until the bony acoustical landmarks of the posterior elements of the L5 were visualized. The vertebral lamina was used as the landmark for the anterior border of the multifidus muscle. Once the multifidus muscle was identified, a still image was taken and was saved on the hard drive of the ultrasound machine. This would be the CSAL5R. The probe was maintained in the transverse orientation and was maneuvered to the opposite side to image the contralateral multifidus. A still image was captured: CSAL5L. The probe was then moved one level cephalad and the process was repeated at L4, and L3, representing CSAL4R, CSAL4L, CSAL3R, and CSAL3L.

After the axial images were obtained, the probe was rotated 90° into the sagittal plane. The bony acoustical landmark of the first sacral segment on the left was identified. The probe was then maneuvered so that the articular processes of the left third, fourth, and fifth lumbar vertebrae were visualized on the same image. A still image was taken and stored on the hard drive of the ultrasound machine. The process was repeated on the right side. These images represent PDSL5R, PSDL5L, PSDL4R, PSDL4L, PSDL3R, and PSDL3L. Subjects were asked not to speak or move during the ultrasound because the multifidus muscle shape, CSA, and PSD can change with movement of most joints. Symmetry measurements, CSAL5SYM, CSAL4SYM, CSAL3SYM, PSDL5SYM, PSDL4SYM, and PSDL3SYM were calculated by comparing right sided measurements to left sided measurements at each level, L5, L4, and L3, by using this equation: [right/left value x 100] - 100 = % difference.

At a different time, the CSA of the lumbar multifidus muscles was measured using the trace functions within the GE Logiq e ultrasound machine (Figure 1). To obtain the CSA measurements, the cursor was traced around the thoracolumbar fascia posteriorly, the fascial boarder laterally, and then along the bony acoustical landmarks of the lamina and spinous processes. This measurement was taken three times and the mean of the three measurements was calculated. The same measurement protocol was used to measure CSAs on all axial images. The PSD of the lumbar multifidus was measured on the sagittal images using the measuring calipers of the ultrasound machine. Measurements were taken from the thoracolumbar fascia to the bony acoustical landmarks of the lumbar articular processes. The parasagittal diameters were measured three times and the mean of the three measurements was calculated.

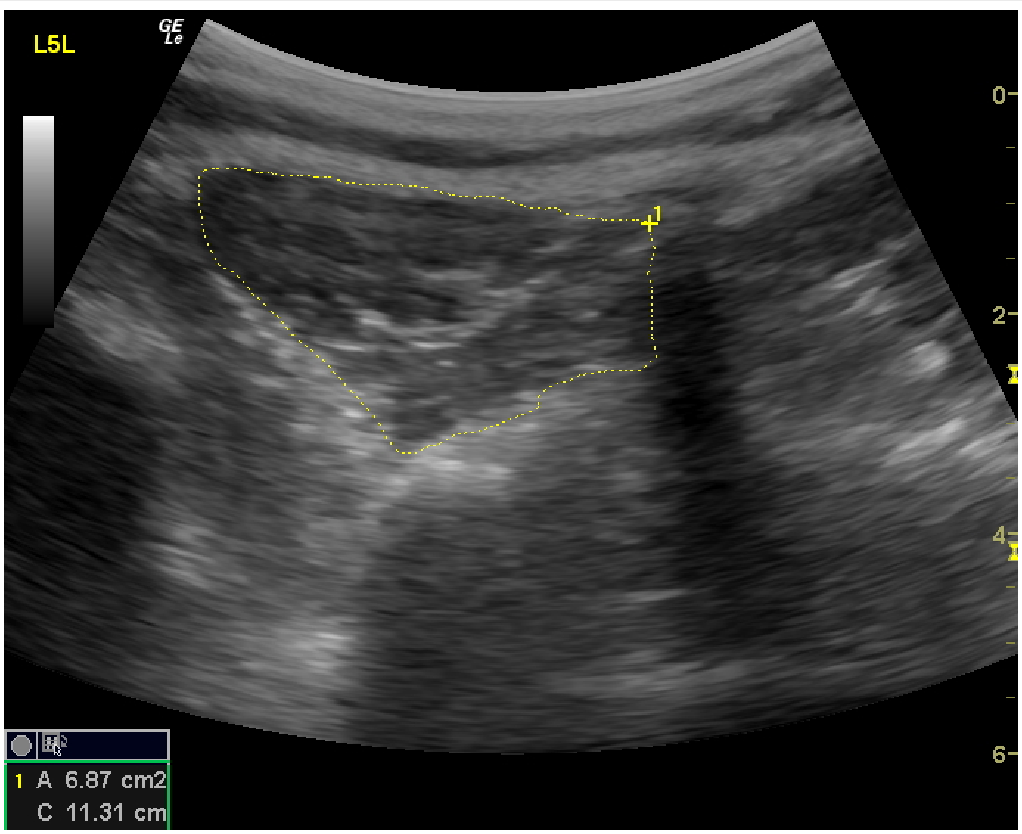

Figure 1. The CSA of CSAL5L with written permission of Logan College of Chiropractic

The PSD of the lumbar multifidus was measured on the sagittal images using the measuring calipers of the ultrasound machine. Measurements were taken from the thoracolumbar fascia to the bony acoustical landmarks of the lumbar articular processes (Figure 2). The parasagittal diameters were measured three times and the mean of the three measurements was calculated.

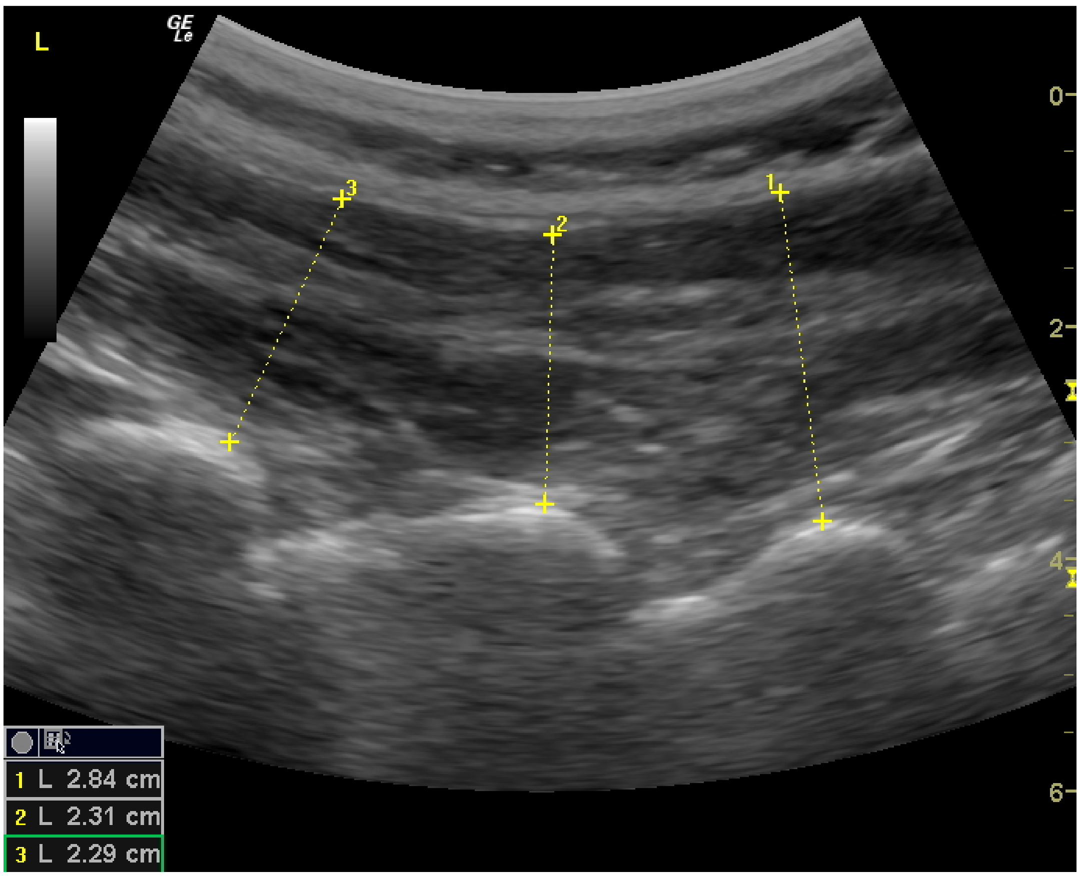

Figure 2. Parasagittal Dimension of L3, L4, and L5 with written permission from Logan College of Chiropractic

Reliability

According to Stokes et al., (2005) the ICC's (intraclass correlation coefficients) for multifidus CSA ranged between .98 and 1.00. Standard error measurement (SEM) also has been considered to be more reliable than mean measurements (Kidd, Magee, &

Richardson, 2002). The ICC for parasagittal measurements are calculated at > .85. If a blind study is used and a second researcher takes the measurements, the ICC goes up to .95.

Threats to Internal and External Validity

The following three tables discuss threats to valid inferences from this study. Valid inferences relate to generalizations and conclusions that are drawn from the effects of the independent variable on the dependent variable (Kirk, 1982). There are generally accepted in the Social Sciences, three categories of threats to valid inferences: external validity, internal validity, and statistical conclusion validity (Cook & Campbell, 1979; Shadish, Cook, & Campbell, 2002). For the purposes of this study, all threats to valid inferences were observed and controlled wherever possible. Tables 4, 5, and 6 present a listing of threats to valid inferences for this study.

Table 4

Threats to External Validity

Threat	Controlled	Explanation
Multiple Treatment Interference	Partially	Student athletes may have been involved in other sports/activities that had rotational/non-rotational muscle demands. It is also difficult to control the specificity of training backgrounds and exposure to certain strength and conditioning protocols during the playing career of athletes.
Reactive Effects of Experimental Setting	Yes	Collection of research data was conducted in a setting familiar to participants.
Interaction of Selection Biases Treatment	Yes	The study group was based on the identifying variable of being a student athlete at Lindenwood University. Comparison groups were formed based upon the distinctions of body morphology, gender, and rotational nature of the sport.

Table 5

Threats to Internal Validity

Threat	Controlled	Explanation
History	Yes	Full disclosure of history of back pain was attained before participation in the study. No study participant had experienced ultrasound measurements for CSA or PSD before this study.
Maturation	Yes	Short-term capture of research data facilitated comparisons within the same study year.
Testing	Yes	Reliability of ultrasound measurements was found to be within acceptable parameters similar to past studies using such technology.
Instrumentation	Yes	The same measuring device and "measurer" was used to obtain ultrasound data for all study participants.
Statistical Regression	Yes	Participants were found to be homogeneous in terms of demographic subject characteristics.
Selection Bias	Partially	Although subjects were screened before participation, the study sample was still collected using non-random convenience sampling.
Mortality	Yes	Data was collected all at one time for each participant, thus attrition was not a factor for the study.
Causal Time Order	Yes	Sample data were collected systematically.
Diffusion	Yes	Nature of the study did not require restriction of contact between comparison groups. However, all measurements and data were collected individually and confidentially.
Demoralization	Yes	Comparison groups were not administered any negative treatments or treated unfairly.
Compensatory Rivalry	Partially	Comparison groups were not kept mutually exclusive during testing procedures.
Compensation	Yes	No compensation was provided to study participants.

Table 6

Threats to Statistical Conclusion Validity

Threat	Controlled	Explanation
Low Statistical Power	Partially	Although the sample consisted of > 30 subjects, for purposes of inter-group comparison some groups were < 30 subjects (e.g.., non-rotational athlete group).
Reliability of Measures	Yes	Ultrasound measurements conducted on the basis of established reliabilities and testing protocols.
Statistical Assumptions	Yes	Standard statistical assumptions were observed both through data collection and in data analysis.
Random Heterogeneity	Yes	No significant differences were found among members of the same comparison groups on selected variables.
Reliability of Treatment	Yes	All study participants experienced identical measurement protocols in terms of CSA and PSD muscle measurements.

Statistical Treatment of Data

The first step in the data analysis was to ensure accuracy of input through an extensive performance of data-cleaning procedures. Frequency and descriptive statistics were run to examine correctness of input variables and to ensure there were no mistakes in data entry. Outliers or numerical discrepancies were re-examined by looking back through the hard-copies of data entry forms using the corresponding UI locator number. Following data cleaning, appropriate data analyses were run to address directly the hypotheses for the study. SPSS 20.0 (Statistical Package for the Social Sciences) was used to analyze data.

In order to run comparisons between groups, a number of dummy-code variables were added to the data-set. These will be discussed in more detail in the next section.

Hypothesis #1. Subjects with no history of low back pain (LBP) will have symmetrical cross sectional area (CSA) measurements. In order to calculate symmetry of the CSA, a new variable was created that took the CSA value for the dominant limb minus the CSA value for the non-dominant limb. This gave a positive or negative value depending on whether the right or left muscle measurement proved to be larger. Values closer to “0” represent the most symmetrical CSA statistic. For comparison purposes, two groups were artificially created based upon history of back pain. An independent samples T-Test was run to determine whether differences existed between the “Back Pain” group and the “No-Back Pain” group on symmetry of the CSA. A statistical significance of $p < .05$ was set for every analysis in the study.

Hypothesis #2. Subjects with no history of LBP will have symmetrical PSD measurements. In a similar manner to that described previously, a new symmetry PSD variable was created by calculating dominant leg PSD measurements minus non-dominant leg PSD measurements. Values closest to “0” suggested greater PSD muscle symmetry. An independent samples T-Test was conducted to assess differences between comparison groups on the variable back pain.

Hypothesis #3. CSA and PSD measurements will be greater in taller athletes (males ≥180.3cm and females ≥175.3cm). A dummy code variable was computed that coded a “1” for tall athletes *(males ≥180.3cm and females ≥175.3cm)* and a “2” for short athletes *(males $<$180.3cm and females $<$175.3cm).* These were arbitrary points based upon average heights of athletes according to population norms. Independent sample T-

Tests were run to determine whether differences existed between height groups on CSA and PSD measurements. It was assumed that the body morphology would significantly impact multifidus measures.

Hypothesis #4. CSA and PSD measurements will be greater in male athletes than female athletes. Aside from basic morphology differences, the researcher wanted to ascertain whether there were also gender differences in terms of multifidus muscle measurements. An independent sample T-Test was used to analyze whether differences existed between gender groups on CSA and PSD measurements.

Hypothesis #5. Rotational athletes will have greater CSA measurements compared to non-rotational athletes. Athletes were placed into one of two groups based upon whether they were a rotational athlete (baseball, softball, swimming, and volleyball) or a non-rotational athlete (track and cross-country). An independent samples T-Test was run to assess whether differences existed on CSA measurements at the $p < .05$ level of statistical significance.

Hypothesis #6. Rotational athletes will have greater PSD measurements compared to non-rotational athletes. Similarly to the above hypothesis, the same analyses were run to assess whether rotational athletes differed on PSD measurements when compared to non-rotational athletes.

Hypothesis #7. One-sided dominant sport athletes (e.g. volleyball, baseball, and softball) will have higher CSA measurements compared to non-dominant sided sport athletes (e.g. swimming and track). It was hypothesized that athletes who utilize rotational skills on a predominant side of the body (baseball, softball, and volleyball) would have less overall CSA symmetry than athletes who are more symmetrical in the execution of sporting skills (swimming and track). A one-way ANOVA (Analysis of Variance) test was conducted to assess whether there were statistically significant differences between sports for CSA symmetry measurements. After determining a statistically significant ANOVA, a post-hoc analysis was conducted using a Least Square Difference (LSD) test to determine exactly where the differences were to be found.

Hypothesis #8. One-sided dominant sports (e.g. volleyball, baseball, and softball) will have higher PSD measurements compared to non-dominant sided sports (e.g. swimming and track). It was hypothesized that athletes who utilize rotational skills on a predominant side of the body would have less overall PSD symmetry than athletes who are more symmetrical in the execution of sporting skills. Again, a one-way Analysis of Variance (ANOVA) test and post-hoc analysis were conducted to assess whether there were statistically significant differences between sports for PSD symmetry measurements.

Summary

This exploratory study examined the CSA and PSD measurements of the lumbar multifidus muscle in collegiate athletes. Ninety one athletes from men's and women's volleyball, track and field, and swimming, as well as baseball and softball volunteered to participate in this study. It took approximately 20 minutes of their time to get through five stations consisting of manual muscle testing of the shoulders and upper back and hips and lower extremity, spine ROM, special tests, and an ultrasound image. The researcher hypothesized that collegiate athletes with no history of low back pain will have symmetrical CSA and PSD measurements, taller athletes will have significantly greater CSA and PSD measurements, males will have significantly greater CSA and PSD measurements, rotational athletes will have significantly greater CSA and PSD measurements, and one-sided dominant sports will also have significantly greater CSA and PSD measurements.

With athletes and individuals having so many issues with their backs, finding a correlation between LBP and measurements of CSA and PSD in various morphological considerations or sport biomechanics could lead to a way allied health professionals help athletes prevent back injuries. In the past, making accurate diagnoses, limiting time off for the athlete, and preventing the recurrence of LBP was the best practice allied health professionals have to offer their athletes or patients. With the help of the ultrasound, accurate testing, and effective treatment, an athlete may be able to play their sport longer, take less medication, and overall live a healthier life.

Chapter Four: Results

Overview

The purpose of this study is to compare the relationship of CSA and PSD measurements of the lumbar multifidus muscle by history of injury, body morphology, gender, biomechanical nature of sport, and one-sided dominant sport. Ninety-one collegiate athletes from four different non-contact sports, men's and women's volleyball, men's and women's swimming, men's and women's track and field, and baseball and softball, participated in this study.

To address the research hypotheses pertaining to the size of the lumbar multifidus muscle, independent sample t-tests were used to address the first six hypotheses. To calculate the last two hypotheses, ANOVA and LSD post hoc tests were applied to the data. CSA measurements were taken on the right side of the body at levels L3, L4, and L5, and the same on the left side at L3, L4, and L5. PSD measurements were taken on each side at the same levels. When looking at symmetry, the right and left side independent measurements were compared at each level. The right side of the body was the dominant limb for most individuals (n = 79) so during calculations for symmetry, the left side was subtracted from the right side.

Analysis of Data

The Participant Questionnaire first asked for demographic information. Their age, sport, sports position or event, and dominant limb were recorded. The age of the athletes ranged from 18-25, with a mean of 19.9 years. Dominant limb was identified as very right hand dominated with 86.8% (n = 79). The researchers chose to use the right as being the dominant limb because of the larger percentage. Questions on sports experience pertained to number of years participating in collegiate sports and participation in other sports in high school besides their collegiate sport. Many athletes misread the question and recorded the number of years they participated in their sport throughout their life. Sixteen athletes (17.6%) participated in other sports in high school in addition to their collegiate sport. There was only one athlete who participated in two collegiate sports, volleyball and track and field. This individual was documented as a volleyball player.

Previous injury history questions were all pertaining to low back injuries. Surprisingly, just over 50% (n = 47) reported having back pain during their sporting season, but only 18 remember how the injury occurred. Six players received their injury while participating in the current sport, six while participating in a different sport, two while lifting weights, one during an illness, and three resulted from vehicle accidents. Of the 46 athletes who received treatment for their back, the age these athletes started having pain ranged from 13 to 21 years of age, an average of 17.1 years of age. The most common ages for athletes to receive treatment on their backs was age 16-19, with 10 individuals starting at the age of 17, and nine individuals at each 18 and 19 years of age. The answers to the question that asked at what age their back pain was the worst ranged from 13-22 and most individuals had their worst pain at age 18 (n = 11) and 19 (n = 10). This too could have been caused by growth spurts or an increase in physical activity requirements at the collegiate level. Five of the 47 individuals that reported back pain had to switch playing positions on their team because of their back injury. When asked how long they were out of competition/practice because of their injury, the 10 athletes who recalled being out of their sport averaged 61.9 days, but this was skewed because one person was out for a full year and another for four months. The most common answer was two weeks (n = 3).

Few athletes actually knew what their diagnosis was on the date of data collection. Athletes stated herniated disk, herniated disk and compression fracture, torn ligaments (n = 2), and uneven pelvis, scoliosis with an uneven pelvis, and the rest of the answers were slipped disk, tight hamstrings, back sprain, mal-alignment of hips, and nerve impingement. Table 7 identifies allied health professionals consulted by the athletes for evaluation and treatment of their back injury or injuries.

Table 7

Allied Health Professionals Consulted for Treatment

Allied Health Professional	N
Athletic Trainers only	16
Athletic Trainers and others	30
Chiropractors only	5
Chiropractors and others	15
Physical Therapist only	1
Physical Therapist and others	5
Family Practitioner	4
Medical Doctor	8
Totals	37

Of the 37 who reported having treatment on their back, 14 individuals had a combination of allied health professionals working with them. Four individuals consulted with four of the above professionals, three athletes consulted with three allied professionals and seven consulted with two.

The athletes were then asked what type of treatment was received because of their back injury. Their options were exercises (at home or in the clinic), modalities (e.g., electrical stimulation, ultrasound, heat, ice, massage), mobilization (i.e., slight movement of vertebrae by clinician), manipulation (from physical therapist, chiropractor, medical doctor, doctor of osteopathic medicine) or surgery. None had surgery or was pregnant so no one was excluded from this research. Twenty one received exercises for their back condition, six received mobilizations, 23 had modalities, and 16 had manipulations. Only 34 reported receiving any treatment for their back out of the 47 had claimed back pain during sports (72.3%).

The last few questions relate to their current back pain. On the day of data collection, eight presented with back pain, 27 had pain within the last month, and 18 had pain within the last six months. Only 38 athletes could recall the location of their pain. Ten said it was on one side or the other compared to 13 stating it was in the middle and 15 said it was on both sides. Only one person reporting currently taking medication for their back, but pain ratings on a Likert Scale identified eight individuals rating their pain at a five or above.

Questions were also asked about current pain in the thoracic and cervical spine as well as the shoulder and hip. In the thoracic spine, four reported current pain, 10 reported pain within the last month, most reported pain rating to be 2/10 and only one was taking any medication for their pain. The cervical spine was not too much different than the thoracic spine. Ten reported pain within the last month, six currently, most common response on the pain scale was 2/10, and one person taking medication. Hip pain was slightly different. Ten reported having pain presently, and 18 of them within the last month, most frequently answer for pain was a four on the Likert Scale and three are taking medication. The shoulder complaints were much higher. If you consider the sports chosen, that would explain why this occurred. Of the 91 individuals that filled out this questionnaire, 36 complained of shoulder pain within the last month and 27 of them presently. The Likert Scale identified seven individuals rating their pain at either a 2/10 or 6/10 each and two athletes rated their pain at 8/10 and 9/10. It was quite surprising to see that only five were presently taking medication for their condition, and all the sports were participating in in-season competition or out-of-season competition at the time of data collection.

Table 8 represents an overall sample description of study characteristics for those participating in the study.

Table 8

Frequency Statistics for Student-Athletes Participating in the Study

Variable	Frequency	Percent
Gender Distribution		
Male	56	61.5%
Female	35	38.5%
Height Distribution		
Tall (males ≥180.3cm and females ≥175.3cm)	50	54.9%
Short (males <180.3cm and females <175.3cm)	41	45.1%
Dominant-Side Limbs		
Right	79	86.8%
Left	12	13.2%
Lower Back Pain (LBP)		
Athletes Experiencing LBP	47	51.6%
Athletes Not Experiencing LBP	44	48.4%
Multiple Sport Participation		
Played More Than One Sport	75	82.4%
Played One Sport	16	17.6%

The average age for study participants was 19.93 years with a standard deviation of 1.56 and a range from 18 to 25 years of age.

Table 9

Descriptive Statistics for CSA and PSD Ultrasound Measurements (N=91)

Variable	Minimum	Maximum	Mean	Standard Deviation
CSAL5R	5.48	15.19	9.63	1.77
CSAL5L	5.97	13.63	9.66	1.82
CSAL5SYM	-1.99	2.88	-0.03	1.01
CSAL4R	4.43	13.36	9.53	1.69
CSAL4L	3.12	15.20	9.60	1.86
CSAL4SYM	-2.60	3.59	- 0.07	0.98
CSAL3R	3.85	12.86	7.24	1.77
CSAL3L	3.79	13.36	7.34	1.81
CSAL3SYM	-2.47	1.36	-0.09	0.76
PSDL5R	1.96	4.52	3.18	0.49
PSDL5L	2.05	4.61	3.19	0.52
PSDL5SYM	-0.61	0.92	0.00	0.21
PSDL4R	1.62	4.10	3.07	0.47
PSDL4L	1.04	4.20	3.05	0.52
PSDL4SYM	-0.53	3.06	0 .02	0.40
PSDL3R	1.55	3.75	2.76	0.48
PSDL3L	1.77	3.91	2.79	0.49
PSDL3SYM	-0.75	0.48	-0.04	0.22

Table 9 presents the ultrasound measurements and symmetry measurements for CSA and PSD muscle measurements for the whole sample (N=91).

Table 10 is a summary of the descriptive statistics for the CSA Symmetry measurements based upon which athletes presented a previous diagnosis of lower back pain (Hypothesis #1).

Table 10

Descriptive Statistics for CSA Symmetry Based upon Incidence of Back Pain

Variable	N	Mean	Std. Dev.
CSAL5SYM			
Back Pain	47	-0.25	0.97
No Back Pain	44	0.20	1.01
CSAL4SYM			
Back Pain	47	-0.07	1.00
No Back Pain	44	-0.06	0.98
CSAL3SYM			
Back Pain	47	0.00	0.77
No Back Pain	44	-0.21	0.74

To address the Null Hypothesis #1, there is no difference for CSA symmetrical measurements based upon self-report of back pain an independent sample t-test was conducted to compare CSA symmetry measurements based upon membership in either the back pain or no back pain group (see Table 11).

Table 11

Independent Sample T-test for CSA Symmetry Based upon Incidence of Back Pain

Variable	t	df	Sig.
CSAL5SYM	-2.129	89	0.036*
CSAL4SYM	-.057	89	0.955
CSAL3SYM	1.342	89	0.183

Note. Significance at *p<.05; **p<01; ***p<.001

The only one of the three symmetry measures for which data supported a statistically significant difference was theCSAL5SYM, which corresponds to the CSA measurements taken in the L5 region. This represents that the athlete group with no back pain has significantly higher in right-side CSA measurements and is overall closer to symmetry than the group diagnosed as previously experiencing back pain. The independent t-test identified no significant difference for L3 and L4.

Table 12 is a summary of the descriptive statistics for the PSD Symmetry measurements based upon which athletes presented a previous diagnosis of LBP (Hypothesis #2). The PSD measures the thoracolumbar subcutaneous tissue. To identify the significant difference of this measurement, the t-test ($p < .05$) was used.

Table 12

Descriptive Statistics for PSD Symmetry Based upon Incidence of Back Pain

Variable		N	Mean	Std. Dev.
PSDL5SYM	Back Pain	47	0.04	0.23
	No Back Pain	44	-0.05	0.18
PSDL4SYM	Back Pain	47	0.08	0.53
	No Back Pain	44	-0.06	0.18
PSDL3SYM	Back Pain	47	-0.03	0.23
	No Back Pain	44	-0.05	0.20

To address the Null Hypothesis #2, there is no difference for PSD symmetrical measurements based upon self-report of back pain, an independent sample t-test was conducted to compare PSD symmetry measurements based upon membership in either the back pain or no back pain group (see Table 13).

Table 13

Independent Sample T-test for PSD Symmetry Based upon Incidence of Back Pain

Variable	t	df	Sig.
PSDL5SYM	2.066	89	.042*
PSDL4SYM	1.654	89	.102
PSDL3SYM	.514	89	.609

Note. Significance at *p<.05; **p<01; ***p<.001

The only one of the three symmetry measures to suggest a statistically significant difference was for PSDL5SYM, which corresponds to the PSD measurements taken in the Lumbar 5 (L5) segment. This illustrates that the athlete group with back pain has significantly higher right-side PSD measurements than the no-back pain group. However, it should be noted that although this is a statistically significant finding, overall measurements for both L3 and L4 segments are very close to zero in terms of symmetry measurement (-.05 and .04 respectively).

Table 14 is a summary of the descriptive statistics for the CSA and PSD measurements based upon height of student athletes (Hypothesis #3).

Table 14

Descriptive Statistics for CSA and PSD Based upon Height of Student Athletes

Variable		N	Mean	Std. Dev.
CSAL5R	Short	41	8.94	1.53
	Tall	50	10.17	1.78
CSAL5L	Short	41	9.02	1.78
	Tall	50	10.18	1.69
CSAL4R	Short	41	8.83	1.58
	Tall	50	10.12	1.56
CSAL4L	Short	41	8.87	1.87
	Tall	50	10.20	1.56
CSAL3R	Short	41	6.61	1.44
	Tall	50	7.76	1.85
CSAL3L	Short	41	6.81	1.63
	Tall	50	7.77	1.84
PSDL5R	Short	41	3.05	.49
	Tall	50	3.29	.46
PSDL5L	Short	41	3.07	.51
	Tall	50	3.29	.51
PSDL4R	Short	41	2.95	.48
	Tall	50	3.16	.44
PSDL4L	Short	41	2.98	.46
	Tall	50	3.12	.56
PSDL3R	Short	41	2.62	.48
	Tall	50	2.86	.45
PSDL3L	Short	41	2.66	.51
	Tall	50	2.90	.46

To address the Null Hypothesis #3, there is no difference for CSA and PSD measurements based upon height, an independent samples t-test was conducted to compare CSA and PSD measurements based upon membership in either the short or tall student athlete group (see Table 15).

Table 15

Independent Sample T-test for CSA and PSD Based upon Student Athlete Height

Variable	t	df	Sig.
CSAL5R	-3.422	89	.001***
CSAL5L	-3.177	89	.002**
CSAL4R	-3.898	89	.000***
CSAL4L	-3.622	89	.000***
CSAL3R	-3.265	89	.002**
CSAL3L	-2.615	89	.010*
PSDL5R	-2.398	89	.019*
PSDL5L	-2.039	89	.044*
PSDL4R	-2.229	89	.028*
PSDL4L	-1.279	89	2.04
PSDL3R	-2.481	89	.015*
PSDL3L	-2.400	89	.018*

Note. Significance at *p<.05; **p<.01; ***p<.001

All six of the CSA measurements and five of the six PSD measurements included differences found to be statistically significant at minimally the .05 statistical level of significant. This supports an agreement with the research hypothesis that athletes that are taller have significantly higher CSA and PSD measurements than their shorter counterparts, with the exception of the PSDL4L segment.

Table 16 is a summary of the descriptive statistics for the CSA and PSD measurements based upon gender of student athletes (Hypothesis #4). Independent samples t-tests ($p < .05$) were calculated.

Table 16

Descriptive Statistics for CSA and PSD Based upon Gender of Student Athletes

Variable		N	Mean	Std. Dev.
CSAL5R	Male	56	9.96	1.74
	Female	35	9.09	1.70
CSAL5L	Male	56	10.07	1.72
	Female	35	8.99	1.80
CSAL4R	Male	56	10.17	1.42
	Female	35	8.51	1.60
CSAL4L	Male	56	10.27	1.63
	Female	35	8.54	1.72
CSAL3R	Male	56	7.88	1.63
	Female	35	6.21	1.48
CSAL3L	Male	56	8.08	1.70
	Female	35	6.15	1.26
PSDL5R	Male	56	3.33	.42
	Female	35	2.95	.50
PSDL5L	Male	56	3.36	.47
	Female	35	2.92	.48
PSDL4R	Male	56	3.21	.38
	Female	35	2.84	.51
PSDL4L	Male	56	3.23	.51
	Female	35	2.77	.41
PSDL3R	Male	56	2.95	.41
	Female	35	2.45	.41
PSDL3L	Male	56	3.01	.42
	Female	35	2.45	.41

To address the Null Hypothesis #4, there will be no difference for CSA and PSD measurements based on gender, an independent sample t-test was conducted to compare CSA and PSD measurements based upon gender group of the student athletes in the sample.

Table 17

Independent Sample T-test for CSA and PSD Measurements Based upon Gender

Variable	t	df	Sig.
CSAL5R	2.332	89	0.022*
CSAL5L	2.830	89	0.006**
CSAL4R	5.129	89	0.000***
CSAL4L	4.819	89	0.000***
CSAL3R	4.927	89	0.000***
CSAL3L	5.803	89	0.000***
PSDL5R	3.888	89	0.000***
PSDL5L	4.248	89	0.000***
PSDL4R	3.988	89	0.000***
PSDL4L	4.514	89	0.000***
PSDL3R	5.557	89	0.000***
PSDL3L	6.333	89	0.000***

Note. Significance at *p<.05; **p<.01; ***p<.001

All six of the CSA measurements and all six PSD measurements included difference in measurement found to be statistically significant with 10 out of 12 measurements significant at the .000 statistical level of significance. This supports an agreement with the research hypothesis that male athletes have significantly higher CSA and PSD measurements than their female counterparts.

Table 18 is a summary of the descriptive statistics for the CSA measurements based upon rotational nature of sport (Hypothesis #5).

Table 18

Descriptive Statistics for CSA Measurements Based upon Rotational Nature of Sport

Variable		N	Mean	Std. Dev.
CSAL5R	Rotational	74	9.92	1.70
	Non-Rotational	17	8.37	1.55
CSAL5L	Rotational	74	9.93	1.68
	Non-Rotational	17	8.46	1.97
CSAL4R	Rotational	74	9.87	1.52
	Non-Rotational	17	8.08	1.64
CSAL4L	Rotational	74	9.89	1.82
	Non-Rotational	17	8.34	1.50
CSAL3R	Rotational	74	7.44	1.78
	Non-Rotational	17	6.35	1.39
CSAL3L	Rotational	74	7.51	1.85
	Non-Rotational	17	6.57	1.39

To address the Null Hypothesis #5, there will be no difference for CSA measurements based on rotational nature of sport athletes, an independent sample t-test was conducted to compare CSA measurements based upon rotational nature of sport (see Table 19).

Table 19

Independent Sample T-test for CSA Based upon Rotational Nature of Sport

Variable	t	df	Sig.
CSAL5R	3.447	89	.001**
CSAL5L	3.144	89	.002**
CSAL4R	4.287	89	.000***
CSAL4L	3.272	89	.002**
CSAL3R	2.371	89	.020*
CSAL3L	1.981	89	.050*

Note. Significance at *p<.05; **p<.01; ***p<.001

All six of the CSA measurements were found to be statistically significant at minimally the $p < .05$ level of significance. This supports an agreement with the research hypothesis that CSA measurements for rotational athletes are significantly greater than athletes in the non-rotational sports.

Table 20 is a summary of the descriptive statistics for the PSD measurements based upon rotational nature of sport (Hypothesis #6).

Table 20

Descriptive Statistics for PSD Measurements Based upon Rotational Nature of Sport

Variable	N	Mean	Std. Dev.
PSDL5R			
Rotational	74	3.22	0.47
Non-Rotational	17	3.02	0.53
PSDL5L			
Rotational	74	3.22	0.52
Non-Rotational	17	3.07	0.53
PSDL4R			
Rotational	74	3.13	0.44
Non-Rotational	17	2.81	0.52
PSDL4L			
Rotational	74	3.09	0.54
Non-Rotational	17	2.89	0.43
PSDL3R			
Rotational	74	2.80	0.46
Non-Rotational	17	2.58	0.50
PSDL3L			
Rotational	74	2.85	0.48
Non-Rotational	17	2.57	0.52

To address the Null Hypothesis #6, there will be no difference for PSD measurements based on rotational nature of sport athletes, an independent sample t-test was conducted to compare PSD measurements based upon rotational nature of sport (see Table 21).

Table 21

Independent Sample T-test for PSD Based upon Rotational Nature of Sport

Variable	t	df	Sig.
PSDL5R	1.563	89	0.122
PSDL5L	1.073	89	0.286
PSDL4R	2.534	89	0.013*
PSDL4L	1.409	89	0.162
PSDL3R	1.695	89	0.094
PSDL3L	2.097	89	0.039*

Note. *p<.05; **p<.01; ***p<.001

Only two of the PSD measurements were found to have difference in measurement that was statistically significant at the $p < .05$ level of significance. This supports an agreement with the research hypothesis that PSD measurements for rotational athletes are significantly greater than athletes in the rotational sports for PSDL4R and PSDL3L. It is important to note that the small sample size of "non-rotational" athletes very likely compromised the generalizability findings for PSD measurements.

To address Null Hypothesis #7, there will be no difference for CSA measurements based on one-sided dominant athletes, Table 22 illustrates the results of a ANOVA to investigate whether any differences exist between the specific sports in terms of measurements on CSA ultrasounds. Due to the similar nature of baseball and softball, they were combined as one for purposes of analysis.

Table 22

Analysis of Variance for CSA Measurements Based upon Sports Participation

Variable	Sum of Squares	df	MS	F	Sig.
CSAL5R					
Between Groups	54.61	3	18.20	6.973	0.000***
Within Group	227.14	87	2.61		-
Total	281.75	90	-		-
CSAL5L					
Between Groups	50.84	3	16.95	5.949	0.001***
Within Group	247.83	87	2.61		-
Total	298.67	90	-		-
CSAL4R					
Between Groups	48.52	3	16.17	6.756	0.000***
Within Group	208.26	87	2.39		-
Total	258.78	90	-		-
CSAL4L					
Between Groups	36.33	3	12.11	3.815	0.013*
Within Group	276.13	87	3.17		-
Total	312.46	90	-		-
CSAL3R					
Between Groups	15.22	3	5.07	1.661	0.181
Within Group	265.73	87	3.05		-
Total	280.95	90	-		-
CSAL3L					
Between Groups	8.95	3	2.98	0.911	0.439
Within Group	284.99	87	3.28		-
Total	293.94	90	-		-

Note. Significance at *p<.05; **p<.01; ***p<.001

The research identified CSAL5R, CSAL5L, and CSAL4R to have significant difference based upon sport at $p < .001$ and CSAL4L at $p < .05$. An LSD post hoc test (see Table 23) was then run to determine where difference existed.

Table 23

Descriptive Statistics and Post Hoc Analysis for CSA Measurements Based upon Sport

Variable	N	Mean	Std. Dev.
CSAL5R			
Baseball/Softball	47	10.18	1.68
Volleyball	19	9.89	1.56
Track & Field	18	8.28	1.55
Swimming	7	8.66	1.46
CSAL5L			
Baseball/Softball	47	10.19	1.73
Volleyball	19	9.90	1.43
Track & Field	18	8.47	1.91
Swimming	7	8.43	1.36
CSAL4R			
Baseball/Softball	47	10.05	1.52
Volleyball	19	9.68	1.61
Track & Field	18	8.14	1.61
Swimming	7	9.22	1.35
CSAL4L			
Baseball/Softball	47	10.07	2.02
Volleyball	19	9.69	1.53
Track & Field	18	8.43	1.50
Swimming	7	9.24	1.16

Post hoc analysis using an LSD test determined that the following statistically significant differences were found for CSA measurements between athletes from the different sports:

CSAL5R -- Baseball/softball scored significantly higher than swimming ($p<.05$) and track ($p<.001$). Volleyball also scored significantly higher than track on this variable ($p<.05$).

CSAL5L -- Baseball/softball scored significantly higher than swimming ($p<.05$) and track ($p<.000$).

CSAL4R -- Baseball/softball scored significantly higher than track ($p<.000$). Volleyball also scored significantly higher than track on CSAL4R ($p<.05$).

CSAL4L -- Baseball/softball scored significantly higher than track ($p<.001$). Volleyball also scored significantly higher than track on CSAL4R ($p<.05$).

To address Null Hypothesis #8, there will be no difference for PSD measurements based on one-sided dominance, Table 24 illustrates the results of an ANOVA to investigate whether any differences exist between the specific sports in terms of measurements on PSD ultrasounds. Due to the similar nature of baseball and softball, they were combined as one for purposes of analysis.

Table 24

Analysis of Variance for PSD Measurements Based upon Sports Participation

Variable	Sum of Squares	df	MS	F	Sig.
PSDL5R					
Between Groups	0.51	3	0.17	0.714	0.546
Within Group	20.86	87	0.24	-	-
Total	21.37	90	-	-	-
PSDL5L					
Between Groups	1.09	3	0.36	1.376	0.256
Within Group	23.01	87	0.26	-	-
Total	24.10	90	-	-	-
PSDL4R					
Between Groups	1.36	3	0.45	2.128	0.102
Within Group	18.50	87	0.21	-	-
Total	19.86	90	-	-	-
PSDL4L					
Between Groups	0.97	3	0.33	1.204	0.313
Within Group	23.45	87	0.27	-	-
Total	24.43	90	-	-	-
PSDL3R					
Between Groups	0.80	3	0.271	0.179	0.322
Within Group	19.57	87	0.23	-	-
Total	20.36	90	-	-	-
PSDL3L					
Between Groups	1.89	3	0.63	2.719	0.049*
Within Group	20.12	87	0.23	-	-
Total	22.01	90	-	-	-

Note. Significance at *p<.05; **p<.01; ***p<.001

The CSA for the PSDL3L was the only statistically significant ANOVA. Consequently a post hoc LSD test was only conducted for the PSDL3L variable (see Table 25).

Table 25

Descriptive Statistics and Post Hoc Analysis for PSD Measurements Based upon Sport

Variable		N	Mean	Std. Dev.
PSDL3L	Baseball/Softball	47	2.92	0.45
	Volleyball	19	2.77	0.50
	Track & Field	18	2.62	0.54
	Swimming	7	2.49	0.41

Measurements on PSDL3L were significantly higher for baseball/softball group than track and field ($p<.05$).

Summary

Athletes in this study presented with 51. 6% (n = 47) having a back injury while participating in sports but only 18 remember how they hurt their back. Between the ages of 16 and 19, the majority (n= 34) of these particular athletes started receiving treatment. Their treatments consisted of seeing allied health professionals such as athletic trainers, physical therapists, chiropractors and doctors. The athletes reported the worst pain between the ages of 17 and 20. The most common number of days off for a back injury was 14 days. Three of the 10 athletes took time off of their sport for those two weeks and five reported that they needed to switch positions on the team because of their back.

Pain experience within the last month was documented to have 27 for LBP, 10 for thoracic spine, and 10 for cervical spine. The shoulder and hip pain was 36 and 18, respectively. Pain presently for the same areas are as follows: low back14, thorax 4, cervical 6, shoulder 27, and hip 10. The athletes rated their pain in each joint on a Likert scale. The low back that had the most responses were at 10 on 3/10 and eight on 4/10. The thoracic spine ranged their pain level from 1/10 to 7/10 with the most common response to be at 2/10. The most common response for the cervical unit pain rating was a 2/10 (n = 4). Shoulder pain had the most responses in general (n = 34). Seven athletes each chose their pain rating range from 2/10 to 6/10 and five of those athletes each chose from 4/10 to 5/10. This is not surprising with the number of one-sided dominant sports chosen for this research. The Likert Scale illustrated six responses at 4/10 for hip pain. Totally, only 11 athletes were taking medication for their pain, and only one for back pain.

Chapter Five: Discussion, Implementation, Recommendations

Overview

The current collaborative study examined 91 collegiate athletes' bilateral lumbar multifidus muscles and the relationship of their measurement of symmetry to LBP in intercollegiate athletes who participate in men's and women's swimming, men's and women's track and field/cross-country, men's and women's volleyball, women's fast-pitch softball, and men's baseball. The CSA and PSD measurements of the bilateral lumbar multifidus muscles were compared by history of injury, body morphology, gender, biomechanical nature of sport, and one-sided dominant sport. Measurements were taken at L3, L4, and L5 of both CSA and PSD. Statistical information was obtained from independent t-tests and by comparing measurements to check for symmetry. During symmetry calculations, right over left was chosen to form ratios because 86.8% (n = 79) of the athletes who participated were right handed. The ANOVA and LSD post hoc tests were run on the dominant sided hypotheses statements. There were no participant exclusions during this study. There was one athlete who participated in two sports, volleyball and track. In this study, the researchers identified the athlete as a volleyball player.

Discussion of Results

The researchers had eight hypotheses and a questionnaire that were addressed through statistical measures. Many studies have been written on LBP, a few on the multifidus muscle, but even fewer on the multifidus muscle and its relationship to specific sports. This particular study focused on the non-contact collegiate sports because few studies involve this population.

The results of a self-report questionnaire revealed that 51.6% (n = 47) of the athletes complained of LBP and 48.4% (n = 44) did not complain of LBP. The average age of participants was 19.9 years, with the range of 18 to 25. Reported injuries to these athletes' low back occurred (a) while in the sport the athlete was participating in at the time of the study (n = 6),(b) while in a different high school or club sport (n = 6), (c) while lifting weights (n = 2), and (d) miscellaneous accidents not related to sports (n = 4). Of the 46 athletes who received treatment for their back, the onset of pain ranged from 13 to 21 years of age, an average of 17.1 years of age. The most common ages for athletes to receive treatment on their back was age 16-19, with 10 individuals starting at the age of 17, and nine individuals each at 18 and 19 years of age. On the day of data collection, 14 reported current LBP and 29.7% (n = 27) reported pain within the last month.

In the study by Brennan et al. (2007b) 11.8% of the collegiate students in physically active majors complained of back pain within the last month. In this current study, the number of athletes injured was much higher in comparison to the students in Brennan et al. (2007b) study. Surprisingly just over half the athletes who participated in the study had back pain and complained of back pain as far back as age 13. The difference between the two groups could be due to the type of physical activity required in their major or past history of back injury prior to college. According to Alexander (1976), more injuries occur because of the combination of extension and rotation. The students in the Brennan et al. (2007b) study probably did not combine as much extension and rotation as the athletes in this study. The individuals within Brennan et al. (2007b) study also may not have had access to the sports medicine team that athletes are able to use on a regular basis. It is costly for students to pursue treatment for their injuries whereas athletes get assistance daily with their aches and pains at no cost.

Treatments for LBP among this study's participants were reportedly performed by allied health professionals in 37 of the 47 reported injuries. Ten percent of these individuals worked with a group of four allied health professionals. This group included athletic trainers, physical therapists, chiropractors, and various medical doctors. Treatments most commonly used for low back injury were modalities (heat, ice, electrical stimulation), exercises, and mobilization of the spine, respectively. With athletic trainers employed at most high schools and some allied health professionals available with just a phone call, it is still not easy for athletes to receive treatment of their injuries. From my personal experience at various high schools, a certified athletic trainer is pulled to various fields for practices or games, preparing athletes for practice in the athletic training room, performing immediate care of injuries when necessary, and if there is time and space rehabilitating injuries. Athletic trainers need to prioritize the school's needs and their time which may limit the number of athletes rehabilitated in the athletic training room. Quite often there is no time for treatment in the high school athletic training room because of all the sports going on at the same time. Many high school athletes do not get appropriate and effective treatment for minor injuries due to availability of their athletic trainer. This can lead to chronic injuries in their collegiate years. Collaboration with other allied health professionals at any level of competition will create the greatest outcome for the injured athletes.

Hypothesis #1. Subjects with no history of LBP will have symmetrical CSA measurements. Data from this study supported this hypothesis for symmetrical CSA for

L3 and L4 for those athletes who report no back pain. The data did not support symmetrical CSA for L5 (see Table 11). Many studies have found symmetrical differences of CSA measurements at L5 when LBP has occurred (Brennan et al., 2007b; Hides et al., 1994; Hides et al., 2008; Kader et al., 2000; Stokes et al., 2005). The results of this study also confirmed that the CSA symmetry measurement of L5 was deficient. More athletes with no back pain have a larger right-sided multifidus CSA measurement, therefore, identifying atrophy in the left-sided multifidus, an indication of an injured back. There were 47 of the 91 athletes in this study who complained of LBP. This study did not identify the exact location of the pain. It is still unknown why the multifidus muscle atrophies at L5 after an injury when there are five branches that expand two to four segments and atrophy at only one level, specifically L5. There is speculation that atrophy is due to disuse, denervation, or reflex inhibition (Hodges et al., 2006). This study did not address causes of atrophy as a hypothesis. When injuries to the low back occur, the focus of treatment should consistently be at L5. The athletic trainers and strength and conditioning team should also focus their preventative skills on the lumbar, particularly L5. After an injury, L5 is where the multifidus muscle shows consistent atrophy, therefore treatment and exercises should focus on this particular area of the back. This particular study identified a smaller multifidus muscle on the left side of the body at L5.

Hypothesis #2. Subjects with no history of low back pain (LBP) will have symmetrical parasagittal dimension (PSD) measurements. Data from this study supported this hypothesis for symmetrical PSD for L3 and L4 for those athletes with no report of back pain. The data did not support symmetrical PSD for L5. The PSD measurement analysis yielded lack of symmetry at L5 as well, but the group with back pain had a larger right sided measurement than the athletes with no back pain, which was the opposite of the situation hypothesized (see Table 13).

Compensation for pain may be an explanation for the difference in sides having significantly different dimensions. Muscle compensation also might lead to spasm in the superficial muscles if the LBP turns to chronic pain. With the apparent reduction in use of the multifidus muscle shown in CSAL5SYM measurement, the muscles that lie superficial to the multifidus may be working harder to stabilize and support the spine, therefore becoming larger. Magnetic resistance imaging (MRI) results identified erector spinae muscles having degeneration within a healthy population but “significantly less [degeneration] than patients with LBP” which supports the findings of this study (Kader et al., 2000, p 148).

The number of right handed athletes and one-sided dominant sport athletes could have played a role in this finding. College athletes typically have played their sport for many years. The right sided muscles could be over-developed due to the sport mechanics and hand dominants. Seventy nine of the 91 participants in this study are right handed and 66 participate in a one-sided dominant collegiate sport. It is also not uncommon for athletes to have played other sports that are also one-hand dominant.

When educating allied health professionals and students, it will be important to observe and treat the muscles in the entire low back area, not just the one or ones that are directly involved in the injury. It is important to consider the muscles on both sides of the spine even if the complaint of injury is only on one side of the back. In this study, it is apparent that even though there may be an injury in the area, other muscles are affected by that injury. In Hypothesis #1, atrophy was identified to the multifidus muscle on the left side, but when looking at the muscle and its surrounding tissues (Hypothesis #2), it is identified as being larger on the left side for the participants who complain of back pain.

Hypothesis #3. CSA and PSD measurements will be greater in taller athletes (males ≥180.3cm and females ≥175.3cm). The data in this study supported greater CSA and PSD measurements in taller athletes than shorter athletes, except for PSDL4L. At PSDL4L, there were no significant findings.

With taller individuals having greater CSA and PSD measurements, one might think that taller athletes, males or females, have less back pain. According to observable data, this was found not to be the case. Of the 91 athletes who volunteered for this study, 61.5% were males and 54.9% of those were identified as being tall. Of the tall males, 40% reported having LBP. Of the tall females, 70% reported having LBP. On Table 14, the CSA mean values from right to left sides of the multifidus muscle show between 0.01 and 0.08 differences, except for L3. The measurement at CSAL3 has a 0.2 difference for shorter individuals. Hypothesis #1 had identified L5 as showing atrophy on the right side. Through deductive reasoning, there should be a larger difference at L5, not L3. This area, L3, might be of interest for future researchers.

There was also a very large difference in mean measurements at L3 compared to L4, nearly 3.0 differences in CSA measurements and over 2.0 in PSD measurements. The natural anatomical curve changes after L3 and so do the forces applied in this area. Fiber type differences might also be different from L3 to L4. Further research in this area could tell us more about why this occurred in the present study.

There were no large observable PSD differences between the mean of L3 to L5 for either taller or shorter athletes, and there was absolutely no difference in mean at PDSL5 for taller individuals. In hypothesis #1, the researchers identified significant differences for the PSDL5SYM measurement. These differences found in hypothesis #1 are not observably identified in relation to height. Rotational forces come in to play when looking at PDS measurements. The type of activity required for each sport could play a roll in these findings. Follow up research needs to look at height and rotational requirements of each sport evaluated in this study.

Few studies have found height as a significant factor in greater CSA and PSD measurements (Hides et al., 2008; Wallwork et al., 2008). Hides et al., (2008) study used athletes but had a small number, which were divided up into two groups, LBP and no reports of LBP. This 2008 study found no significant differences between height in athletes with LBP (n = 7) and no reports of LBP (n = 14) (Hides et al., 2008). Most of the studies that referenced height as potential factors in CSA or PSD measurements were performed on general populations (Wallwork et al., 2008) and some had subjects with mean heights that did not reach 171cm (Kiesel, Underwood et al., 2007). Very few studies use height as an indicator to assess LBP. Height and LBP could be an area with great potential for future studies, specifically looking at the L3 area. Fiber type and forces applied at L3 might tell us more about LBP.

On the contrary, studies have identified height as being an indicator of recurrent injuries in the low back (Cholewicki et al., 2005; Silfies et al., 2007). Taller and heavier athletes were more prone to reinjury (Silfies et al., 2007). Given that the multifidus muscle does not recover immediately after the pain resolves after an injury, it makes sense that any individuals will have recurrent back pain. Looking at gymnasts or generally shorter athletes' sports and comparing them to tall athletes' sports like volleyball and basketball might also warrant further investigation. Both types of sports require extension and rotation at the same time when the athlete is performing.

This study identified all taller athletes to have larger CSA and PSD measurements than shorter athletes, except at PSDL4L.

Hypothesis #4. CSA and PSD measurements will be greater in male athletes than female athletes. The data in this study supported greater CSA and PSD measurements in male athletes as opposed to female athletes. One may believe this is due to the larger structure of the male build, but not according to Stokes et al., (2005). They compared CSA measurements to body mass and found no correlation after normalizing data. A study using physically active collegiate students also established gender as not being a factor relevant to the size of the multifidus muscle (Brennan et al., 2007b). Hides et al. (1994) recognized male and female patients who complained of LBP to have a "rounder muscle shape" (p. 170). This study did not look at the shape of the muscle, which could be a topic for future study. Observably, 50% of the 56 male athletes reported LBP as did 54% of the 35 females. In summary, there are greater measurements in both males than females, in all segments of the back whether it is CSA or PSD.

Hypothesis #5. Rotational athletes will have greater CSA measurements compared to non-rotational athletes. The data from this study supported greater CSA measurements in athletes participating in rotationally-related sports than those participating in non-rotationally-related sports. Rotational athletic activities have not been well researched. All six of the CSA measurements were found to be greater when comparing rotational to non-rotational athletes (See Table 19). Data from a healthy population might turn out differently. In an in vitro study, rotation was identified at L4 as controlled by multifidus muscle branch that runs off of the transverse processes (Wilke et al., 1995). The multifidus branch that ran superior had no significant function in rotation but did in extension and lateral bending. The multifidus fibers which ran off the transverse process was significant in both extension and rotation (Wilke et al., 1995).

Most injuries of the back occur at L5. The study by White and Panjabi (1978) supported Wilke's et al. (1995) findings by identifying L5 as having the most rotation during flexion and extension range of motion (White & Panjabi, 1978). During rotation, L5 performs most of the range of motion in the lumbar. This too supports the theory that extension and rotation movements cause most injuries (Alexander, 1976; Bergstrøm et al., 2004). In this study there are interesting findings at L3. Both right and left measurements yielded significant differences for rotational athletes. White and Panjabi (1978) identified lateral bending range of motion to have the most rotation at L3. Researchers might look at the affects L3 has on the muscles and applied forces in the area which may also affect L4 and L5.

One might think that if most of the rotation during flexion, extension, and rotation occurs at L5, then L5 would be larger in rotational athletes. Previous data from this research concluded L5L as showing atrophy therefore explaining why non-rotational athletes have a greater L5R. It does not explain why rotational athletes have a greater L5L though. This study identified larger CSA measurements in rotational athletes at each spinal segment on all sides of the spine.

Hypothesis #6. Rotational athletes will have greater PSD measurements compared to non-rotational athletes. Data from this study did support greater PSD measurements in the rotational-sports athlete, as opposed to the non-rotational sport athlete. The data supported the findings that rotational sports athlete yielded greater PSD measurements than the non-rotational at PSDL4R and PSDL3L. In this study, there was a greater measurement at PSDL4R and PSDL3L to support greater differences for the non-rotational athlete, as compared to the rotational athlete. It is important to note that the small sample size of non-rotational athletes very likely compromised the generalizability of significant findings for PSD measurements. It is very difficult to find athletes who practice and compete strictly in a straight line. Nearly 19% of these athletes in this study were track athletes and 53% of these had LBP according to observational analysis. I find these observations surprising due to this being a non-rotational sport where flexion or extension and rotation are not used on a daily practice and nature of activities of daily living requiring the human body to be erect most of the day. There is little research to support or deny these findings. There are so few sports that focus on non-rotational training and competition. Compiling data on cyclists or rowers might be a good addition to the non-rotational population for upcoming studies. Further research is required in this area to either support or refute the findings of this study.

The function of the multifidus muscle is to stabilize first, then assist with erection of the spine, extension of the lumbar, and counter balance flexion of the segments during rotation. One might think that because humans stand erect most of the day that the muscle in non-rotational athletes might be stronger, but according to this exploratory study, non-rotational athletes only have larger PSD measurements at PSDL4R and

PSDL3L.This might be due to fiber type or injury. Type II fibers are able to respond to sudden movements or loads whereas Type I fibers are used more for maintaining posture (Matějke et al., 2006; Norris, 2000). More Type I fibers are found within the lumbar multifidus muscle. Norris (2000) stated that Type I fibers atrophy faster while Matějke et al. (2006) believed it is Type II fibers that atrophy faster. Due to the multifidus muscle having five branches, and each one consisting of different combinations of Type I and II fibers, Hypothesis #6 may be difficult to conclusively support or not support. Further research is suggested and should take into account the limited number of sports which require only forward motion. A larger randomized sample than represented in this study may lend support to the reliability and generalizability of results. Additional non-rotational sports such as cycling, rowing and possibly weight lifting might be taken into consideration. A larger sample will create greater reliability and validity. Non-rotational athletes have been found to have a greater PSDL4R and PSDL3L in this study.

Hypothesis #7. One-sided dominant sports (e.g. volleyball, baseball, and softball) will have higher CSA measurements compared to non-dominant sided sports (e.g. swimming and track). Data from this study supported larger CSA measurements in the one-sided dominant sports for the CSAL5R, CSAL5L, CSAL4R, and CSAL4L regions. This hypothesis compared CSA measurements of the lumbar multifidus in athletes participating in volleyball, softball, and baseball (one-sided dominant sports) to those of athletes participating in non-dominant sports (swimming and track). Dominant-sided sports represent an area which needs further research concerning the relationship between lumbar pain and CSA/PSD measurement. This study used ANOVA to check for measureable difference and found that a difference in measurement exists for the CSA of

L5 and L4 on both the right and the left side of the spine but discovered no significant differences at L3 (see Table 24). A post hoc test was run to identify which sports yielded the significant findings. Combining the men and women together for each sport made the sample numbers in baseball, softball and volleyball large (n = 66), and the sample numbers for track and field and swimming small (n = 25). Of the 25 non-dominant sided athletes in this study, 56% (n = 14) reported LBP. Of the 66 one-sided dominant sided athletes, 50% (n = 33) had LBP. Further research in this area may be worthwhile.

Looking at the number of athletes who reported LBP in this study, there were no observable differences found between the one-side dominant sport athletes and the non-one-sided dominant sport athletes because both groups had at least 50% of the athletes self-report LBP. Therefore, one-side dominant sports have no effect on back pain. When it comes to CSA measurements, the one-side dominant sports were found to have larger L5 and L4 segments on both sides of the body. One-sided dominant sports typically use excessive flexion, extension, and rotation. Swimming uses excessive flexion and extension, but mainly with the butterfly stroke and during in turns of the other strokes. Breathing technique in swimmers is when rotation is used the most, but that is found in the neck, not low back. Cross country and track and field athletes use flexion and extension of the spine on hills and during field events mainly. It has been identified that L5 creates the most rotation during flexion, extension, and rotation. The multifidus branch that ran posterior, along with more superficial muscles, create rotation so it makes sense that the CSA measurement for L5 would be greater in one-sided dominant athletes, but not necessarily on both sides. Greater measurements at L4R and L4L are also confusing because significantly less rotation occurs at this segment for one-sided dominant athletes. Atrophy identified at L5 on the right side apparently has no effect on this measurement. One-sided dominant sport athletes have an increased CSA measurement at L5 and L4, on both right and left sides.

Hypothesis #8. One-sided dominant sports (e.g. volleyball, baseball, and softball) will have higher PSD measurements compared to non-dominant sided sports (e.g. swimming and track). Data from this study supports higher PSD measurements in the one-sided dominant sports athletes of the baseball/softball group, rather than the non-dominant sports athletes of track and field for the PSDL3L region. Data does not support larger muscle measurements in participants of one-sided dominant sports for the other regions (see Table 26). Due to the lack of research on dominant and non-dominant sports, this provides an excellent opportunity for future researchers to investigate.

In a study of just runners and walkers, Woolf and Glaser (2004) identified 73.6% of surveyed subjects studied (n = 539) to have a lifetime cumulative incidence of LBP and 13.6% had LBP at the time of data collection. This study did identify that aerobic activity decreased the chronic episodes of low back injury by 13% in runners and 33% in walkers, but did not change for walkers or runners with current back pain. Weight lifting apparently increased current LBP in walkers. No other sports activities had correlation between previous and current LBP (Woolf & Glaser, 2004).

The fact that this study identified differences that some studies have not, could be a reflection on the population used. The athletes have all worked with strength and conditioning specialists therefore lifted weights within the past year. Positioning used during the US was modified slightly compared to other studies. The sonographer did not use a pillow under the pelvis during ultrasound measurements. This could potentially be a factor. The number of participants in this study was also larger than most populations used during multifidus muscle studies. Reliability of diagnostic ultrasound in the study was standard in comparison with other studies. Measurements were taken three times and the mean was calculated. Stokes et al. (2005) felt the PSD measurement had equal bearing to the CSA measurements as long as there was not atrophy within the area. This data was agreed upon by Kiesel, Underwood et al. in a 2007 study.

Discussion of Implications for the Professional

The results of this study can assist individuals with LBP, whether athlete or not, as well as allied health professionals in their education efforts. According to research, individuals with LBP that has subsided may actually show multifidus muscle deficits within their L5 region for an extended period of time after the injury. This study was not designed to identify what causes this extended deficit, and results of other research has not indicated a conclusion as of yet. This study will lead to better care from the allied health professionals as a result of the detailed study of the types of movement in athletes leading to atrophy in specific areas within the lumbar region.

Injured individuals commonly get x-rays, which are not usually helpful unless identifying disk or bony issues. Diagnostic ultrasound can give much more information on what is going on with the muscles in the area and can help identify complications specific to the area. Diagnostic ultrasound unfortunately cannot identify disk injuries due to bony anatomical structures being in the way. It also might not be worth the money for a college to hire an ultrasound technician and to purchase the equipment, but if there are resources in the area, it only takes about three minutes for a skilled sonographer to ultrasound the lumbar area of an athlete. Calculating the measurements will take slightly longer. This non-invasive procedure could be completed during team physicals. Identifying deficits whether the athlete complains of low back or not, allows the athletic trainers to do what they do best—prevent injuries by giving them appropriate exercises to create symmetry within the multifidus muscles. This also allows the athletic trainer or other allied health professionals to compare before and after injury ultrasound records to assist with specific diagnosis of injury. According to Nachemson and Spitzer (1987), the first diagnosis for the back is only right 2% of the time. I feel the use of ultrasound would greatly increase the efficiency of these diagnoses. Exercises to prevent back injuries should be a part of every athlete's warm-up or taught during strength and conditioning no matter if their sport has high-contact or no-contact. This process leads to research-based practice for prevention and diagnosis of lumbar injury.

The cost of financing low back injuries is astronomical in the United States—over $15 billion (Frymoyer & Cats-Baril, 1991). Educating the general population on how to handle back issues will be extremely beneficial to all parties involved. Using research-based practice can help eliminate some of those costs to the injured individual and the employer. There are several studies that identify exercises for the multifidus muscle. Once that muscle is strengthened, normal function of the back can be restored with a solid foundation. It would be great to get rid of the stereo-type thinking that "back pain is a way of life" and increase the success rate to a range of 85% to 90% of reduction in back pain as successful, not 50%. There is no comparison between worker's compensation and athletic play, but there are many more individuals not going back to work compared to athletes not getting on the field or court. Collegiate athletes do their best to get back in the game because they know that there are only a couple of years left to participate at this level of competition. Athletes also have no legal representation to help resolve their issues, and they do have access to allied health professionals usually free of charge on a daily basis. The safe return to work or play is the most important aspect of care, no matter how long it takes. Identifying asymmetry in CSA and PSD measurements can lead to strengthening exercises that could potentially decrease the number of permanent disabilities.

Athletes are notorious for participating with pain or returning to play just after the pain goes away. Educating the athlete about the healing process and delayed recovery of the multifidus muscle will be essential to the athlete both in the present and in the future. In the subjects surveyed in this study, the most common age to get treatment for back pain was 17, 18, and 19 years of age. This could be due to the athletic trainers being in their high schools, the increase in activity on a varsity sport, growth spurts, or parents finally believing the athlete has a back injury since some reported that they complained of pain since age 13. Education to the injured is the responsibility of the allied health professional. Following results of this study, recommendations for rehabilitation exercises should be focused on the L5 area. Further research needs to continue to look at findings of L3 and L4.

Recommendations for the strength training specialist would be to work on stabilizers of the back by adding short quick rotational movements and rotation with extension into the workout. Back extension exercises are helpful, but if the superficial muscles are already in spasm from back issues, the benefits will be limited and could make the issue worse. Prone back exercises with minimal limb movement will assist with activation of the lumbar multifidus muscle to further strengthen the stabilizing muscles.

Recommendations for Future Research

Recommendations for further research would include a comparison of non-contact athletes CSA and PSD measurements with high-contact athletes' measurement. Lack of symmetry in measurements among high-contact versus non-contact athletes might suggest strength training changes in designated workouts to include transverse abdominis and multifidus muscle exercises. It has been identified that L5 continues to be an area of concern for LBP. The analysis of data gathered from athletes in this study supports this conclusion.

If this study were reproduced, more questions should be asked about exact location of injury, recurrence of injury, and history of lifting weights. Correlation between the low back pain and body morphology, gender, rotation, and one-sided dominant sport could take this study to the next level. Using participants in contact sports which require a lot of pushing and pulling, like wrestling and football, could provide additional data. Their extensive weight lifting regimen to prevent back and neck injuries might show differences of measurement within an application of the methodology from this same study. Adding cyclists, rowers, and possibly weight lifters to the non-rotational sporting list may show differences within this study's results because this would increase the number of non-rotational athletes, allowing better (equal) comparisons. With the function of the lumbar multifidus muscles being a stabilizer when the extremities are being used, specific populations might be a considered addition to provide a worthwhile research focus. Specifically speaking, looking at individuals with spinal cord injury below level L2. This population could also help future researchers who are interested in studying segmental atrophy.

According to Bejjani et al. (1984), women lift heavy items differently than men, so this could relate to the statistically significant findings. Performing ultrasound while men and women lift weights might identify why women lift items differently or identify stability function or malfunction when injured. There are so many back injuries that occur with extension and rotation that investigating the sports that have the most extension and rotation usage could be useful.

It is the opinion of the researchers that education will be most helpful in the prevention and treatment of back injuries. Education should include mechanism of injury, treatment of injury, healing process and its timeline, and future implications of back injuries. Educating the athletes, the youth, and the general population can be beneficial financially and to the physical and mental health of these individuals.

Conclusion

The multifidus muscle is a small but powerful muscle. In the low back it is susceptible to injury and sometimes may not recover completely. This collaborative study revealed significant differences in all categories studied for height, gender, and rotational athletes as related to CSA and PSD measurements found using diagnostic ultrasound. Taller individuals have greater CSA and PSD measurements compared to shorter individuals. Males have greater CSA and PSD measurements compared to females, except at PSD. Rotational athletes (volleyball, swimming, baseball/softball) also have greater CSA and PSD measurements than non-rotational athletes (track and field). Researchers also found significant differences at L5 for those athletes with LBP and at CSAL5R, CSAL5L, CSAL4R, CSAL4L, and PSDL3Lin one-sided dominant sport athletes (baseball/softball, volleyball) compared to non-dominated sport athletes (swimming and track and field). Asymmetrical findings at L5 and CSA and PSD measurements related to gender differences have also been recognized in other studies. This study has exposed possibilities for further research on height relating to CSA and PSD measurements within the athletic population. This is the only study which has found height to be a significant factor when looking at CSA and PSD measurements. No other study found has used rotational sports or one-sided dominant sports as a variable within research relating to the multifidus muscle. There are many unanswered questions which still remain. Additional research might include evaluating athletes in sports which normally utilize smaller framed athletes, (e.g. gymnastics and cheerleading) to look at height differences, increasing subject size of non-rotational athletes, focusing on one-sided dominant sport athletes, looking at athletes who perform extension and rotation during their sporting activity, and exploring possible answers to atrophy at L5 with people who have sustained lumbar spinal cord injuries. Most importantly, the recommendations following this study emphasize that screening for potential low back injuries can be done quickly and cost effectively if there are resources in the area. The knowledge of identifying contributing factors for LBP using CSA and PSD measurements, along with identification of which lumbar segments are most affected, can help allied health professionals educate and create planned strategies for both athletes and non-athletes concerning activity during the healing process, strategies for prevention of further injury, and treatments modified if a specific segment shows atrophy.

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Appendix A

Lindenwood University

Institutional Review Board Disposition Report

To: Delaine Young
CC: Dr. Beth Kania-Gosche
IRB Project Number 10-83
Title: The comparison of cross sectional area and parasagittal diameter measurements of the multifidi muscles and back pain among collegiate athletes.

The IRB has reviewed your application for research according to the terms and conditions below, and it has been approved.

Original IRB Approval Date:8/23/10
Original Expiration Date:8/23/11
Extension via amendment:12/11
Type of Review:Full Review
Research Risk Level:Level 1- Minimal

The Lindenwood IRB complies with Federal regulations 45 CFR 46, 45CFR164, 21CFR 50 and 21 CFR 56, which allows for the use of an expedited review procedure for research which presents no more than minimal risk to human participants and meets the criteria for one or more of the categories of research published in the Federal Register . All actions and recommendations approved under expedited review are reported to a Full Board meeting.

Changes in the conduct of the study, including the consent process or materials, require submission of an amendment application which must be approved by the IRB prior to implementation of the changes.

According to Federal regulations, this project requires IRB continuing review. As such, prior to the project expiration date above, you must submit either a Renewal through the abbreviated application form or a Final Report.
If you have questions or require additional information, please contact the Chair.

Ricardo Delgado	3/22/11
Institutional Review Board Chair	Date

Appendix B

SIGN-IN SHEET

NAME (PRINTED)	CONTACT INFORMATION	UI NUMBER

Appendix C

LUIHLC Version 2008

LINDENWOOD UNIVERSITY

RELEASE, PARTICIPANT WAIVER, AND HOLD HARMLESS FORM

ACTIVITY: ____

1. In consideration for receiving permission to participate in the above-mentioned activity, (herein referred to as ACTIVITY), which is sanctioned or sponsored by Lindenwood University (herein referred to as SPONSOR), I (PARTICIPANT), hereby **RELEASE, WAIVE, DISCHARGE, AND COVENANT NOT TO SUE, AND AGREE TO HOLD HARMLESS** SPONSOR, Lindenwood University, its Board of Directors, its officers, agents, volunteers, other students, third parties, or employees (collectively referred to as RELEASEES) **FROM ANY AND ALL LIABILITIES, CLAIMS, DEMANDS, OR INJURY, INCLUDING DEATH**, unless specifically exempted herein, that may be sustained by me while participating in such ACTIVITY, travel to and from the activity, or while on the premises owned or leased by RELEASEES, **including injuries sustained as a result of the negligence and FUTURE NEGLIGENCE of RELEASEES.** I am able to participate in this activity and I know of no medical, physical, or mental, reason why I should not participate.

2. I am fully aware that there are inherent risks involved with the ACTIVITY, and I choose to voluntarily participate in said ACTIVITY with full knowledge that said ACTIVITY may be hazardous to me and my property. **IVOLUNTARILY ASSUME FULL RESPONSIBILITY FOR ANY RISKS OF LOSS, PROPERTY DAMAGE OR PERSONAL INJURY, INCLUDING DEATH,** that may be sustained by me as a result of participating in said ACTIVITY, **including injuries sustained as a result of the negligence or FUTURE NEGLIGENCE of RELEASEES,** unless specifically exempted herein. I further agree to indemnify and hold harmless the RELEASEES for any loss, liability, damage or costs, including court costs and attorney's fees that may occur as a result of my participation in said ACTIVITY, unless specifically exempted herein.

3. I authorize university staff and other medical personnel to take any action deemed necessary in case of emergency medical situations. I understand that RELEASEES may not maintain insurance covering circumstances arising from my participation in this ACTIVITY or any event related to that participation. As such, I am aware that I should review my personal insurance coverage and my personal insurance will be used when appropriate and applicable.

4. It is my express intent that this document shall bind the members of my family and spouse, if I am alive, and my heirs, assigns and personal representatives, if I am deceased.

5. In signing this Release, Waiver, and Hold Harmless, I acknowledge and represent that I have read the foregoing document, acknowledge that I have the right to review it with my own legal counsel, understand it, and sign it voluntarily as my own free act and deed. No oral representations, statements, or inducements apart form the foregoing agreement that has been reduced to writing have been made. I execute this document for full, adequate and complete consideration fully intending to be bound by the same, now and in the future.

6. All other terms notwithstanding, this document does not release, and expressly excludesfrom its terms, claims, liabilities, or causes of action which are non-releasable under State or Federal Laws, including, but not limited to, intentional torts, gross recklessness, gross negligence, fraud, or activities involving the public interest, depending on the jurisdiction.

Participant Signature:

____

Printed Name:____

Address:
____

Date:__________________________Telephone:_______________________________

Parent or Legal Guardian Printed Name, & Signature (If under Participant is under

18 years old): ____

Appendix D

Lindenwood University
INFORMED CONSENT

Informed Consent to Participate in a Research Study

Title of Research:
The comparison of cross sectional area and parasagittal dimension measurements of the multifidi muscles on collegiate athletes who participate in rotational and non-rotational sports.

Name of Principal Investigator/Primary Researcher:

Delaine Young, Assistant Professor Health & Fitness Sciences
Phone Number of Principal Investigator/Primary Researcher:

Delaine Young	dyoung@lindenwood.edu	636-949-4684

Name and Phone Number of Committee Chair:

Dr. Paul Wright Committee Chair	pwright@lindenwood.edu	636-949-4801

A. PURPOSE AND BACKGROUND
Under the supervision of Dr. Paul Wright, Assistant Professor of Health & Fitness Sciences at Lindenwood University, Delaine Young, a doctoral student, and Melissa Engelson, DC,are conducting collaborated research on low back pain in athletes at the NAIA collegiate level and non-athletes.

The researchers will be looking at the comparison of cross sectional area and parasaginal diameter measurements of the multifidus muscles and back pain on NAIA collegiate athletes.

B. PROCEDURES

If I agree to participate in this research study, the following will occur:

1. I will be asked to complete the pre-screening forms including a liability waiver and this informed consent (~ 5 minutes)

2. I will be asked to fill out a preliminary questionnaire (~5 minutes).

3. If I qualify, I will be interviewed by primary and secondary investigator and measurements of cervical, thoracic and lumbar range of motion and shoulder and hip strength and range of motion (~ 30)

4. If I qualify, I will be taken to Logan College of Chiropractic for a sonography of my low back muscles.

C. RISKS and VOLUNTARY WITHDRAWAL FROM STUDY

Any risks to the subject are listed below:

All subjects will already have a valid physical on file in the athletic training room or will receive a physical prior to participation. All subjects will be given a physical activity readiness survey before participation in testing assessments.Ultrasound is a non-invasive method.Therefore, there are no known or anticipated risks to those that participate in this study.

D. CONFIDENTIALITY

The records from this study will be kept as confidential as possible. No individual identities will be used in any reports or publications resulting from the study. Each subject will be given a unique identifier that is random and in no way linked to the subject.

All hard copy research information will be kept in locked files at all times. The primary and secondary investigator will have access to the files. All electronic data will be password protected and available only to the primary investigator and committee chairman. After the study is completed and all data has been transcribed, the data will be held for 25 years.

D. DIRECT BENEFITS

1. Identifying why subjects might have chronic back pain.
2. Increase focus in the classroom and work, and performance in their sport with less back pain.
3. Prevention of future back pain.

E. ALTERNATIVES

I am free to choose not to participate in this research study.

F. COSTS

There will be no costs to me as a result of taking part in this research study.

G. COMPENSATION

Athletes should increase their performance if their multifidus muscles are larger in size or if asymmetry of these muscles is decreased. Students with no back pain should be able to focus better in the classroom.

H. QUESTIONS

I have spoken with Delaine Young, Melissa Engelson, and/or Dr. Paul Wright about this study and have had my questions answered. If I have any further questions about the study, I can contact Delaine Young at dyoung@lindenwood.edu or 636-949-4684.

I. CONSENT

I have been given a copy of this consent form to keep.
PARTICIPATION IN THIS RESEARCH STUDY IS VOLUNTARY. I am free to decline to participate in this research study, or I may withdraw my participation at any point without penalty. My decision whether or not to participate in this research study will have no influence on my present or future status at Lindenwood University.

Signature ________________________________ Date ________________
Research Participant

Signature ________________________________ Date ________________
Primary Investigator

Signature ________________________________ Date ________________
Secondary Investigator

Appendix E

UI NUMBER____________

PARTICIPANT QUESTIONNAIRE

DATE ______________ AGE ___________SPORT ______________________________

SPORT POSITION(S)/EVENTS____

DOMINANT LIMB R L HEIGHT(cm) ___________________________

SPORTS EXPERIENCE

HOW LONG HAVE YOU BEEN PLAYING IN THIS COLLEGIATE SPORT?

_________ YEAR(S)

HAVE YOU PLAYED OTHER SPORTS IN HIGH SCHOOL OR COLLEGE? Y N

WHAT SPORTS/EVENTS HAVE YOU PLAYED AND HOW LONG HAVE YOU PLAYED THEM?

____

PREVIOUS INJURY HISTORY

LOW BACK PAIN – DEFINED AS PAIN LOCATED BETWEEN YOUR LAST RIB TO THE UPPER BUTTOCKS

HAVE YOU HAD LOW BACK PAIN DURING YOUR SPORTING CAREER?

Y N

AT WHAT AGE DID THE LOW BACK PAIN START? ___________ YEARS AGO

DO YOU REMEMBER HURTING YOUR LOW BACK? Y N

IF YES, PLEASE STATE HOW IT HAPPENED________________________

AT WHAT AGE DID YOU START TREATING YOUR BACK PAIN?

________ YEARS OF AGE

AT WHAT AGE WAS THE PAIN AT ITS WORST? _____________ YEARS OF AGE

HAS YOUR LOW BACK PAIN MADE YOU CHANGE POSITIONS IN YOUR SPORT? Y N

HAS YOUR LOW BACK PAIN MADE YOU STOP PLAYING YOUR CURRENT SPORT AT ANY TIME OF YOUR CAREER? Y N

HOW LONG WERE YOU OUT? __________

WHAT WAS YOUR DIAGNOSIS OF INJURY? ____________________________________

TREATMENT OF LOW BACK PAIN

WHO DID YOU SEEK FOR TREATMENT? (CHECK ALL THAT ARE RELEVANT)

MEDICAL DOCTOR (MD) FAMILY PHYSICIAN

CHIROPRACTOR (DC) DR. OF OSTEOPATHIC (DO)

ATHLETIC TRAINER ORTHOPEDIC NEUROLOGIST

NEUROSURGEON PHYSICAL THERAPIST

WHAT TYPE OF TREATMENT DID YOU RECEIVE FOR LOW BACK PAIN (CHECK ALL THAT ARE RELEVANT)

EXERCISES (AT HOME OR IN THE CLINIC)

MODALITIES (ELECTRICAL STIMULATION, ULTRASOUND, HEAT, ICE, MASSAGE)

MOBILIZATIONS (SLIGHT MOVEMENT OF VERTEBRAE BY CLINICIAN)

MANIPULATION (FROM PHYSICAL THERAPIST, CHIROPRACTOR, MD, DO)

SURGERY

CURRENT PAIN

LOW BACK PAIN

WHEN WAS THE LAST TIME YOU HAD BACK PAIN?

MONTH/YEAR ___________________________

HAVE YOU HAD BACK PAIN WITHIN THE LAST MONTH? Y N

DO YOU HAVE LOW BACK PAIN AT THIS TIME? Y N

WHAT SIDE DO YOU HAVE PAIN? R L BOTH MIDDLE

HOW DO YOU CURRENTLY RATE YOUR LOW BACK PAIN?

0 (NO PAIN) 1 2 3 4 5 6 7 8 9 10 (GET ME TO ER)

ARE YOU TAKING MEDICATION FOR YOUR LOW BACK PAIN? Y N

IF YES, WHAT TYPE? ____

<u>THORACIC PAIN</u> – DEFINED AS ANY PAIN BELOW THE NECK AND ABOVE LAST RIB

HAVE YOU HAD THORACIC PAIN WITHIN THE LAST MONTH? Y N

DO YOU HAVE THORACIC PAIN AT THIS TIME? Y N

WHAT SIDE DO YOU HAVE PAIN? R L BOTH MIDDLE

HOW DO YOU CURRENTLY RATE YOUR THORACIC PAIN?

0 (NO PAIN) 1 2 3 4 5 6 7 8 9 10 (GET ME TO ER)

ARE YOU TAKING MEDICATION FOR YOUR THORACIC PAIN? Y N

IF YES, WHAT TYPE?

____

<u>CERVICAL PAIN</u> – DEFINED AS PAIN BETWEEN THE BASE OF YOUR SKULL AND ABOVE YOUR SHOULDERS

HAVE YOU HAD CERVICAL PAIN WITHIN THE LAST MONTH? Y N

DO YOU HAVE CERVICAL PAIN AT THIS TIME? Y N

WHAT SIDE DO YOU HAVE PAIN? R L BOTH MIDDLE

HOW DO YOU CURRENTLY RATE YOUR CERVICAL PAIN?

0 (NO PAIN) 1 2 3 4 5 6 7 8 9 10 (GET ME TO ER)

ARE YOU TAKING MEDICATION FOR YOUR CERVICAL PAIN? Y N

IF YES, WHAT TYPE? ____

SHOULDER PAIN

HAVE YOU HAD SHOULDER PAIN WITHIN THE LAST MONTH? Y N

DO YOU HAVE SHOULDER PAIN AT THIS TIME? Y N

WHAT SIDE DO YOU HAVE PAIN? R L BOTH

HOW DO YOU CURRENTLY RATE YOUR SHOULDER PAIN?

0 (NO PAIN) 1 2 3 4 5 6 7 8 9 10 (GET ME TO ER)

ARE YOU TAKING MEDICATION FOR YOUR SHOULDER PAIN? Y N

IF YES, WHAT TYPE? ____

HIP PAIN

HAVE YOU HAD HIP PAIN WITHIN THE LAST MONTH? Y N

DO YOU HAVE HIP PAIN AT THIS TIME? Y N

WHAT SIDE DO YOU HAVE PAIN? R L BOTH

HOW DO YOU CURRENTLY RATE YOUR HIP PAIN?

0 (NO PAIN) 1 2 3 4 5 6 7 8 9 10 (GET ME TO ER)

ARE YOU TAKING MEDICATION FOR YOUR HIP PAIN? Y N

IF YES, WHAT TYPE? ____

Appendix F

LINDENWOOD UNIVERSITY / LOGAN COLLEGE OF CHIROPRACTIC

EVALUATION FORM - SUBJECT EXAMINATION

SUBJECT NUMBER:________________ AGE: _________ SEX: _______________________

SPORT: ____ **DATE OF EXAM:** ___________________

NOTES / COMMENTS: ____

____

CERVICAL REGIONAL EXAMINATION

Examination of the neck		
Muscles	**WNL**	**ABN-** ***Describe abnormal findings***
Tone		
Symmetry		
Tenderness		
Swelling		
Mass		
Heat		

Ranges of motion	***Active***		***Passive***		***Resisted***		***Describe and localize the pain if pain is elicited during the test***
	Measured	**Pain**	**No Pain**	**Pain**	**No Pain**	**Pain**	
Flexion 50^o							
Extension 60^o							
R. Rotation 80^o							
L. Rotation 80^o							
R. Lat. Flex. 45^o							
L. Lat. Flex. 45^o							

Nerve root Level	***Sensory***					
	L			***R***		
	WNL	**HYPO**	**HYPER**	**WNL**	**HYPO**	**HYPER**
C2						
C3						
C4						
C5						
C6						
C7						
C8						
T1						

Deep Tendon Reflexes		
(graded 0-4)	***L***	***R***
Biceps (C5)		
Triceps (C7)		
Brachioradialis (C6)		

Motor (graded 0-5)		
Muscles	***R***	***L***
Deltoid (C5)		
Biceps (C6)		
Wrist Extension (C6)		
Triceps (C7)		
Finger Extension (C7)		
Finger Flexion (C8)		
Finger adduction (T1)		

Orthopedic Tests: Indicate by R or L if there is a positive response on one side or by a check if the test does not require bilateral testing

Tests	**NEG**	**POS**	**PAIN**	***Describe and localize the pain if pain is elicited during the test***
Foraminal Compression				
Max Foraminal compression				
Jackson's Compression				
Spurling's				
Cervical Distraction				
Shoulder Depression				
Valsalva				
Dejerine's Triad				

SHOULDER REGIONAL EXAMINATION

Scapulo-Humeral Rhythm (3:1 ratio)			
G/H abduction	***Scapular abduction***		
	Normal	***L***	***R***
30^o	(10^o)		
60^o	(20^o)		
90^o	(30^o)		

Shoulder Ranges of motion		***Active***			***Passive***		***Resisted***		***Describe and localize the pain if pain is elicited during the test***
		Measure	**Pain**	**WNL**	**Pain**	**No Pain**	**Pain**	**No Pain**	
Flexion 180^o	**L**								
	R								
Extension 50^o	**L**								
	R								
Abduction 180^o	**L**								
	R								
Adduction 50^o	**L**								
	R								
Int. Rotation 90^o	**L**								
	R								
Ext. Rotation 90^o	**L**								
	R								

***Orthopedic tests** – For each test indicate No finding bilaterally (N/Bil.) or pain/positive test on the left, right or both sides (check L, R, or both)*				
Shoulder Tests	**N/Bil.**	**L**	**R**	***Describe and localize the pain if pain is elicited during the test***
Dugas				
Apprehension				
Drop Arm Test				
Apley's Scratch				
Supraspinatus Press				
Subacromial Push Butto				
Impingement Test				
Dawburn's				
Yergason's				
Abbot-Saunders				
Speed's				
Transverse humeral ligament test				
Thoracic Outlet Tests	**N/Bil.**	**L**	**R**	***Describe and localize the pain if pain is elicited during the test***
Allen's Sign				
Wright's				
Adson's, & Modified Adson's				
Costoclavicular				
Eden's				
Reverse Bakody's				

THORACIC, LUMBAR, AND HIP REGIONAL EXAMINATION

Standing Orthopedic Tests		
Test Toe Walk (S1,S2)	WNL	ABN- ***Describe abnormal findings***
Heel Walk (L4,L5)		

Sensory													
Nerve root Level	***L***			***R***			***Nerve root Level***	***L***			***R***		
	WNL	HYPO	HYPER	WNL	HYPO	HYPER		WNL	HYPO	HYPER	WNL	HYPO	HYPER
T1							***T7***						
T2							***T8***						
T3							***T9***						
T4							***T10***						
T5							***T11***						
T6							***T12***						

Deep Tendon Reflexes (graded 0-4)	***L***	***R***
Patellar (L4)		
Achilles (S1)		

Motor - Muscles graded 0-5	***L***	***R***
Hip Flexion – Iliopsoas (L1,2,3)		
Leg Extension – Quadriceps (L2,3,4)		
Gluteus Medius (L5)		
Hip Extension – Gluteus Maximus (S1)		
Hip Adduction (L2,3,4)		
Tibialis Anterior (L4)		

Extensor HallucisLongus (L5)		
Peroneus Longus, &Brevis (S1)		

Thoracic Ranges of motion	***Active***		***Passive***		***Resisted***		***Describe and localize the pain if pain is elicited during the test***
	Measured	**Pain**	**No Pain**	**Pain**	**No Pain**	**Pain**	
Flexion 35-50°							
Extension 0°							
R. Rotation 25-35°							
L. Rotation 25-35°							
R. Lat. Flex. 20-40°							
L. Lat. Flex. 20-40°							

Lumbar Ranges of motion	***Active***		***Passive***		***Resisted***		***Describe and localize the pain if pain is elicited during the test***
	Measured	**Pain**	**No Pain**	**Pain**	**No Pain**	**Pain**	
Flexion 60°							
Extension 25°							
R. Rotation 45°							
L. Rotation 45°							
R. Lat. Flex. 25°							
L. Lat. Flex. 25°							

Orthopedic Tests: Indicate by R or L if there is a positive response on one side or by a check if the test does not require bilateral testing				
Seated Tests	**NEG**	**POS**	**PAIN**	***Describe and localize the pain if pain is elicited during the test***
Schepelman Sign				
Valsalva				
Dejerine's Triad				
Chest Expansion				
Passive Scapular Approximation				
Kemp's				
Bechterew's				
Tripod Sign				
Supine Tests	**NEG**	**POS**	**PAIN**	***Describe and localize the pain if pain is elicited during the test***
Sternal Compression				
Straight Leg Raise				
Well Leg Raise				
Braggard's				
Sicard's				
Milgram's				
Goldthwait's				
Patrick FABERE				
Thomas Test				
Gaenslen's				
Side-lying Test	**N/Bil.**	**L**	**R**	***Describe and localize the pain if pain is elicited during the test***
Ober's Test				

Prone Tests	**NEG**	**POS**	**PAIN**	***Describe and localize the pain if pain is elicited during the test***
Hibb’s				
Nachlas’				
Ely’s				
Yeoman’s				

Hip Ranges of motion		***Active***			***Passive***		***Resisted***		***Describe and localize the pain if pain is elicited during the test***
		Measured	**Pain**	**WNL**	**Pain**	**No Pain**	**Pain**	**No Pain**	
Flexion 100^{o}	**L**								
	R								
Extension 30^{o}	**L**								
	R								
Abduction 45^{o}	**L**								
	R								
Adduction 30^{o}	**L**								
	R								
Int. Rotation 40^{o}	**L**								
	R								
Ext. Rotation 45^{o}	**L**								
	R								

Appendix G

SPECIFIC TESTS

Grading of Manual Muscle Testing

Score	Description
0/5	The subject demonstrates no palpable muscle contraction.
1/5	The subject’s muscle contraction can be palpable, but no movement within the joint.
2/5	The subject is able to move in range of motion, but with gravity eliminated.
3/5	The subject is able to move in range of motion again gravity, but with out manual resistance.
4/5	The subject is able to move in range of motion with resistance.
5/5	The subject is able to move in range of motion with maximum resistance.

Note: (Prentice, 2011a)

Manual Muscle Tests

Test	Reference
Shoulder flexion	Prentice, 2011b
Shoulder extension	Shultz et al., 2005
Shoulder abduction	Dutton, 2002
Shoulder adduction	Hoppenfeld, 1976
Shoulder internal rotation	Anderson, Parr, & Hall, 2009
Shoulder external rotation	Hoppenfeld, 1976
Hip flexion	Prentice, 2011b
Hip extension	Hoppenfeld, 1976
Hip abduction	Anderson et al., 2009

Hip adduction	Shultz et al., 2005
Hip internal rotation	Prentice, 2011b
Hip external rotation	Hoppenfeld, 1976

Special Tests

Test	Reference
Allen’s Test	Evans, 2002
Adson’s Test	Konin, Wiksten, Isear, & Brader, 2006
Wright’s Test	Watkins, 1996
Eden’s Test	Shultz et al., 2005
Costoclavicular Test.	Evans, 2002
Schepelman Sign	Evans, 2002
Passive Scapular Approximation Test	Evans, 2002
Sternal Compression	Evans, 2002
Straight Leg Raise	Dutton, 2002
Well’s Leg Raise Test	Hoppenfeld, 1976
Braggard’s Sign	Konin et al., 2006
Goldthwait’s Sign	Evans, 2002
Sicard’s Sign	Evans, 2002
Milgrams test	Anderson et al., 2009
FABER’s test	Prentice, 2011a
Thomas Test	Shultz et al., 2005
Gaenslen’s Test	Konin et al., 2006

Tripod Test	Evans, 2002
Bechterew’s Sitting Test	Evan’s, 2002
Kemp’s Test	Evans, 2002
Ober’s Test	Prentice, 2011b
Hibbs’ Test	Shultz et al., 2005
Nachlas Test	Evans, 2002
Ely’s Test	Prentice, 2011b
Yeoman’s Test	Konin et al., 2006

Deep Tendon Reflexes Grading

Score	Description
0	No response
1+	Considered normal but the response is very slow
2+	Considered be normal
3+	Considered normal but the response is very quick
4+	Clonus reflex or repeated reflex

Note: (Dutton, 2002).

Reflexes

Nerve	Location	Reference
C5	Biceps reflex	Shultz et al., 2005
C6	Brachioradialis	Hoppenfeld, 1976
C7	Tricep tendon	Anderson et al., 2009
L4	Patella reflex	Prentice, 2011b
S1	Achilles reflex	Prentice, 2011b

Vitae – Ultrasound Specialist

Daniel W. Haun graduated summa cum laude from Logan College of Chiropractic. He completed a three-year residency in diagnostic imaging and a two-year fellowship in advanced imaging at Logan College. He received his diploma of the American Chiropractic Board of Radiology in 2008. He currently serves as associate professor in the clinical science division and chiropractic science division at Logan College of Chiropractic. His professional interests include diagnostic imaging, disorders of the spine, ad peripheral nervous system, clinical research, and chiropractic education. Dr. Haun has published in the Journal of Chiropractic Medicine, the Journal of Manipulative and Physiological Therapeutics, the Journal of Clinical Ultrasound, and the Journal of Ultrasound in Medicine and Biology, The Journal of Medical Ultrasound, and the Journal of Ultrasound in Medicine. Dr. Haun has five years of experience in diagnostic ultrasound of the musculoskeletal system.

Vitae

Delaine Young has been at Lindenwood University since 2000 and is currently working as an Associate Professor and Certified Athletic Trainer. She graduated with her Masters of Education from Southern Illinois University – Edwardsville and bachelors from Lakeland College (Sheboygan, WI) in Health and Fitness. Mrs. Young implemented the exercise science in 2008 and is currently the Program Coordinator. She has taught classes in athletic training, physical education, and exercise science within the Health and Fitness Sciences Department at Lindenwood University. Delaine has worked as an athletic trainer at numerous high schools and in physical therapy clinics in the St. Louis, MO area prior to her employment at Lindenwood. She also worked at Quincy College (IL) as Head Athletic Trainer and Assistant Basketball Coach, and played basketball for Oklahoma City University and Lakeland College.