HOW CORE STABILITY AFFECTS NON-CONTACT LOWER EXTREMITY INJURIES IN COLLEGIATE WOMEN'S VOLLEYBALL AND WOMEN'S AND MEN'S BASKETBALL PLAYERS

By

Janine Krista Pleau

A THESIS

Submitted to
Adams State College
in partial fulfillment of the requirements
for the degree of

M.A. in Human Performance and Physical Education

Exercise Science

Health, Physical Education, and Recreation

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ABSTRACT

HOW CORE STABILITY AFFECTS NON-CONTACT LOWER EXTREMITY INJURIES IN COLLEGIATE WOMEN'S VOLLEYBALL AND WOMEN'S AND MEN'S BASKETBALL

By

Janine Krista Pleau

The purpose of the study was (1) to determine if core musculature strength gains were better with floor exercises or physioball exercises and (2) to determine if the number of non-contact lower extremity injuries would decrease with stronger core musculature in varsity women's volleyball and varsity women's and men's basketball players. Over 8 weeks of summer workouts, 20 female intercollegiate volleyball, 9 female and 16 male intercollegiate basketball players were studied. They were divided into 3 groups, physioball (BAL), floor (FLR), and control and performed core exercises 3 times a week for 8 weeks. Each athlete's core stability was tested via prone core neuromuscular control (NMC), erector spinae stabilization endurance (ESE), and core strength (CST) tests. The control group had significantly weaker core in all 3 tests: NMC (control M= -1.33 mmHg, SD= 3.662 mmHg; BAL M= -7.467mmHg, SD= 4.438 mmHg; FLR M= -6.800 mmHg, SD= 5.493 mmHg); ESE (control M= 1.733 s, SD= 6.273 s, BAL M= 18.733 s, SD= 8.198 s; FLR M= 17.400 s, SD= 6.885 s); CST (control M= 2.133°, SD= 6.802°; BAL M= 22.400°, SD= 9.148°; FLR M= 22.667°, SD= 7.228°). BAL and FLR had 89% less ankle and 100% less knee injuries than the control group throughout this study. Control group had 25% more ankle and 150% more knee injuries than the BAL and FLR throughout this study. Physioball and floor exercises have similar core stability outcomes. Core stability has an important role in injury prevention.

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Chapter 1 - Introduction

As an athletic trainer, finding ways to prevent injuries is part of the job. For example, basketball and volleyball involve a great deal of cutting, twisting, pivoting, and jumping, which can increase the risk of lower extremity injuries. Due to a more sedentary life style in individuals today, extra emphasis should be placed on exercising core musculature in the athletic environment. In the sports where cutting, twisting, pivoting, and jumping are prevalent there is an increase in the number of ankle and knee injuries due to lack of body control. In the 13 years this researcher has been involved in working with numerous collegiate sports, most varsity sport weight training programs have focused on strengthening quadriceps, hamstrings, biceps, triceps, latissimus dorsi, and pectoralis major. They typically have not addressed the rectus abdominis, obliques, paraspinal, or other major stabilizers of the spine. As a result, many of these athletes have developed powerful arms and legs but have neglected to adequately train core musculature.

According to Gambetta and Gray (2006), training programs need to introduce controlled amounts of instability so that an individual must react in order to regain his or her own stability. In order to decrease the likelihood for injury, training programs should stress the core before extremity strength and use body weight for resistance before adding external resistance. The better one's core stability the less likely a person will sustain a lower extremity injury because he or she should have better control of their overall body movements (Juker, McGill, Kropf, & Steffen, 1998).

Gambetta and Gray (2006) also stated the body works synergistically with muscles, joints, and proprioceptors, thus no joint or body part works in isolation. Proprioception is the neural input from the joints, tendons, muscles, and other tissues which stimulate functional movement patterns. It is possible to be strong, fast, or flexible, but without the proprioceptors developed to an optimal level of movement, the movement will not be efficient and the athlete may become increasingly predisposed to injury. In essence, proprioception allows the body as a whole to be greater than individual segments working alone. For example, a volleyball player attacking a ball above the net produces force not only from the shoulder but also from her legs, hips, torso, elbow, and wrist. There is a constant cause and effect relationship in movement between force reduction and force production. Performance is a continuous interchange of force reduction and resulting force production taking place against a setting of stabilization. For motion to occur the body or a segment of the body will decelerate or reduce force before it accelerates to produce force resulting in the subsequent movement (Gambetta & Gray, 2006).

The current study directly focused on core stability and lower extremity injuries. This study hypothesized that collegiate varsity women's volleyball and women's and men's basketball players who performed the core strengthening program on the physioball (an unstable base for exercise) would have fewer injuries than athletes who performed the same core strengthening program on the floor alone; and both intervention groups would have fewer injuries than the control group. This study also hypothesized that there is a relationship between core stability and non-contact lower extremity injuries. This study proposes that more emphasis be placed on the core musculature in athletic lifting programs to avoid injuries to the lower extremities, especially in sports which revolve around quick directional changes such as cutting, twisting, pivoting, and jumping.

Statement of the Problem

The focus of the study was to determine whether there is an effect of core stability on non-contact lower extremity injuries in varsity women's volleyball and women's and men's basketball players.

Purpose of the Study

Specifically, the purpose of the study was (1) to determine if core musculature strength gains were better with floor exercises or physioball exercises and (2) to determine if the number of non-contact lower extremity injuries would decrease with stronger core musculature in varsity women's volleyball and varsity women's and men's basketball players.

Hypotheses

1. Physioball core workouts will show greater gains in core stability than floor workouts.
2. Physioball and floor core workouts will show a significant increase ($p < 0.05$) in core stability over the control group.
3. Non-contact lower extremity injuries will decline in concurrence with increased core stability in both groups.

Variables

The independent variable was the exercise program the athletes would perform: core exercises on the physioball or core exercises on the floor. The dependent variables were the non-contact lower extremity injuries the athletes sustained, pre-test measures for the prone core neuromuscular control test, core strength test, and erector spinae performance test, and post-test measures for these same tests.

Delimitations

The results of this study were delimited to varsity women's volleyball players, men's and women's varsity basketball players at one NCAA Division II institution, Western State College in Colorado. The lower extremity injuries only included the hip, knee, ankle, and foot. Experimental group A performed their exercise program on physioballs, whereas experimental group B performed their exercise program on a padded floor without the use of a physioball. The control group only performed core exercises that the individual teams normally performed as a group. Experimental group A's program consisted of sit-ups, lateral flexion, hyperextended curl up, stability walk outs, leg throws, back extensions, crunches, leg out and holds, seated back extensions, resisted twists, and vertical hip lifts (see Table 2 and Figure 4). Experimental group B's exercise program consisted of sit-ups, lateral flexion, hyperextended curl up, bridge, leg throws, back extensions, crunches, leg out and holds, kneeling back extensions, sitting side-to-sides, and vertical hip lifts (see Table 3 and Figure 5). Both programs consisted of three workouts per week for eight weeks.

Limitations

This study was limited by working with intercollegiate athletes' summer class and work schedules, as well as athletes leaving in order to visit with family and friends at home. If the athlete was gone for a week or more they were given the workout to take with them. If they had a conflict with one or two workout sessions in a week they re-scheduled those sessions, making them up either prior to the conflict or after.

Pre-existing upper and lower extremity injuries also limited this study. Athletes with pre-existing lower extremity injuries such as ankle, knee, or hip severe sprains and/or surgeries without medical clearance also limited this study because they were not able to perform one or more exercises and/or pre/post-testing exercises. Other lower extremity injuries such as pulled muscles and contusions which prevented an athlete from fully participating in practice for three or more days also limited this study due to the flexibility needed to perform many of the exercises and/or pre/post-testing exercises. Pre-existing upper extremity injuries such as hand, wrist, elbow, or shoulder severe sprains and/or surgeries without medical clearance also limited this study because participants were unable to perform one or more upper body exercises. These subjects were excluded from the study. For example, if the athlete was in experimental group B all exercises could be done with one arm; however, if placed in experimental group A they were excluded because they were unable to perform many of the physioball exercises.

If an athlete quit the varsity volleyball or basketball programs, the study was limited by reducing the number of athletes in the study. Though coaches' permission was granted, the non-compliance of athletes also limited this study.

Assumptions

It was assumed that all athletes put forth their maximal effort during pre-testing, the exercise program, and post-testing activities. It was also assumed that all participants would not perform any core exercises outside of this study, as well as being honest and factual on the pre and post questionnaires.

Definition of Terms

When core musculature was discussed in this study it included the gluteus maximus and medius, lumbar erector spinae, rectus abdominis, quadrates lumborum, internal and external obliques, transverse abdominis, diaphragm, lumbar multifidus, and piriformis musculature.

For this study an injury was defined as an event that occurred during athletic participation (game, practice, or weights) and required treatment or attention from the athletic trainer, team physician, or other medical staff. The event must have resulted in at least one full missed day of athletic participation (excludes contusions of the thigh, hamstrings, quadriceps, or gastrocnemius muscles due to contact making it a contact injury rather than a non-contact injury).

A non-contact injury was an injury in which another person was not involved. It was an injury that resulted from a speed change, cutting, twisting, pivoting, jumping, or landing motion in which no object or person came in contact with the athlete.

For this study, the lower extremities included the feet, ankles, knees, and hips.

For this study, the upper extremities included the hands, wrists, elbows, and shoulders.

A pre-existing condition was any grade three knee sprain (i.e. ACL reconstruction) within the last 15 months, any grade two or lower knee sprain within the last three months, any ankle or foot sprain within the last three months, any hip injury in the last three months, any grade two or higher lower back injury within the last six months, any shoulder surgery in the past three months, and any shoulder sprain in the past one to two months depending on severity (Arnheim & Prentice, 2000; Hubbard & Hicks-Little, 2008; Paulos et al., 1981).

Chapter 2 - Review of Literature

As competitive sports become more prevalent among today's adolescents, so do the injuries that are associated with them. The number of collegiate athletes is also increasing, consequently causing greater numbers of lower extremity injuries. However, the number of injuries reported is far greater than the increase in participants (Gallagher, Finison, Guyer, & Goodenough, 1984). This is in part due to the increased level of competition. It may also be due to the life-style changes of the athletes today. There is not an emphasis on posture as there once was; individuals spend more time at a computer or the television playing games rather than playing outdoor games (Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005). Physical education is being taken out of schools, and coaches emphasize stronger extremities (e.g., biceps, quadriceps) rather than muscles of the anterior and posterior aspects of the trunk (e.g. abdominals and paraspinals). All of this leads to weak core stabilizers. The purpose of the study was to determine if increased core stability would decrease the number of lower extremity injuries in collegiate athletes; if ball or floor exercises had a greater effect on core stability; if ball exercises were significantly better than floor exercises. The relevant findings from previous research in this review of literature served as a foundation for core stability and lower extremity injuries to be examined.

The following literature review was an investigation into previous research of the effects of physioball core stability and balance exercises with conventional floor exercises and their affect on core strength and the potential to reduce the number of injuries. The physioball is a dynamic surface causing individuals to utilize their abdominals and paraspinals to stabilize themselves in order to perform the exercises; whereas the floor is a static or stable surface that causes the abdominals and paraspinals to be in a relaxed state unless specifically engaged (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003).

According to Behn, Kenneth, and Curnew (2002) the primary purpose of instability training is to improve core stability, not strength; therefore a physioball exercise program should aim to gain stability, improve balance, and improve proprioceptive capabilities resulting in more control over one's body. Cosio-Lima et al. (2003) observed the effect of physioball and conventional floor exercises in back and abdominal core stability and balance in college-aged women. The five week functional training program resulted in significant increases in abdominal and erector spinae muscle electromyography (EMG) activity and duration of static balance times when compared to the floor exercises. These results supported the theory that performing abdominal and back exercises on unstable surfaces stressed the musculature and activated the neuroadaptative mechanisms that led to the early phase gains in stability and proprioceptors activity. Smith & Smith (2005) observed that a pilates-based core strengthening program would affect the fitness of older aging adults with decreased muscle function and strength. Pilates is an exercise modality that emphasizes core muscle strengthening via balance in maintaining a certain body position, musculoskeletal alignment, spinal mobility, and joint stabilization. Adults may benefit from pilates in many ways such as core strengthening, improvements in posture, postural stability, joint mobility, as well as balance and coordination from training movement patterns of the inner and outer core musculature (Richardson, Jull, Hodges, & Hides, 1999). A theoretical framework exists for core strengthening to enhance movement and prevent injuries in older aging adults. Current literature has not examined whether these exercises provide the specific training adaptations that could be used by trained athletes, as most of the research has been centered on elderly sedentary individuals (Cosio-Lima, et al., 2003; Smith & Smith, 2005); thus research into physioball and/or pilates exercise training in the collegiate athlete was warranted.

Anatomy

Research has shown that the core acts as an anatomical base for motion of the distal segments. That being stated, most of the prime mover muscles for the distal segments attach to the core of the pelvis and spine as do most of the major stabilizing muscles for the extremities (Kibler, Press, & Sciascia, 2006).

The lumbopelvic and thoracic region muscles compose the core musculature and are vital to postural stability. Richardson et al. (1999) defined the core as two distinct units: the inner and the outer. The outer unit muscles, responsible for secondary stabilization of the trunk include, but are not limited to, the gluteus maximus and medius, lumbar erector spinae, rectus abdominis, quadrates lumborum, and the internal & external obliques. The inner unit musculature is composed of the transverse abdominis, diaphragm, lumbar multifidus, and the piriformis which has been shown to provide the primary stabilization of the spine. Having a strong inner unit will create a strong biomechanical foundation for balance, posture, and movement patterns. If an individual has a weak inner unit, the muscles are recruited later creating an opening for injury and/or musculoskeletal dysfunction. For example, according to Richardson et al. (1999), one of the main causes of low back pain has been linked to a delayed recruitment of the inner unit. If one has a delayed recruitment of the inner unit, balance, posture, and movement patterns will be affected.

There are many muscles that compose the core. The small, short muscles (i.e. multifidi) with small lever arms are activated in "length dependent" muscle activation patterns. The larger, longer muscles are activated in "force dependent" activation patterns and are usually the prime mover muscles that integrate several joints and produce force. The small, short muscles are considered length-dependent muscles because they cross the joints of only one motion segment, whereas force-dependent muscles cross the joints of many motion segments (Kapit & Elson, 2002). Coordination of both activation patterns is required in multi-segmented structures such as the spine (Kibler, Press, & Sciascia, 2006). Therefore the shorter muscles that provide single joint segmental stabilization allow the longer, multi-joint muscles to work more efficiently to control spine motions (see Figure 1).

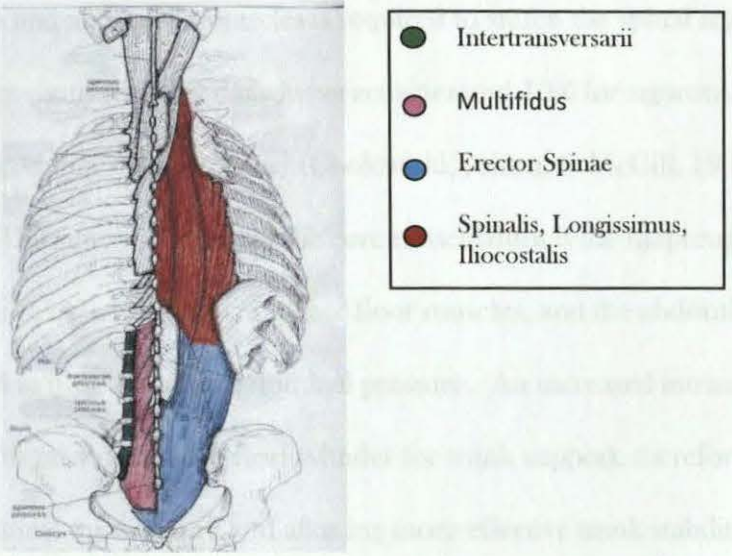

Figure 1. Length dependent muscles – the intertransversarii which cross the joints of only one motion segment (major postural muscles), and multifidus which span 1-3 motion segments from the sacrum to C2. Force dependent muscles – the erector spinae group comprises the principal extensors of the vertebral motion segments. The erector spinae splits into smaller, thinner bundles one attaching to the ribs which is the iliocostalis, the other two, longissimus and spinalis, attach to the upper vertebrae and head (Kapit & Elson, 2002).

The abdominal muscles which comprise the anterior portion of the core musculature consist of the transverse abdominis, the internal and external obliques, and rectus abdominis (Kibler et al., 2006). The transverse abdominals have been shown to be critical in stabilization of the lumbar spine by helping to create a rigid cylinder, and enhancing stiffness of the lumbar spine when contracted. There is evidence that the rectus abdominis and oblique abdominals are activated in direction-specific patterns dependent on extremity movements, thus providing postural support prior to extremity movements (Condro & Nasher, 1982; Kibler et al., 2006; Zattara & Bouisset, 1988). According to

Hodges, Butler, McKenzie, and Gandevia (1997) and Hodges (2003), contractions that increase intra-abdominal pressure occur prior to the initiation of large segment movements of the upper and lower limbs. Therefore, the spine and core of the body are stabilized prior to limb movements to allow the limbs to have a stable base for motion and muscle activation. Clinically, it has been shown that only a very small increase in activation of the multifidi and abdominal muscles is required to stiffen the spinal segments (5% of maximal voluntary contraction for daily living activities and 10% for rigorous activities such as sprinting, cutting, and throwing) (Cholewicki, Juluru, & McGill, 1999; Kibler et al., 2006).

The superior aspect of the core musculature is the diaphragm. Simultaneous contraction of the diaphragm, pelvic floor muscles, and the abdominal muscles are required to increase intra-abdominal pressure. An increased intra-abdominal pressure is needed to provide a more rigid cylinder for trunk support, therefore decreasing the load on the spinal musculature and allowing more effective trunk stability (Kibler et al., 2006).

The core musculature includes the muscles of the trunk and pelvis that are responsible for the maintenance of stability of the spine and pelvis and help in the generation and transfer of energy from large to small body parts during many sports activities. Core stability is an important component maximizing efficient athletic function. Function is most often produced by the kinetic chain, which is the coordinated sequence activation of body segments that places the distal segment in the optimum position at the optimum velocity with the optimum timing to produce the desired athletic task (Kibler et al., 2006). According to Kibler et al. (2006) the core is important in providing local strength and balance and to decrease back injury. Since the core is central to most kinetic chains of sports activities, an individual must be able to control one's core, balance and motion, in order to maximize all kinetic chains of upper and lower extremity function.

Physiology

Muscle activation is based on pre-programmed patterns that are task-oriented, specific for athletic activity, and are improved by repetition. Length-dependent patterns, which present stability around one joint, are mediated by gamma afferent input and involve reciprocal inhibition of muscle to provide stiffness around a joint. Force-dependent patterns incorporate the activation of multiple muscles to move several joints and develop force, and are mediated by Golgi Tendon Receptors (Kibler et al., 2006). The Golgi Tendon Receptors sense muscle tension and the rate of change in muscle tension, whereas the muscle spindle receptors sense muscle length and the rate of change in the muscle length (Baechle & Earle, 2000 and Powers & Howley, 2009). When a muscle generates force, the sensory terminals are compressed. This stretching deforms the terminals of the sensory fibers, opening stretch-sensitive channels, and fires nerve impulses that are transmitted to the spinal cord. This action potential signals the force being developed by motor units within the muscle and represents the whole muscle force (Mann, 2008). For example, the multifidus of the spine works in a length-dependent pattern stabilizing each vertebra, T1-S2, individually. This provides a portion of the stability needed to maintain balance in order to perform exercises on the physioball. Obtaining better control of the core musculature by repetitions on the physioball should create a more efficient or effective stabilizing cylinder therefore assisting in the precision and control of the distal extremities (i.e., arms and legs). An example of a force dependent pattern is the maximum gastrocnemius plantar-flexor (toes pointed downward) power that is generated from the hip muscles. An individual will have a much higher or more powerful jump if movement for the jump begins at the hips than they would if movement only occurred at the ankles.

Biomechanics

According to the "summation of speed" principle, there is a proximal to distal development of force and motion which includes core activation (Putman, 1993). Force control is also maximized through the core. The larger muscles in the central core create a rigid cylinder allowing a stable base for distal mobility. Therefore, the muscular rigid cylinder places most of the work/power of force development in the central core, allowing small changes in rotation around the central core to effect large changes in rotation in the distal segments, similar to the cracking of the end of a whip (Kibler et al., 2006).

Emery et al. (2005) defined proprioception as a sense of joint position and muscular control for joint stability. Proprioceptive balance training is used in rehabilitation following a sports injury and is becoming an important aspect in injury prevention in sports. Running, jumping, or pivoting on one leg relies on a sense of proprioception. There is evidence that static balance may improve following proprioceptive balance training using an unstable platform (Emery et al., 2005).

Injuries

According to Cosio-Lima et al. (2003), individuals may be less likely to be injured if there was more efficient control of upper and lower body muscles by having better body balance. For example, if an individual was walking on a mountain trail with uneven surfaces the individual would be less likely to fall and get injured if they had better body balance. Likewise if a basketball player went up for a shot and was bumped prior to leaving the floor he/she should still be able to complete the shot with slight adjustments due to core training and better overall control of their body. Traditional strengthening programs may not stress the core musculature of the torso, so further research on core stability training in these athletes is warranted. This type of training may be more beneficial than traditional strength training exercises in maintaining body stability and imitating the dynamic movements of sport activity (Cosio-Lima et al., 2003).

According to Emery et al. (2005), sport is the leading cause of injury requiring medical attention among today's healthy, younger population (15-19 years old). The impact of a sport injury in the younger population may be life-long, as there is evidence that knee and ankle injuries may result in an increased risk of osteoarthritis later in life (Blair, Kohl, Barlow, Paffenbarger, Gibbons, & Macera, 1995; Gillquist & Messner, 1999). Eight percent of the younger population drop out of sports activities each year due to an injury; consequently the reduction of physical activity resulting from sport-related injuries could have significant long-term effects on morbidity and mortality (Blair et al., 1995). Gallagher et al. (1984) performed a study analyzing the injury rates for individuals under the age of twenty. Their study revealed that injury rates and level of severity varied considerably, and were dependent on age and sex. Toddlers and teenagers experienced the highest injury rates and the level of severity increased with age particularly for male teenagers (2.06:1 ratio male vs. female). For both emergency room visits and admissions, the males seemed to have a greater injury rate than females for all levels and ages. Athletic participation was shown to be the second most common cause of injury for all ages after falls (most often on stairs). Gallagher et al. (1984) found that one out of every fourteen teenagers required some form of hospital treatment for a sports injury. Most of the injuries reported consisted of sprains, strains, and contusions followed by lacerations and concussions.

Emery et al. (2005) showed that by improving static and dynamic balance with a home-based balancing program, sports related injuries among healthy individuals were reduced. The individuals were given a 6 week home-based balancing program to complete. The sessions were supposed to last for about 20 minutes and progressed from a somewhat stable surface to an unstable surface by week four. Emery et al. (2005) found that individuals with a previous history (within one year) of a lower extremity injury found the training program more effective than an individual who reported no previous history of a lower extremity injury.

Emery et al. (2005) also showed evidence that previous injury may be associated with future injury. For example, an athlete who had a previous history of an ankle or knee injury was more likely to incur future trauma due to muscular compensation from the first injury. This compensation created a muscle imbalance and leads to another injury. Static and dynamic balance training showed effectiveness in preventing self-reported athletic injuries and reduced the risk of ankle sprains in basketball, volleyball, soccer, and hockey. Notably, the above sports involve a high degree of pivoting, change of direction, rapid acceleration and deceleration maneuvers, which may increase the likelihood of ankle and/or knee injuries (Emery et al., 2005).

Exercises

The exercises discussed in this section aided the selection of core exercises for the individual programs used in this study and listed in chapter three. Konrad, Schmitz, & Denner (2001) looked at a wide variety of different trunk exercises that were currently used for training and conditioning purposes in the athletic arena (e.g., competitive sports and rehabilitation). These included abdominal-flexion exercises such as the straight curl-up, cross curl-up, and vertical hip lift, all of which provided spine flexion without hip flexion and showed remarkable isolation of the abdominal muscles (see Figure 2). When the starting position for the curl-up included hyperextension there was a significant increase in oblique muscle activity and a minimal increase in rectus abdominis activity. When the straight curl-up was varied to a sit-up again the oblique muscles showed a significant increase in activity. The most demanding exercise was the vertical hip lift, in which all abdominal muscles were activated. The kneeling back extension exercise was shown to isolate the erector spinae muscles more than the trunk extension exercise or the fixed legs exercise; these exercises added hip extension along with spine extension (Konrad et al., 2001).

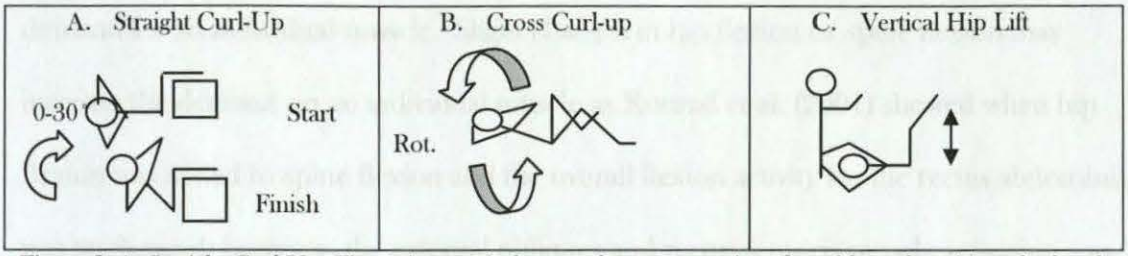

Figure 2. A, Straight Curl-Up. Fingertips touch the temples, arms are in a flexed lateral position, the head and shoulders are lifted, and the feet are not fixed. B, Cross Curl-Up. As in A, but 1 leg is across the other, and the contralateral elbow is moved to the opposite knee. C, Vertical Hip Lift. Knees are flexed between 70° and 90°, arms are fixed, hips are lifted until lumbar spine is lifted off the ground (30°).

Konrad et al. (2001) showed a clear difference for the activation of both abdominal muscles. The rectus abdominis had a single peak pattern in flexion exercises and a biphasic pattern in combined spine and hip flexion movements. High activation peaks were found at the beginning or end of the flexion period. As a general trend the external obliques showed a similar activation summary for flexion movements as the rectus abdominis. For lateral flexion exercises peak activation occurred towards the end of flexion.

Konrad et al. (2001) showed similar activation patterns for the erector spinae during back extension exercises. There was decreasing activation during flexion followed by a constant increase during extension, in which peak activity of the lumbar and thoracic erector spinae occurred at the end of the movement cycle. During the kneeling back extension exercise the lumbar erector spinae showed a constant activation level rather than a peak through the middle range of extension.

Konrad et al. (2001) found the most productive exercise for the back extensor muscles was a prone-lying extension of the whole body from a slight flexed hip position. This could be the combination of the subject's stable position and the activation of the whole extensor chain, which facilitated the activity of all the synergistic muscles. Interestingly, a training exercise does not necessarily generate a certain stimulus or level of demand for an individual muscle. Slight changes in hip flexion or spine flexion may increase the demand on an individual muscle as Konrad et al. (2001) showed when hip flexion was added to spine flexion and the overall flexion activity for the rectus abdominis was unchanged; however, the external obliques and rectus femoris muscle activation was significantly increased. When discussing the muscular training effectiveness and peak activation, Konrad et al. (2001) indicated that the sit-up was the more demanding exercise for both the rectus abdominis and the external obliques due to the increased contraction velocity and the need to accelerate the upper body more quickly during the beginning of the movement. As Axler and McGill (1997) showed, this happens at the cost of higher compressive forces on the lumbar vertebrae which may have unforeseen consequences such as an increased risk of low back pain (LBP). If an athlete has a history of LBP alternative exercises may need to be implemented to reduce the risk of continued pain and further injury. The peak activity for the upper rectus abdominis was significantly increased when the muscle was pre-stretched, as in the hyperextended curl-up (Konrad et al., 2001).

Konrad et al. (2001) showed the most active muscle during the bridging exercise was the erector spinae at the lumbar and thoracic portions (see Figure 3). Good isolation of the thoracic and lumbar erector spinae muscles was achieved with kneeling back extensions due to a flexed and static hip position. Kneeling back extensions along with trunk extension with the legs fixed produced a high neuromuscular activity for the spine extensor muscles labeling them as back training exercises. The greatest erector spinae activity occurs during the end of extension, when the body provides the longest lever arm. From a training standpoint, the last 25% of the extension cycle is the most productive (Konrad et al., 2001). In a comparison study between kneeling and standing back and hip extension, Gallagher et al. (1984) demonstrated that the angle-specific activation of the erector spinae muscle is strongly influenced by the hip and pelvis position and rotation.

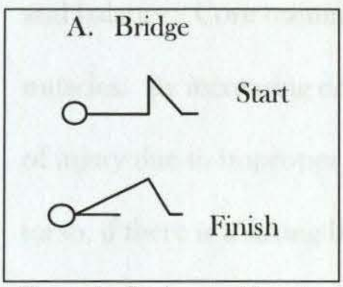

Figure 3. Supine position, trunk and arms resting on ground and hips flexed to 90 degrees, feet flat on the floor, hip extension to 0 degrees or neutral position.

Smith & Smith (2005) demonstrated that muscle imbalances become exaggerated with age and may significantly affect musculoskeletal function & movement patterns. Kendall and McCreary (1983) defined muscle imbalances as a disharmony in the tension relationships of muscles acting around a joint. With poor posture the muscles in slightly shortened positions (i.e., pectoralis) had a tendency to be relatively stronger. Consequently those in slightly elongated positions (i.e., rhomboids) tended to be the opposite, relatively weaker. The above muscle imbalances can be generalized to mature adults and should be considered when designing a program for improved strength, flexibility, posture, and reduced fall risk (Smith & Smith, 2005). Smith & Smith (2005) stated that the thoracic extensors, abdominal trunk flexors, spinal rotators, gluteals, and quadricep muscles had a tendency to be long and weak in individuals with poor posture. These weaknesses, due to postural changes, tended to affect an individual's gait, balance, and diaphragmatic function.

Core strengthening (e.g., trunk muscle strengthening, torso stabilization, and motor control training) has historically been applied to spinal injury rehabilitation (Smith & Smith, 2005). Core strengthening has become a staple for rehabilitation of not only the back, but the upper and lower extremities. Clinically, core training for all ages has been increasingly used as an adjunct to traditional therapies for reducing the occurrence and recurrence of muscle and joint injuries. It has also been shown to improve proprioception, coordination, and balance. Core training strengthens and re-educates weak abdominals and paraspinal muscles. By increasing core strength, postural sway decreases, thereby minimizing the risk of injury due to improper control of the body. Because the extremities are anchored to the torso, if there is a strong base at the torso or core, coordination and balance should be affected in a similar manner. Proprioception should also be affected in a similar manner because a person should have a better sense of where their extremities are due to an increase in whole body control. Therefore, frequently cited benefits of core strengthening include not only reduced injury rates, but also more efficient and powerful movement (Smith & Smith, 2005).

Research has shown that the transverse abdominis activation is independent and continuous during trunk movement, is controlled independently of other trunk muscles, and is recruited prior to limb movement. Taken together, these findings suggest that the transverse abdominis is one of the more important muscles in torso stability (Smith & Smith, 2005). If a neutral spine and pelvis are maintained during core strengthening activities, contraction of the transverse abdominis reduces the tension of muscles and other soft tissues around the lumbopelvic area and maximizes the movement patterns of the extremities (Smith & Smith, 2005). Researchers have shown the transverse abdominis to be continually contracted during trunk movement, responsible for co-activation patterns with the piriformis, and independent of trunk movement (Smith & Smith, 2005). Additionally, researchers have shown the lumbar multifidus to co-contract with the transverse abdominis to provide stiffening of the lumbar spine (Smith & Smith, 2005).

Kibler et al. (2006) viewed core stability as being pivotal for efficient biomechanical function to maximize force generation and minimize joint loads in all types of activities ranging from running to throwing. They also defined core stability as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities. Core stability is best understood as a highly integrated activation of multiple segments that provides force generation, proximal stability for distal mobility, and generated interactive movement for an individual (Gambetta & Gray, 2006; Kibler et al., 2006; Leetun, Ireland, Willson, Ballantyne, & Davis, 2004).

In summary, the core musculature acts as a corset to provide stability for all body parts. If an individual has a solid core, injuries should be less likely to occur because, as mentioned earlier, a person or athlete should have more control of not only their torso but also the extremities. Therefore, a strong core should improve balance, coordination, proprioception, and movement patterns. If a movement pattern is more fluent and has little if any muscle imbalances, then an individual should be able to perform motion patterns with greater efficiency and effectiveness. Taking all of these findings together, it is possible that an individual with better control of his or her core should be less likely to sustain a non-contact lower extremity injury.

Chapter 3 - Procedures

Population

The subjects for this research were 20 female varsity volleyball players, and 9 female and 16 male varsity basketball players from Western State College of Colorado (WSC), an NCAA Division II institution. Athletes in this study ranged from 18-27 years of age.

Setting

The WSC athletic training room and gymnasium were the settings for both experimental groups' (i.e., A & B) training and testing sessions.

Research Design

Prior to the study approval was obtained from the Adams State College Institutional Review Board (see Appendix A). Consent to conduct the study was also obtained prior to testing from coaches of participating athletes. All athletes who volunteered completed an informed consent form (see Appendix B), pre-questionnaire (see Appendix C), and were randomly placed into either experimental group A or B within each individual athletic team. Red shirt volunteers were automatically placed into the control group. A red shirt is an individual who is on a team and practices as usual (including weight training sessions) but does not participate in competitions. Each varsity athletic team performed the exercises together. Experimental group A performed the exercise program on physioballs. Experimental group B performed a similar exercise program as group A except exercises were conducted on the floor. All workout sessions performed at WSC were supervised by this researcher, also a certified athletic trainer.

After completing the informed consent and the pre-questionnaire, all groups performed pre-test measurements to determine core strength and endurance. Pre-test measurements were taken from the *National Academy of Sports Medicine: Integrated Core Stabilization Training* (by Clark, 2001) guideline and consisted of prone core neuromuscular control, erector spinae stabilization muscle endurance, and core strength tests (see Table 1 and Appendix D).

Table 1. Simplified pre-test/post-test measurements (Clark, 2001).

Prone Core Neuromuscular Control	**Core Strength**	**Erector Spinae Stabilization Endurance Test**
Prone w/ arms @ side.	Straight leg lowering test	Prone w/ hands behind head
Navel center of BP cuff. Cuff edges in line w/ R & L ASIS	Supine; BP cuff @ approx. L4-L5; inflated to 40mmHg	Extend lumbar spine 30 degrees & hold
Cuff inflated 70mmHg	Legs full extension; hips raised 90 degrees	Adequate stabilization endurance 30 sec
Pull abs off cuff; breath normal	Drawing in maneuver; flatten back; lower legs	
Hold contraction 10sec.	Over w/ increase or decrease of pressure	
5-10mmHg functional capacity dependent	Measure hip angle w/ goniometer; follow chart	

Next both groups began a one-week supervised familiarization period with exercises in their program. Experimental group A's exercise program utilized the physioball (BAL) and consisted of full sit-ups, lateral flexion, hyperextended curl ups, stability walk outs, leg throws, back extensions, quarter sit-ups, leg out and holds, seated back extensions, resisted twists, resisted pulls, and vertical hip lifts (see Figure 4). See Table 2 for sets and reps of the different exercises for BAL. Experimental group B's exercise program utilized the floor (FLR) and consisted of sit-ups, lateral flexion, hyperextended curl up, bridge, leg throws, back extensions, quarter sit-ups, leg out and holds, kneeling back extensions, sitting side-to-sides, and vertical hip lift (see Figure 5). See Table 3 for sets and reps of the different exercises for FLR.

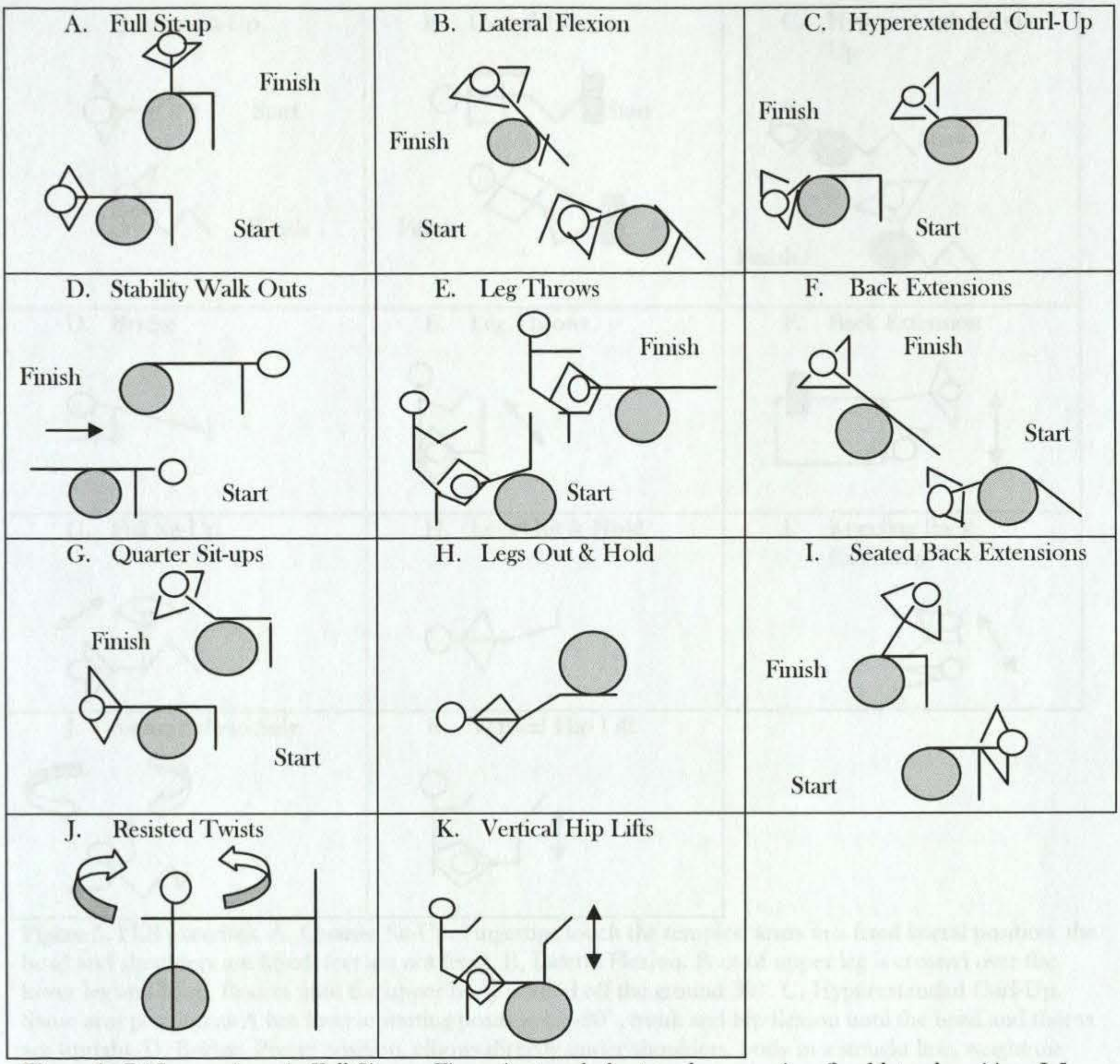

Figure 4. BAL exercises. A, Full Sit-ups. Fingertips touch the temples, arms in a fixed lateral position, L5 placed on top of the ball, the head and shoulders are lifted until the hips are at a 90° angle. B, Lateral Flexion. Brace feet against wall and floor, hip as close to top of ball as possible, hand closest the ground fingertips touch the temple, contralateral hand reaching over head to the floor, as movement begins bring other fingertips to the temple, bring elbow to same hip. C, Hyperextended Curl-Up. Fingertips touch temples, arms are in a fixed lateral position, back is relaxed to the curvature of the ball, head and shoulders are lifted to a quarter curl-up. D, Stability Walk Outs. Same hand and arm position as A, stomach on top of ball, legs straight, walk forward one hand at a time when laces on top of ball hold position, body in straight line. E, Leg Throws. Lower back on top of ball, hold on to another's legs with both hands, flex legs so hips are at 90°, individual will throw legs straight, right, and left, legs should not go below 0° of hip extension. F, Back Extensions. Supine position, brace feet against wall and floor, hips on top of ball, fingertips touch temples, arms are in a fixed lateral position, relax trunk over curvature of ball, raise head and trunk until 0° of hip extension. G, Quarter Sit-ups. Same starting position as A, the head and shoulders are lifted until hips are at a 45° angle. H, Legs Out and Hold. Lying prone, hands under gluteals, hips flexed to 45°, knees flexed at 45°, feet slightly apart, ball on top of lower legs, hold. I, Seated Back Extension. Sitting on top of ball, knees flexed to 90°, same arm position as C, starting position chest-leg contact, isolated spine extension (head and trunk) to 45°. J, Resisted Twists. Thera-band fixated to object, sitting on top of ball facing 90° away from object, hands at chest holding thera-band, twist trunk away from object. L, Vertical Hip Lift. Same starting position as E, legs flexed to 70°, hips are lifted until lumbar spine is lifted off ball (30°) (Friedman, 2004; Konrad et al., 2001; & The Hygenic Corp., 2003).

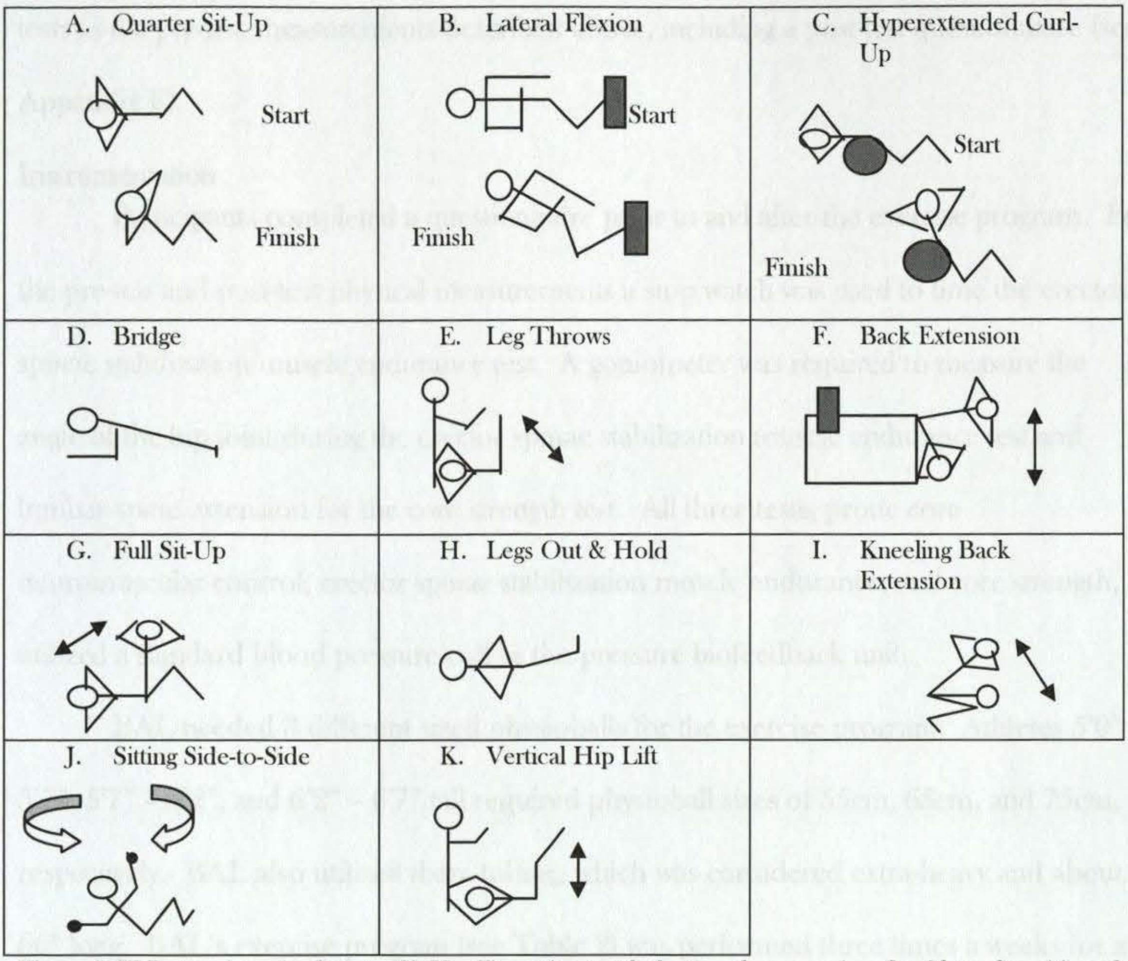

Figure 5. FLR exercises. A, Quarter Sit-Up. Fingertips touch the temples, arms in a fixed lateral position, the head and shoulders are lifted, feet are not fixed. B, Lateral Flexion. Foot of upper leg is crossed over the lower leg and fixed, flexion until the upper body is lifted off the ground 30°. C, Hyperextended Curl-Up. Same arm position as A but inverse starting position by -20°, trunk and hip flexion until the head and thorax are upright. D, Bridge. Prone position, elbows directly under shoulders, body in a straight line, weight on forearms and toes. E, Leg Throws. Legs are flexed to 70°, arms are fixed, partner pushes legs towards the floor straight, left, and right. F, Back Extension. Same arm position as A, lying prone on table with torso extended over the end of table, hips flexed to 80°, raise torso until hips are neutral (0°), feet are fixed. G, Full Sit-Up. Same arm position as A, the head, shoulders, and torso are lifted until shoulders are perpendicular to the floor. H, Legs Out & Hold. Lying in a supine position, hands are under butt, legs together and straight, raise legs 6" to 8" off floor. I, Kneeling Back Extension. Same arm position as A, from a flexed position (chest-leg contact), isolated spine extension (head and torso to 45°). J, Sitting Side-to-Side. Balance on gluts, feet off floor, rotate left to right touching medicine ball on ground each time. K, Vertical Hip Lift. Knees are flexed between 70° and 90°, arms are fixed, hips are lifted until lumbar spine is lifted off the ground (30°) (Konrad et al., 2001).

BAL and FLR followed their exercise protocols three times a week for a total of eight weeks. At the end of eight weeks all three groups, BAL, FLR, and the control group, performed post-test measurements. The post-test measurements consisted of the same tests as the pre-test measurements described above, including a post-test questionnaire (see Appendix E).

Instrumentation

Participants completed a questionnaire prior to and after the exercise program. For the pre-test and post-test physical measurements a stop watch was used to time the erector spinae stabilization muscle endurance test. A goniometer was required to measure the angle of the hip joint during the erector spinae stabilization muscle endurance test and lumbar spine extension for the core strength test. All three tests, prone core neuromuscular control, erector spinae stabilization muscle endurance, and core strength, utilized a standard blood pressure cuff as the pressure biofeedback unit.

BAL needed 3 different sized physioballs for the exercise program. Athletes 5'0" - 5'7", 5'7" - 6'2", and 6'2" - 6'7" tall required physioball sizes of 55cm, 65cm, and 75cm, respectively. BAL also utilized thera-tubing, which was considered extra-heavy and about 66" long. BAL's exercise program (see Table 2) was performed three times a weeks for a total of eight weeks (including one week of practice).

Table 2. BAL's Exercise Program (Bompa, 1999).

Exercises	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	Learning/Training							
Full Sit-up	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Lateral Flexion	2 x 10	2 x 10	2 x 15	2 x 15	3 x 15	3 x 15	3 x 20	3 x 20
Hyperextended Curl Up	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Stability Walk Outs	2 x 30 sec	2 x 30 sec	2 x 40 sec	2 x 40 sec	3 x 40 sec	3 x 40 sec	3 x 45 sec	3 x 45 sec
Leg Throws PB	2 x 10	2 x 10	2 x 15	2 x 15	2 x 20	2 x 20	2 x 25	2 x 25
Back Extensions	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Quarter Sit-up	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Leg Out & Holds	2 x 30 sec	2 x 30 sec	2 x 40 sec	2 x 40 sec	3 x 40 sec	3 x 40 sec	3 x 45 sec	3 x 45 sec
Seated Back Extensions	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
PB Resisted Twists/Pulls	2 x 10	2 x 10	2 x 15	2 x 15	3 x 15	3 x 15	3 x 20	3 x 20
Vertical Hip Lift	2 x 10	2 x 10	2 x 15	2 x 15	2 x 20	2 x 20	2 x 25	2 x 25

Table 3. FLR's Exercise Program (Bompa, 1999).

Exercises	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Sit-ups	Learning/Training 2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Lateral Flexion	2 x 10	2 x 10	2 x 15	2 x 15	3 x 15	3 x 15	3 x 20	3 x 20
Hyperextended Curl up	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Bridge	2 x 30 sec	2 x 30 sec	2 x 40 sec	2 x 40 sec	3 x 40 sec	3 x 40 sec	3 x 45 sec	3 x 45 sec
Leg Throws	2 x 10	2 x 10	2 x 15	2 x 15	2 x 20	2 x 20	2 x 25	2 x 25
Back Extensions	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Crunches	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Leg Out & Holds	2 x 30 sec	2 x 30 sec	2 x 40 sec	2 x 40 sec	3 x 40 sec	3 x 40 sec	3 x 45 sec	3 x 45 sec
Kneeling Back Extensions	2 x 15	2 x 15	2 x 20	2 x 20	3 x 15	3 x 15	3 x 20	3 x 20
Sitting Side-to-Sides (10 lbs)	2 x 10	2 x 10	2 x 15	2 x 15	3 x 15	3 x 15	3 x 20	3 x 20
Vertical Hip Lift	2 x 10	2 x 10	2 x 15	2 x 15	2 x 20	2 x 20	2 x 25	2 x 25

FLR's exercise program consisted of using 5 lb and 10 lb weight plates for the sitting side-to-side exercise. FLR also utilized basketballs for the hyperextended curl up. FLR's exercise program (see Table 3) was performed three times a week for a total of eight weeks.

Internal Validity

Previous research had not viewed core stability in the collegiate varsity athlete. Athletic trainers see an increasing number of foot, ankle, knee, and lower back injuries. This experiment proposed that an increase in core stability decreased the number and severity of lower, non-contact extremity injuries among varsity collegiate athletes.

External Validity

Due to the sample size, these results should not be generalized to a larger population, but applied only to male and female collegiate athletes who participate in organized varsity volleyball and basketball competition in the Rocky Mountain Athletic

Conference (RMAC), an NCAA Division II organization. The physical demands of a collegiate athlete are much higher than the demands of the average individual.

Treatment of Data

A one-way between groups ANOVA was used to compare the experimental groups, ball and floor, and control group's individual differences in percent change (Δ scores). The one-way between groups ANOVA stated statistical significance at $p < 0.05$. Individual t-tests were used to look at the difference between volleyball and basketball within each group with a stated statistical significance at $p < 0.05$.

The pre- and post-test questionnaires were used for base line descriptive characteristics. The injuries were tracked via an injury report in Microsoft Access injury reporting system and through the use of questionnaires. Due to the nature of the control group, non-contact lower extremity injuries were viewed as a descriptive characteristic. Descriptive data from the questionnaires were also used as needed during the results and discussion of the final thesis to underscore the importance of specific outcomes, such as possible injury prevention, when using floor or physioball exercises in accordance with regular conditioning and/or during rehabilitation of sport injuries.

Chapter 4 – Results

Descriptive Data

There were two main purposes to this study: One purpose was to determine if core musculature strength gains were better with floor exercises (FLR) or physioball exercises (BAL); the other was to determine if the number of non-contact lower extremity injuries would decrease with stronger core musculature.

It was hypothesized that physioball core workouts would show greater gains in core stability than floor workouts; physioball and floor core workouts would show a significant increase ($p < 0.05$) in core stability over the control group; and that non-contact lower extremity injuries would decline in concurrence with increased core stability gained from either floor or physioball exercises. There were a total of 50 participants that started the 8-week training program with 45 athletes completing the program. Each experimental group (BAL & FLR) consisted of eight volleyball, five men's basketball, and two women's basketball players. The control group consisted of four volleyball, six men's basketball, and five women's basketball players. The athletes that chose to discontinue the program did so because they left the college. Among the 45 athletes that did complete the 8-week training program, the compliance was 96% attendance for all training sessions.

Table 4 shows the average (mean ± SD) age, height, weight, and BMI of all the athletes in the floor, ball, and control groups. The average (mean ± SD) age, height, weight, and BMI of the volleyball team were 18.75 ± 1.33 years (range: 18-21 yrs), 67.69 ± 2.25 inches (range: 63.75 - 71 inches), 142.85 ± 16.06 pounds (range: 126-184 lbs), and 21.91 ± 2.05 kg/m² (range: 19.8-27.6 kg/m²), respectively. The average (mean ± SD) age, height, weight, and BMI of the women's basketball team were 20.22 ± 1.30 years (range: 18-21 yrs), 65.14 ± 6.53 inches (range: 54.75 - 72.75 inches), 150.33 ± 16.90 pounds (range: 123-168 lbs), and 23.4 ± 2.91 kg/m² (range: 18.7-28.8 kg/m²), respectively. The average (mean ± SD) age, height, weight, and BMI of the men's basketball team were 20.19 ± 1.56 years (range: 18-24 yrs), 74.02 ± 4.05 inches (range: 65.75 – 79 inches), 186.31 ± 20.68 pounds (range: 152-221 lbs), and 23.95 ± 1.85 kg/m² (range: 19.6-27.6 kg/m²), respectively.

The floor group was slightly younger, taller, and heavier than the ball or control groups. The floor group's BMI was slightly less than the control group and greater than the ball group's BMI. The ball group was slightly older, shorter, and lighter than the control group. However none of the differences were significant.

Table 4. Descriptive statistics for varsity athletes participating in an 8 week training session (N = 45).

Group	Floor (n = 15)		Ball (n = 15)		Control (n = 15)	
Dependent Variables	Mean	SD	Mean	SD	Mean	SD
Age (yrs)	18.87	1.25	20.07	1.44	19.73	1.79
Height (in)	69.57	6.38	69.32	3.68	69.4	5.9
Weight (lbs)	161.07	28.75	157.53	21.94	160.8	30.44
BMI (kg/m²)	22.81	2.09	21.74	5.95	22.91	2.48

One-way between-groups ANOVA

A one-way between-groups analysis of variance was conducted to explore the impact of different training surfaces on core muscles, as measured by the prone core neuromuscular control test (NMC). Subjects were divided into three groups; all red shirt athletes were placed in the control group, and the remaining volleyball and basketball athletes were randomly selected to either experimental group, BAL or FLR. Note: All forthcoming scores/data are reported as percent change from pre/post data unless otherwise stated. There was a statistically significant difference at the $p < 0.05$ level in NMC scores for the three groups: $F(2, 42) = 11.695$, $p < 0.001$. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for the control group (M = -0.133

mmHg, SD = 3.662 mmHg) was significantly different from BAL (M = -7.467 mmHg, SD = 4.438 mmHg) and FLR (M = -6.800 mmHg, SD = 5.493 mmHg). The difference between the control group and BAL and FLR groups was statistically significant at $p < 0.001$. There was no significant difference shown between the experimental groups. For the 95% confidence intervals for the mean see Table 5. See Table 6 for the percent change of the mean scores.

Table 5. 95% Confidence Interval for Mean Differences.

	NMC (mmHg)		**ESE** (Seconds)		**CST** (Degrees)	
Group	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Control	-2.161	1.895	-1.741	5.207	-1.634	5.900
Ball	-9.842	-3.758	13.587	21.213	18.664	26.669
Floor	-9.924	-5.009	14.193	23.273	17.334	27.466

A one-way between-groups analysis of variance was conducted to explore the impact of different training surfaces on core muscles, as measured by the erector spinae stabilization endurance test (ESE). Subjects were divided into three groups; all red shirt athletes were placed in the control group, and the remaining athletes were randomly selected to either BAL or FLR. There was statistically significant difference at the $p < 0.05$ level in ESE scores for the three groups: $F(2, 42) = 26.121$, $p < 0.001$. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for the control group (M = 1.733 seconds, SD = 6.273 seconds) was significantly different from BAL (M = 18.733 seconds, SD = 8.198 seconds) and FLR (M = 17.400 seconds, SD = 6.885 seconds). The difference between the control group and the experimental groups was statistically significant at $p < 0.001$. Again, no significant difference was shown between the experimental groups. For the 95% confidence intervals for the mean see Table 5. See Table 6 for the percent change of the mean scores.

A one-way between-groups analysis of variance was conducted to explore the impact of different training surfaces on core muscles, as measured by the core strength test (CST). Subjects were divided into three groups; all red shirt athletes were placed in the control group, and the remaining athletes were randomly selected to either BAL or FLR. There was statistically significant difference at the $p < 0.05$ level in CST scores for the three groups: $F(2, 42) = 34.267$, $p < 0.001$. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for the control group (M = 2.133 degrees, SD = 6.802 degrees) was significantly different from BAL (M = 22.400 degrees, SD = 9.148 degrees) and FLR (M = 22.667 degrees, SD = 7.228 degrees). The difference between the control group and the experimental groups was statistically significant at $p < 0.001$. There was no significant difference between the experimental groups. For the 95% confidence intervals for the mean see Table 5. See Table 6 for the percent change of the mean scores. For all raw data see Appendix F.

Table 6. Δ Percent Change.

Groups	NMC (mmHg)	ESE (Seconds)	CST (Degrees)
Control	0.196%	6.251%	3.053%
BAL	10.815%	73.378%	34.637%
FLR	9.808%	68.856%	32.162%

Injuries

According to the Microsoft Access database of injuries, as well as previous history according to the pre-test questionnaires, eight athletes per group, including BAL, FLR, and control groups sustained injuries in the previous season. Of the eight from the BAL and FLR groups, three sustained two injuries with the other five sustaining only one injury per group. The control group had two athletes sustain two injuries and six athletes sustain a single injury in the previous season. During this study the injuries in FLR were reduced to four athletes each sustaining one injury; of the four injuries only one was a recurring injury from the previous season and the other three injuries were new injuries. BAL was reduced to two injured athletes each with one injury of which both were new injuries, and the control group incurred up to 10 injured athletes with four athletes having two injuries and six athletes sustaining a single injury (see Figure 6). Eight out of the 10 injured athletes sustained an injury in the previous season, of those eight two athletes had recurring injuries.

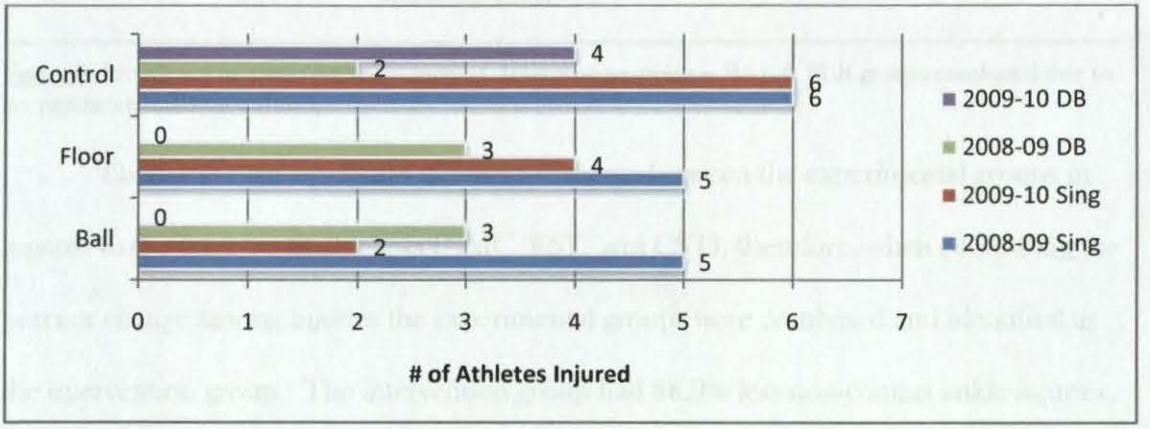

Figure 6. Single (sing) & double (DB) injuries sustained the year prior to & during the experiment according to treatment group.

Of the injuries that occurred during the 2008-09 season, volleyball players accounted for a total of 12 injuries: three from BAL, six from FLR, and three from the control group. During the 2008-09 season, basketball players accounted for a total of 20 injuries: eight from BAL, five from FLR, and nine from the control group (see Figure 7, note intervention group is BAL and FLR combined). Of the injuries that occurred during the 2009-10 season, volleyball players accounted for a total of 11 injuries: two from BAL, four from FLR, and five from the control group (see Appendix G for individual injury types). During the 2009-10 season, basketball players accounted for a total of nine injuries. All nine injuries incurred were from the control group (see Appendix G for individual injury types). To see the prevalence of pre and post lower extremity injuries between groups and sports see Appendix H.

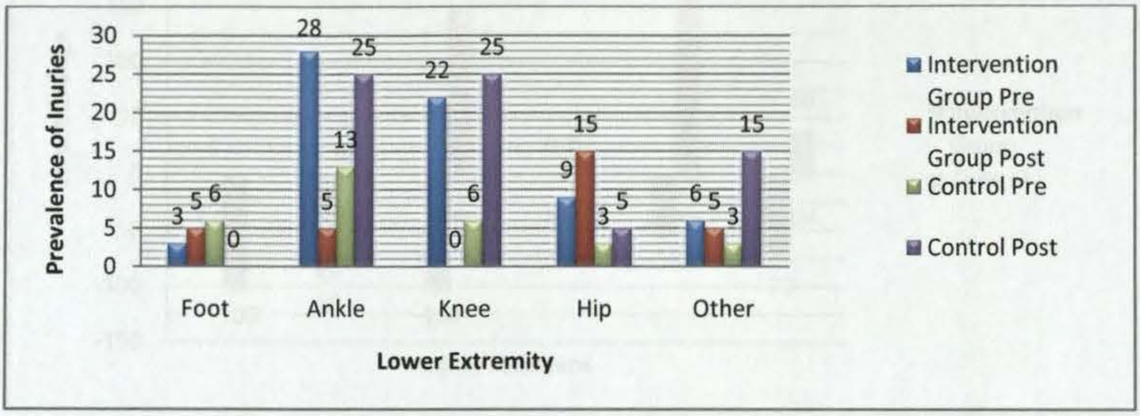

Figure 7. Prevalence of lower extremity injuries. Intervention group is BAL & FLR groups combined due to no significant difference shown.

There were no significant differences shown between the experimental groups in regards to the three muscular tests (NMC, ESE, and CST); therefore, when comparing the percent change among injuries the experimental groups were combined and identified as the intervention group. The intervention group had 88.9% less non-contact ankle injuries, 100% less non-contact knee injuries, and 72.7% less non-contact injuries from pre-training to post-training. The control group had 25% more non-contact ankle injuries, 150% more non-contact knee injuries, and 40% more non-contact injuries from pre-training to post-training (see Figure 8, note intervention group is BAL and FLR combined).

Lower Back Pain

Although low back pain (LBP) was not a focus of this study, it is worth noting that according to pre-questionnaires, there were seven athletes in BAL, four athletes in FLR, and three athletes in the control group with a history of LBP. Upon the post-questionnaire only two athletes from BAL and no athletes from FLR continued to have LBP. The control group showed an increase in LBP with eight athletes reporting LBP in their post-questionnaires (see Figure 9).

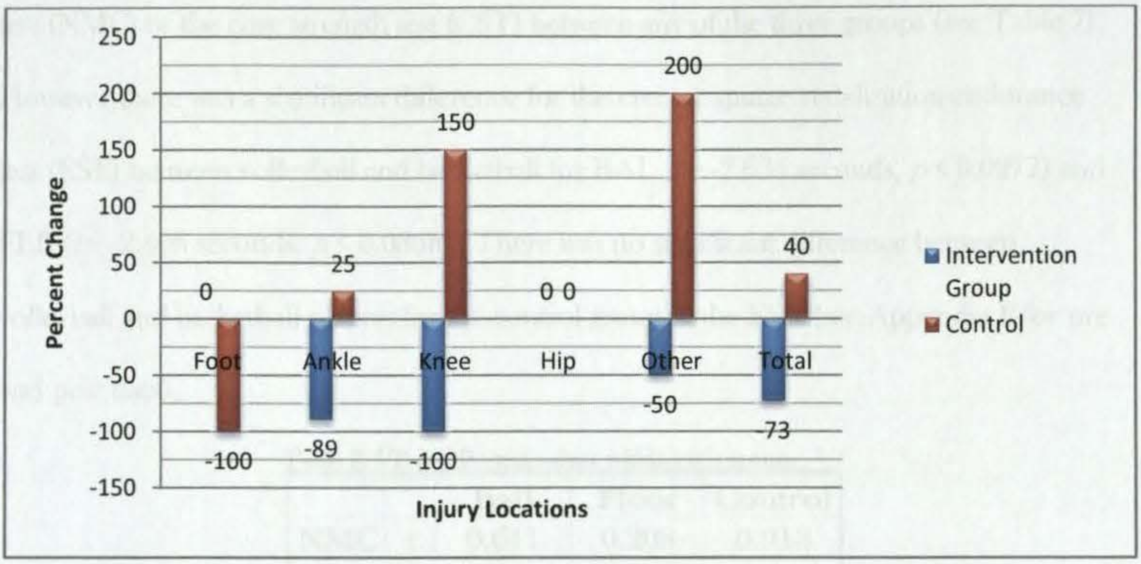

Figure 8. Percent change of injuries from pre-training to post-training. Intervention group is BAL & FLR groups combined due to no significant difference shown.

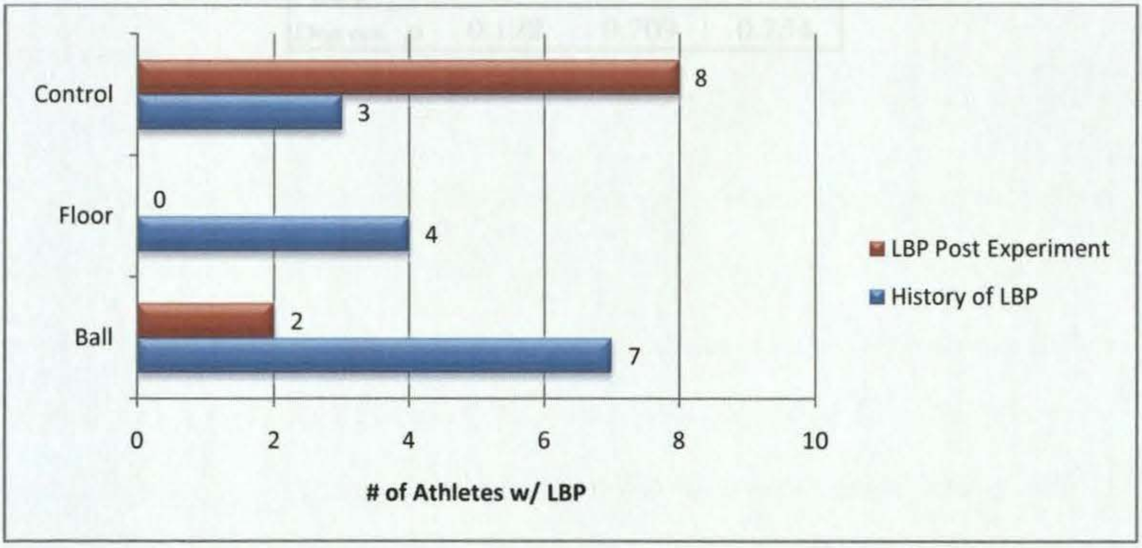

Figure 9. Pre and post experiment LBP.

Volleyball vs. Basketball Players

Independent t-tests were used to see if there was a significant difference ($p < 0.05$) between the volleyball and basketball players within each group: BAL, FLR, and control groups. Based on percent change from pre/post data there were no significant differences shown between volleyball and basketball players for the prone core neuromuscular control test (NMC) or the core strength test (CST) between any of the three groups (see Table 7). However there was a significant difference for the erector spinae stabilization endurance test (ESE) between volleyball and basketball for BAL (t = -2.635 seconds, $p < 0.0277$) and FLR (t = -2.406 seconds, $p < 0.0368$). There was no significant difference between volleyball and basketball players for the control group in the ESE (see Appendix F for pre and post data).

Table 7. VB & BB t-test values within each group.

		Ball	Floor	Control
NMC	t	0.611	0.208	0.913
mmHg	p	0.563	0.840	0.409
ESE	t	-2.635	-2.406	0.183
Seconds	p	0.028	0.037	0.862
CST	t	-1.749	0.384	-0.334
Degrees	p	0.122	0.709	0.754

Chapter 5 – Discussion

There was a significant difference in core stability scores between BAL and FLR in comparison with the control group. The control group was significantly weaker according to core stability scores after the 8-week training session in all three core strength tests (prone core neuromuscular control, erector spinae stabilization endurance, and core strength). Axler and McGill (1997) stressed the importance of the rate or speed of performance on muscle recruitment during abdominal exercises. If an individual has weak core stabilizers the recruitment of muscles will be insufficient, resulting in poor core strength scores. The core is central to almost all kinetic chains of sport activities; therefore a weak core would have more inefficient movements of upper and lower extremity function than a core that is strong (Kibler et al., 2006).

BAL vs. FLR

Core stability is vital for efficient biomechanical function to minimize joint loads in all types of activities (Kibler et al., 2006). Because BAL and FLR were performing similar core strengthening exercise programs there was no statistically significant difference shown between the two groups as hypothesized; however, BAL appeared to have slightly greater improvements in core strength. Cosio-Lima et al. (2003), showed similar findings with greater core stability and balance when studying physioball versus floor exercises. Due to the nature of their individual sports, volleyball and basketball, each athlete is presented with multiple unstable situations/activities every time they practice or compete in a game. For example, a volleyball player may have to readjust her jump just prior to take off to hit a ball that is set slightly behind her while landing off balance on one leg. Or a basketball player that pulls up for a short jump shot and is contacted on the hip by another player but has the ability to finish the shot and land successfully. One could argue that both experimental groups were training on an unstable surface resulting in similar core strength advances, such as constant mid air corrections of their individual sports outside of the given intervention (i.e. BAL vs. FLR). BAL, overall, showed slightly, but not significantly, greater improvements than FLR in all probability due to the physioball's unstable training surface. By training on the physioball, a round unstable object, BAL had to concentrate more on activating and engaging their core musculature in order to stay balanced while performing the exercises in the training program thereby resulting in slightly greater improvements. The control group would not receive these same core strength advances from practice situations because they would not have the same muscle base to react in a similar fashion.

It is interesting that within BAL and FLR groups there was a significant difference, at the $p < 0.05$ level, between volleyball and basketball players shown in the erector spinae stabilization endurance test (ESE). No significant difference was shown for the prone core neuromuscular control or the core strength tests. The ESE is the only test of the three that assesses the posterior musculature, mainly the erector spinae muscle group (Clark, 2001). The prone core neuromuscular control test mainly evaluates the transverse abdominis, whereas the core strength test evaluates the inner unit musculature, namely the transverse abdominis, internal oblique, and multifidus (Clark, 2001; Smith & Smith, 2005). This significant difference could be due to the specialized sport activities of volleyball (i.e., serving and spiking) versus basketball, or in that the basketball group was a combination of both sexes.

Differences between groups may also have occurred because of weight training programs. This researcher believes it has more to do with the specialized, sport specific activities because there was no significant difference in the control group which would have been performing the same weight training programs. The control group, consisting of red shirt athletes, did not receive the amount of repetitions in practice as the other athletes nor were they participating in competitions. Further research is needed for clarification.

Injuries

The experimental groups, BAL and FLR, also showed a decrease in non-contact lower extremity injuries; the control group experienced an increase in injuries. According to Cosio-Lima et al. (2003), the primary purpose of instability training is to improve core stability. By improving core stability one should also improve balance and proprioception capabilities thereby decreasing non-contact lower extremity injuries because one would have more awareness of where one's limbs are landing. In the present study, the experimental groups also showed a decrease in the number of re-injury or multiple injuries to a single athlete; whereas the control group had an increase in re-injury or multiple injuries to a single athlete.

Core stability is seen as being crucial for efficient biomechanical function; therefore an individual may be less likely to be injured if there was more efficient control of the upper and lower body muscles by having enhanced core stability (Cosio-Lima et al., 2003; Kibler et al., 2006). The control group was the only circumstance where an athlete encountered a season ending knee injury (ACL rupture). Notably, core stability is the product of motor control and muscular capacity of the lumbo-pelvic-hip complex. A weakness in this complex allows for more frequent non-contact lower extremity injuries due to excessive femoral adduction and internal rotation (Cosio-Lima et al., 2003; Kibler, et al., 2006; Leetun et al., 2004).

One would expect more non-contact injuries in basketball due to increased speed of directional changes, added frequency, higher velocity acceleration and deceleration changes, and fatigue; however, the findings from the present study do not support this theory, nor does past research on the topic (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007; Agel, Olsen, Dick, Arendt, Marshall, & Sikka, 2007; Dick, Hertel, Agel, Grossmen, & Marshall, 2007). The 2008-09 season injury report for this study was not as expected with basketball injuries at 20 and volleyball at 12. According to the NCAA Injury Surveillance System from 1988-89 through 2003-04, men's and women's basketball players incurred less non-contact lower extremity injuries than volleyball players (Agel et al., 2007; Agel et al., 2007; Dick et al., 2007). However during the 2009-10 season, which is when the 8-week core strength training program took place, basketball injuries decreased to only nine injuries and volleyball injuries totaled 11, decreasing by one. All nine basketball injuries were incurred by the control group, whereas the volleyball injuries were dispersed between the three groups with BAL sustaining two, FLR sustaining four, and the control group sustaining five. The volleyball injuries incurred by BAL were a muscular strain and a joint sprain, FLR sustained three muscular strains and a joint sprain, and the control group incurred three muscular strains and two joint sprains. It would have been interesting to evaluate the 2008-09 season's weight training programs for each sport to see the type of core strength training the individual programs had and if it had an effect on the number of injuries; however, this was not possible due to the lack of records. Also, since 64% of the injuries incurred by volleyball players were muscular strains it would be interesting in a further study to incorporate a stretching regime as well as a core strengthening program. For future research, the number of minutes played and the time of the injury should also be documented to see how much fatigue or coming off the bench after body temperature has returned to normal plays a part in sustaining an injury.

Chapter 6 - Conclusions

Summary & Conclusions

Core stability is a critical element in normal athletic activities. The body works synergistically with muscles, joints, and proprioceptors working as one unit; it's a constant cause and effect relationship between force production and force reduction (Gambetta & Gray, 2007). When a weak link is acquired in the cause and effect relationship, the likelihood of an injury is greater. The current study has shown it does not appear to matter whether one performs floor or physioball exercises. The gain in core stability and strength is similar. However, if one does not perform any core stability overload movements or other similar exercises, one may have an increased probability of a non-contact lower extremity injury as well as an increased probability of LBP.

The other element of core stability is represented by the athlete's ability to generate force or maintain force over time (endurance) in the lumbo-pelvic-hip complex. Leetun et al. (2004) suggest that the value or importance of the trunk muscles' endurance capacity is greater than the ability of these muscles to generate force in the prevention of low back pain. The endurance of the trunk extensors has been found to predict the occurrence of LBP among 30 to 60 year old adults (Leetun et al., 2004). Though the age group in the current study involved a population that ranged in age from 18 to 27, similar results were found. Cholewicki, Simons, and Radebold (2000) suggested the response of the trunk during sudden events depends on both the mechanical stability level of the spine before loading as well as the reflex response of the trunk muscles immediately after loading. Therefore, should an injury occur the athlete may lack the ability to generate sufficient force or resist external forces during high velocity twisting, cutting, jumping, and other events of that nature resulting in low back and/or lower extremity injury (Cholewicki et al., 2000).

Though LBP was not a focus of this study, it should be noted that there was a decrease in the number of LBP complaints in both experimental groups. Of the seven athletes that showed a history of LBP in BAL, only two had continued back pain after the eight week training session. Both of these athletes also showed a history of bulging discs in the lumbar area. There were four athletes who showed a history of LBP in FLR, and upon completion of the eight week training program all four had resolved. The control group had three athletes with a history of LBP and at the end of the eight week training session those three continued to have LBP as well as five new LBP complaints, for a total of eight LBP complaints.

Spine stability is achieved through the regulation of force in the surrounding muscles. Muscle force is somewhat linearly proportional to muscle stiffness; therefore, co-activation of agonistic and antagonistic trunk muscles stiffens the lumbar spine and increases its stability (Cholewiki et al., 2000). Possibly, these findings support the prescribed implementation of core exercises for rehabilitation of low back injuries and potentially for their incorporation into fitness training programs. The reason for this is that agonistic and antagonistic musculature is conditioned to be more stable resulting in more effective muscle stiffness and thereby reducing or eliminating LBP due to greater stabilization (Axler & McGill, 1997; Cholewiki et al., 2000). In the current study, the control group's core stability scores declined with the lack of core training and resulted in increased LBP. In accordance with Cholewiki et al. (2000), lower core stability scores would have resulted in less muscle stiffness, therefore decreasing spine stability and increasing LBP.

Recommendations

An eight week exercise program should be administered during the summer when athletes are in their non competitive season. The average exerciser should perform a similar eight week exercise program prior to starting any heavy lifting or vigorous plyometric workouts. If neither of the above is going to be attempted by the average exerciser, it is still a good idea to incorporate core strength/stability exercises into a workout three days a week for normal everyday activities. For more practical application this study should be revisited during the athlete's competitive season. During the athlete's competitive season he or she is practicing, playing, and weight training on a more regular basis. They are also in a more competitive environment which may increase their risk of injury. To elevate risk of injury to a potentially greater level, athletes routinely compete for a starting position and/or league title.

An additional study design improvement may be attempting to utilize a true random selection into the three different groups, thereby improving validity and strengthening current conclusions and/or recommendations. This researcher believes the only way this would be possible is if the teams were in a rebuilding year and the coach and/or institution did not mind putting key players at a potentially greater risk of injury. This is based on the current study which has shown if a key player is selected to the control group they have an increased probability of injury. On another note, a red shirt athlete is usually a walk-on athlete, typically younger and less experienced with long term training. Therefore they may be at an increased risk of injury from the very beginning. Lastly, a larger sample size would be an asset in order to apply the results to a broader group of elite college athletes.

Due to collegiate student-athletes' intense schedules, balancing academics, strength training, practices, games, travel, and possibly employment, restructuring the training program to include specific core strengthening exercises might be beneficial. In the current study the training sessions lasted roughly 45 minutes; splitting the exercises in half and performing half of the exercises one day and the other half of the exercises the next day may be a better approach. This researcher believes the athletes' attention span, and more importantly, efforts, would be enhanced and possibly result in even greater core stability/strength gains.

All the exercises in the eight week training program either overloaded the anterior, posterior, or lateral aspects of the core musculature and occasionally a combination of the three. This researcher noticed during the last 15-20 minutes of workouts a lack in attention to detail occurred. Therefore, more verbal cues were needed to correct posture and body position. Splitting the exercises in half and performing them on separate days would probably decrease the fatigue of the core musculature, thereby allowing for greater efforts on all exercises rather than a decreased effort on the later exercises due to fatigue or loss of focus. Because the athletes also tended to generate conversations amongst themselves, they tended to lose their concentration on simple but critical elements of the exercises such as pulling their naval towards their spine and keeping their core musculature tight throughout each targeted exercise.

Another way to possibly limit fatigue would be to rotate the exercises so different exercises are being performed at the end of each session. For example, the exercise that is performed last during one session would be performed first the next session. Continue this rotation throughout the established training cycle (5 week, 8 week, 12 week, etc). This type of rotation may also limit a training plateau in the later exercises. This researcher would recommend a combination of splitting the exercises as well rotating them.

For more practical application, this study should be revisited with larger groups of both male and female volleyball and basketball players. It would be interesting to see if the same significant difference showed up between volleyball and basketball players in the erector spinae stabilization endurance test. Future research should also examine other twisting, cutting, and jumping sports in addition to endurance sports to understand if there is a similar outcome. For example, a researcher could examine football and soccer because of the similarity with twisting, cutting, jumping, speed and directional changes, as well as track, cross country running and golf for their speed changes, rotary and terrain (grass, trails, water, mud, etc) components. Cholewicki et al. (2000) suggested that, in a more athletic population, isometric hip strength measures, in particular external rotation, are more accurate predictors of back and lower extremity injuries. Finally, core strength measures combined with isometric hip strength measures could strengthen the results of this study and its real world application.

This study provides support for the necessity of proper core strength for intercollegiate volleyball and basketball players in order to reduce the risk of non-contact lower extremity injuries as well as decrease the number of LBP complaints. This study has also shown that physioball and floor core strengthening exercises resulted in similar strength outcomes, thereby reducing non-contact lower extremity injuries and LBP. Due to the positive outcomes of reduced lower extremity injury and LBP, it would be recommended that one implement a similar program during an athlete's summer workouts or prior to pre-season training and especially in red shirt athletes with no current injury who may be more susceptible to injury.

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APPENDIX A

Stamped Approval Form

ASC IRB Committee

Informed Consent (Athletes)

Title of Project:

The effects of core stability on non-contact lower extremity injuries in colligate volleyball and basketball players.

Name of Principle Investigator: Janine Pleau, ATC, Master's student candidate, HPPE

Contact Names and Phone Numbers for Questions/Problems: Janine Pleau 970/260-5072 (c), 970/943-3168 (w); Tracey L. Robinson, Ph.D., Thesis Advisor, 719/587-7663; Brent King, Ph.D, Chair of IRB, 719/587-7010.

Purpose for the Research:

The purpose of the study is to determine if increased core stability will decrease the number of non-contact lower extremity injuries in collegiate volleyball and basketball players.

Procedure:

You will fill out a an informed consent form, pre-study questionnaire, and be randomly placed into either the control group or the experimental group within your athletic team. Each varsity athletic team will perform the exercises together, half in the experimental group, the other half in the control group. The control group will be performing a similar exercise program as the experimental group except they will be performing the exercises on the floor. The experimental group will be performing the exercise program on physioballs. All workout sessions performed at WSC will be supervised by the principle investigator, also a certified athletic trainer.

After completing the pre-questionnaire and the informed consent form both groups will be performing pre-test measurements. Pre-test measurements will be taken from the *National Academy of Sports Medicine: Integrated Core Stabilization Training* and consist of the prone core neuromuscular control test, erector spinae stabilization muscle endurance test, and core strength test.

Then, both groups will begin a one week practice training of the exercises in their program. The experimental exercise program will consist of full sit-ups, lateral flexion, hyperextended curl ups, stability walk outs, leg throws, back extensions, quarter sit-ups, leg out and holds, seated back extensions, resisted twists, and vertical hip lifts. The control group's exercise program will consist of sit-ups, lateral flexion, hyperextended curl up, bridge, leg throws, back extensions, quarter sit-ups, leg out and holds, kneeling back extensions, sitting side-to-sides, and vertical hip lift. The experimental group and control group will follow their exercise protocols 3 times a week for a total of 8 weeks, including the week of practice training. At the end of 8 weeks both the control group and the experimental group will perform post-test measurements. The post-test measurements will consist of the same tests as the pre-test measurements listed above, and a post-study questionnaire.

Risks:

There is a possibility of suffering an injury in the collegiate sport in which one participates. This risk is no different than normal collegiate athletic training or participation. One may experience some muscle soreness during the first one to two weeks of the exercise program. This would be caused by using muscles that have not been used in a while or have not been stressed in such a manner. In an attempt to minimize muscle soreness you will be put through a pre-exercise warm-up for 10 minutes and stretching before and after each training session. There is also a possibility of muscle cramping. In an attempt to minimize the risk of muscle cramping the athletes will be given a lecture on proper hydration and nutrition. There will also be water available during each exercise session to encourage proper hydration.

Confidentiality:

You will not put your name on the pre or post test questionnaire. You will be issued a number at the beginning of the study. Use this number for all documents throughout this study to ensure confidentiality. No names will be used, and no bias will be given to any one subject.

Participation:

Your participation in the research is voluntary. If you decide to participate in this study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

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Participant's Name (printed)

__________________________ __________________

Participant's Signature Date

__________________________ __________________

Investigator's Signature Date

ADAMS STATE COLLEGE
INSTITUTIONAL REVIEW BOARD
Approved on: JUL 15 2009
Expires on: JUL 15 2010

ADAMS STATE COLLEGE
INSTITUTIONAL REVIEW BOARD
Approved on: JUL 15 2010
Expires on: JUL 15 2011

APPENDIX B

Informed Consent

Informed Consent

Title of Project:

The effects of core stability on non-contact lower extremity injuries in colligate volleyball and basketball players.

Name of Principle Investigator: Janine Pleau, ATC, Master's student candidate, HPPE

Contact Names and Phone Numbers for Questions/Problems: Janine Pleau 970/260-5072 (c), 970/943-3168 (w); Tracey L. Robinson, Ph.D., Thesis Advisor, 719/587-7663; Brent King, Ph.D, Chair of IRB, 719/587-7010.

Purpose for the Research:

The purpose of the study is to determine if increased core stability will decrease the number of non-contact lower extremity injuries in collegiate volleyball and basketball players.

Procedure:

You will fill out an informed consent form, a pre-study questionnaire, and be randomly placed into either the experimental group A or experimental group B within each individual athletic team. Red shirts will be placed into the control group. Each varsity athletic team will perform the exercises together. Experimental group A will be performing the exercise program on physioballs. Experimental group B will be performing a similar exercise program as the experimental group A except they will be performing the exercises on the floor. All workout sessions performed at WSC will be supervised by the principle investigator, who is a certified athletic trainer.

After completing the pre-questionnaire and the informed consent form both groups will be performing pre-test measurements. Pre-test measurements will be taken from the *National Academy of Sports Medicine: Integrated Core Stabilization Training* and consist of the prone core neuromuscular control test, erector spinae stabilization muscle endurance test, and core strength test.

Then, both groups will begin a one week practice training of the exercises in their program. The experimental group and control group will follow their exercise protocols 3 times a week for a total of 8 weeks, including the week of practice training. At the end of 8 weeks both the control group and the experimental group will perform post-test measurements. The post-test measurements will consist of the same tests as the pre-test measurements listed above, and a post-study questionnaire.

Risks:

There is a possibility of suffering an injury in the collegiate sport in which one participates. This risk is no different than normal collegiate athletic training or participation. One may experience some muscle soreness during the first one to two weeks of the exercise program. This would be caused by using muscles that have not been used in a while or have not been stressed in such a manner. In an attempt to minimize muscle soreness you will be put through a pre-exercise warm-up for 10 minutes and stretching before and after each training session. There is also a possibility of muscle cramping. In an attempt to minimize the risk of muscle cramping the athletes will be given a lecture on proper hydration and nutrition. There will also be water available during each exercise session to encourage proper hydration.

Confidentiality:

You will not put your name on the pre or post test questionnaire. You will be issued a number at the beginning of the study. Use this number for all documents throughout this study to ensure confidentiality. No names will be used, and no bias will be given to any one subject.

Participation:

Your participation in the research is voluntary. If you decide to participate in this study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

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Participant's Name (printed)

___________________________ ___________________

Participant's Signature Date

___________________________ ___________________

Investigator's Signature Date

APPENDIX C

Thesis Questionnaire (Pre-test)

Thesis Questionnaire
(Pre-Test)

1) Which is your dominant leg?

2) Have you ever performed exercises on a Physioball before?

3) Do you currently perform any abdominal exercises?

4) If yes, what exercises do you perform and how many set/reps do you perform?

5) Do you currently perform any back exercises?

6) If yes, what exercises do you perform and how many set/reps do you perform?

7) Do you have any previous history of foot injuries?

8) If yes, what was the injury?

9) If yes, how long ago did the injury occur?

10) If yes, did you perform any structured rehabilitation for the injury?

11) If yes, how many times have you re-injured the same area?

12) Do you have any previous history of ankle injuries?

13) If yes, what was the injury?

14) If yes, how long ago did the injury occur?

15) If yes, did you perform any structured rehabilitation for the injury?

16) If yes, how many times have you re-injured the same area?

17) Do you have any previous history of knee injuries?

18) If yes, what was the injury?

19) If yes, how long ago did the injury occur?

20) If yes, did you perform any structured rehabilitation for the injury?

21) If yes, how many times have you re-injured the same area?

22) Do you have any previous history of hip injuries?

23) If yes, what was the injury?

24) If yes, how long ago did the injury occur?

25) If yes, did you perform any structured rehabilitation for the injury?

26) If yes, how many times have you re-injured the same area?

APPENDIX D

National Academy of Sports Medicine
Integrated Core Stabilization Training

"For the prone core neuromuscular control test one must first explain the concept of drawing-in. To draw-in instruct the athlete to pull their navel directly into their spine, without moving their pelvis. This should be practiced several times prior to initiating the neuromuscular control test. The formula test is conducted in a prone lying position, using a pressure biofeedback unit (blood pressure cuff) to obtain a measurement of the ability of the athlete to perform this abdominal isolation test. Isolated contraction of the transverse abdominis is more difficult in the prone position. The athlete will lay prone with their arms by their side. The pressure biofeedback unit (BP cuff) is placed under the abdomen with the navel in the center and the distal edge of the pad in line with the right and left anterior superior iliac spines. The BP cuff will be inflated to 70mmHg and allowed to stabilize. This pressure has been identified to be that which inflates the pad sufficiently to detect changes in the position of the abdominal wall but is comfortable and does not press into the abdominal contents. Instruct the athlete to pull their abdominal contents off the pad, while maintaining their normal breathing pattern. The athlete is required to hold the contraction for 10 seconds and produce a drop in pressure of 5-10 mmHg (depending on the functional capacity of each client)(70 mmHg starting → 65/60 mmHg ending). A pressure increase may occur in athletes who are compensating with the rectus abdominis and external oblique. The athlete may also try to perform a posterior pelvic tilt to accomplish this task which would also appear as an increase in pressure as well as pelvic movement (Clark, M., 2001)."

"Core strength can be assessed by utilizing the straight leg lowering test. The athlete will be placed supine with the BP cuff placed under the lumbar spine at approximately L4-L5. The BP cuff pressure is raised to 40 mmHg. The athlete's legs are maintained in full extension while flexing the hips to 90 degrees. The individual is instructed to perform the drawing-in maneuver and then flatten their back maximally into the table and BP cuff. The individual will then be instructed to lower their legs toward the table while maintaining their back flat. The test will be over when the pressure in the cuff decreases (back extends → hip flexor overactive) or increase (back flattens out→ rectus abdominis and/or external oblique become overactive). The hip angle is then measured with a goniometer to determine the angle. The chart below can be utilized to estimate the athlete's core strength level (Clark, M., 2001)."

Assessment of Core Strength	
Range of Motion (Degrees)	Percent Strength
90	0
75	15
60	30
45	45
30	60
15	75
0	100

"Erector spinae performance can be assessed by having the individual lying prone on a table, hands crossed behind their head. The axilla (arm pit) will be used as a reference for the axis of a goniometer. The adjustable arm will be aligned with the body and chin while the stationary arm is parallel to the table. The athlete is instructed to extend at the lumbar spine to 30 degrees and hold this position for as long as they can while one times the test. Research has demonstrated that an adequate time for stabilization endurance is 30 seconds without compensating then they need to work on stabilization endurance (Clark, M., 2001)."

National Academy of Sports Medicine
Written Consent

Janine,

I have forwarded you request to the appropriate team and have received a positive response. The National Academy of Sports Medicine has granted your request to use a portion of our material, provided that you use the proper citation within your Master's thesis (e.g., APA style). It is important to cite your sources and give the appropriate credit where needed. Our Academic team may contact you if they have further questions about your thesis.

Best Regards,

Mabel Robles BS, PES, CES, NASM-CPT
Education Support Representative
National Academy of Sports Medicine
1-800-460-6276 ext. 241
mabel.robles@nasm.org

Janine,

After review, please add the National Academy of Sports Medicine to your Appendix.

Thank you,

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APPENDIX E

Thesis Questionnaire (Post-Test)

Thesis Questionnaire
(Post-Test)

1) Did you perform any abdominal exercises outside of team conditioning?

2) If yes, what types of exercises? How many reps/sets?

3) Did you perform any back exercises outside of team conditioning?

4) If yes, what types of exercises? How many reps/sets?

5) Did you perform any balancing exercises outside of team conditioning?

6) If yes, what types of exercises? How many reps/sets?

7) Did you get injured at all during this past season?

8) If yes, what type(s) of injury(ies) did you sustain and did this(ese) injury(ies) occur during practice, game or weight lifting?

(Practice/Game or Weight Lifting)

Foot:

Ankle:

Knee:

Hip:

Low Back:

APPENDIX F

Pre and Post Data Collected

Pre-Test Floor		Post Floor		
Prone Core NM Control				Diff
		mmHg	mmHg	mmHg
1	VB	68	66	-2
2	VB	76	68	-8
3	VB	74	62	-12
4	VB	66	62	-4
5	VB	66	60	-6
6	VB	66	60	-6
7	VB	74	64	-10
8	VB	64	60	-4
VB Mean		69.25	62.75	-6.5
1	MBB	60	60	0
3	MBB	72	66	-6
4	MBB	80	60	-20
5	MBB	66	58	-8
6	MBB	80	66	-14
1	WBB	60	60	0
2	WBB	68	66	-2
BB Mean		69.43	62.29	-7.14
Mean		69.33	62.53	-6.8

Pre-Test Ball		Post Ball		
Prone Core NM Control				Diff
		mmHg	mmHg	mmHg
10	VB	66	60	-6
11	VB	66	60	-6
12	VB	76	68	-8
13	VB	74	66	-8
14	VB	68	62	-6
15	VB	74	68	-6
16	VB	66	60	-6
17	VB	68	60	-8
VB Mean		69.75	63	-6.75
7	MBB	68	60	-8
8	MBB	78	62	-16
9	MBB	62	60	-2
10	MBB	72	60	-12
11	MBB	62	58	-4
7	WBB	76	60	-16
9	WBB	60	60	0
BB Mean		68.29	60	-8.29
Mean		69.07	61.6	-7.46

Pre-Test Control		Post Control		
Prone Core NM Control				Diff
		mmHg	mmHg	mmHg
18	VB	76	74	-2
19	VB	66	74	8
20	VB	66	66	0
21	VB	66	66	0
VB Mean		68.5	70	1.5
12	MBB	68	62	-6
13	MBB	66	68	2
14	MBB	64	60	-4
15	MBB	66	68	2
16	MBB	62	66	4
17	MBB	74	68	-6
10	WBB	74	74	0
11	WBB	68	68	0
12	WBB	60	60	0
13	WBB	72	74	2
14	WBB	70	68	-2
BB Mean		67.64	66.91	-0.73
Mean		67.87	67.73	-0.13

Pre-Test Floor			Post Floor		Pre-Test Ball			Post Ball	
Erector Spinae Stabilization Endurance				Diff	Erector Spinae Stabilization Endurance				Diff
		Sec.	Sec.	Seconds			Sec.	Sec.	Seconds
1	VB	22	38	16	10	VB	23	36	13
2	VB	14	22	8	11	VB	28	41	13
3	VB	17	31	14	12	VB	32	48	16
4	VB	25	38	13	13	VB	37	58	21
5	VB	41	62	21	14	VB	22	39	17
6	VB	27	43	16	15	VB	13	21	8
7	VB	18	25	7	16	VB	28	36	8
8	VB	31	47	16	17	VB	23	41	18
VB Mean		24.38	38.25	13.88	VB Mean		25.75	40	14.25
1	MBB	20	50	30	7	MBB	36	51	15
3	MBB	31	51	20	8	MBB	36	53	17
4	MBB	21	47	26	9	MBB	34	47	13
5	MBB	28	47	19	10	MBB	18	48	30
6	MBB	39	60	21	11	MBB	23	54	31
1	WBB	25	51	26	7	WBB	15	42	27
2	WBB	20	28	8	9	WBB	15	49	34
BB Mean		26.29	47.71	21.43	BB Mean		25.29	49.14	23.86
Mean		25.27	42.67	17.4	Mean		25.53	44.27	18.73

Pre-Test Control			Post Control	
Erector Spinae Stabilization Endurance				Diff
		Sec.	Sec.	Seconds
18	VB	29	37	8
19	VB	5	13	8
20	VB	28	25	-3
21	VB	32	28	-4
VB Mean		23.5	25.75	2.25
12	MBB	38	34	-4
13	MBB	42	36	-6
14	MBB	33	36	3
15	MBB	25	38	13
16	MBB	28	40	12
17	MBB	28	30	2
10	WBB	20	25	5
11	WBB	18	20	2
12	WBB	27	25	-2
13	WBB	31	27	-4
14	WBB	32	28	-4
BB Mean		29.27	30.82	1.55
Mean		27.73	29.47	1.73

† The closer to 0 the better core strength measure.

Pre-Test Floor				Post Floor		Pre-Test Ball				Post Ball	
Core Strength					Diff	Core Strength					Diff
		Degree	†	Degree	Degrees			Degree	†	Degree	Degrees
1	VB	76	†	43	33	10	VB	40	†	23	17
2	VB	85	†	65	20	11	VB	65	†	47	18
3	VB	80	†	61	19	12	VB	77	†	60	17
4	VB	68	†	54	14	13	VB	67	†	42	25
5	VB	55	†	33	22	14	VB	80	†	65	15
6	VB	70	†	40	30	15	VB	73	†	48	25
7	VB	67	†	43	24	16	VB	60	†	45	15
8	VB	77	†	52	25	17	VB	70	†	52	17
VB Mean		72.25	†	48.86	23.38	VB Mean		66.5	†	47.75	18.63
1	MBB	63	†	48	15	7	MBB	65	†	35	30
3	MBB	75	†	46	29	8	MBB	72	†	42	30
4	MBB	59	†	37	22	9	MBB	45	†	22	23
5	MBB	65	†	49	16	10	MBB	62	†	32	30
6	MBB	62	†	36	26	11	MBB	60	†	45	15
1	WBB	70	†	60	10	7	WBB	67	†	20	47
2	WBB	85	†	50	35	9	WBB	67	†	55	12
BB Mean		68.43	†	46.57	21.86	BB Mean		62.57	†	35.86	26.71
Mean		70.47	†	47.8	22.67	Mean		64.67	†	42.2	22.4

Pre-Test Control				Post Control	
Core Strength					Diff
		Degree	†	Degree	Degrees
18	VB	75	†	67	8
19	VB	65	†	76	-11
20	VB	70	†	68	2
21	VB	70	†	65	5
VB Mean		70	†	69	1
12	MBB	49	†	45	4
13	MBB	68	†	65	3
14	MBB	63	†	63	0
15	MBB	78	†	75	3
16	MBB	70	†	65	5
17	MBB	76	†	73	13
10	WBB	75	†	70	5
11	WBB	80	†	85	-5
12	WBB	78	†	70	8
13	WBB	66	†	72	4
14	WBB	65	†	77	-12
BB Mean		69.82	†	69.09	2.55
Mean		69.87	†	69.07	2.13

† The closer to 0° the better core strength measure.

APPENDIX G

Injuries Sustained Pre & Post

Injuries Sustained Pre & Post

Table 9. Injuries sustained the year prior to core workout exercises.

Control 2008-09	Ball 2008-09	Floor 2008-09
Knee Overuse; Ankle Sprain	MCL Sprain; LMT	Toe Sprain; Hip Flexor Strain
Toe Sprain; Hip Flexor Strain	Ankle Sprain; Ankle Sprain	Knee Overuse; Groin Strain
Toe Sprain	Ankle Sprain; Ankle Sprain	Ankle Sprain; Knee Overuse
Knee Overuse	Knee Overuse	Quad Strain
Ankle Sprain	Ankle Sprain	Hip Flexor Strain
Ankle Sprain	Knee Overuse	Hip Flexor Strain
Ankle Sprain	Ankle Sprain	Ankle Sprain
Lower Leg Strain	Knee Strain	Ankle Sprain

Table 10. Injuries sustained during the same year as core workout exercises.

Control 2009-10	Ball 2009-10	Floor 2009-10
MCL Sprain; MMT	Hip Flexor Strain	Groin Strain
Hip Flexor Strain; Groin Strain	Ankle Sprain	Toe Sprain
Knee Overuse; Ankle Sprain		Hip Flexor Strain
Ankle Sprain; Ankle Sprain		Hip Flexor Strain
Quad Strain		
Knee Overuse		
Ankle Sprain		
Groin Strain		
ACL Rupture		
Ankle Sprain		

‡ One box is equivalent to one athlete.

APPENDIX H

Prevalence of Injury between Groups & Sports

Prevalence of Injury between Groups & Sports