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Predicting and Preventing Common Volleyball Injuries with Functional Tests

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Honors Thesis
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Abstract

The purpose of this thesis is to provide a compilation of screening tests best suited for predicting and preventing volleyball's most common injuries. Research displays a gap in knowledge pertaining to volleyball-specific injury prevention tests. A literary analysis was completed for information regarding; correct volleyball techniques, incorrect techniques that are commonly observed, common injuries resulting from faulty technique, and tests best designed to prevent these injuries. It was found that knees and ankles were the two joints most often injured. These injuries mainly occurred during the landing phase of the jumping-landing sequence. Therefore, ankle and knee injury rates were higher in front row attackers and blockers. Because data is more abundant for these two joints, the tests that were studied place a greater emphasis on ankle and knee injury prediction. All the tests used were designed to imitate game-like movements to provide the best results. These included; multiple variations of a single leg hop test to observe leg strength, and ankle and knee control upon landing, single leg squat test and drop jump to display correct knee technique, and to expose hip strength, the groin flexibility test to potentially predict adductor strains, core strength screenings that tested both abdominal and lower back strength, and finally, shoulder mobility and control tests. In conclusion, due to the growing popularity of volleyball, definitive sport-specific tests should be put into place to help reduce injury rates and prevent injury-related participation restriction.

Keywords: volleyball, injury, and prevention

Predicting and Preventing Common Volleyball Injuries with Functional Tests

Volleyball is an increasingly popular sport; meaning its physical demands are only growing with its popularity. Demanding practices and a competitive atmosphere and mind can create a hostile environment when it comes to an athlete's physical well-being. Fortunately, volleyball has relatively low rates of injury compared to other sports, such as football, basketball, or soccer, but injury rates are on the rise according to a recent study (Eerkes, 2012, p. 251). A majority of these injuries occur during preseason, with fewer injuries in the regular season and postseason (Hootman, Dick, & Agel, 2007, pp. 311-317). More specifically, recent research shows that seventy percent of all injuries, overuse or acute, occur in practice. This fact is opposite of other sports where injury occurs during competition (Baugh, Weintraub, Gregory, Djoko, Dompier, & Kerr, 2015, pp. 1-9). Research does not show the correlation between volleyball practices and the higher injury record.

Commonly injured areas include ankles, knees, shoulders, core/back, and groin/hip ("NCAA," 2009). A large portion of these injuries are due to overuse from repetitive jumping and landing sequences or arm swings during a serve or attack. Injuries from overuse and many acute injuries could be predicted and possibly prevented. Functional Movement Screen rates an athlete's range of motion and strength on multiple planes and in several areas (Kiesel, Plisky, & Voight, 2007, p. 148). This grouping of tests is rarely sport specific, so different sports will be tested in similar ways. Meaning, a soccer player who only uses her legs may be tested on the same spectrum as a volleyball player who uses her upper and lower body. The results of the tests are designed to show asymmetries between limbs and areas presenting abnormalities. These concerns may indicate that an athlete's predisposition to injury. Functional Movement Screening is commonly used for football players to predict injury and is proving very successful (Kiesel et

al., 2007). However, there is a gap in research failing to provide details about which specific functional tests are best suited for female volleyball players. Volleyball is a technique heavy game with many dynamic movements. The complexity of the sport leaves plenty of room for compensatory movements. With a volleyball-specific list of functionality tests, many of these injuries and participation restrictions might be prevented.

Methods

Search Strategy

A methodical literary analysis was conducted on articles published through January 2018. The following online databases were used for the literature review and results sections: PubMed, Google Scholar, JSTOR, and CINAHL Complete. For the results and discussion portions the websites, Shirley Ryan AgilityLab and Topend Sports, were utilized. Key terms for research included volleyball, kinetics, technique, injury, overuse and acute, compensation, ankle, knee, hip and groin, spine, shoulder, neuropathy, tend*, sprain and strain, injury and prediction, injury and prevention, mobility and flexibility, and strength. Articles concerning sports other than volleyball, but involving similar movements were included. Articles explaining mechanism of injury included, but were not limited to, volleyball or even sport-related injuries.

Literature Analysis

Articles were organized into four main categories: volleyball skills technique, common injuries, predictors of injury, and tests that may prevent these injuries. The injury, injury prediction, and injury preventative tests portions were then divided into five subcategories based on the anatomical areas most frequently injured. These regions include the ankle, knee, hip/groin/core, spine, and shoulder. Identifying the main volleyball-related injuries and understanding the kinetics of correct technique versus incorrect/compensatory movements helped narrow the search for predictor tests. Tests were selected by their ability to imitate match-like movements and expose underlying musculoskeletal weaknesses or issues. Many of the tests can be placed into one of the following categories: flexibility, mobility, agility, endurance, or strength. By testing an athlete in the preceding areas injury prediction may turn into injury prevention.

Literature Review

Kinetics and Correct Technique of Volleyball

Three main methods of contacting a volleyball discussed in this thesis include: serving, passing/digging, and attacking. The following descriptions for these movements are based on a right hand and right foot dominant athlete. The explanations will also follow the correct sequence of a volleyball rally.

Standing Serve. A rally is initiated by a serve, which can occur one of two ways. The standing serve requires the athlete to stand near the court's backline with their feet shoulder width apart, and their right foot slightly in front of the left. Holding the ball in her left hand, with the left arm fully extended in front of the body, the angle between her upper arm and her chest should be roughly 90-degrees. The right arm should be close to fully extended vertically above the head with the upper arm parallel to the right ear. The server will toss the ball with her left hand, slightly out in front of her body, at a height of approximately one and a half feet above her head. At the same time the server's right arm will slightly cock back in the ready position, and then swing forward in one fluid motion. The right hand will contact the middle of the ball roughly a foot above the head and in slightly in front of the body. This is achieved while stepping forward with the left foot and engaging the core to give more power to the serve. The standing serve is sequenced in *Figure 1*.

Jump Serve. In a jump serve the shoulder motion is the same, but multiple steps, usually three, are added to gain momentum. A jump is produced from the final, planting step and is concurrent with the toss and contact (Ciufarella et al., 2016, p. 29). *Figure 2* demonstrates this sequence of events. Jump serving is a quicker, generally more powerful movement, designed to speed up the game and put more pressure on the opponent. Acute injuries from serving are

unlikely, however, it can be common to sustain overuse injuries in the shoulder from standing and jump serves, and overuse injuries in the ankles from jump serves (Reeser & Bahr, 2017, p. 93; Attenborough et al., 2014, pp. 1546-1553).

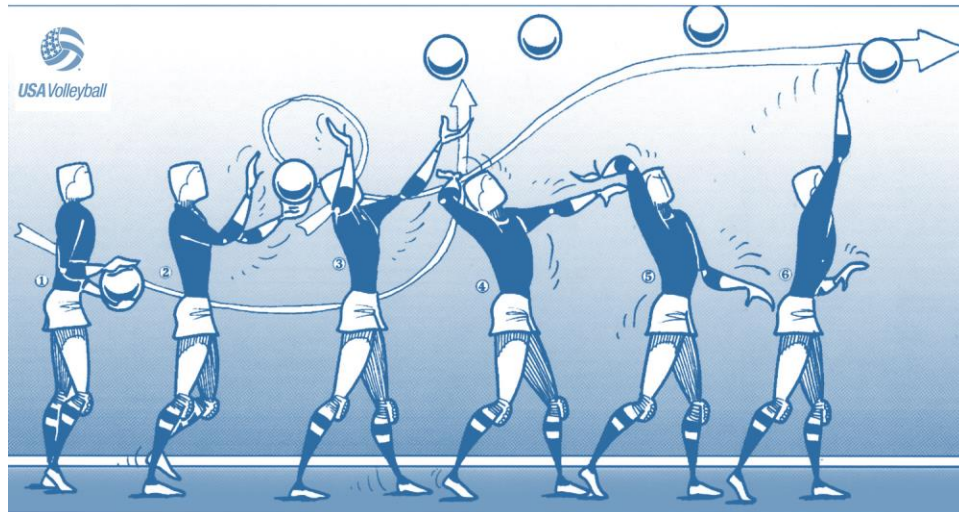


Figure 1: Standing Serve Sequence (“USA Volleyball,” n.d.)



Figure 2: Jump Serve Sequence (“Volleyball Training Ground,” n.d.)

Digging. Defensive movements are some of the most explosive in a rally. A defensive player has only a split second to react to a ball moving roughly 50-60 mph (average collegiate male speed; women’s not available) in her general direction, according to Shea from Livestrong.com (2017). It is her responsibility to keep the ball from hitting the floor. Sometimes this requires sharp lateral movements or diving to the floor. In anticipation of the attack, defensive players hold a half squat position, facing the attacker, with her feet just over shoulder

width apart. The upper body will lean forward slightly, and arms will be extended out in front of the body. It is crucial for the athlete to be on the balls of her feet to make bounding movements to the ball quicker and easier. Staying in this low, loaded position gives the defensive player more time to react and more power to move to the ball. This is considered an excellent base position. Once the ball has crossed the plane of the net the defensive player's first movement should be towards the ball. Second, the player will extend her arms perpendicularly to the body, with hands clasped. The arms should make a 90-degree angle with the body. The athlete's body should still be low and the shoulders should move forward to create this angle, as seen in *Figure 3*. The ball should meet the player's extended forearms just proximal of the wrists, this is known as her platform. As the ball hits the player's platform, the player will rise from her half-squatted position using her legs to lift the ball, and slightly drop a shoulder to angle it towards the target, or setter. Very few injuries are sustained from the dig itself. The majority of injuries seen in defensive players stem from the cutting movements that put the knee at risk just prior to a dig (Weltin, Gollhofer, & Mornieux, 2016, pp. 265-270). Other complications can arise from making fast movements in the crouched, base position without first stabilizing the core (Smith, Nyland, Caudill, Brosky, & Caborn, 2008, pp. 703-720).

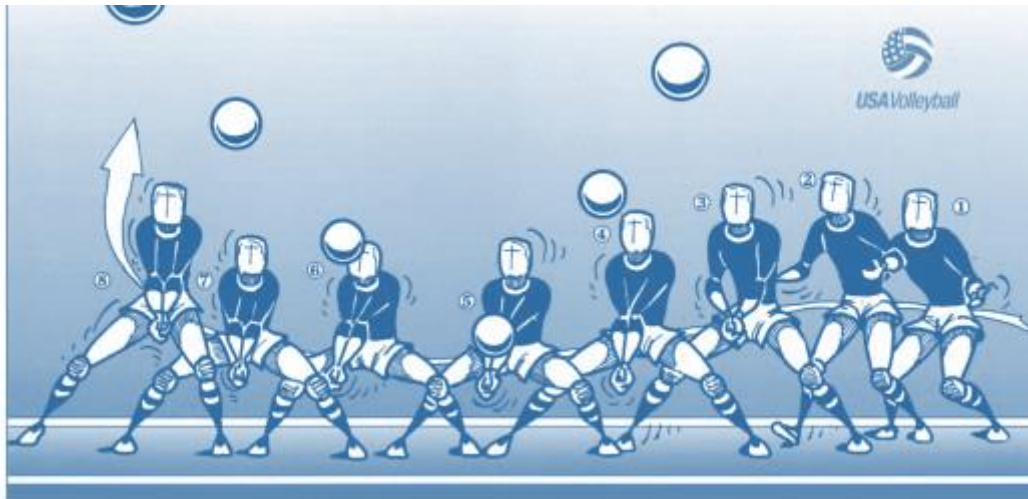


Figure 3: Digging Sequence (“USA Volleyball,” n.d.)

Setting. Setters are the third position most susceptible to injury (Bhat & Balamurugan, 2017, p. 68). The setter is responsible for running an offense and does so using an overhead technique with her hands. After a defensive player has passed the ball the setter will adjust her positioning to be directly under the ball (This may be a sprint across the court or a couple steps.). A perfect pass will fall directly onto the setter’s hands roughly two feet from the net and approximately eight feet from the right sideline. The setter’s body is positioned perpendicular to the net, facing the left front position, with feet shoulder width apart. As the ball reaches its peak, the athlete will raise both arms, almost completely extended, simultaneously with open hands. As the ball falls into their hands, the wrists will extend and the elbows will slightly flex. The ball is then launched to out to left front as the wrist follows through to a neutral position and the elbows fully extend slightly in front of the player. This is displayed below in *Figure 4*. This propels the ball in a high arch to the waiting attacker. Collegiate setter’s often hop as they follow through the set to speed up the set. This may put her at an increased risk for acute ankle injuries either due to ankle instability or landing on another player’s foot (Skazalski et al., 2017, p. 390).



Figure 4: Setting Sequence (“USA Volleyball,” n.d.)

Attacking. Front row attackers, specifically outside hitters, yield the most injuries compared to the other positions (Smith et al., 2008, pp. 703-720). For an attacker to begin the sequence, she must start around twelve feet from the net. When the ball is set, and reaches its peak height the attacker will take a large step with her left foot, then two quick steps with her right foot and left foot again, bringing them close to two feet from the net. The athlete will plant after this final step, lower into deep knee flexion and jump. During the approach the player’s arms will swing backwards and quickly follow through to gain momentum for the jump. As she jumps the left and right arm will simultaneously rise vertically until they are parallel to the ears. Similar to a serve, the right arm will slightly cock back and then rapidly accelerate forward to contact the ball with the hand and hit it over the net. The player’s back will flex as the arm cocks to engage her core in the follow through and give more power to the swing. Because of its complexity, seen in *Figure 5*, and frequency, the jumping-landing sequence (JLS) may produce inconsistent and incorrect techniques that could lead to injury. It is very important that the athlete land with both feet at the same time and absorb the landing in slight knee flexion. Landing

unbalanced or on one foot may lead to an acute injury, such as a knee ligament tear or sprained ankle. Landing in deep knee flexion, without knee valgus collapse (KVC), may decrease the athlete's chances of knee ligaments tears as well (Salsbery, 2018).



Figure 5: Attack Sequence (“USA Volleyball,” n.d.)

Blocking. Blocking holds the second highest percentage of injuries (Bhat & Balamurugan, 2017, p. 68). A blocker's sole job is to align her body in front of an attacker and attempt to stop the ball from crossing the plane of the net, as shown below in *Figure 6*. This is done by facing the net, standing no more than a foot away. As the opponent attacker contacts the ball, the blocker will flex at the knees and load with her arms. The athlete will then spring upward, fully extending her arms and reaching as high as they can above the net. Arms should be parallel with and touching the ears. Fingers will be spread apart and hands should be no more than a volleyball's width wide. It is important that the player does not come in contact with the net. Blockers will often slightly flex at the waist to create more room between her body and the net. This rule is very important. If a player is in the net then she may land over the center line,

which poses the threat of landing on an opponent. This is a common mechanism of ankle sprains in front row players (Skazalski et al., 2017). As seen in the attacking JLS, landing on one leg or with knee valgus may also pose potential risks for knee injury (Hurd, 2018).

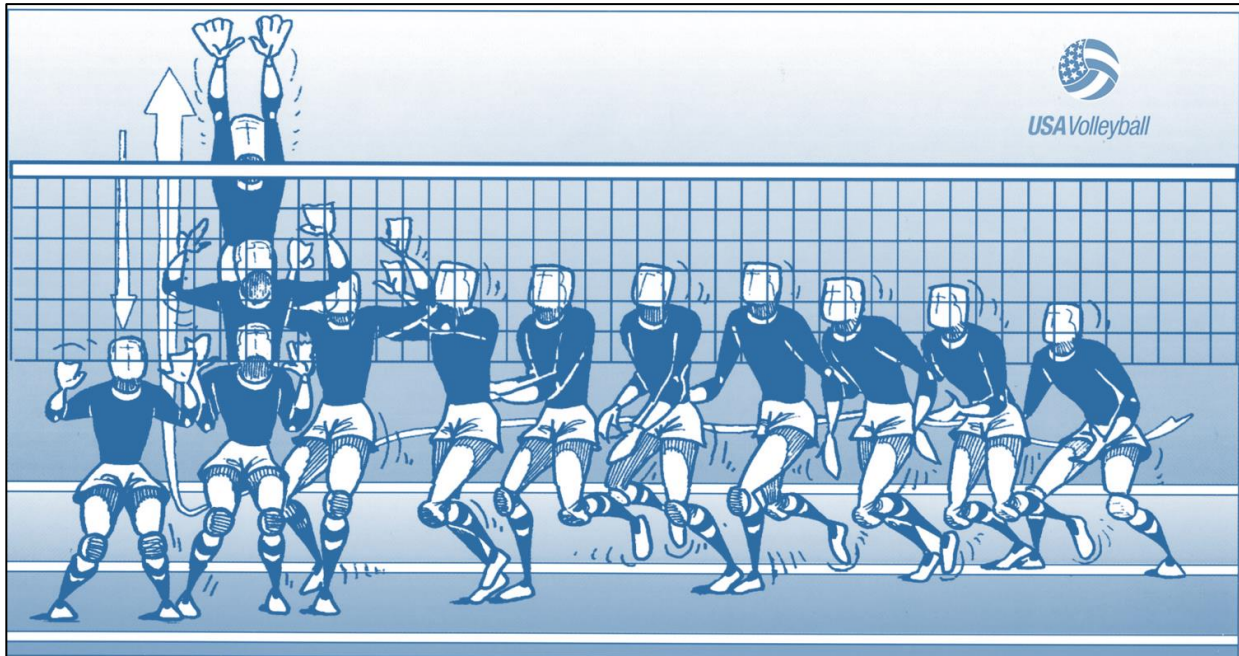


Figure 6: Blocking Sequence (“USA Volleyball,” n.d.)

Injury Descriptions

Volleyball injuries are vast and span across multiple regions. This is because volleyball is a dynamic sport involving overhead and lower extremity movements all in relation to an individual’s core strength. Repeated motions, such as the arm swing of a serve or an attack may result in overuse injuries. Overuse injury is defined as, “Any type of muscle or joint injury that’s caused by repetitive trauma. An overuse injury typically stems from: training errors. Training errors can occur when you take on too much physical activity too quickly” (Mayo Clinic Staff, 2016). Acute injuries happen rapidly, often in a swift movement, such as the landing on an opponent after a block. An acute injury can be defined as, “An injury that occurs suddenly during activity, often a sprain or strain” (“Physiocool” 2018). Both injury types are prevalent in

volleyball. Overuse injuries account for roughly 45.6% of all injuries, and acute injuries constituted 54.4% of all injuries seen in 2013-2015 collegiate seasons (Baugh et al., 2017, pp. 1-10). Injuries can also be categorized by amount of time lost from participation. Injuries that require more than 24 hours of non-participation are considered time loss injuries (TL), and injuries that led to participation restriction of less than 24 hours are considered non-time loss injuries (NTL) (Hootman et al., 2007).

Compensatory Movements Leading to Injury

Injuries in volleyball may be resultant of incorrect technique, or training errors, caused by weakness, lessened or excessive mobility, or lack of endurance. If one joint is weaker than the other, the pair will be asymmetrical. Asymmetry puts both limbs at risk for different reasons. The stronger of the two will be put under too much pressure, while the weaker limb will be underprepared for any amount of pressure. Thus, possibly putting both joints at a higher risk for injury because they may not be able to support the body as well as a fully functional joint (Ithurburn, Paterno, Ford, Hewett, & Schmitt, 2015, pp. 2727-2728).

Mobility issues can be seen in every aspect of volleyball, but are more likely to be seen in the JLS and arm swings. This could be due to a knee's or a shoulder's inability to properly function as a game progresses. Hypermobility in the shoulder and inflexibility in the knee may pose as threats for overuse injuries (DiFiori, Brenner, & Jayanthi, 2016, p. 93). If considered in a game-like scenario endurance may affect the joint's mobility as time goes on. If at any point, a joint becomes incapable of its normal function then a risk for injury may present itself.

Most Common Injuries Organized by Region

Ankle Injuries. The ankle is the most commonly injured region in volleyball; 23% of injuries occur at this joint (Smith et al., 2008). This joint is required for every movement and supports the body while under great pressure.

Ankle Sprains. Sprained ankles are the main cause of participation loss in volleyball. A sprain is defined as the overstretching of ligaments. This can occur from an abnormal landing or from sharp lateral movements. Sprained ankles account for 15.6% of injuries in the 2008-2009 NCAA season (“NCAA,” 2009). The most common mechanisms of ankle sprains are plantar flexion and inversion of the ankle, and excessive dorsiflexion (Allet, Zumstein, Eichelberger, Armand, & Punt, 2016, p. 241). This can be seen in *Figure 7* in the picture on the left.

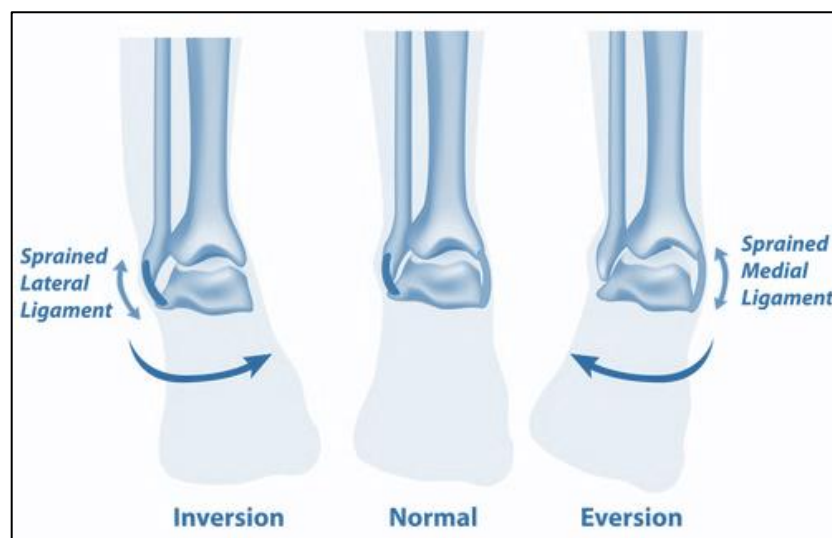


Figure 7: Inversion and Eversion Ankle Sprains (“BodyHeal.com,” 2013)

Ankle Instability. Ankle instability is the recurrent, uncontrollable laxity of the supporting ankle ligaments. Instability is often observed after acute ankle sprains and may continue to be problematic for more than two years post-sprain (Attenborough et al., 2014). Athletes with a history of ankle sprains are very susceptible to reoccurring ankle injuries. They are up to five times more likely to re-injure the joint (McKay, Goldie, Payne, & Oakes, 2001, pp.

103-108). Incorrect landing position of the foot (i.e. eversion or inversion) may also be at fault for causing ankle instability over time (Allet, et al., 2016).

Knee Injuries. Acute knee injuries are rare in volleyball, but still occur. They mainly happen when front row players land incorrectly and when defensive players make sharp lateral movements. In contrast, overuse injuries of the knee account for the largest amount of NTL injuries in volleyball. Overuse injuries can result from repetitive jumping/landing (Hootman et al., 2007).

Ligament Tears. The cruciate ligaments are vital in knee stabilization in vertical and lateral movements. Being part of a joint that is a connecting point for many structures, and is put through a lot of strain, creates hostile conditions for these ligaments. The ligaments of the knee include the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), the medial collateral ligament (MCL), and the lateral collateral ligament (LCL), and can be seen below in *Figure 8*.

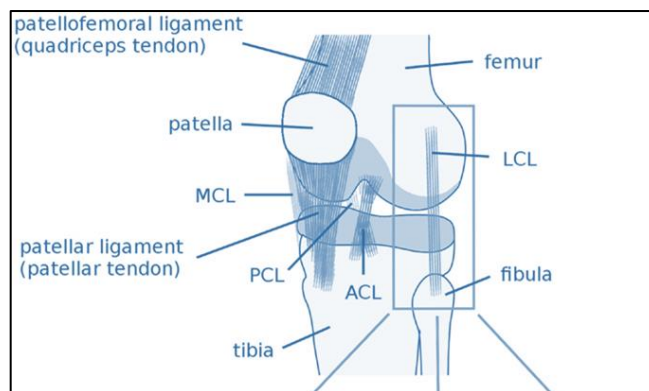


Figure 8: Anatomy of the Knee Ligaments (Galbusera, 2014)

Similar to ankle sprains, knee ligaments can be over-stretched or completely torn. The most common knee ligament injury for volleyball players is the ACL. ACL tears commonly result from incorrect positioning of the knees upon impact of landing (Hurd, 2018).

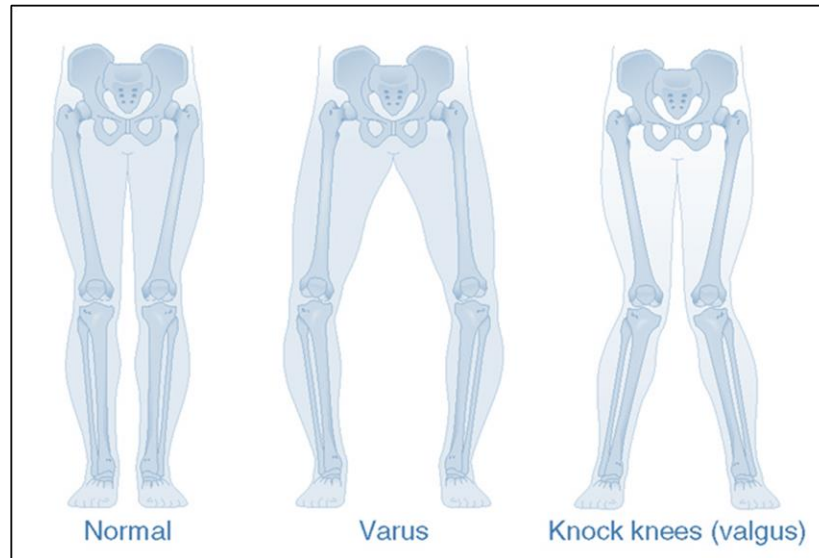


Figure 9: Correct Landing Position vs. Valgus Landing Position (“All Health Post,” n.d.)

A shoulder width stance with knees pointed forward (in alignment with the shoulders) and a slight bend at the knee, to absorb the impact, is considered correct landing technique (Ericksen, Thomas, Gribble, Doebel, & Pietrosimone, 2015, pp. 112-118). This is displayed in *Figure 9*. Medial rotation of the knees, or valgus collapse puts too much strain on the ACL. Research shows athletes who land in a slightly valgus position are more than 2.5 times more likely to completely tear the anterior cruciate ligament (Hewett, Myers, & Ford, 2005, p. 492). These tears normally result in time loss, approximately a four to six-month restriction period. Activity within this time frame is variable. Before being completely released, athletes are slowly eased back into less dynamic movements (Harris et al., 2014, p.103).

Patellar Tendinosis/Tendinopathy. Patellar tendinopathy encompasses a wide range of injuries to the patellar tendon. Causes are often due to overuse and tendon fatigue damage from incorrect JLS techniques (Bisseling, Hof, Bredeweg, Zwerver, & Mulder, 2008, pp. 483-488). An accumulation of small “tears” in the tendon may build up over time and amount to more serious complications, proving that tendinopathy injuries are not a result of a single acute event.

The build-up of micro-injuries may be caused by fatigue loading. This is the repeated loading of the joint, i.e. loading in the JLS and absorption of the landing (Shepherd & Screen, 2013, pp. 260-270). Therefore, this injury is most commonly seen in front row players. Research shows that players who land more stiffly (little to no deep knee flexion) may be at a higher risk for patellar tendinopathy (Bisseling et al., 2008).

Hip and Groin Injuries. Hip and groin injuries comprise roughly 13.8% of all injuries, according to NCAA's injury report from the 2004-2009 seasons ("NCAA," 2009). These injuries are usually acute with short restriction periods or no time loss. A recent study compared injury mechanism and participation restriction in 189 female athletes with hip/groin injuries. Of the 189 players, only 14 (7.4%) were restricted from competing (Baugh et al., 2017, p. 5).

Hip and Groin Strains. Adductor strains are common for defensive players due to their rapid change in direction and constant acceleration and deceleration (Sedaghati, Alizadeh, Shirzad, & Arjmand, 2013, pp.107-113). The specific muscle group can be seen below in *Figure 10* and *Figure 11*. Pushing off laterally may cause the adductor muscles to over-stretch into an extensive lateral lunge. It is also hypothesized that a history of adductor weakness and strains may increase the odds of recurrent injuries (Sedaghati et al., 2013).

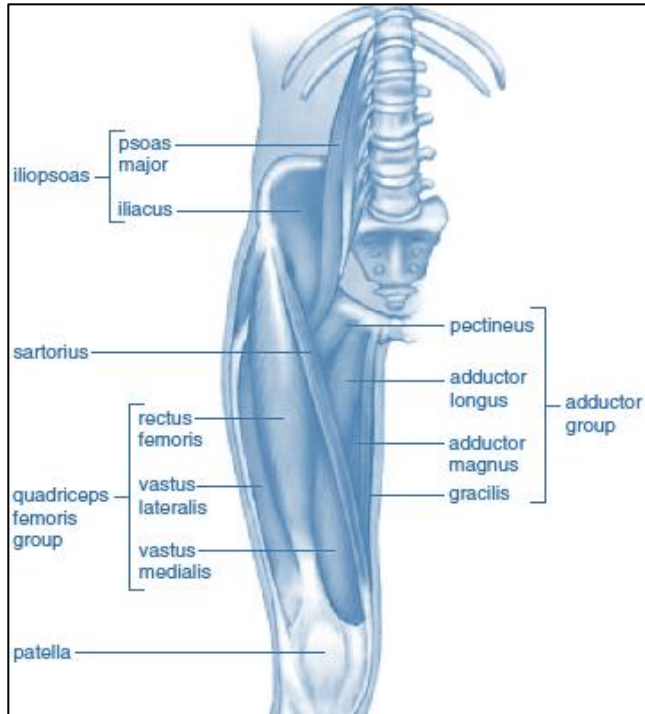


Figure 10: Superficial Hip/Groin Muscles

(“Encyclopedia.Lubopitko,” n.d.)

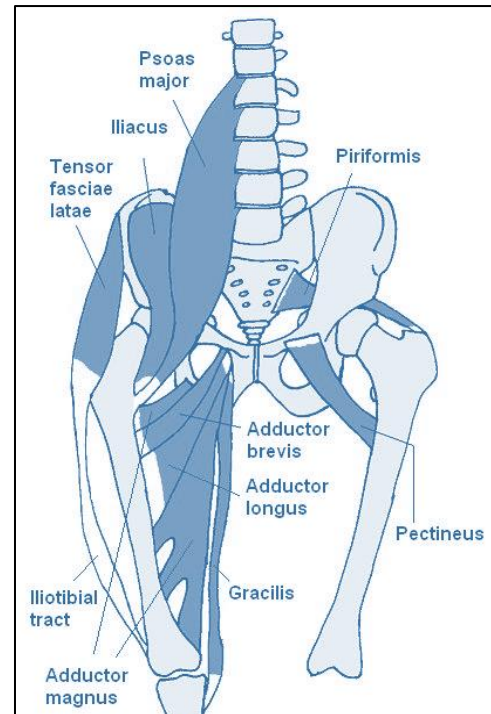


Figure 11: Deep Hip/Groin Muscles

(“Wikipedia,” n.d.)

Hip Labral Tears. The hip labrum is a fibrocartilage structure that lines the inside of the ball and socket hip joint, as seen in *Figure 12*. It aids in distributing pressure evenly across the joint, lubricating, and absorbs shock. If injured, the hip loses stabilization and can result in hip and groin pain (Nguyen & Safran, 2017, pp. 23-26). Micro-injuries can accumulate over time, making it, mainly, a degenerative/overuse injury. Frequent impact, i.e. landing, or twisting with the lower limb planted and flexed may cause these tears. These movements could put any position in volleyball at risk. Tears usually result in surgery and potentially a twelve-week recovery period, making it one of the highest time loss injuries for volleyball, per other complications (Groh & Herrera, 2009, p. 105).

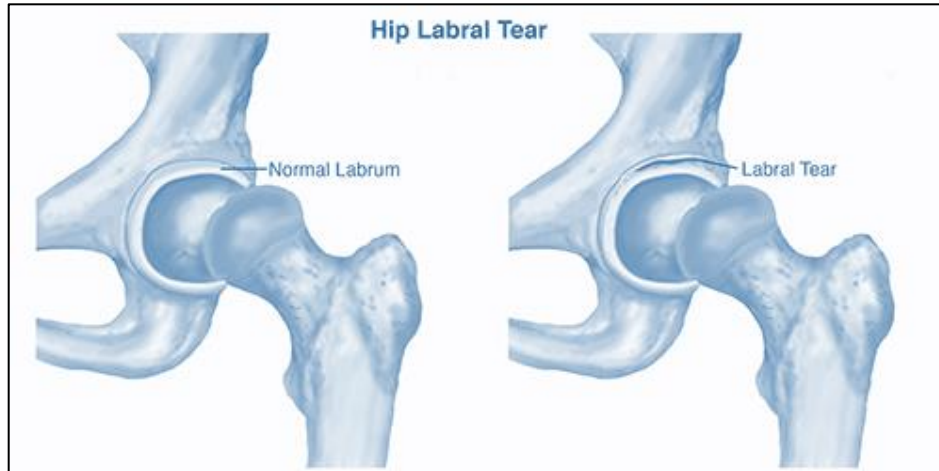


Figure 12: Healthy and Injured Hip Labrum (“Move Forward Physical Therapy,” n.d.)

Core Injuries. Core injuries are a common occurrence in volleyball. The main injuries are found in the lumbar spine and abdominal muscles. The back is the third most injured area in collegiate volleyball, accounting for 16% of all injuries (“NCAA,” 2009). Most vertebral complications will normally produce lower back pain from pinched nerves caused from disc thinning may or may not require time restriction (Mortazavi, Zebardast, & Mirzashahi, 2015, p. 24718). Back injuries are often chronic and may last a player’s entire career (Smith et al., 2008). Volleyball demands trunk stability in repeated attacking, serving, and digging motions. Without a strong core that cannot engage properly, the spine is left vulnerable during these movements. This can lead to multiple injuries as described below.

Abdominal Strains. Abdominal strains may be seen in front row attackers who flex their backs to gain more power on the follow through of the hit. The micro-tears occur during the back flexion, and are often seen in the rectus abdominis, shown in *Figure 13*. It is also common for an attacker to misread the set. This generally causes them to awkwardly readjust their body position mid-air. This act may require an exaggerated extension, as seen from points B through D in *Figure 14*, then a quick, powerful contraction of the core muscles. When these two movements

are combined, the possibility of straining an abdominal muscle might be increased. Especially when the motion is repeated multiple times throughout a practice/match. However, very little sport-specific research was found to assist these assumptions on the mechanism of abdominal strains in volleyball players (Tubez et al., 2015, pp. 402-412).

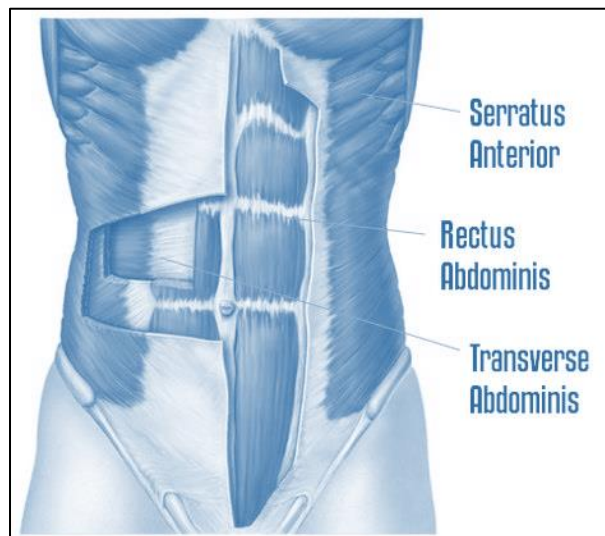


Figure 13: Abdominal Muscles (“Pinterest,” n.d.)

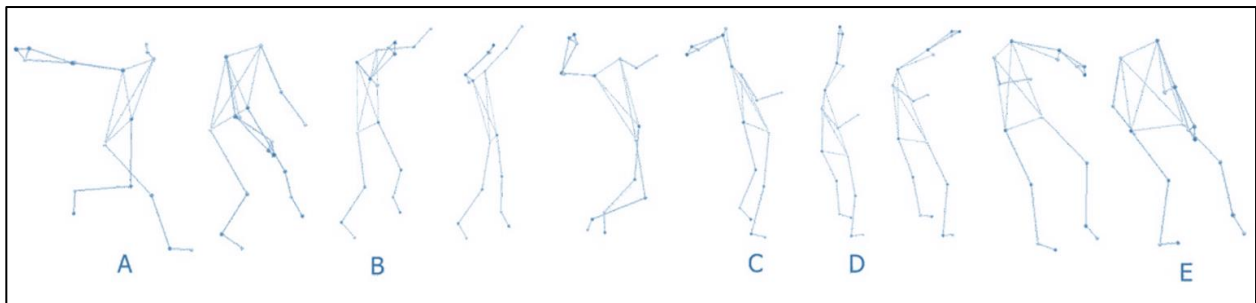


Figure 14: Hitting Sequence (“Volleyball Spike Biomechanics Blogspot,” 2015)

Spinal Instability. The spine is supported by many interconnecting ligaments, tendons, and muscles that ensure stability, shown below in *Figure 15*. Throughout a play, stabilizing the trunk becomes more difficult for most athletes. This may be due to poor muscle endurance or muscle stiffness (Smith et al., 2008). When surrounding muscles are already weak, and can’t activate quickly enough, the spine may be at risk. Overtime this can lead to degeneration of the

stabilizing ligaments, tendons, and muscles of the back. As seen in previously discussed injuries, this degeneration may lead to micro-tears or laxity, which could transform into a displaced vertebra, also known as spondylolisthesis. This may then result in chronic pain during high intensity movements. Servers and attackers who consistently hyperextend may experience instability. Twisting and lateral movements performed by defensive players may also lead to instability. Spinal instability alone is not normally a time-loss injury and can be monitored based on the athlete's pain. However, if it progresses into spondylolisthesis participation will be restricted.

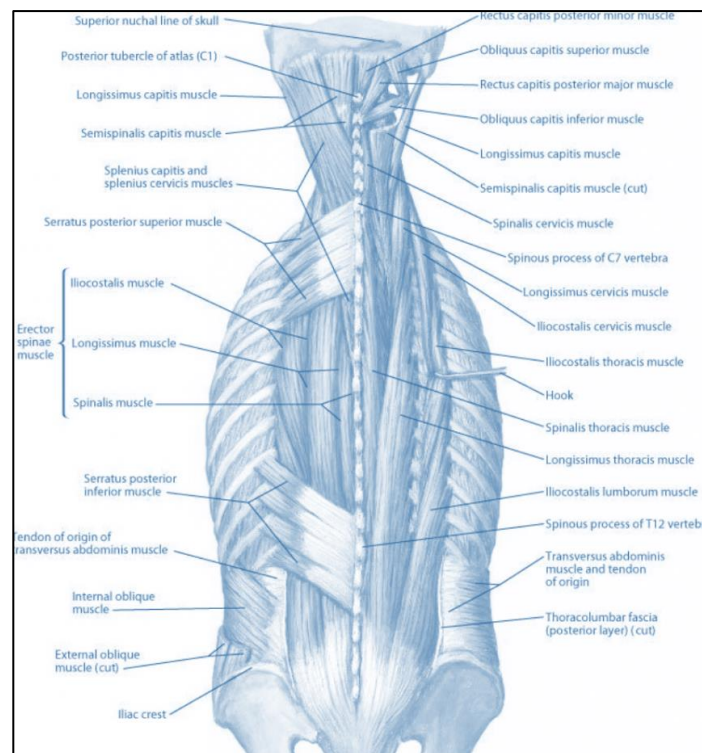


Figure 15: Spinal Connective Tissues (“Anatomy Inner Body,” 2017)

Spondylosis. Spondylosis is an umbrella term for multiple degenerative spine disorders. These include the degeneration and displacement of vertebrae, and potentially severe vertebral fractures. These disorders, along with spinal instability and displaced discs, often go hand in hand with one another, and can even cascade into a sequence of worsening events, as displayed

in *Figure 16*. For example, an athlete will commonly begin with lower back pain that may be diagnosed as spinal instability. If this laxity progresses, a vertebra may displace from its normal alignment. This may create abnormal pressure on the vertebra's spinous process, and vertebral disc, causing the thinning of the disc and a hairline fracture, also known as a pars fracture. If left untreated the pars fracture can cause the process to completely detach from the vertebral body. This is known as spondylolisthesis and is the most extreme form of spondylosis.

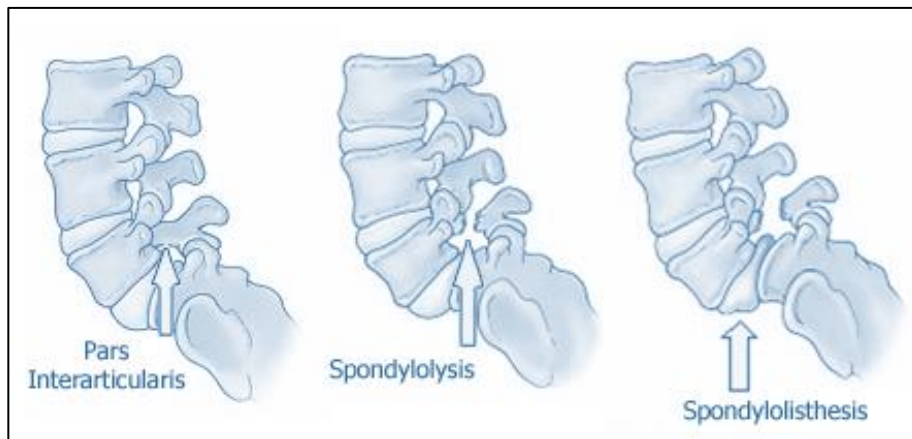


Figure 16: Sequence of Spondylolysis (“Georgia Clinic of Chiropractic,” n.d.)

Herniated Discs. Vertebral discs are wrapped in a gelatinous matrix that separate and cushion vertebra. They are responsible for shock absorption of the spine. Various degrees of disc herniation can occur when a large amount of stress is placed on the spine, depicted below in *Figure 17*. This may result from excessive lumbar flexion (Mortazavi et al., 2015). Disc pathology consists of normal variations and can be asymptomatic or quite problematic depending on the number of discs involved and the severity (Deyo & Mirza, 2016, p. 1763). Herniated discs are defined as only the outer ring of the disc protruding into the intervertebral foramen (Venes & Taber, 1989, p. 822). Depending on which spinal nerve root the prolapsed disc matter contacts, athletes may experience intense nerve pain that can span down one or both legs and can extend all the way to the foot. The most common disc to have issues is between the L5-S1 joint

(Mortazavi et al., 2015). If not improved with conservative interventions, athletes with herniated discs often undergo surgery and slowly progress back into playing within a four to five-month post-operation.

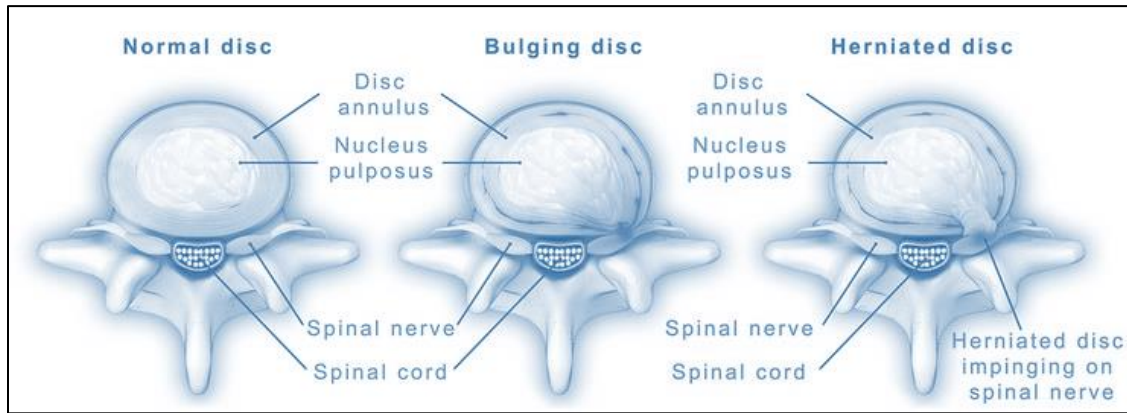


Figure 17: Normal vs. Bulging vs. Herniated Discs (“Saunders Therapy,” 2016)

Shoulder Injuries. In a recent study, shoulder injuries accounted for approximately 4.2% of time loss injuries and 10.5% of non-time loss injuries (Baugh et al., 2017, p. 5). Injuries in the shoulder are much more common in front row players and consistent servers.

Suprascapular Neuropathy. Suprascapular neuropathy rates among volleyball players is increasing (Lee, Yegappan, & Thiagarajan, 2007, p. 1033). The suprascapular nerve runs from the cervical spine to the suprascapular notch, a key feature of the scapula. Repetitive overhead movements are the greatest cause of impingement near the suprascapular notch (Lee et al., 2007). A recent study shows that impingement may be worsened with instability and hypermobility in overhead actions (Weiss, Arkader, Wells, & Ganley, 2013, p. 133). Athletes present with dull pain in the posterolateral region of shoulder and arm weakness. The pain may intensify with overhead swings. Surgery is usually required to decompress the nerve if physical therapy doesn’t give the athlete any relief (Lee et al., 2007).

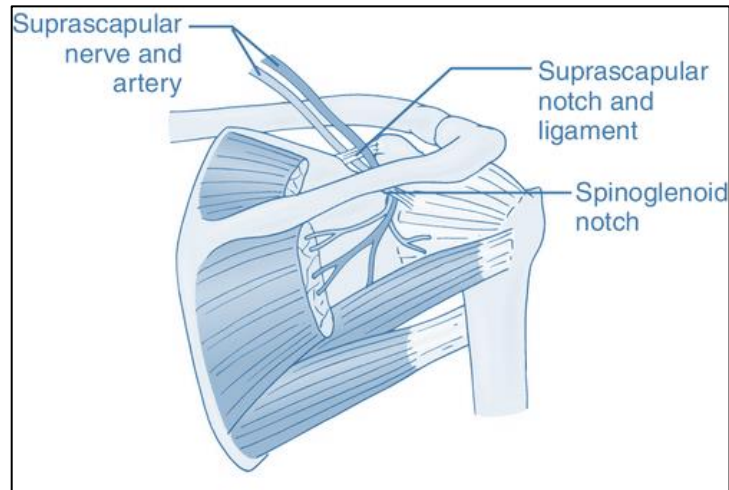


Figure 18: Suprascapular Nerve Impingement (“Clinical Gate,” 2015)

Shoulder Labral Tears. Labral tears may be suspected if overhead activities, such as serving, become difficult and dull pain and weakness are present in the shoulder (Lee et al., 2007). Overtime, or throughout a match, surrounding ligaments can become too lax. As a result, shoulder labrums can succumb to micro-tears from overuse, i.e. serving and attacking (Skelley & Smith, 2015, p. 27).

Rotator Cuff Injuries. Rotator cuff injuries are common overuse injuries in sports requiring overhead motions. During a serve or attack it is common for an athlete to excessively rotate their shoulder externally, while also adding an abductive movement. This increases the demand on the rotator cuff and may cause impingement. A recent study shows that this impingement may be worsened with continuous instability and hypermobility in overhead actions. This impingement and instability can then result in rotator cuff tears (Weiss et al., 2013).

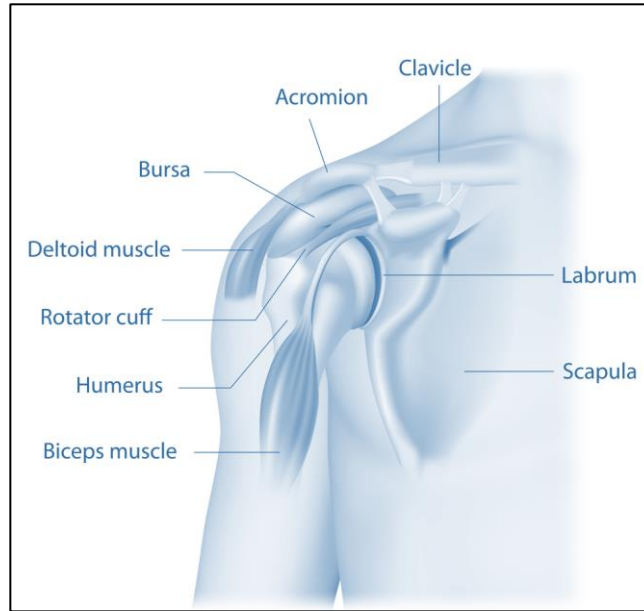


Figure 19: Rotator Cuff

(“Mark H. Getelman, MD Orthopedic Surgery and Sports Medicine,” n.d.)

Results

To compile a list of tests that could be used to predict and prevent injury, it is important to narrow the results to tests that best resemble competition-like movements. Some tests merely measure a single maintained motion, such as joint flexibility. Others involve more dynamic movements, like a vertical jump. These can be combined with balance or fatigue components to be more game-like. When specific elements are added, certain tests may be used as predictive tools for multiple regions. Because ankle and knee injuries are the two leading causes of injury in volleyball, this thesis will emphasize preventative techniques specific for these joints (Hootman et al., 2007). Overall, this composition of tests may provide the observer with strong evidence to predict and prevent potential injuries specific to female volleyball players.

Single Leg Hop Tests

A single leg hop test (SLHT) can be used to observe multiple areas for potential injury. Different variations can focus on a single joint and test its strength and stability when placed under explosive or fatiguing conditions. Single leg hop tests may be used to observe the ankle, the knee, and the hip. When conducting a SLHT, bilateral asymmetry should always be noted. Norms in limb symmetry for hop tests performed by collegiate athletes should fall between 85%-115% (Goodstat, Snyder-Mackler, & Axe, 2010, p. 96). This means that each leg, compared with the other, should fall within this range. If a vertical or distance is higher/further or shorter, then the athlete may be underprepared to take on her sport.

Single Leg Hop Test for Vertical. A standard SLHT will measure the athlete's vertical during a single leg jump for height. This test will use a vertical jump mat designed to take the time from when the foot leaves the mat to when it returns, and configure it as a vertical height. The test will be repeated on the opposite limb to compare verticals. Ideally, scores should be

compared to normative values with similar sports. However, for this test there are no normative values specifically for female collegiate volleyball players. In comparison, the cut off vertical (for both dominant and non-dominant limbs) for the average collegiate athlete is roughly 21.46-23.81 cm (Shin & Woo, 2013, p. 57). Roughly 92% of the athlete's vertical should be kept bilaterally ("Shirley Ryan Ability Lab", 2018). Failing to reach this height may mean the athlete is at risk for future ankle or knee injury because the limbs are underprepared.

When strictly observing the ankle, isolating one limb requires it to bear more weight while balancing and stabilizing the rest of the body. Studying the ankle's landing position under this set of conditions is ideal for observing excessive plantar flexion, and ankle eversion and inversion (Allet et al., 2016). Abnormal flexion and inversion may lead to ankle sprains and instability. After both legs have been tested, observations will be compared for asymmetry. If one ankle shows more flexion, eversion, or inversion than the other, the possibility of an ankle sprain may increase.

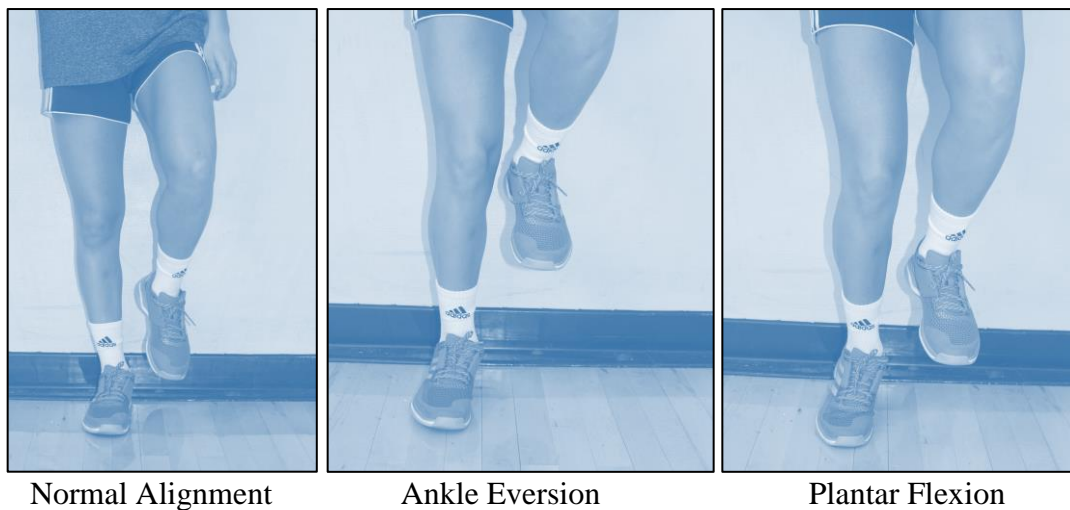


Figure 20: Collegiate volleyball player demonstrating normal ankle alignment, ankle eversion, and plantar flexion.

This variation of the SLHT can also observe the knee during game-like movements, such as the JLS. As previously mentioned in the literature review, landing unbalanced or on one leg is a common fault of the JLS (Hurd, 2018). Recreating this movement in a SLHT can help point out the severity of this flaw and its potential for causing injury. An unbalanced landing may put the athlete at risk for acute knee ligament strains (Hurd, 2018). The severity of this risk can be determined from the degree of knee valgus collapse present during landing. The greater the amount of valgus collapse seen may increase the risk of knee injury (Hurd, 2018).

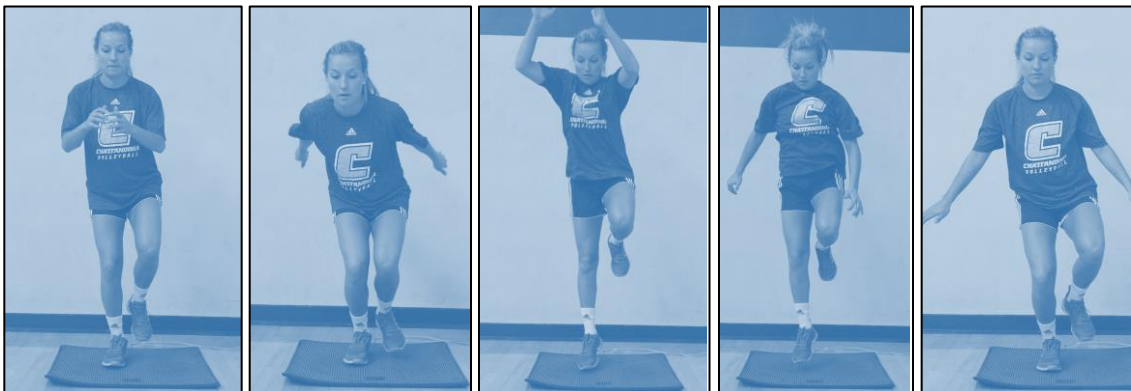


Figure 21: Collegiate volleyball player performing the single leg vertical hop test on a jump mat.

Single Leg Hop Test for Endurance. This variation of the SLHT should expose an athlete's susceptibility to lower extremity fatigue. Once again, the athlete will jump for height on a vertical jump mat. However, this time they will complete thirty consecutive single leg hops ("Topend Sports," 2018). The heights from jumps one through five will be compared to the verticals from jumps twenty-five to thirty to demonstrate the effect of thirty jumps on vertical height. Results should show a gradual decline in vertical as the number of jumps increase and the athlete becomes more fatigued (Kamandulis et al., 2016, p. 163). To pass this test, each leg should demonstrate the same amount of fatigue, no amount of fatigue, or small differences in fatigue. No normative data is given to predict injury in volleyball players, but a fatigue rate of 11.3-14.7% for normal to hard activity is considered average (Nur, Dawal, Dahari, & Sanusi,

2015, pp. 2323-2325). Therefore, no more than roughly 15% of vertical height should be lost over the span of thirty hops. If the volleyball player is at risk for injury their fatigue test may show large bilateral differences in fatigue.

According to athletic trainer Madeline Kalke, a right-side attacker may jump an average of sixty-three times over the course of a forty-five-minute warm-up and a five-set match (Kalke, 2017). This is more than two times the number of jumps required for this test. If a player shows a distinct decline in vertical hop height after merely twenty-five hops, he/she may be more prone to injury. Fatigue-related injuries resulting from jumping could present as an acute ACL rupture or strained knee ligament (Kamandulis, et al., 2016, p. 163).

Single Leg Hop Test for Distance. The final variation of a single leg hop test will measure the player's power and control in relation to the knee. This is very important during landing for hitters and lateral movements for defensive players. For this SLHT, athletes will now jump for distance instead of height. The distance covered is a direct reflection of the power and strength of the athlete's lower extremities, but this power may be compromised with an unstable landing. Landing on one leg requires balance and stability through deceleration. The further an athlete can leap, and land in a stable position, the more power and control they have (Allet et al., 2016). Normative distances performed by collegiate athletes are generally between 132-166 cm per leg (Myers, Jenkins, Killian, & Rundquist, 2014, p. 600). Normative symmetries for sports with a high risk of ACL injury should aim to hop roughly 75-105% of their measured height (Hogg, Warren, Smith, & Chimera, 2016, p. 949). Distances below this mark may predict ACL injury (Hogg et al., 2016, p. 945). If both legs are within the acceptable range, but one leg produced a much shorter hop, then this asymmetry may also be used to predict a future injury.

Power and strength are important in volleyball, but being able to control these movements and stabilize after is just as important. This is especially true when it comes to knee ligaments (Allet et al., 2016). Observing an athlete's landing technique can help expose knee valgus collapse, which may later cause ligament sprains and tears.



Figure 22: Collegiate volleyball player performing the single leg hop test for distance from a lateral view.

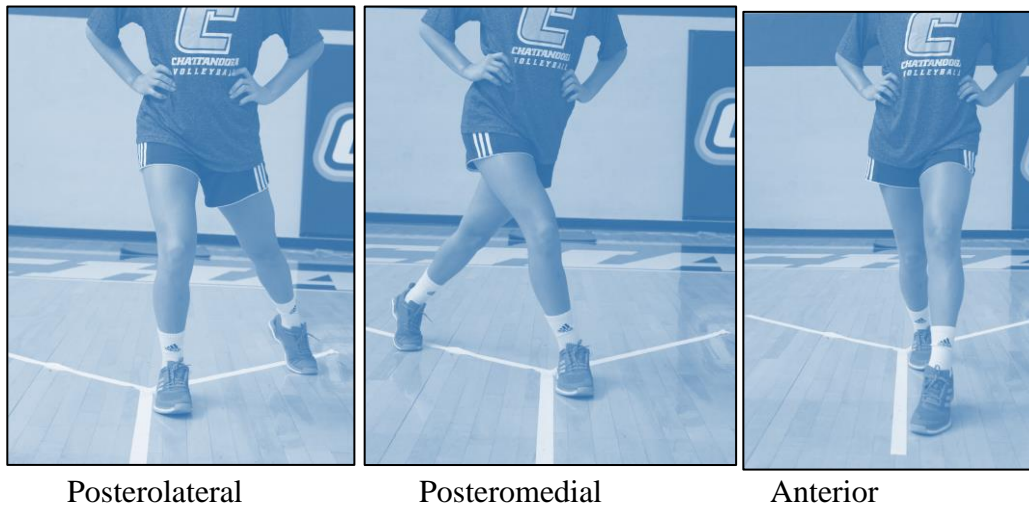


Figure 23: Collegiate volleyball player performing the single leg hop test from an anterior view.

Lower Body Y-Balance Test. Poor coordination and neuromuscular control, and lack of balance are all risk factors for lower extremity injury. The Y-balance test can be used to measure abnormalities and weaknesses related to ankle injuries, as well as other joints (Gonell, Romero, & Soler, 2015, p. 955). The athlete will move their non-stabilizing leg anteriorly, posteromedially, and posterolaterally. The distance reached by the moving limb is measured and configured in relation to the length of the limb. According to the Shirley Ryan Ability Lab (2018), the normalized average scores of healthy adults (22-25 years old) were as follows: anterior reach was 53.32-63.84 cm, posteromedial reach was 92.46-108.42 cm, and posterolateral reach was 88.79-108.7 cm (“Shirley Ryan Ability Lab,” 2018). Distances reached within these ranges indicate good control and stability. Leg dominance had little effect over bilateral distances reached (Lee, Sim, & Jiemin, 2017, p. 79).

Longer distances may indicate better control over lower extremities and better balance, suggesting a lower risk for injury (“Topend Sports,” 2018). Large bilateral differences in distance, and failing to reach the average distances may suggest a future ankle injury. This test

was chosen to help prevent ankle sprains and instability. Smaller distances have also been proven to correlate with knee valgus collapse (Lee et al., 2017).



Posterolateral

Posteromedial

Anterior

Figure 24: Collegiate volleyball player performing the lower body Y-balance test. The picture on the left is displaying posterolateral movement, the middle picture displays posteromedial movement, and the picture on the right shows anterior movement.

Isokinetic Strength Tests. An isokinetic test isolates a joint and tests for its relationship between strength, speed, and power. Many joints can be isolated and tested for isokinetic strength, however, because this thesis emphasizes knee complications the isokinetic test will solely focus on the knee. This test is performed by a machine using a constant speed with varying resistances. Knee extension and flexion isokinetic strength will be measured. Normative values for dominant knee extension at $60^{\circ}\cdot s^{-1}$ are $3.41 \text{ Nm}\cdot\text{kg}^{-1}$, and $1.85 \text{ Nm}\cdot\text{kg}^{-1}$ for dominant knee flexion (Kobayashi, Kubo, Matsubayashi, Matsuo, Kobayashi, & Ishii, 2013, p. 63). Normative values for non-dominant knee extension at $60^{\circ}\cdot s^{-1}$ are $3.26 \text{ Nm}\cdot\text{kg}^{-1}$, and $1.78 \text{ Nm}\cdot\text{kg}^{-1}$ for non-dominant knee flexion leg (Kobayashi et al., 2013). As angles increase normative isokinetic knee strengths decrease (Kobayashi et al., 2013). Isokinetic strengths should fall near these values. Note, however, that these values were produced by college-age athletic males.

Results of this test can provide information about agonist versus antagonist muscular strengths and may indicate weaknesses (“Topend Sports,” 2018). A drastic unilateral (or bilateral) weakness may pose as an injury threat to athletes. Symmetrical measurements should fall within 21%-66% for an extended knee and 70%-91% for a flexed knee (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007, p. 2047). Athletes demonstrating a joint that falls outside of this range (either higher or lower) may be underprepared for play. The weaker limb may not be ready and the stronger may be overprepared. In a recent study, it has been shown that the angle to strength ratio may be indicative of performance (Greig & Naylor, 2017, p. 728).



Figure 25: Isokinetic Strength Machine

Drop Landing Test. In a drop landing test, the athlete will be observed by their ability to drop from a box and land on two feet with correct technique. This test will imitate landing from a hitting sequence. Athletes who land without knee valgus may be less susceptible to knee injury. Athletes who do present signs of collapse may be more prone to injury (Hurd, 2018). When left unaddressed, knee valgus has been shown to increase the risk for ACL tears (Munro & Herrington, 2014, pp. 891-894).

The drop landing test has also been used to predict ankle injuries and patellar tendinopathy. Vertical stiffness asymmetries upon landing have recently been linked to ankle stiffness asymmetries to predict knee valgus collapse leading to tendinopathy (Maloney, Richards, Nixon, Harvey, & Fletcher, 2016, p. 661).

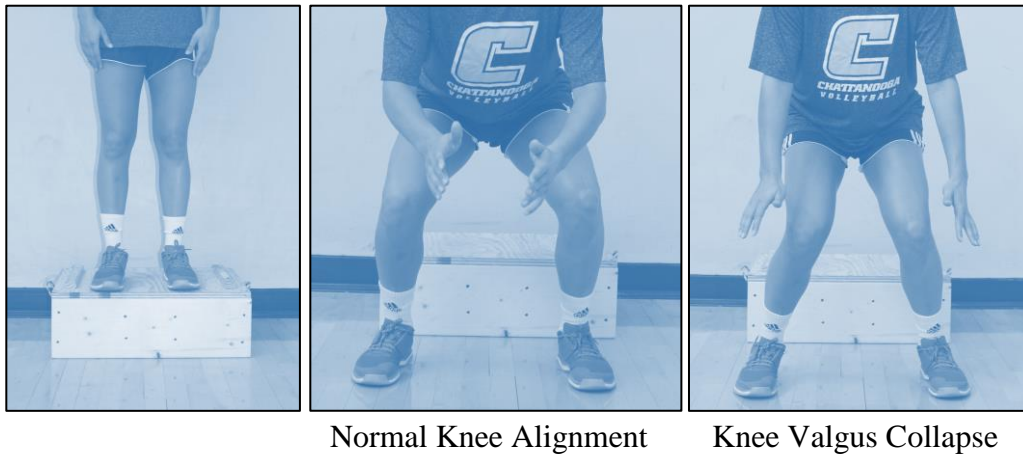


Figure 26: Collegiate volleyball player performing the drop jump test. The picture on the right demonstrates knee valgus upon landing.

Single Leg Squat. The single leg squat (SLS) test can expose a more excessive knee valgus collapse. Athletes will be asked to balance on one leg while lowering into deep knee flexion, to just contacting a chair, and raise into full knee extension in one fluid motion (“Topend Sports,” 2018). The knee will be observed in the frontal plane to determine collapse. A recent study shows that increased hip muscle strength may decrease the odds of knee valgus (Chaudhari & Andriacchi, 2006, p. 330). If valgus collapse is closely related to weakened hip muscles, a SLS test may indirectly suggest a future adductor strain.

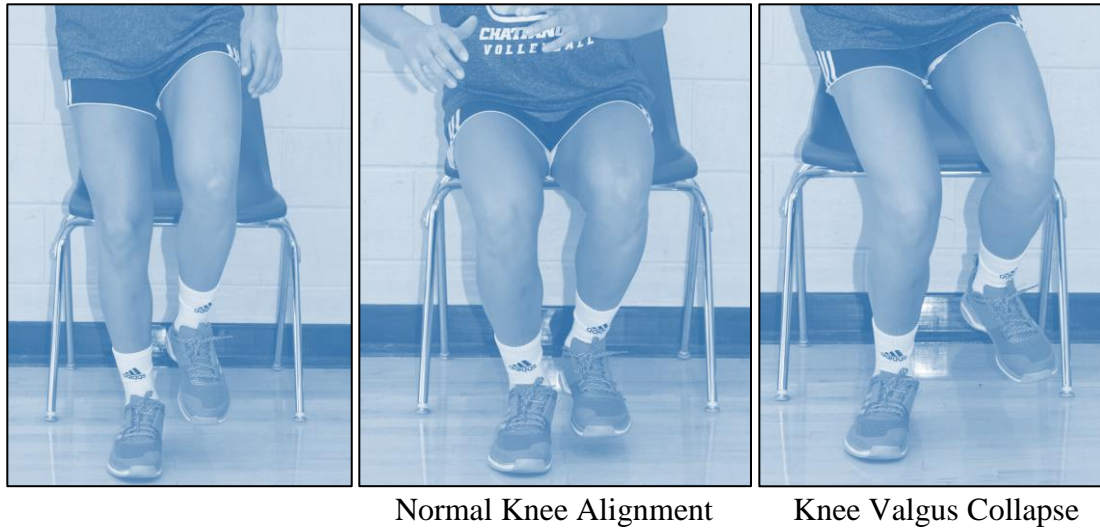


Figure 27: Collegiate volleyball player performing the single leg squat test against a chair. The middle picture displays correct technique, but the picture on to the right shows knee valgus collapse.

Groin Flexibility Test. Since one of the more common hip/groin injuries in volleyball is a hip adductor strain, it is important to test for the adductors' willingness to stretch. This test, commonly referred to as the "butterfly stretch," is a simple way to measure adductor flexibility. Sitting in this stretch, the closer the athlete's feet are to their groin, the more flexibility they have in this area ("Topend Sports," 2018). Groin flexibility is a key component to a defensive player's ability to make lateral bounds (Cejudo, Ayala, Baranda, & Santonja, 2015, p. 977). The adductor muscles must be able to quickly lengthen when tracking down a ball during play. This can help monitor an athlete's predisposition to muscle strains (Cejudo et al., 2015). If the athlete's heels are less than five cm from their pubic symphysis, their flexibility is considered excellent and they may have a reduced risk of injury ("Topend Sports," 2018).

Hip inflexibility is currently being studied as an indicator to abdominal strains, but the correlations are not fully supported at this point (Young, Dakic, Stroia, Nguyen, Harris, & Safran, 2014, p. 2655).



Figure 28: Collegiate volleyball player performing the groin flexibility test.

Beiring-Sørensen Test . This test is used to highlight the back’s extensor muscles. This muscle group may be important to some attackers who over extend and flex during hitting. It may also pertain to defensive players who are in. It has recently been shown to predict lower back pain in male patients who have not been able to hold the position for 176 seconds (“Shirley Ryan Ability Lab,” 2018). A time greater than 198 seconds has been proven to predict the absence of lower back pain (“Shirley Ryan Ability Lab,” 2018). However, there is currently no research to support this claim for females (“Shirley Ryan Ability Lab,” 2018). This test may help prevent injuries involving spinal instability, ultimately leading to disc issues, and even degeneration.



Figure 29: Collegiate volleyball player performing the Biering-Sørensen test.

Straight Leg Lower Test. The straight leg lower test is similar to the Biering-Sørensen test; however, it is almost reversed. This test can help predict core strength and its relation to lower back stability. Athletes will lay on their back and fully extend their legs above the ground at a 90° angle (“Topend Sports,” 2018). Athletes will slowly lower their legs while engaging their core and not arching their lower back. Once the back begins to arch the angle between the ground and their legs will be measured. Below-average and poor angles are within 60°-90° and may suggest a future core injury (“Topend Sports,” 2018). An angle of 45° is considered average and angles from 0°-30° are considered excellent to above average (“Topend Sports,” 2018). Collegiate athletes should aim to fall in the 45°-0° range to pass and help prevent injury.

This test is measured on a pass or fail basis, and like the Biering-Sørensen test, may help indicate potential injury to the back and abdominal muscles (“Topend Sports,” 2018). This test is important for exposing athletes with a weak core. A weak core will leave the spine vulnerable and may cause injury (Malanga, Aydin, Holder, & Petrin, 2016, p. 186). Core muscles connect the upper and lower body, and if they are weak it may increase the likelihood of shoulder injuries, hip injuries, and knee injuries (Young, et al., 2014).

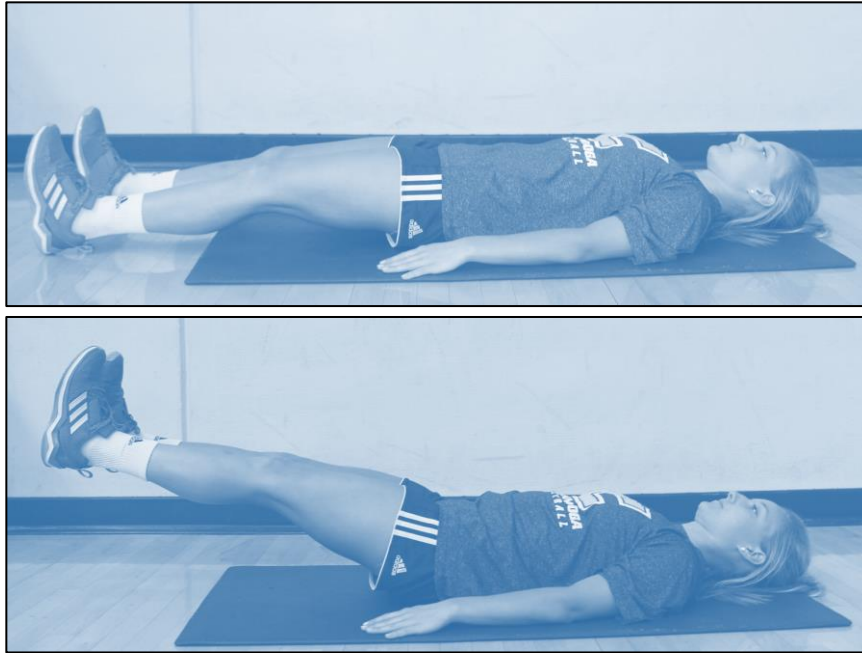


Figure 30: Collegiate volleyball player performing the straight leg lift test.

Apley Scratch Test. The Apley Scratch test is designed to measure an athlete's shoulder flexibility. The player's shoulder will be stretched in shoulder flexion and shoulder extension. An athlete will stand and raise one arm above their head, and bend at the elbow to reach behind their head. The other arm will fall at their side and reach up behind their back. The athlete will try to touch their hands together in the center of their back. Being able to touch hands is a good indicator that risk for injury is low ("Topend Sports," 2018). Fingers that do not touch, but are less than five cm apart are considered average, while fingers that are further than five cm are considered poor and may indicate a future injury ("Topend Sports," 2018). Bilateral asymmetry between limbs should be noted as a possible indicator for injury.

Measuring the mobility, or lack of, in the shoulder may be important for injury prediction. It has recently been shown that overhead athletes might be predisposed to posterior shoulder stiffness from repetitive overhead movements, such as serving or hitting (Cools, Johansson, Borms, & Maenhout, 2015, pp. 331-336). Shoulder impingement was once thought to be caused

by loose shoulder ligaments, but is being reconsidered. It is now believed that stiffness may cause shoulder impingement (Braman, Zhao, Lawrence, Harrison, and Ludewig, 2013, p. 211). On the opposite side of the spectrum, too much shoulder flexibility may indicate that the shoulder isn't fully capable of stabilizing itself. This hyperflexibility may lead to overuse injuries (Liaghat, Juul-Kristensen, Frydendal, Larsen, Sjøgaard, & Salo, 2018, p. 7). These overuse injuries are generally displayed as micro tears in surrounding ligaments, and can present as rotator cuff tears and even labral tears (Cools et al., 2015). Excess shoulder mobility research is common for swimming, but is lacking for volleyball.

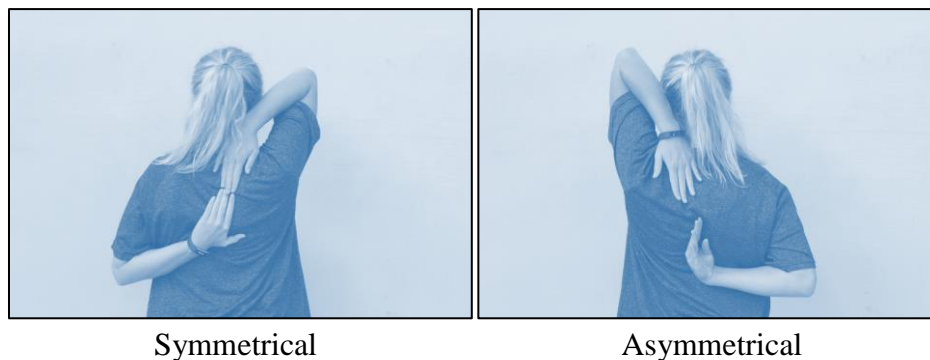


Figure 31: Collegiate volleyball player performing the Apley Scratch test.

Research shows a lack of tests designed specifically for shoulder mobility before and after dynamic movement. As a proposal, combining a volleyball drill and ROM test may fill this void. The athlete's shoulder flexibility will be measured prior to a hitting exercise, and will be reevaluated after the player completes seven game-like swings. This test may produce a change in shoulder mobility before and after dynamic movement. These changes could resemble shoulder stiffness or shoulder hypermobility after multiple swings. This test may provide insight to overuse mechanisms resulting from lack of or excessive flexibility as movement repetition increases.

Upper Body Y-Balance Test. The upper body Y-balance test is similar to the lower body test in that it can measure abnormalities and weakness. However, this version associates these faults with shoulder injuries instead. One arm will bear weight, while the limb being tested will move three directions; medial, inferolateral, and superolateral. This test will measure the athlete's mobility and stability of the scapular region in relation to weight loading (Cramer et al., 2017, 117). As stated earlier, the distance reached is configured with arm length. Further reaches may correlate with better stabilization and control of the stationary shoulder, indicating a lower risk for injury. Normative reach in the medial direction is 10.6 cm, 9.3 cm in the superolateral direction, and 10.1 cm in the inferolateral direction ("Shirley Ryan Ability Lab," 2018). Distinct asymmetries between shoulders could cause injury ("Topend Sports," 2018).

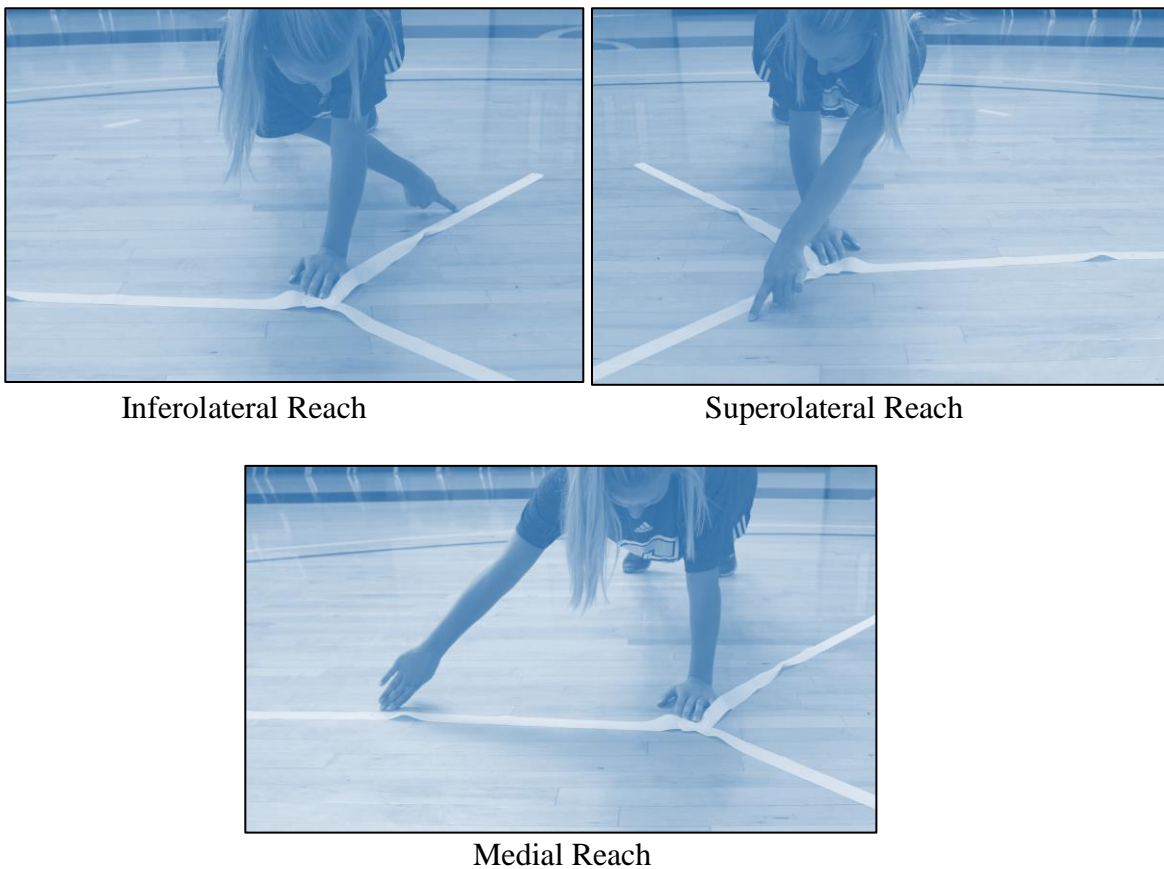


Figure 32: Collegiate volleyball player performing the upper body Y-balance test.

Conclusion

Research shows a large gap in injury prediction and prevention techniques for athletes, especially for the growing sports, such as volleyball. An increase in participation creates an increase in injuries. In turn, this should require an increase of knowledge in sport-specific injury mechanism and prevention.

This thesis is designed to help fill the gap of information. There is a large range of predictive tests, but very few are sport-specific. It may be more effective to study, in detail, correct volleyball techniques and how these can be executed poorly in competition, such as the dynamic movements of defensive players and the jumping landing sequence of attackers. If a technique is abnormal, injuries may occur at a higher percentage. This will attribute to the most common injuries in volleyball. Common injuries are also something very important to consider when constructing an injury prevention program. The tests in the program should exemplify a balance between range of motion, strength, and power, similar to movements in competition. A final list of tests is as follows: single leg hop tests for vertical, endurance, and distance, the lower body Y-balance test, isokinetic strength test, drop landing test, single leg squat test, groin flexibility test, Biering-Sørensen test, straight leg lift test, shoulder flexibility test, and upper body Y-balance test. Combining this information and acknowledging how it all effects the athlete may create the best compilation of tests to predict, and in turn, prevent common volleyball injuries.

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4 rules for avoiding overuse injuries. (2016, February 09).

Appendix A

Additional Information Regarding Common Volleyball-Related Injuries

Comparatively speaking, incidences of injury in volleyball are still considered low (Baugh et al., 2017, p. 2). However, they are still plentiful. NCAA injury reports from the 2013-2014 and 2014-2015 seasons showed ankle injuries being the most frequent TL injury (24.3% of all TL injuries reported) (Baugh et al., 2017, p. 3). Knee injuries were reported as the main NTL injury, comprising 16.3% of all NTL injuries (Baugh et al., 2017, p.3). No specificities are offered to explain the mechanism or severity of these injuries to support this data.

A large portion, roughly 19.1% of all TL injuries resulted from blocking (mainly ankle and knee complications) (Baugh et al., 2017, p. 3). Blocking also produced many finger and wrist injuries due to direct ball contact. Very few resulted in time loss (3.7%), and 10.8% of all injuries were hand-related with no time loss (Baugh et al., 2017, p. 5). Finger and wrist injuries are not discussed in this thesis because they are random. No evidence shows that weakness or abnormal mobility is connected to hand-related injuries. Also, no tests are known to help predict or prevent these occurrences.

Concussions are another common injury in volleyball. According to NCAA's injury report from the 2004/05-2008/09 seasons, concussions composed 4.1% of all known injuries (2009). Concussions mainly results from ball contact during blocking and digging (Baugh et al., 2017, p. 9). Concussions make up 14.8% of all TL injuries for the 2013/14- 2014/15 seasons (Baugh et al., 2017, p. 6). Similar to hand injuries, concussions are random and cannot be predicted or prevented by functional tests.

Core injuries, mainly abdominal strains and spinal instability in the lumbar spine, made up 8.5% of TL injuries and 11.8% of NTL injuries (Baugh et al., 2017, p. 5). Shoulder injuries

make up 42.% TL injuries and 10.5% of NTL injuries (Baugh et al., 2017, p. 5). The majority of these incidences were caused from overuse. Of all overuse injuries 13.2% result in time loss and 32.4% result in no time loss (Baugh et al., 2017, p. 7). It has also been reported that females have a higher NTL overuse injury rate (4.12 injuries per 1,000 practices/games, or exposure to injury) and lower TL injury rate (3.6 injuries per 1,000 exposures to injury) compared to males (Baugh et al., 2017, p. 4). This difference may be attributed to gender-based anatomical differences (Baugh et al., 2017, p. 9). Another factor may be females' very high injury incidences in preseason practices (Baugh et al., 2017, p. 3).

Appendix B

Uncited References Used for Background Research

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