CHAPTER II

REVIEW OF LITERATURE

Injury prevention is a primary goal of every athletic trainer, coach, and athlete. This is definitely true in Division I-A football in the United States. If a player is injured, he is unable to participate at his optimal level or, even worse, not able to play at all. The athletic training staff has to work extremely hard to not only get this athlete back to playing, but for him to play at as close to his peak level as possible without increasing the risk of re-injury. This allied health professional works extremely close with athletes and is unequivocally the individual who is most responsible for the prevention and treatment of injuries to athletes (Arnheim & Prentice, 2000). The coach has the pressure of producing winning teams. If athletes are injured, it is more difficult for him to put his best team on the field each game. Finally, at the Division I-A level, the athlete is on the team to produce. If he becomes injured, he not only has to deal with the pain and discomfort of the injury, but he has to go through the intensive rehabilitation in order to return to his optimal playing level as soon as possible. It is for all of these reasons, and many more, that it is in the best interest of all parties involved with the football team for the players to minimize the chances of injuries. It is also for these reasons that sports medicine professionals have attempted to determine which athletes have a greater chance of getting injured by developing a variety of evaluative tools intended to identify risk factors, weaknesses, and deficiencies that can predispose athletes to injuries.

Extrinsic/External Risk Factors

Extrinsic or external risk factors are environmental factors out of direct control of the athlete (van Mechelen, Hlobil & Kemper, 1992). These types of factors include the type of sport, player’s position, nature of event, state of the flooring or grounds, safety measures, equipment, coaching, weather conditions, and application of the rules by both the players and officials (Koester, 2000; Meeuwisse, 1991; Taimela, Kujala, & Osterman 1990; van Mechelen et al, 1992).

Bird (1992) reported that not only is football a high-injury sport due to the nature of the game, but other external factors such as equipment, coaching, playing time, and playing conditions all contribute to an athlete’s proneness to injuries. Venue, weather and playing surfaces are also considered extrinsic risk factors. Factors such as hard, soft, and uneven playing surfaces, poor lighting, dry field conditions; shoes that are inappropriate or worn out, inappropriate equipment, and environmental conditions, such as hot, cold, and humidity can all contribute to athletic injuries (Boden, Griffin & Garrett, 2000; Brukner & Khan, 2001; Orchard et al., 2001; Najera, 2001; Pfeiffer & Mangus, 1998). Meisenheimer (1997) stated that at the University of Florida, coaching is one of the biggest factors that affects injuries. Another extrinsic risk factor that is often overlooked is inadequate rehabilitation following a previous injury (Najera, 2001). Finally, other potential extrinsic risk factors that will not be discussed in detail are corticosteroid injections, rules, and fair play (Najera, 2001; Safan & Shapiro, 1998).

Nature of the Sport and Exposure

Since football is a collision sport, it is well known that the injury rate in this sport is high as compared to other sports, even other collision sports. McKeag (n.d.) reported that football had one of the highest overall injury rates in college sports, along with men's wrestling, soccer, and lacrosse, and women's gymnastics and soccer. Except for gymnastics, all of the sports mentioned above are either collision or contact sports. One reason for the high number of injuries in football is the number of exposures that a player experiences over the course of a complete season. A player is exposed to numerous collisions in practices and games. Not only is the athlete participating in practices and games, he is exposed to collision on almost every play. Mueller, Zemper, & Peters (1996, p. 18) state, "there appears to be a direct relationship between the amount of contact a player gives or receives and the incidence of injury." Therefore, the more plays an athlete is in, the more likely he could be injured.

Training Errors

Training errors on the part of the athlete and coach are also causes of athletic injuries. Brukner & Khan (2001) reported that excessive training volume and intensity, sudden changes in the type of training, excessive fatigue, inadequate recovery, and faulty technique are all training errors that can cause overuse injuries in athletes. Also, it was found that inadequate warm-up is a predisposing factor to injuries such as hamstring strains (Safran & Shapiro, 1998). This type of risk factor is often tied to coaching and instruction technique for athletes.

Level of Competition

It can be assumed that the higher the level of competition in football, the higher the injury rate would be. This assumption is supported in the literature by Bird (1992, p. 1), who stated:

> according to the National Football League Players' Association, most of the current 1650 NFL players will not be playing in 4 years because of career-ending injuries. Whereas,

> peewee football players are seldom injured, because the kids are so light and slow they don't collide with much force.

While the injury rate may not be as high as in the NFL, Division I-A football is the next level below the NFL. Therefore, it can be assumed that the injury rates at this level should be slightly less than the NFL.

Artificial Turf

Artificial turf has long been thought to cause more injuries than natural grass. The literature tends to support this claim. In a Synopsis of Research Studies and Articles, the research reported that the injury rate on artificial turf was higher than on natural grass (Halpern, 1999; Zemper, 1997). Zemper (1989, p. 7) reported that "the overall injury rate was 60% greater on artificial turf than on natural grass." In the NCAA Injury Surveillance System, the data reports that between the years of 1988 and 2000, the injury rate during games was higher when played on artificial turf than on grass nine out of the thirteen years (NCAA, 2001).

Spring Football Practice

The time of year in which football is played at the Division I-A level is also a risk factor when considering the likelihood of a player becoming injured. The injury rate during spring practices is significantly higher than during the fall. "The risk of a spring injury is double the rate of fall practice because spring practices tend to be more physical. In the fall, coaches are more cautious because they don't want to lose a player for that week's game" (Whiteside, 2001, p. 2C). The NCAA, which reported a similar comment, also supported this statement (The NCAA News, 1996; The NCAA News, 1997). Rates of injury are consistent year to year. Every year between 1989 and 1999, the injury rate during spring practices and games was higher than the rate during the fall (NCAA, 2001).

Injury Rate: Games versus Practices

The rate of football injuries during games is much higher than in practice. Zemper found that "the injury rate was 8.6 times higher in games than in practices" (1989, p. 3). McKeag (n.d.) reported an 8.7 times higher rate of injuries in games as compared to practices. Similar findings were reported by the NCAA which found that between the years of 1985 and 2000, the injury rate was 8.87 times higher in games than during practices (NCAA Health and Safety, 2001). Powell and Barber-Foss (1999, p. 278) found that "the relative risk of sustaining an injury in a game is 7 to 10 times greater than in practice." As can be concluded by the research, football players are much more likely to get injured in a game than in practice.

Another risk factor that is often overlooked is the point at the game in which most injuries occur. Zemper (1989) found that most of the game injuries occur during the third quarter. He suggested that this might be because the players rested and cooled off during halftime, rather than staying warm and flexible.

Player Position

The position played by the athlete is also an extrinsic risk factor that can contribute to an injury (McKeag, n.d.). The literature supports the premise that depending on the position an athlete plays on the football team, the chances of injury are either greater or lesser; however, the information conflicts as to which position is at greater risk over others. Mueller, Zemper and Peters (1996, p. 18) report "there appears to be a direct relationship between the amount of contact a player gives or receives and the incidence of injury." They reported that 46% of the total number of loss-time injuries occurred to offensive and defensive linemen, with offensive linemen being the highest at 29%. The latter are engaged in direct contact with other players on every play (Mueller et al., 1996). Zemper found offensive players were injured the most at 50.9% of all reported injuries, while defensive players accounted for 45.2% of reported injuries (Zemper, 1989).

Contrary to the findings of Mueller and his colleagues, Meisenhimer (1997) reported that at the University of Florida defensive linemen were the most frequently injured. However, this study found that the positions associated with the highest rate of injury were the line-of-scrimmage positions. Zemper (1989) found that flankers/wide receivers and running backs had the highest injury rate. On the defensive side of the ball, linebackers and halfbacks/cornerbacks were the most injured.

Boughton (2001) does not discuss which player positions sustain more injuries. Rather, she described the various types of injuries that athletes who play different positions suffer and the reasons for those injuries. She stated that offensive and defensive linemen were more prone to shoulder injuries because of the amounts of force at that body part during playing. Offensive linemen suffer more back problems because of the two and three-point stances they maintain during a large part of competition. In comparison, skill players strain their hamstrings more often due to the sprinting they perform. Quarterbacks, similar to baseball pitchers, suffer from more elbow injuries due to throwing. Therefore, not only does the position he plays predispose him to more or fewer injuries that position also predispose him to injuries to specific areas of the body.

Intrinsic/Internal Risk Factors

Van Mechelen, Hlobil, & Kemper (1992) state that intrinsic or internal risk factors, personal to the athlete, can contribute to athlete injuries. Unlike extrinsic risk factors, intrinsic risk factors cannot be corrected quickly. They include age, gender, injury history, body size, height, weight, local anatomy and biomechanics, aerobic fitness, muscle strength, imbalance, and tightness, ligamentous laxity, central motor control, psychological and psychosocial factors, and general mental ability (Lysens, de Weerdt, & Nieuwboer, 1991; Taimela, Kujala, & Osterman, 1990; van Mechelen et al., 1992). Lighting in a gymnasium can be correctly quickly, whereas, aerobic fitness takes time to improve, while age cannot not be corrected at all.

History of Previous Injury

If an athlete suffers one injury, he is more likely to sustain another injury, often in the same body part. This statement is supported in the literature in that athletes who have histories of previous injuries tend to have a higher injury reoccurrence rate than athletes with no prior injury (Lysens et al., 1991; Safran & Shapiro, 1998; Taimela et al., 1990). One reason why the risk of re-injury is greater may be due during the healing process of an injury. The injured area is more susceptible to re-injury because the content and quality of the collagen (scar tissue) may be deficient for months following an injury (Arnheim & Prentice, 2000; Kisner & Colby, 1990).

Aerobic Fitness

Lack of aerobic fitness and general conditioning has been documented as a risk factor for injury (Pfeiffer & Mangus, 1998). It was found that men who are less physically active suffer from more low back pain than males who are active (Taimela et al., 1990). Meisenheimer found that poor conditioning was one of the main factors that affect injuries (1997).

Gender

Gender is a risk factor that has begun to receive a lot of attention in recent years, specifically in relation to anterior cruciate ligament (ACL) injuries in females. The "data show that female athletes injure the ACL more frequently than their male counterparts do" (Moeller & Lamb, 1997, p. 1). "It has been estimated that one out of 10 collegiate women playing basketball will sustain an ACL injury during her college career" (Griffin, 2000, p. 1). Some hypothesized reasons why female athletes injure their ACL more often than males include estrogen hormone levels, and the shape of the intercondylar notch in the femur. The different playing styles of women as compared to men, and the neuromuscular control of the quadriceps and hamstring muscles are also factors why female athletes have a higher rate of ACL injuries as compared to males (Boden, Griffin & Garrett, 2000; Griffin, 2000). However, research concludes that females do suffer from certain injuries more than males. One example is that male athletes sustain more acute fractures than females. However, female athletes sustain more stress fractures (Hame, LeFemina, Schaadt, McAllister & Dorey, 2001).

Joint Instability and Ligamentous Laxity

Joint instability and ligamentous laxity are risk factors for potential injuries. Bird stated, “joint looseness, or a tendency toward joint hyperextension, increases the risk of injury, even in

“Athletes with insufficient ligament stability are more prone to hyperextension knee injuries” (Mueller et al., 1996, p. 17). Examples of how joint instability and ligament laxity can be a risk factor for injuries are found throughout the body. General ligamentous laxity has been found to contribute to shoulder subluxations, patellofemoral pain syndrome, and ankle pain/sprains (Pfeiffer & Mangus, 1998).

Psychological Variables

Psychological factors also play a role in the incidence of injuries in athletes. Bird (1992) reported that studies show that well adjusted people, who are comfortable with their surroundings, have fewer injuries than those who are neurotic or are going through some stressful life events. Also, people who lack caution, or who have low levels of anxiety when it comes to taking risks, are injured more than the timid types.

Stress is also a factor as it relates to athletic injuries. It was found that female college-aged lacrosse players who had high negative life stress had significantly more days injured than similar athletes who had low negative life stress (Mann & Lacke, 2001). Other research also supports the premise that stress contributes to athletic injuries because the collection of life stress is one element in the compound system of risk factors for injury proneness (Lysens et al., 1991; Taimela et al., 1990).

Overall intelligence has been presented as a possible risk factor for injury in athletes (Pfeiffer & Mangus, 1998). It was reported, “athletes who are anxious, tense, restless, have low self-confidence and low self-esteem are more prone to some injuries” (Arnheim & Prentice, 2000, p. 258). In contrast, Lysens reported that “psychological characteristics such as extroversion, acting-out behavior, and risk-taking seem to be associated with repeated accidents" (Lysens et al., 1991, p. 285). "Athletes who are undisciplined in developing skills in their sport and who lack structure in their personal and social life may be accident-prone" (Arnheim & Prentice, 2000, p. 258).

Height and Body Weight

Taimela et al. (1990, p. 209) reported, "excessive height and weight have been shown to predispose athletes to a higher chance of injury. This may be due to the height of the center of gravity from the base of support and the length of the extremities. Longer extremity length contributes to greater leverage that makes changing directions for the athlete more difficult." In the Irish sports of Hurling and Gaelic football, Watson (1999) found that players who were taller sustained more ankle sprains. Mueller et al. found that there was a higher incidence of knee injuries in football players who were taller and heavier (1996).

Greater body weight is also a risk factor that increases the likelihood of an athlete sustaining an injury when compared to lower body weight. It was found in soccer players; players who weighed over 90 kilograms had a 2.5 times higher injury rate than lighter players (Kaplan, Digel, Scavo & Arellana, 1995). Pfeiffer and Mangus also found body size to be a causative factor in injury (1998). This may be because "excess weight puts added stress on the body during activity" (Bird, 1992, p. 1).

Relative Body Weight

Relative body weight is also referred to as the Body Mass Index (BMI). "The BMI is a body weight relative to height. It is a useful, indirect measure of body composition because it correlates highly with body fat in most people" (American Heart Association, 2001, p. 1).

> The BMI, a weight-for-height ratio widely used in epidemiological studies, is calculated by weight in kilograms, divided by height in meters squared. Obesity standards based on BMI have been developed, and high BMI is associated with increased risk of chronic disease. (American College of Sports Medicine, 2001, pp. 393-394)

If a person has a BMI over 25, he is considered overweight. If the BMI is over 30, he is considered obese (American Heart Association, 2001). However, for this study, body composition was not an issue because only body weight as it relates to an athlete's height was considered. Also, for this particular population, utilizing the BMI would not be indicative of potential health risks. This is because almost every athlete in this study would be considered overweight or obese.

In Division I-A football players the effectiveness of using the BMI for the purpose of predicting chronic health risks would have significant limitations. The BMI in relation to Division I football players would be considered a “poor predictor of percent of body fat, and it often misclassifies persons as obese if they have more musculature and skeletal mass rather than excess fat” (American College of Sports Medicine, 2001, p. 394). The BMI is similar to height weight tables in estimating if someone is overweight or obese because both “fail to consider the body’s proportional composition” (McArdle, Katch & Katch, 1999, p. 382). The chances of misclassifying an athlete as overweight or obese definitely applies to large-size athletes such as football players (McArdle, Katch & Katch, 2000). McArdle et al. wrote, “the BMI for seven defensive linemen average 31.9 (team BMI averaged 28.7), clearly signaling these professional athletes as overweight” (1999, p. 383). Statistics similar to these are not a one-time incidence. In their publication, Sports and Exercise Nutrition, McArdle et al. (1999) showed the BMI for all roster players in the National Football League between 1920 and 1996 (N = 53,333). The athletes were placed in five categories based upon position (defensive back, defensive line, linebacker, offensive line, and skill player). From the data presented, “offensive and defensive linemen from 1980 to the present would be classified as obese” (p. 382).

<u>Local Anatomy and Biomechanics</u>

The local anatomy, particularly the skeletal structure of an individual, may be a risk factor for athletic injuries. The literature demonstrates that musculoskeletal injuries are associated with related structural risk factors. It is documented that “hereditary, congenital, or acquired defects may predispose an athlete to a specific type of injury, and that anomalies in anatomical structure may make an athlete prone to injuries” (Arnheim & Prentice, 2000, p. 258). If an athlete has a postural deviation, it is often a major underlying cause of sports injuries (Arnheim & Prentice, 2000). Arnheim and Prentice wrote, “postural malalignments may be the result of unilateral muscle and soft-tissue asymmetries or bone asymmetries. As a result, the athlete engages in poor mechanics of movement” (2000, p. 258). When the postural deviations cause an imbalance, the body looks to reestablish around a new center of gravity, which can be a principal cause of injury (Arnheim & Prentice, 2000). Examples of the postural and structural deviations as they relate to athletic injuries are documented.

In the cervical region, a long, thin neck predisposes an athlete to cervical spine injuries, and cervical stenosis and can contribute to cervical neurapraxia (Mueller et al., 1996; Pfeiffer & Mangus, 1998). In the upper extremity, an accessory cervical rib can contribute to thoracic outlet syndrome (Pfeiffer & Mangus, 1998). For the lumbar region, structural considerations are also risk factors for injury. Spondylosis and spondylolisthesis can contribute to low back pain (Pfeiffer & Mangus, 1998). Najera (2001, p. 1) reported "that knee injuries were associated with a higher degree of lumbar lordosis and sway back. Also low back injuries were associated with poor shoulder symmetry, scapular abduction, back asymmetry, kyphosis, lordosis, and scoliosis."

In the lower extremities, structural malalignments can result in numerous non-contact injuries. Brukner & Khan (2001) say that malalignments in the low extremities such as pes planus and cavus, rearfoot varus, tibia vara, genu valgum and varum, patella alta, femoral neck anteversion, tibial torsion, and leg length discrepancies can all be risk factors for overuse injuries. Mueller et al. found that as high as "88% of knee injuries occurred to athletes who had

Iliotibial band syndrome can be caused by a prominent lateral epicondyle on the femur, genu varum, internal tibial torsion, or hyperpronated feet (Pfeiffer & Mangus, 1998).

Flexibility/Mobility

One other cause of non-contact athletic injuries is lack of mobility. Athletic Testing Services (2000, p. 3) states, "mobility is essentially the combination of muscle flexibility, joint range of motion and body segment's freedom of movement." If an athlete does not have adequate mobility for his/her sport, it increases the chances of sustaining an injury. The literature supports this statement. "Muscles, tendons, ligaments and joint capsules that are less flexible are often more susceptible to injury" (Rooks & Mecheli, 1988, p. 643). Muscles that cross two or more joints, such as the hamstrings, become injured most often (Pfeiffer & Mangus, 1998; Safran & Shapiro, 1998). Ross (1999, p. 124) states, "insufficient hamstring flexibility has been proposed as a possible cause of hamstring strains." Krivickas and Fienberg (1996, p. 1139) reported that "lack of flexibility may produce early muscle fatigue or alter normal biomechanics of movement, predisposing to injury." They go further to state, "these restrictions in motion may alter functional biomechanics, interfering with performance and predisposing the athlete to injury" (Krivickas & Fienberg, 1996, p. 1142). Injuries that occur as a result of decreased flexibility include muscle strains, sprains and overuse injury (Krivickas & Fienberg, 1996). They go on further to report

> studies of athletes in a variety of sports have shown that more than half of all injuries are sprains and strain. Muscle strains and overuse injuries are most likely to be prevented by improved flexibility, especially when the athlete has adequate strength to control the flexibility. Restrictions in range of motion may also predispose the athlete to injury by macrotrauma (p. 1139).

Documentation demonstrates evidence that lack of muscular flexibility is a primary cause of injury. Pfeiffer and Mangus (1998) reported that tight shoulder musculature is related to shoulder impingement syndrome. In the low back, tight lumbosacral fascia, hamstrings, and hip flexors are associated with low back pain (Pfeiffer & Mangus, 1998). In the lower extremities, "athletes with tight heel cords may be more susceptible to lower extremity injuries" (Mueller et al., 1996, p. 17). Other literature shows that a tight iliotibial band is associated with iliotibial band syndrome (Pfeiffer & Mangus, 1998). Hamstring strains are often the result of tight hamstrings (Pfeiffer & Mangus, 1998; Safran & Shapiro, 1998). In the knee, tight hamstrings are known to cause patellofemoral pain syndrome, and inflexible quadriceps are known to be associated with Osgood-Schlatter disease and patellar tendonitis. Finally, anterior tibial pain is related to tight muscular compartments in the leg (Pfeiffer & Mangus, 1998).

If an athlete develops tightness in the muscles and joints, he will compensate the movement patterns in order to perform the activities. "Athletes will always sacrifice quality of motion to maintain quantity of motion, which means that athletes will develop compensatory movement patterns in order to overcome functional deficits" (Athletic Testing Services, 2000, p. 3). Regan (2000) found that limitations in hip rotation range of motion and strength could result in compensatory motion in the lumbar and thoracic regions during rotational activities. If an athlete has tight hip flexors, it becomes difficult for him to control the lumbro-pelvic area (Tyson, 2000). Ninos (2001) reports that if an individual has limited flexibility in the hip internal and external rotators, it increases stress on the pelvis, sacroiliac joint, and lumbar and thoracic spinal region. However, when the hips are allowed to move through the greatest allowable range of motion, it can decrease the amount of motion needed in other regions of the body thereby minimizing the microtrauma that can develop in repetitive types of injuries discussed in the FMS. When these altered movements are utilized, the chances of an injury increase.

However, if flexibility and joint range of motion are within normal limits, the likelihood of an injury decreases. Rooks and Micheli (1988, p. 643) reported that "by increasing the range of a joint and its muscles, the chance of a tear-type injury may be reduced." If a sports medicine professional can help an athlete improve his or her flexibility, the chances of a non-contact injury can be decreased. Kriveckas and Fienberg supported this by stating "the detection of muscle tightness followed by implementation of a corrective stretching and rehabilitation program may be one way to reduce injury" (1996, p. 1143). This may be because when a football player is flexible, he can actually run faster as the result of greater lower extremity separation. This makes him more able to avoid injuries (Boughton, 2001).

Muscle Strength Imbalances

Muscle strength imbalances within athletes can also contribute to injuries in football players. This is particularly true for non-contact overuse injuries (Bruker & Khan, 2001; Mueller et al., 1996; Najera, 2001). From the perspective of the FMS, "the word imbalance indicates that the muscular forces about a certain joint or body segment are not equal, thus creating joint stress and reduced control" (Athletic Testing Services, 2000, p. 5). These imbalances can be "identified between the right and left sides of the body, as well as the medial/lateral and/or anterior/posterior aspects of a specific joint" (Athletic Testing Services, 2000, p. 5). This is because this muscle strength imbalance occurs when "one group of muscles surrounding a joint is proportionally stronger than an opposing groups of muscles" (Chandler, Ellenbecker & Roetert, 1998, p. 7). If these imbalances persist, they can lead to injuries, particularly overuse types of conditions.

Knapik, Hones, Bauman and Harris (1992, p. 281) "found that athletes with knee flexion R/L imbalances greater than 15% were 2.6 times more likely to suffer lower extremity injuries than subjects without this imbalance." The same can be true for anterior/posterior aspects of a joint. Knapik also reports that "subjects with knee flexion/knee extension ratios less than 0.75 (isokinetic strength at 180 degrees/second) were 1.6 times more likely to get injured." Chandler et al. reports that often in tennis players and other throwing athletes, the anterior shoulder muscles are stronger than the posterior musculature. If this type of imbalance occurs, the athlete may not be able to stabilize and decelerate the arm, which can result in decreased performance and increase the chances of attaining an overuse or non-contact injury (1998). If these imbalances are detected and corrected, the incidence of injury in those athletes can be decreased.

Muscle and joint imbalance can also lead to potential injuries. Knapik et al. (1992) cites research by Merrifield and Cowan in 1973, that "subjects were 5.6 times more likely to suffer hip adductor strains if they had a hip adduction flexibility imbalance of 4 degrees or more" (p. 285). Again, if the muscle strength and mobility imbalance are identified and corrected, the number of musculoskeletal, non-contacted injuries can be reduced.

<u>Muscular Strength</u>

Muscle strength, particularly dynamic core body strength and stability, is critical for the prevention of non-contact athletic injuries. Athletic Testing Services describes stability "as ligamentous integrity about a joint, is the ability to maintain a posture or control motion" (2000, p. 3). To aid in the prevention of non-contact athletic injuries, dynamic stability is imperative. When an individual is performing an activity, dynamic strength/stability is needed in the core of the body. The core is considered the abdominal and lumbopelvic musculature. Specifically, the core consists of the muscles of the abdominals, hips, shoulder stabilizers, and lumbar, thoracic and cervical spines (Boughton, 2001; Hedrick, 2000).

In order to maximize performance and decrease the likelihood of sustaining an injury, it is important to have adequate trunk strength and control (Tyson, 2000). Clark (2000, p. 67-68) reports that adequate core stabilization "will improve dynamic postural control, ensure appropriate muscular balance and joint arthrokinematics around the lumbopelvic-hip complex, allow for the expression of dynamic functional strength, and improve neuromuscular efficiency throughout the entire kinetic chain." If the trunk is weak and poorly developed, it results in poor posture, resulting in less efficient movements. This causes the athlete to move out of proper body alignment and makes him a prime candidate for an injury (Hedrick, 2000). This statement is particularly true in the game of football because a strong core allows football players to perform multiple movements that require quick changes in direction (Boughton, 2001). Hedrick (2000, p. 50) supports this by stating "strength is critical because all movements either originate in or are coupled through the trunk. This coupling action created by a strong core connects movements of the lower body to those of the upper body and visa versa." If an athlete is to play uninjured, he needs to have a strong, stable core.

A strong, stable core is necessary because "the body works as a functions unit when the core is strong and stable" (Gambetta & Clark, 1998, p. 25). Therefore, if an athlete has a strong midsection, the upper and lower extremities function more effectively (Owens, 1998). In athletics, athletes need to perform activities that require quick direction changes, acceleration, deceleration, starts and stops. If the core musculature is not strong, the likelihood of attaining an injury is increased. Clark (2000) supported this by stating, “the core musculature is an integral component of the protective mechanism” (p. 68). For an athlete to perform activities proficiently and safely, core stability needs to be strong. This is because a person needs to have proximal stability before he has distal mobility. Clark (2000) acknowledged this by stating, “proximal stability provides for efficient lower extremity movements. If the extremity muscles are strong and the core is weak, not enough force will be created to produce efficient movements; efficient movements lead to injury” (p. 68). An example of this was expressed by McMullen and Uhl (2000), who found “proximal hip muscle activation is delayed in patients with severe ankle joint injury compared to noninjured controlled during hip active extension” (p. 330).

> They also reported that a pattern of proximal muscle activation before distal movement serves as a foundation for using the trunk and legs to drive the scapula and shoulder during the rehabilitation process. This is because the proximal trunk segment, rather than the more distal arm, acts as the ‘initiator’ for appropriate shoulder motion. (McMullen & Uhl, 2000, p. 330)

Athletic Testing Services (2000, p. 4) supports this by stating ”often the glenohumeral joint will become less stable as a result of the thoracic spine’s ability to flex, extend, or rotate.” From the research discussed above, it can be concluded that a lack of core stability can lead to altered movement patterns. These altered patterns can result in an injury to an athlete.

Localized muscle weakness is also a cause of athletic injuries. Overuse injuries are often caused by muscle weakness (Bruker & Khan, 2001). It is documented that weak hamstring strength is a predisposing factor for hamstring strains (Pfeiffer & Mangus, 1998; Safran & Shapiro, 1998). Pfeiffer and Mangus (1998) state that weak neck muscles are a risk factor for cervical spine injuries, and shoulder girdle muscle weakness is a cause of glenohumeral joint subluxation. In the low back region, weak abdominal and paraspinal musculature are related risk factors for low back pain. Weak quadriceps are associated with patellofemoral pain syndrome, Osgood-Schlatter disease, and patellar tendonitis. Finally, ankle pain/sprains are linked to weak ankle musculature, especially the peroneal muscles.

By detecting the compensatory movement patterns, the FMS can help to determine the deficits in an athlete’s flexibility, muscular balance, and core stability. This testing system “is designed to assess mobility and stability with a simple grading system. It will help focus the orthopedic exam with respect to functional movement limitations, create specific criteria for exercise prescription, help identify underlying problems due to imbalances that are created by field and court sport, and serve as a base line of pre-injury level function following rehabilitation" (Athletic Testing Services, 2000, p. 1). In a sense, the FMS assesses the functional strength of an athlete. Because functional strength "focuses on working several muscle and joints in harmony- as a body does in athletic movement" (Conca & Burton, 1998, p. 40). In traditional strength testing, specific movements are isolated. While this does measure strength in a specific area, it does not evaluate the body as a functional unit.

Injury Recording

The documenting of athletic injuries is often a problem when attempting to track injury rates. This makes the researching injury prevention tools quite difficult. There are several reasons for this quandary.

Problem #1: Athlete exposure. Just because a player dresses for a practice or game, it does not consider how many plays the athlete was in.

> McKeag concluded when collecting athlete-exposure data, the time element is ignored, and data recorded on the number of players at each practice and the number who actually get into the games and are exposed, however briefly, to the possibility of injury (not the number who dress for the game). (n.d., p. 15)

The reason is that injury surveillance services, such as the NCAA Injury Surveillance System (ISS), defines an exposure as "one athlete participating in one practice or game where he is exposed to the possibility of athletic injury" (NCAA, 2001, p. 2).

Problem #2: The individual methodologies used when researching athletic injuries. When using data from non-local sources, different methods of data collection may be used, or a different definition of an injury can be implemented. This can result in major differences in statistical outcomes that effect the conclusions drawn. If this occurs, the comparisons between the results would be invalid (McKeag, n.d.). If similar definitions and calculations are not used for all studies, the conclusions can only be based on a specific population, and not athletes in general.

Problem #3: The studies are not conducted long enough in duration or there are not enough subjects in the study, or both. This is due to the fact that multiple variables are the cause of athletic injuries. McKeag stated that

> from a epidemiological perspective, the only way to control the numerous variables is to do a large-scale, long-term study with as many teams as possible so that the impact of the uncontrollable and essentially unrecordable variables (proper brace placement, practice intensity, condition of playing surface, weather) will wash out in the data collection process. At the same time, the more easily recordable variables (position played and previous injury) will be recorded in sufficient numbers to provide more reliable results." (n.d., p. 14)

Problem #4: The reporting of injuries is not always consistent. "The NCAA analyzes data collected from the ISS to monitor any emerging injury patterns. If trends are detected, the competitive safeguards committee and sport rules committee find ways to counter the injuries, either through rules changes, equipment regulations or suggested coaching and care techniques" (Courson, 2001, p. 53).

Since rules in sports are often changed due to the trends in injuries, cooperation is needed from athletic trainers to accurately report all injuries so that the officials making the rule changes have complete records, thereby making the injury reporting systems effective.

Pre-participation Physicals and Performance Testing

Commonly implemented measures that attempt to prevent athletic injuries include mass pre-participation physicals and performance testing on athletes prior to the start of their athletic seasons. These interventions are conducted "to identify disease, injury and abnormalities that would predispose someone to unnecessary injury during athletic competition. Performance tests are used to demonstrate the athlete's ability with regard to strength, speed, power, agility and coordination" (Athletic Testing Services, 2000, p. 2).

Pre-participation physicals and performance testing do have their merits. Pre-participation physicals help to identify individuals who may be at increased risk during participation in athletics. Usually pre-participation physicals entail height and weight measurement, blood pressure and pulse rate, blood tests, urinalysis, visual acuity, and a general medical examination (Hillman, 2000). Often, during the pre-participation physical, performance testing on the athletes is also conducted.

Performance testing is also an advantageous system of assessing athletes by identifying individuals with potential problems which can lead to injury, as well as signify an athlete's chances of difficulty during sports participation. Performance testing also allows a sports medicine professional to develop individual baseline parameters for athletes in order to design conditioning and rehabilitation programs. Components of performance usually assess muscular strength, endurance, and power; cardiovascular performance, speed, flexibility, agility, and body composition (Hillman, 2000). However, performance does have its weaknesses:

> The primary drawback with performance testing is that the athletes who score high on these tests are also the ones who are constantly injured as the result of non-contact injuries. This is because both the physicals and performance tests do not assess the functional performance of the athletes. (Athletic Testing Services, 2000, p. 3)

In other words, the athletes are not assessed in the same manner by which they are injured. One of the main deficiencies in pre-participating screening is that while they do quantify performance in athletes, they do not assess the quality of movement "as it relates to the efficiency in which an athlete performs. Also left uncovered are the underlying movement problems and musculo-skeletal anomalies that only inhibit maximal performance potential, which may lead to increased tendency of non-contact injuries" (Athletic Testing Services, Inc., 2001, p. 1).

However, there is an instrument that exists which is designed to identify athletes who may be at a greater risk of sustaining a non-contact injury during athletic participation. This tool is The Functional Movement Screen™ (FMS). It should be stated that while many contact injuries, such as acute fractures and concussions, are unavoidable, many non-contact injuries can be prevented.

This is a great concern in Sports Medicine. As stated earlier, most contact injuries cannot be prevented. However, many non-contact types of injuries can be avoided if specific deficits and risk factors within the athlete are addressed and corrected prior to athletic competition. With most athletic injuries, there is no one exact cause for the injuries. This is due to the fact that athletic injuries are multifactoral in nature (Lysens et al., 1991; Rooks & Micheli, 1988). There are several theories or hypotheses that attempt to describe these risk factors. One theory is the kinetic chain model or link theory. In this model, "normal, efficient motion and muscle activation are believed to occur in a proximal-to-distal sequence" (McMullen & Uhl, 2000, p. 329). The problem arises when "abnormal forces distally are transmitted more proximally and distally" (Nadler, Wu, Galski & Fienberg, 1998, pp. 831-832). Other factors within the athlete that contribute to possible non-contact injuries are termed extrinsic or external and intrinsic or internal risk factors.

It is obvious that multiple factors play a role concurrently to contribute to the injury of an athlete. However, "this multifactorial nature of athletic injuries has rarely been studied comprehensively" (Lysens et al., 1991, p. 282). Meeuwisse (1991) concurs in that "there has been abundant research to identify the existence of risk factors for injury. There is little epidemiological evidence, however, for identifying at risk athletes. Locating players who are more likely to get injured is possible through single or multiple factor analysis, but one problem finding significant results appears to be due to the wide individual variability in predisposing risk factors" (p. 14).

Univariate approaches to screening for the purpose of identifying at risk athletes are one means of identifying possible injuries before they occur. Interventions, such as orthopedic assessments, flexibility and strength tests, and aerobic fitness assessments, usually measure one variable that can predispose an athlete to injuries. If that variable is deficient, an athlete may get injured. However, many extrinsic and intrinsic risk factors are involved in athletic performance. For this reason, the most appropriate approach for attempting to predict potential injury rates is to examine as many of these risk factors as possible. This multivariate approach would allow the researcher to determine how the interaction between the factors contribute to the likelihood of attaining an injury, rather than claiming that one single variable is responsible for athletic injuries. Until an assessment tool is developed that uses multiple risk factors from different categories, the sports medicine professional should implement as many screening approaches as appropriate in an attempt to truly locate certain athletes who are at a greater risk of suffering injuries during their sports seasons.

A question must also be asked as to whether a screening tool actually assesses the parameters that it claims. One of the purposes of this study was to determine if an athlete's height and body weight were factors affecting an athlete's scores on the FMS. This is because research states that taller and heavier athletes are more likely to get injured. Therefore, if a tall or heavy athlete scores low on the FMS, it may not be due to mobility and stability deficiencies.

The Functional Movement Screen™

The FMS "has been designed to assess mechanical factors of mobility and stability that are not well addressed during either the pre-participation physical or standardized performance testing" (Athletic Testing Services, 2000, p. 3). The testing procedure for the FMS utilizes a dynamic (whole body) musculoskeletal approach employing functional movement patterns to identify limitations of an athlete's fundamental mobility and stability. These mobility and stability patterns revolve around the lumbropelvic hip complex. If mobility and stability are not adequate during functional activities, it can "lead to increased mechanical stress on the contractile and non-contractile tissues, leading to repetitive microtrauma, abnormal biomechanics, and injury" (Clark, 2000, p. 68). If an athlete "scores low on the Functional Movement Screen ™, that athlete may be predisposed to a non-contact injury" (Athletic Testing Services, 2000, p. 5). This is because if an athlete "demonstrates a low score on the FMS, they are breaking certain mechanical laws, expending excessive energy, and predisposing themselves to injury" (Athletic Testing Services, 2000, pp. 6-7).

In the FMS, local anatomy and biomechanics, and muscle strength, imbalance and tightness are addressed. The reason for this is that "the FMS is designed to assess mechanical factors of mobility and stability that are not well addressed during either the pre-participation physical or standardized performance testing" (Athletic Testing Services, 2000, p. 3). As a general rule, most of the other intrinsic risk factors are included in the pre-participation physicals and/or standardized performance testing.

Relative body weight was examined in the study because there is very little research conducted on how relative body weight relates to the likelihood of athletes sustaining injuries. For this reason, relative body weight, Body Mass Index (BMI), was also examined in this study as it relates to scores athletes achieve on the FMS.

While the BMI is not an effective predictor of body composition in football players, it is useful in this study as it relates to an athlete's FMS score. As mentioned above, there is little or no research relating BMI to athletic injuries. If a relationship is found that Division I-A football players who have higher BMI get lower FMS scores, then this variable can be used in developing normative "passing scores" for individual athletes.

If a Sports Medicine specialist can assess athletes and identify those who are at risk of getting injured prior the start of their sports season, it can be an invaluable tool for having healthy athletes, while keeping rehabilitation costs to a minimum.