JOINT PROPRIOCEPTION AND INJURY INCIDENCE IN FEMALE SOFTBALL PLAYERS

THESIS

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ABSTRACT

Previous research has failed to determine whether proprioceptive ability is related to the incidence of lower-extremity (LE) joint injury. The purpose of this study was to determine the relationship among measures of proprioceptive ability, history of LE joint injury, position, and the incidence of LE joint injury in collegiate female softball players. Subjects were 18 collegiate female softball players, ages 18-22 years. Each subject was tested individually for proprioceptive ability at the beginning of a collegiate season of softball competition. Subjects underwent timed tests for static, dynamic, and functional proprioceptive ability. Subjects were also rated (good/poor) according to the proficiency of their performance on these tests. Any history of previous LE joint injury was also recorded, as well as competitive position (infield, outfield, or pitcher). Subjects were then monitored for a 10-week period of practice and competition, and the occurrence of any LE injury was recorded. Ankle injuries were the only type of LE joint injury observed during this period. Logistic regression analysis revealed no relationship between subjects' history of ankle injury and performance on the timed tests for static ($\chi^2 = 0.71$, $p > .05$), dynamic ($\chi^2 = 0.07$, $p > .05$), and functional ($\chi^2 = 0.31$, $p > .05$) proprioceptive ability. Also, there was no relationship between the occurrence of ankle injury and subjects' performance on the timed tests for static ($\chi^2 = 1.53$, $p > .05$), dynamic ($\chi^2 = 0.76$, $p > .05$), and functional ($\chi^2 = 0.23$, $p > .05$) proprioceptive ability. Chi-square analysis

revealed a significant relationship between subject's history of ankle injury and the occurrence of injury ($\chi^2 = 4.11$, $p < .05$). Subjects who had suffered ankle injuries in the past were more likely (2 out of 3) to sustain an ankle injury than subjects with no previous history of ankle injury (1 out of 14). Also, a significant relationship between subject's performance ratings (good/poor) on the static tests of proprioceptive ability and the occurrence of injury was observed ($\chi^2 = 5.85$, $p < .05$). Subjects rated "poor" on the proprioceptive ability tests were more likely (2 out of 5) to become injured that subjects rated "good" (0 out of 13). Finally, a significant relationship between subject's position (infield/outfield/pitcher) and the history of injury was also observed ($\chi^2 = 6.43$, $p< .05$). Pitchers were more likely to have suffered a previous injury (3 out of 5) than infielders (0 out of 8) or outfielders (1 out of 5). These data demonstrate that ratings of proprioceptive ability are useful for identifying athletes likely to suffer ankle injuries during a competitive softball season. Also, pitchers are more likely to have a history of previous ankle injury; consequently, they may need more bracing or preventative measures to prevent ankle injuries than other players.

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Joint Proprioception and Injury Incidence in Female Softball Players

Tracking incidence of athletic injuries in football began at the high school, collegiate, and professional levels as early as the 1930's (1). Various systems tracking all injuries in up to ten different sports have been continuously active since 1972 (1,5). Analyzing valid, reliable sports injury data can help decrease injury incidence. If properly interpreted, data collected on incidence of injury can be used to assist professionals to understand risks and etiology so that they may take steps towards combating injury (1,47). Injury prevention programs should be in place, precluding re-injury through daily injury management (47). The athletic training profession is firmly committed to research that identifies associated variables and reduces the causes of athletic injuries. Prevention of athletic injury has even become a major professional domain in the National Athletic Trainer's Association (NATA), and the NATA funds injury tracking in 150 to 200 high schools in each sport nationwide (1). In addition, organizations such as the American College of Sports Medicine and the American Academy of Orthopedic Surgeons provide much support for research and identification of athletically related injuries. Several journals such as the American Journal of Sports Medicine, the Journal of Orthopedic Sports Physical Therapy, Medicine and Science in Sports and Exercise, and the Journal of Athletic Training provide forums for much discussion concerning the incidence and rehabilitation of athletic injuries.

Previous research has focused specifically on prevention of ankle and knee injuries (11,17,40,52). Ankle injuries are commonly studied since they are often cited as the most common of all athletic injuries (46), especially in basketball, soccer, field hockey, and volleyball (47). Several studies have also been conducted on knee injuries, particularly injury to the anterior cruciate ligament (ACL, 2,10,23,28,40,45,48,50,55).

Incidence of ligamentous injuries of the ankle and knee, particularly in female athletes (10,23,24,27,28,37,48), are of special concern. There have been well-documented gender differences in previous research concerning athletic injury (5,28,37,47,54,55). Fast-pitch softball players are among the less frequently studied female athletes, primarily because the sport has only recently gained popularity. The NCAA Injury Surveillance Survey has included softball in the injury collection surveys since 1982, compiling data from a geographic cross-section of Division I, II, and III institutions nationwide (43).

Several etiological theories regarding the increased incidence of athletic injury in the female population have been reported (5,10,17,23,27,28,37,41,55). Lack of muscle strength (28), greater joint laxity (17,24,28,48), hormonal differences (24,28), acute knee and hip alignment (Q-angle) (17,28), and poor joint proprioception (2,28,38,40,54) are among the most recently proposed causes.

Joint proprioception, or the awareness of the body's position in space, monitors muscle function and reflex stabilization of the structures in and around the joint. Enhanced joint proprioception may play a preventative role in the incidence of athletic injuries (28,35). In addition, improving proprioception deficits are thought to decrease chronic injury and re-injury in the joints (28,35). It has been suggested that previous history of joint injury as well as diminished joint proprioception precede chronic joint injury (3,11,13,19,30,34-36,45,52,53). The effects of training on proprioception and injury have also been examined (3,5,7,18,26,38,52). Predicting joint injury may be done by detecting individuals with proprioception deficits who may be potentially at high risk (33,46). Previous research has failed to determine if proprioceptive deficits can be preliminarily identified. Previous research has also failed to determine whether training can reduce proprioceptive deficiencies prior to competition, and consequently reduce the occurrence of athletic injury. No documentation has shown whether the occurrence of lower extremity joint injuries can be reduced through the improvement of proprioception deficiencies prior to competition, as a result of training. Therefore there is a need for research that identifies proprioception deficiencies and their relation to injury incidence.

Purpose

The purpose of this study was to determine the relationship between baseline proprioceptive abilities and incidence of lower extremity injury. This study also examined the effect of history of lower extremity injury and specific softball position on incidence of lower extremity injury in female collegiate softball athletes.

Hypotheses

1. It was hypothesized that there is a negative relationship between proprioceptive ability and the incidence of lower extremity joint injury in female collegiate softball athletes.
2. It was hypothesized that previous history of lower extremity (LE) joint injury increases the incidence of joint injury in female collegiate softball athletes.
3. It was hypothesized that softball pitchers have a lower incidence of lower extremity joint injury than field players, regardless of lower extremity history or proprioceptive ability.

Delimitations

1. This study was delimited to female collegiate softball players at Southwest Texas State University.
2. The observation period for the incidence of lower extremity joint injury was delimited to a 10-week period of NCAA Division I competition.
3. The proprioceptive measurements were delimited to static, dynamic, and functional unilateral balance techniques.

4. The proprioceptive measurements were delimited to dual examiner agreement on objectivity ratings of high, moderate and low, as well as timed quantifications of balance ability.

Definition of terms

1. Proprioception The ability to receive information, sent from the muscles, tendons and joints, and process it in a meaningful way in the central nervous system
2. Mechanical Instability Instability in the joint of the body where there is anatomical laxity, or looseness, usually tested manually by an examiner.
3. Functional Instability Instability in the joint of the body where a person describes subjectively, the feeling or presence of 'giving way' or joint movement.
4. Center of Gravity The point at which is the center, as imposed by gravity, or the body's mass is equally distributed.
5. Center of Pressure The intersection of the line of the total force (gravity and other acceleration forces) and the surface of a force plate
6. Postural Sway Displacements in the center of gravity.
7. Stabilometry a method which makes it possible to study postural equilibrium quantitatively and independent of subjective influences, by using a mechanical force plate.

Significance of the Study

Because injury often prevents an athlete from obtaining his or her competitive goals and aspirations, injury incidence is of major concern for coaches, parents, sports medicine professionals, and athletes. By identifying methods for preventing or reducing the incidence of injuries, an athlete's functional health and performance might be enhanced. The results of this study revealed that preventative measures should be taken in order to improve proprioceptive deficits and possibly reduce the risk of injury.

Injury to the lower extremity can cause severe detriment to an athlete's performance. Serious injury may result not only in permanent loss of sport skill and/or daily function, but even in permanent disability. Moderately serious injuries usually require missed time from practice, training, or even competition. For athletes and coaches, the results of this study could dramatically reduce the amount of time lost from training or competition due to injury. For the sports medicine professional, these results justify specific proprioceptive training for athletes, as well as aid in the understanding and application of such training.

Prevention of athletic injury, specifically those to the ankle and knee, has been a topic of research for many professionals (40,52). In both the ankle and knee, prophylactic taping and semi-rigid bracing have been found to be effective in the prevention of injury (17,52). These methods are generally the most common and most available to athletes, coaches, and parents. It has been suggested that these external supports provide restriction of certain biomechanical motions, but they have also been identified as a factor in improving proprioception (15). In addition, strength training has been identified as an important factor in the rehabilitation of lower extremity injuries, and has also been suggested as a preventative measure (7,13,18,29,32,36,38,46,52).

Proprioceptive training has been found to affect dynamic balance, postural control, and the incidence of subsequent injury in athletes (18,38,52). Tropp et al. (52), and Gauffin et al. (18) found that coordination training utilizing an ankle disk with a hemispherical undersurface, improved functional stability (incidence of ankle sprains) and postural control. Ankle disk training was also found to positively influence the ability to balance dynamically in subjects with a history of ankle injury (38).

Proprioception has also been the topic of recent research related to injury. Previous research has established the presence of proprioceptive deficits in injured extremities (13,18,33,35,46,53). Previous research has identified proprioceptive training as a preventative measure, as well as a rehabilitation method for acute and chronic injury (3,6,13,18,26,38). Muscle reaction and proprioceptive ability have also been shown to be affected by acute or chronic injury (31,32,36).

While these variables have been identified and studied, the isolation and comparison of the results is difficult. Even though there is documentation regarding the role of proprioception in the rehabilitation of injuries (17,35,46), little is known about how proprioception may be utilized to prevent injuries.

Additional baseline data on proprioceptive ability in female athletes would assist sports medicine professionals by identifying those athletes potentially at risk for injury. Because collegiate women's fast-pitch softball is a recently emerging sport, baseline proprioception data on these athletes is limited. Previous research has not investigated baseline proprioceptive ability as a predictor of joint injury in females. Consequently, there is a need for isolated baseline measurements taken with low cost field equipment on female softball players. There is also a need for determining the incidence of lower extremity joint injury as it relates to joint proprioception. Recent studies measuring proprioception have utilized instrumentation such as a force plate stabilometer, which is expensive and not readily available to practitioners (6,33,49,53). Low cost equipment makes the field tests of proprioception analyzed in this study applicable and replicable in almost any athletic training setting. The results of this study might be used to prevent joint injuries before they occur in athletes in the future.

Chapter 2

Review of the Literature

Lower extremity injuries are very common in the athletic population as well as all active individuals (1,47); consequently, many healthcare professionals are concerned with determining causes, treatments, methods of prevention, and the related variables involved in these types of injuries. Ankle injuries, for example, are the most common injuries in sports, accounting for up to 30-35% of all athletic injuries (13,14,46). Ankle sprains produce damage to surrounding ligaments, muscles, and sensory nerve fibers within the joint capsule (13). Knee injury is also a common and devastating injury to athletes. Among the most serious is the anterior cruciate ligament (ACL) injury. Rehabilitation from ACL injury can take up to one year if the ligament is ruptured, reconstructed surgically, then rehabilitated to active competition. Knee and ankle instability have been recently attributed to joint laxity, muscle weakness, and proprioceptive deficits (2,17,35,36,51).

After an injury, the presence of functional (feeling of giving way) and mechanical (ligamentous laxity) instability is common, often resulting in recurrent injury (13,53). Although the mechanism behind this instability has not completely been identified, several researchers have studied the attributions of joint laxity, muscle weakness, and proprioceptive deficits (32,34,35,36,51).

The effects of injury on proprioception and its relation to mechanical or functional laxity (13,16,19,22), and muscle reaction time (18,30,56) have also been examined thoroughly (32,33,53). The effects of chronic laxity, or instability, on proprioception specifically have been reported as a possible explanation of recurrence of injury (13,35). Impaired proprioception has also been identified as a potential etiological factor in injury to the lower extremity (13,18,33,35,46,53). Thirdly, training methods involving multiaxial tilting circular platforms or various other balance activities (6,13,18,26), and strength training (7) have been shown to be effective for improving proprioception (3,38). Additionally, females have been recently found to have a greater frequency of injury versus their male counterparts (23,28,43,55). This review will define proprioception and discuss its modes of quantification, analyses, and training techniques. In addition, this review will discuss subject specifications studied in previous research done on proprioception. Furthermore, this review will discuss previous research concerning proprioception and its relation to joint injury, including functional instability, mechanical instability, and muscular involvement.

Proprioception

Proprioception is defined as the ability to receive input from muscles, tendons, and joints and then process that information in a meaningful way in the central nervous system (29). Normally, to control balance, the central nervous system uses sensory input from the vestibular, somatosensory (proprioceptors), and visual systems. Information from all three sensory systems enables the central nervous system to recognize and control the 1) body's orientation in space, 2) relative orientation of body segments, and 3) relative interaction of the body's center of gravity and center of pressure (29,42) within the area of support provided by the feet (14,15). From this information, the body is able to maintain balance while being aware of its physical location. In the absence of visual cues, joint angle formation becomes conscious through a mental image of our body (4).

Since the joint capsules contain complex innervations of multiple types of mechanoreceptors, combined epithelial and nerve cells, and sensory neurons (afferents) that are mechanically sensitive, their importance as a source of sensory input is indicated. Consciously, proprioception is generally manifested into a sensation (21). It is believed that in respect to the joints, there is sensory information concerning: knowledge of the angle of the joint, when in motion and when stationary, and an awareness of the direction and speed of angular changes (4).

When a joint is moved or loaded in a certain way, the mechanoreceptors that innervate it are excited and action potentials are initiated (21). Since these are afferent neurons, neurons that carry signals to the brain, the action potentials are transduced into a neural impulse code that is conveyed to the central nervous system (21). A joint rotation, then, may cause the activation of many populations of neurons originating in peripheral tissues and will also cause the subject to experience a sensation of joint movement or of a change in joint position (21). When a joint is stationary, the receptors are tonic, or stimulated, they might also provide ongoing signals that specify the position of the joint in the absence of movement (4).

Grigg (21) compared different types of mechanoreceptors and their roles in proprioception and found that proprioception is a complex combination of sensations that are mediated by many types of sensory neurons. The role of muscle afferents appear to intercede position sense and the presence of joint motion, while joint afferents are important in sensations associated with moving the joint at the ends of its range of motion (4,21,56).

Quantification and Training Techniques of Proprioception

While there is general agreement over the definition of proprioception, there is controversy regarding measurement. It is also important to note that measurement and analysis of proprioception often correlates directly with training techniques. While injury cause the muscles to 'forget' their role in controlling lower extremity acceleration and deceleration, developing proprioception is essential for accurately training and performing functional activities in rehabilitation. Several studies have examined the effect of training and rehabilitation on proprioception using similar techniques and sport specificity (3,6,18,26,38,52).

In order to discuss these techniques, it is important to first identify two main categories of therapeutic exercise, and thus proprioception: 1) open kinetic chain and 2) closed kinetic chain. The term kinetic chain, or kinematic chain, refers to a combination of successfully linked motor segments (9,44). Closed chain movements, where the extremity is fixed in a kinematic system, will produce a predictable pattern of motion in other connected segments of the system (20,44). The open kinematic chain system consists of end segments moving freely in space and not necessarily producing predictable movement from another segment in the system (9,39).

Biomechanically, a closed kinetic chain involves a person who is in a weight bearing or standing position. Two main procedures, the modified Rhomberg single leg stance and stabilometry, both utilize a closed kinetic chain, and will be mentioned in detail later. An open kinetic chain is in effect when the limb is moving freely as in a leg extension on an isometric weight bench, or an isokinetic machine measuring passive joint position sense, an additional method to be discussed later. Closed kinetic chain exercises have been found to have advantages over open kinetic chain exercises (8,9,20). Closed kinetic chain actions provide more functional patterns of movement in athletics (20), appear to be clinically safer than open chained exercises, and are able to develop the highest level of proprioceptors (50,57). Therefore, studies that assess the ability to perceive or reproduce open chained passive joint position may not be highly relevant to the understanding of the proprioceptive deficiency that is responsible for functional instability (16,19,22).

Additionally, two different categories are used to specify type of analysis or training techniques of proprioception: 1) static, where a steady surface is used, or 2) dynamic, where the surface or action is in motion. Statically, postural sway was an initial record of proprioceptive instability. Freeman et al. (13) described it as a modification of the Rhomberg's test: a single leg balance that is used as an indication of impaired stability and disturbance in proprioception. The modified Rhomberg test as an assessment of instability is objective in nature, and based on the examiner's visual impression combined with the judgment of the subject. This method has been used in several studies (15,18,30,33,35). Postural sway can also be measured by using stabilometry (6,33,49,53). Here, from a single leg stance, a force plate is used to measure the force from the foot to the plate. When adaptations are made by the lower extremity in order to maintain balance, those movements are transferred into vertical forces, and measured by the sensors beneath the plate. This device is capable of measuring motions in both the frontal and sagital planes.

Proprioception is trained and tested dynamically where an unstable surface is utilized. One method uses a single plane balance board (SPBB, 38). This board is capable of only one plane of motion at a time, either in the sagital or frontal plane. The rectangular shaped board is placed on top of a smaller cylindrical axis of rotation. This allows only one side of the board to come in contact with the floor at one time, (38) similar to a teeter totter design. The subject stands in a double, or single leg stance, on the board and attempts to attain balance and equilibrium where no edges of the board touch the ground. By counting the number of times that the subject allows the sides of the board to touch the ground, the examiner is provided with a measurable value. These scores correlate with the subject's proprioceptive ability.

Another dynamic method used for measurement and/or training is the ankle disk (18,26,52). This is generally a hemispherical object where the subject, standing on the flat side, again in single leg stance, is directed to either maintain balance and equilibrium, or touch all sides of the board to the ground in a rotational fashion. Other patented disk shaped boards employ similar designs. One, called the Biomechanical Ankle Platform System (BAPS, 3), is a circular disk with small variable sized hemispheres that attach to the underside of the board and allow an unstable surface. Also, a board called the Kinesthetic Ankle Board (KAB, 38) utilizes a disk mounted on top of 2 movable disks contained in a "+" shaped track.

Passive joint position sense is another way to measure proprioception. Gross (22) tested individuals with multiple unilateral ankle sprains using a passive joint angle position that they would have to replicate. Also using passive movement sense, Lentell et al. (34) measured the angles at which passive motion was sensed in a closed kinetic chain with the foot placed on a platform, which rotated on an axis in the frontal plane. Glencross and Thornton (19) measured passive joint position sense as well. The patient was placed in 105, 120, 130, and 140 degrees of ankle plantar flexion and then asked to replicate that angle. Lentell et al (34) tested passive movement sense. The subject's foot was placed on a platform, in a closed kinetic chain, which rotated on an axis in the frontal plane. The angles were measured and recorded where the subject initially sensed a passive motion.

Subject Specifications

Researchers have often considered injured extremities in relation to uninjured controls or contralateral, uninjured extremities (12,15,36). Several studies have been done to identify proprioceptive deficits in the injured, or chronically injured population (12,15,19,30,31,33,34,53). Tropp et al. (53) and Payne et al. (46) studied proprioception deficits, in conjunction with strength or functional instability, as a predictor of injury to the ankle in healthy subjects. Tropp et al. (53) found that subjects showing abnormal stabilometric values ran a significantly higher risk of sustaining an ankle injury compared to subjects with normal values. These findings were consistent with Payne et al. (46) who found that ankle joint proprioception deficits significantly affected incidence of injury in a 9-week trial. Hoffman and Payne (26), also using healthy subjects, studied the effects of ankle disk training on proprioception. The subjects were found to have significant improvements in all tested parameters of postural sway when compared to a control group, indicating that the uninjured population can benefit from training.

Previous research has also focused on the change in proprioceptive ability among athletes in different sports. Soccer (51-53) and basketball (46) athletes have been studied most often while gymnasts (12,30), dancers (33), and recreational athletes (15,19,34) have also been examined. Gymnasts and dancers are often recruited for proprioception studies because of the extreme balance and kinesthetic awareness necessary for their activities (29). Sports that require constant jumping, cutting and pivoting lend themselves to high risk for lower extremity injury, and thus topic for this discussion. Ankle and knee joint injuries may occur more often in these activities because the joint's integrity is often compromised when the cleats or the traction of rubber soled shoes results in the stability of the foot or the lower leg only.

Female athletic involvement has increased in recent years, resulting in an increase in prevalence of injuries among female athletes (28). Upon the enactment of Title IX, requiring gender equity in schools and in the athletic community, opportunities for greater female participation in athletics have been created (24). This has led to investigations concerning gender differences in the incidence of athletic injuries. Barrack (2) studied proprioception in the knee and found that females were less sensitive to knee joint position changes than males. Consequently, other researchers have also compared or isolated gender when studying categorical incidence of injury (24,28,30,46,47,52). Some have reported higher rates of injuries in females than males (28).

Proprioception and Injury

The relationship of proprioception, ligamentous injury, and deafferentation was initially studied by Freeman et al. (13). They postulated that when joint injury or trauma occurs, joint proprioceptors in the capsule, the area that encapsulates the joint, are also damaged. The joint proprioceptors are thought to be damaged because they possess less tensile strength than the ligamentous fibers. This is believed to cause deafferentation, the diminished relay of messages from the injured joint, which interrupts proprioceptive function. As a result, they proposed that joint injury results in proprioceptive deficits and symptoms of functional instability (giving way) could be substantially reduced with coordination exercises. Konradsen et al. (32), studied deafferentation to investigate if injecting local anesthesia to muscle fibers, to simulate the interruption that occurs during injury, did in fact weaken the relay of signals to the CNS. They found that passive joint position sense was significantly decreased after the injection. Conversely, at least two studies found that postural sway did not increase with deafferentation of the ankle joint (8,25).

Relation to Functional and Mechanical Instability

Various studies have examined the ankles with history of injury, subsequent instability, its effects on proprioception (12,15,19,30,33-35,51-53). Friden et al. (15) using stabilometry, studied subjects with acute ankle sprains, within 3 to 8 days after the injury. These subject's stabilometry readings were done bilaterally, and the results of the injured ankle were compared to the uninjured one. A significant difference was found between stabilometric readings of the injured ankle compared to the injured one. Isakov and Mizrahi

(30) studied female gymnasts with functional and mechanical instability (joint laxity) using stabilometry as well. Results of this study, however, found no significance between the injured and uninjured ankles.

Using a modified Rhomberg test, Lentell at al. (35) tested 33 subjects with unilateral chronic instability. By objectively observing balance asymmetries between the injured and uninjured extremities, investigators found 55% of the subjects to have asymmetry, 94% of those had balance deficits in the inured extremity. This result suggests that unilateral deficits may have been pre-existent, and that injury to that extremity may have predisposed.

Injured joints have also been found to lose their ability to detect motion or position of the joint (16,19). Lentell et al. (34) studied recreational athletes who had previously sustained ankle injury, prior to three months before the study, but still had chronic complaints. Using the closed kinetic chain method described earlier, passive movement sense was tested to evaluate proprioceptive ability. They found that subject's ability to detect motion was at significantly greater amounts compared with the uninjured ankles. The results of this study suggest that deficits in proprioception, specifically passive movement sense, should be addressed when managing and rehabilitating injured ankles with functional instability.

Glencross and Thornton (19) investigated subjects with injured ankles compared to the contralateral uninjured one. The subject's proprioceptive ability was measured using passive joint position sense and the mean errors of the angles were measured and recorded. The results of this study showed significantly greater error in the injured ankles compared to the uninjured ones. The authors concluded that the loss of precision in the judgment of position sense, months after the injury, and normal functioning of the joint in skilled actions is likely to be inadequate as a result of the distortion of proprioceptive signals.

Forkin et al. (12) studied active, collegiate level gymnasts with a history of unilateral, multiple ankle sprains occurring one year prior to the study. This study compared the subject's ability to detect passive plantar flexion motion, and balance abilities during a single leg stance on the injured limb versus the contralateral, uninjured limb. The results indicated a significantly diminished ability to sense passive motion and ability to balance on the injured limb, as perceived by independent observers.

Garn and Newton (16) also found that subjects showed significantly less ability to detect passive movement in their injured ankles relative to their uninjured ones. Gross (22), however, found no significant difference between the injured ankle and the contralateral uninjured ankle in its detection of passive motion.

Muscular Involvement

Instabilities and chronic injury have been reported to be related to muscle response and/or weakness (31,32,36). Konradsen and Ravn (32) sought to substantiate the connection between functional instability, when the ankle gives way as a result of injury, and the presence of a defect in reflex stabilization of the muscles in the foot. The muscular reflexes were studied by comparing reaction times of the peroneal muscles in the lower leg and foot when exposed to sudden ankle inversion. The authors found that athletes with severe complaints of functional instability had a significantly increased muscle reaction time, supporting the theory that this may be induced by proprioceptive reflex deficit. The same athletes with functional instability were also found to have decreased postural control during single leg stance. Tropp (51), studied athletes with unilateral ankle functional instability. He found the pronator muscles in the foot, to be weaker in the ankle with functional instability when compared to the stable ankle. Tropp's (51) additional findings support the theory that deficits occur centrally rather than locally. Subjects demonstrated impaired postural control when standing on either foot.

Since many researchers have found proprioception deficits in chronically injured and unstable ankles, proprioception deficits have been accepted as a predictable consequence of injury (12,32,35,36,52). Some researchers have also shown that the proprioception deficiencies correlate to incidence of ankle injury (46,53). Payne et al. (46) followed collegiate basketball players after measuring their proprioceptive abilities with passive, open kinetic chain, joint position sense. They concluded that baseline proprioception was a predictor of right and left ankle injury, specifically left side inversion and right side inversion, eversion, and dorsiflexion measurements. The results of this study were consistent with those of another study of soccer players with functional instability at the ankle joint (53). These subjects were observed for approximately one season of competition for the incidence of ankle injury. Of the 23 players who sustained ankle joint injury, 12 had pathologic stabilometry readings, whereas the players with normal values (11 of 98) had a significantly lower risk. Tropp (53) found no significant difference between the incidences of re-injury in those subjects with previous ankle injury versus those without. In addition, this study found no correlation between incidence of re-injury and stabilometry readings. As a result, Tropp (51-53) concluded that impaired postural control, as recorded by stabilometry, proved to be a predictor of ankle injury. Although joint injury results in proprioceptive deficits and symptoms of functional instability (giving way), they can be substantially reduced with coordination exercises (3,13,18,26,38,52). It is feasible, therefore, that proprioception could also play a necessary role in prevention of lower extremity injury or re-injury. For example, if proprioception is recognized to be deficient prior to competition, proprioceptive training might be implemented into the pre-season routine to prevent possible joint injury.

Summary

Previous research has identified several factors concerning the relationship between injury and proprioception. Numerous methods for testing proprioception have also been reported. The quantification of proprioception ranges from the most simplistic and least technological methods to neurological analysis requiring intricate instrumentation. The sample characteristics of previous research vary according to status, gender, and the skill level of the athletes. Suggested training techniques have varied from simple tasks to sport specific skills. As technology improves, so does the ability to quantify movements and mechanics. There is a need for field tests of proprioception that are applicable to sports medicine professionals or coaches with limited equipment or facilities.

Due to the variation in quantification and other variables among studies of proprioception, comparison of their results is difficult. Recovery times of identical injuries, and their resultant long-term instability may vary among individuals regardless of proprioceptive quantification or testing procedures. This may be due to the ability of certain individuals to compensate for impaired joint proprioception through enhancement of other related sensory mechanisms (2). Furthermore, knowledge of baseline measurements of proprioception from a large sample of individuals is needed when evaluating pathologic conditions. There is a clear need for research that examines baseline proprioception abilities in collegiate female athletes while comparing history and incidence of lower extremity joint injury using low cost equipment.

Chapter 3

Methods

The purpose of this study was to examine the relationship between proprioceptive abilities and incidence of lower extremity joint injury. In addition, this study will determine the effect of history of lower extremity joint injury, and particular softball position on proprioception ability.

Subjects

A total of 18 females were recruited for this study. The subjects were all members of an available subject pool as members of the Southwest Texas State University NCAA Division I fast pitch varsity women softball team. Each subject was between the ages of 18 and 22 years old. In addition, each subject had undergone off-season strength, conditioning, and softball training during the semester prior to the test season. An interview regarding history of lower extremity injury as well as each subject's softball position was recorded. *History* of lower extremity joint injury was defined as more than one ligamentous injury or the feeling of "giving-way" 3-12 months prior to testing (7,12). During the 3 months prior to initial testing, all subjects had full weight-bearing capacity, were pain-free, and the functional use of both lower extremities was unimpaired (30,38). No neurologic disease or injury and no current musculoskeletal injuries to the back or contralateral extremity were present in any of the subjects. Each subject signed an informed consent form and was be advised of the results of the study.

Instruments

Postural sway, using both static and functional techniques, was measured with objective categories, and time measurements. For this, a stopwatch measured in hundredths of a second was used. Also, a 12-inch box was used as the surface from which the subject stepped off of prior to the functional measurement. For the dynamic component, a 3-foot by 2-foot mini trampoline was used as for measurement. For the static surface, a hard tile floor surface was used for measurement.

Procedure

Each subject was tested individually, out of sight from other subjects. The testing room was the athletic training room, which is free of windows and outside entrances. Each subject was tested prior to the commencement of pre-season training which was 23 days prior to initial competition. Upon arrival to the testing site, each subject filled out history and consent forms.

The subjects was familiarized with each testing apparatus prior to testing but was not be able to practice. Each subject performed 3 repetitions of each of the proprioception tests on each leg while blindfolded. First, a single leg stance test was preformed on a stable tile surface and an unstable mini trampoline surface. Additionally, the subjects stepped off of a 12-inch box and were instructed to land and maintain balance on a single leg.

For each of the scenarios, two evaluators noted an objective measurement of proprioceptive ability, low, moderate or high. This method is based on that described by Lentell et al. (35). The objective ratings will be 1) high: none to minimal movement of arms and trunk used to maintain balance, 2) moderate: moderate movement of arms and trunk to maintain balance, and 3): low: extreme movement of arms and trunk to maintain balance. For the purpose of analysis, the high and moderate ratings will be noted as "good" and the low rating will be classified as "poor." The two evaluators also recorded the time that the subject was able to maintain balance on the single leg, up to one minute for each testing condition. The timer was stopped and recorded for the subject when her free leg came in contact with the floor or any part of the body. The subjects were timed with a hand stopwatch, which measured in hundredths of a second.

Observer agreement checks were done on 100% of the subjects. Observer agreement was determined from the objective categorical measurement of proprioception as well as the timed measurement. The scores and values that each observer noted were compared (38). All of the categorical values noted for each subject that did not match were omitted from record. In the time measurement, if the two times were different, and more than 2 seconds apart, that trial was omitted from record. However, if the times of the two observers were less than 2 seconds apart, the two times were be averaged. Each categorical value and each timed value was recorded for each trial for each condition. For each subject the average of the trial scores for each condition was averaged and recorded.

For a 10-week period, during the normal supervised SWT varsity softball season, the subjects were monitored for injury. The incidence and specific assessment of each lower extremity joint injury were recorded. At the end of the testing period each subject's injury data was collected.

Design and Analysis

The dependant variable for this study is occurrence of lower extremity injury

The independent variables are

1) Previous history of lower extremity injury
2) Softball position
3) The proprioception abilities recorded in time (seconds)
4) The proprioception abilities recorded with a categorical rating of
    a. good
    b. poor

This study investigated the relationship between proprioceptive ability and the incidence of lower extremity injury, history of lower extremity injury, and softball position. A chi-square analysis was used to compare the incidence of injury and categorical proprioception rating. A logistic regression model was used to examine the relationship between proprioceptive ability (in time), the position, and the incidence of lower extremity injury. A chi-square analysis was also used to examine the relationship between incidence of injury and previous history of lower extremity.

Chapter 4

Results

The purpose of this study was to examine the relationship between proprioceptive abilities and incidence of lower extremity joint injury. In addition, this study determined the effect of history of lower extremity joint injury and softball position on incidence of lower extremity injury and proprioceptive ability among collegiate female softball players. It was hypothesized that there is a negative relationship between proprioceptive ability and the incidence of lower extremity joint injury in female softball players. It was also hypothesized that previous history of lower extremity joint injury increases the incidence of joint injury, and that softball pitchers would have a lower incidence of lower extremity joint injury than field players, regardless of proprioceptive ability.

History and Injury

A comparison of history of ankle injury versus incidence of ankle injury is reported in Table 1. A significant relationship (83.3% agreement) was found between history and incidence of ankle injury ($\chi^2(1)= 4.11$, $p<.05$).

Of the three ankle joints that were injured during the trial period, two of them had a history of ankle dysfunction (2 out of 3) while only one subject out of fourteen (1 out of 14) sustained an injury who did not have a history. This analysis examined both right and left ankles for incidence of injury and their correlation with history. It should be noted that of the three ankles injured, two were right ankles and one was a left, and that while there was a positive correlation when comparing all ankle histories and incidences of injuries, there was none found when examining the right or left sides of the body individually.

Table 1

		History- Ankle		
		NO	YES	Totals
Injury-Ankle	NO	13	2	15
	YES	1	2	3
	Totals	14	4	18

Proprioception and Injury

The results of the comparison between proprioceptive ratings versus injury incidence of the right ankles are reported in Table 2. A chi square analysis revealed a significant relationship between ratings and incidence of injury. There was an 83.3% agreement when comparing these factors (χ^2 (1)=5.85, p<.05).

Table 2

		Injury-Ankle (R)		
		NO	YES	Totals
Proprioception Rating	GOOD	13	0	13
	POOR	3	2	5
	Totals	16	2	18

Of the thirteen right ankles that were rated "good" for proprioceptive ability during the static test trials, zero were injured (0 out of 13). However, out of the five right ankles that received a "poor" rating, two were injured during the season (2 out of 5).

Position and History of Injury

Table 3 reports the relationship between softball position and history of ankle injury. Position was significantly related to history of ankle injury ($\chi^2(1)=6.43$, $p<.05$).

Table 3

Position		History-Ankle		
		NO	YES	Totals
	INFIELD	8	0	8
	OUTFIELD	4	1	5
	PITCHER	2	3	5
	Totals	14	4	18

When comparing the position of the female softball player with history of injury, pitchers were more likely to have a history of injury (3 out of 5). In-fielders (0 out of 8) and out-fielders (1 out of 5) were less likely to have a history of injury. Also, there was no relationship between softball position versus incidence of joint injury ($\chi^2(1)= 0.18$, p>05).

Three techniques were used to test proprioceptive ability, a static method using the tile surface, a dynamic method using the mini trampoline surface, and a functional test where the subject stepped off of a 12-inch box. There was no relationship between any of the three methods and history or incidence of injury. History of lower extremity joint injury was found to be unrelated to static balance ($\chi^2(1)= 0.71$, $p>.05$), dynamic balance ($\chi^2(1)= 0.07$, $p>.05$), or functional balance ($\chi^2(1)= 0.31$, $p>.05$). Incidence of lower extremity joint injury was also found to be unrelated to the timed tests for static balance ($\chi^2(1)= 1.53$, $p>.05$), dynamic balance ($\chi^2(1)=0.76$, $p>.05$), or functional balance ($\chi^2(1)= 1.53$, $p>.05$).

Chapter 5

Discussion, Summary, and Conclusions

This study found that previous history of ankle injury increases the likelihood of ankle injury in female collegiate softball players. This study also found that there is a negative relationship between ratings of proprioceptive ability and the incidence of ankle injury. Players who rated lower in proprioceptive ability were more likely to be injured. Additionally, it was found that pitchers were more likely to have a history of ankle joint injury than infield or outfield players.

History of Joint Injury

This study found that there is significant relationship between history and incidence of ankle joint injury in female collegiate softball players. Previous research has demonstrated that both functional and mechanical instability are linked to recurring or chronic injury (13,51). Research has also identified insufficient muscular involvement that results from joint injury. Slowed muscular responses about the joint (32) or muscular weakness (51) have also been reported as causes of chronic joint instabilities.

Research has also identified proprioception deficits as identifiers of chronic joint instability (12,32,36,51,52). Konradsen et al. (32) found that athletes with functional instability due to previous injury had decreased amount of postural control during single leg stance. These results are consistent with Tropp's (51) conclusion that athletes with unilateral functional instability, due to history of injury, had impaired postural control when standing on either foot.

Proprioception and Injury

This investigation found that the athletes with initial proprioception deficiencies were more likely to have sustained an ankle joint injury during the trial season. This result is consistent with researchers who have suggested that proprioception deficits could be used as a predictor of ankle joint injury (46,52,53). Tropp and colleagues (51-53), using static balance stabilometry readings, found that soccer players with pathologic readings were more likely to sustain an ankle joint injury than those with normal values. In addition, Payne et al. (46) found that baseline proprioceptive measurements were predictors of right and left inversion ankle sprains in collegiate basketball players.

Previous research has shown conclusively that joint injury results in proprioceptive deficits. (12,16,19,32,34-36,52). When compared to uninjured ankles, unstable ankle joints were found to have decreased postural control (32,35,51), inferior stabilometry readings (15), and impaired ability to detect passive movement at the joint (12,16,19,34). Different theories exist as to why and to what extent subjects with unilateral joint injury have impaired proprioception. It has been suggested that proprioceptive deficits might be predisposed since Lentell et al. (35) found balance asymmetries in only 55% of subjects with unilateral joint instabilities. Also, as Tropp (51) suggests, the deficits may occur centrally rather than locally, since subjects in one study demonstrated impaired postural control when standing on either the injured or the uninjured extremity.

Although this study found static proprioception ratings to be predictive of ankle joint injury, the dynamic and functional readings were not predictive. A review of the literature did not reveal previous research attempting to use dynamic or functional proprioception measurements as a tool for predicting injuries; however, many investigations have used these techniques to either measure or train proprioception (3,18,26,38,52). The results of this study may be influenced by the inability to accurately measure dynamic or functional proprioception without special equipment.

Softball Position and Injury

Fast-pitch softball requires different tasks and skills depending on the position. This study attempted to identify the most susceptible softball position for joint injury. In this study the pitchers were found to be most likely to have a history of ankle joint injury. Although three out of five of the pitchers in this study did not bat for the team during the trial period, they all had batted for their respective teams before they came to Southwest Texas State University. After further investigation, four out of the five pitchers revealed that they had participated in more activities than solely pitching during the twelve months prior to the trial, including off-season activity. In addition, each of the three injuries was sited as occurring during non-pitching activities. The pitchers in this study did not, however, prove to be less or more likely to sustain a lower extremity joint injury. Although one pitcher did sustain an ankle joint injury during the trial, their likelihood of sustaining upper extremity injuries may be greater than the fielders. The in-field and out-field positions did not reveal a significantly greater or less likelihood of sustaining a joint injury than the pitchers. These results may be due to the inability to separate each player's activity while they all play in the same cleats, and perform very similar activities during batting and playing the field.

Timed Proprioceptive Tests and Injury

This study found no relationship between measurements of timed proprioception versus incidence of injury. Static measurements including stabilometry (15,30,53) or simply observations of balance asymmetries (35) are commonly used to measure proprioception. Previous research has not attempted to use timed static balance as a predictor of joint injury incidence. Previous research has, however, used timed proprioception and coordination exercises, which may be used to reduce recurrence of injury and symptoms of functional instability (3,13,26,30,38,52).

Although the timed measurements were found in this study to have no significant relationship with the incidence of injury, the ratings of proprioceptive ability did. This may be due to several factors. The method of the administration of the timed measurements was done with dual observer agreement. Each timed trial was measured by two evaluators and was averaged. Each measurement that was more than two seconds different was eliminated to reduce evaluator error. The timed measurements may have required a longer trial period to display incidence of injury. In addition, only eighteen softball players remained throughout the entire study. A larger sample size may give a more accurate display of abilities and incidences. Also, a longer trial period for which to monitor the athletes during off-season or competition may exhibit a greater likelihood that a relationship exists between timed proprioception deficiencies and lower extremity joint injury incidence.

This study found a relationship between history of ankle joint injury and incidence of ankle joint injury. These results suggest that the injured ankle joint has a greater possibility of subsequent injury confirming much previous research (12,13,32,36,51,52). In addition this study found that the presence of proprioception deficiencies in female collegiate softball players increased susceptibility of incidence of ankle joint injury. These results suggest that the identification of proprioception deficiencies may allow members of the sports medicine team to train these deficiencies and prevent joint injury. This study also found that softball pitchers were more likely to have a history of ankle joint injury than field players, suggesting that pitchers may have, if examined for a longer period of time, a higher probability of sustaining a lower extremity joint injury than the field players. As a result, pitchers may need to be braced, protected and trained further in order to prevent lower extremity injuries.

Conclusions

Based on the results of this study the following conclusions can be made:

1. Female collegiate fast-pitch softball players with a history of ankle joint injury are more likely to sustain an ankle joint injury. These results are consistent with previous research identifying ligamentous laxity in the joint, nerve damage in the joint, and muscle weakness as possible reasons for recurring injury.
2. Female collegiate fast-pitch softball players with deficient proprioception ratings, when measured statically, are more likely to sustain an ankle joint injury during the trial period. There is no relationship between timed proprioception measurements and incidence of lower extremity joint injury. These results may be due to the inability to accurately measure proprioception with timed unilateral balance. In addition, these results may have been due to the limited time period for the observation trials and a limited sample size.
3. Female collegiate fast-pitch softball pitchers were more likely to have a history of ankle injury than infield or outfield players. This result may be due to the active role that the pitchers played in the twelve months prior to the initial testing period, including off-season drills. There was no

difference in the incidence or history of joint injury between the infield or outfield players. These results may be due to the inability to separate the activities of similar tasks necessary of the two positional groups.

4. There is no relationship between dynamic or functional proprioceptive ratings and incidence of lower extremity joint injury. These results may be due to the inability to accurately measure ones ability to balance dynamically or functionally without more specific, scientific equipment.
5. There is no relationship between static, dynamic, or functional proprioceptive measurements and history of lower extremity joint injury. These results may be due to the unknown definition of "history," length of time necessary for the joint to recover from joint injury must be a consideration. This study assigned a "history" of injury to an injury occurring between twelve months and three months prior to the initiation of this study.

Recommendations for Future Research

1. The time needed for complete recovery and the disappearance of all subsequent symptoms of joint injury symptoms needs to be investigated in order to identify risks of re-injury.
2. The relationship between proprioception and both incidence and recurrence of joint injury should be further investigated using standard

equipment and tools in order to combat recurring joint injury and make the techniques useful to all athletic settings.

3. Further examination of female athletes and joint injury incidence in order to take steps towards prevention of them, especially those involved in sports about which little or no baseline information has been compiled.

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APPENDIX A

Joint Proprioception and Injury Incidence in Female Softball Players

History of Athletic Injury

Name ____________________ Age _____ Birthdate ___________
Address _________________________________
____

Phone # ________________ # of collegiate softball seasons_______

Please list the level(s) of competition in those seasons- listed in chronological order, first to most recent. List all (Ex: NCAA, NAIA, NJCAA) ________________

Please list softball positions currently played in order of prevalence (most to least) 1_______________ 2______________ 3________________
Others (if any)_______________ ______________ ________________

Please list all injuries to bones, joints, or muscles you have sustained to any part of your legs, from hip down to foot, in the last 5 years, and its approximate date. (Be specific and please indicate side, right or left) ___________________________
____

In the last 3 months have you sustained any injury to your lower extremity (hip, knee, ankle or foot)? ______

If so, when (month and year) –please list all ______________________________

In the last 12 months, but prior to the last 3 months from this date, have you sustained a hip injury? _________ If so, when and what type. (Be specific) ___
____

In the last 12 months, but prior to the last 3 months from this date, have you sustained a knee injury? _________ If so, when and what type. (Be specific) ___
____

In the last 12 months, but prior to the last 3 months from this date, have you sustained an ankle injury? _________ If so, when and what type. (Be specific)
____

In the last 12 months, but prior to the last 3 months from this date, have you sustained a foot injury? _________ If so, when and what type. (Be specific) ___

Joint Proprioception and Injury Incidence in Female Softball Players

Informed Consent Form

You are invited to participate in a study to determine the relationship between previous history of lower extremity injury and softball position on incidence of lower extremity ligamentous injury. Also, the relationship between proprioceptive abilities and incidence of lower extremity ligamentous injury will be examined. I am a graduate student at Southwest Texas State University in San Marcos, Texas. This study will be in partial fulfillment of my thesis requirements and graduation from SWT and the Health, Physical Education, Recreation, and Dance. I hope to learn whether proprioceptive abilities, history of previous injury, and/or softball position affect the incidence of lower extremity ligamentous injury.

You were selected as a possible participant in this study because you are a female collegiate softball player. You will be one of 20 subjects chosen to participate in this study.

If you decide to participate in this study, you will be asked to perform three different trial conditions that allow us to measure your proprioceptive, or central nervous system balancing abilities. Also, you will be asked to fill out an injury/medical form including listing your main softball positions. The testing trials should only take approximately 20- 40 minutes. After the testing trials, I will record any incidental injury that occurs to you during the supervised activities of SWT softball, per head coach Ricci Woodard. There will be no more potential risk during the testing that you would not normally be subjected to as a SWT varsity softball player.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential, and will be disclosed only with your permission.

Your decision whether or not to participate will not prejudice your future with SWT or the Athletic Department and SWT softball. If you decide to participate, you are free to discontinue participation at any time without prejudice. Also, if any of the procedure causes harm or pain, please let us know and you are free to discontinue participation.

If you have any questions please ask us at any time.

You may obtain a copy of this form to keep.

I understand that measurements of my proprioceptive abilities will be taken during this procedure and that any subsequent, incidental injury that occurs to me will be recorded and treated, just as it would normally in SWT athletics.

You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and decided to participate. You may withdraw at any time without prejudice after signing this form, should you choose to discontinue participation in this study.

________________________________ ____________

Signature of Participant Date

APPENDIX B

	tile(sec				tramp				box				tile		tramp		box		pos.	hx	hx
	R-1	L-1	R-2	L-2	R-1	L-1	R-2	L-2	R-1	L-1	R-2	L-2	avg-R	avg-L	avg-R	avg-L	avg-R	avg-L	#	hip	knee
Wissel- SM	48.19	42 42	47 54	2 53	2 08	3.51	2 34	6 26	48 73	2.33	0 98	41.23									
	mod	mod	mod	mod	low	low	low	low	mod	low	mod	mod									
JL	49 21	42 21	46 59	2 18	1 87	4 56	1 96	6 25	48 56	2 25	1.21	41 43									
	mod	mod	mod	low	low	low	low	low	mod	low	low	mod									
obs-avg time	48 7	42 32	47 07	2 355	1 975	4 035	2 15	6 255	48 65	2 29	1 095	41.33	47 8825	22.335	2 0625	5 145	24 87	21 81	SS	N	N
obs-avg ratng	mod	mod	mod		low	low	low	low	mod	low		mod									
Hughes- SM	2 98	29 42	12 71	14 94	11 18	3 17	8 7	2 2	13 27	10 19	17 87	23.86									
	low	mod	low	mod	low	mod	low	low	mod	low	mod	mod									
JL	3	29 5	12 81	14.93	11 06	3.09	8 71	2	13.18	10.06	17.71	23.75									
	low	mod	mod	mod	low	mod	low	low	mod	low	mod	mod									
obs-avg time	2 99	29 46	12 76	14 94	11 12	3 13	8 705	2 1	13 23	10.13	17 79	23.81	7 875	22 1975	9.9125	2 615	15 5075	16 965	LF/CF	N	N
obs-avg ratng	low	mod		mod	low	mod	low	low	mod	low	mod	mod									
Spring- SM	1 15	0 59	5.98	2 87	1 27	4 04	1 48	2.73	1.45	2.02	5 52	36.52									
	low	low	low	low	low	mod	low	low	low	low	mod	mod									
JL	1 03	0 87	6 9	3.03	1 56	3 9	1 5	2 65	1 93	2 65	5 5										
	low	low	low	low	low	low	low	low	low	low	mod	mod									
obs-avg time	1 09	0 73	6 44	2 95	1 415	3 97	1 49	2 69	1 69	2 335	5 51		3 765	1 84	1 4525	3 33	3.6	2 335	RF/LF	N	N
obs-avg ratng	low	low	low	low	low		low	low	low	low	mod	mod									
Tomme-SM	15 68	19 06	16 32	2.4	2 05	5.39	1 15	3 43	3 68	4 43	27 94	12.97									
	mod	high	high	low	low	mod	low	mod	low	mod	high	mod									
JL	15 75	19	16 12	2 56	2	5 34	1 09	3 31	3 59	3 1	28 03	12 56									
	mod	high	high	low	low	mod	low	mod	mod	mod	high	mod									
obs-avg time	15 72	19 03	16 22	2 48	2 025	5 365	1.12	3 37	3 635	3 765	27 99	12 77	15 9675	10 755	1 5725	4 3675	15 81	8 265	C	N	N
obs-avg ratng	mod	high	high	low	low	mod	low	mod		mod	high	mod									
Kmiec-SM	6 67	3 46	9 03	4.3	6 47	2.23	1 43	4 86	2 67	2 77	3 49	4 87									
	mod	low	mod	low	low	low	low	mod	mod	mod	mod	high									
JL	6.46	3 12	8.84	4.28	6 5	2 34	2 7	4 81	2 71	2.65	3 43	4.81									
	mod	low	mod	low	low	low	low	mod	mod	mod	mod	high									
obs-avg time	6 565	3 29	8 935	4 29	6 485	2.285	2 065	4 835	2 69	2.71	3 46	4 84	7 75	3 79	4 275	3 56	3 075	3 775	3RD	N	N
obs-avg ratng	mod	low	mod	low	low	low	low	low	mod	mod	mod	high									
Chase-SM	2.73	3.69	10 02	6 09	5.93	2 26	6 57	1 12	11.26	14.52	19.43	42.92									
	mod	mod	low	low	mod	low	mod	low	low	mod	high	mod									
JLL	2.71	3.53	9 84	7.78	5 93	2	6 59	1 15	11.12	14.84	19 25	42.59									
	mod	mod	low	low	mod	low	mod	low	low	mod	high	mod									
obs-avg time	2.72	3 61	9.93	6 935	5.93	2 13	6 58	1.135	11.19	14.68	19 34	42.76	6 325	5 2725	6 255	1 6325	15.265	28 7175	P	N	N
obs-avg ratng	mod	mod	low	low	mod	low	mod	low	low	mod	high	mod									
Nuererburg	15.13	1.62	2 73	0 97	5 84	2.45	18.57	11 86	2.94	17.66	3 38	4.18									

	mod	low	low	low	mod	low	mod	mod	mod	mod	low	low									
JL	15.09	1 37	2 59	0 78		2 5	18 59	11 59	3.12	17 84	3 37	3 93									
	mod	low	low	low	mod	low	mod	mod	mod	mod	low	mod									
obs-avg tıme	15 11	1.495	2 66	0.875	2 92	2.475	18.58	11 73	3 03	17.75	3 375	4 055	8.885	1.185	10 75	7 1	3 2025	10 9025	P	N	N
obs-avg ratng	mod	low	low	low	mod	low	mod	mod	mod	mod	low										
Youngdale	52 72	2.93	17 07	11 46	3 29	5.07	5 9	1 38		11.13	3.37	21 89									
	hıgh	low	mod	mod	mod	low	mod	low		mod	low	mod									
JL	52.5	2.78	17 06	11 59	3 06	5 06	5.93	1 28	3 34	11 18	2.9	22.31									
	hıgh	low	mod	mod	mod	low	mod	low	low	mod	low	mod									
obs-avg tıme	52.61	2 855	17 07	11 53	3 175	5 065	5 915	1.33	1 67	11 16	3.135	22 1	34 8375	7 19	4 545	3 1975	2 4025	16 6275	1ST	N	N
obs-avg ratng	high	low	mod	mod	mod	low	mod	low		mod	low	mod									
Yarbrough	16.26	.00.0	00 0	24 81	27 83	24.11	17.27	17 07	.00.0	36 81	.00.0	.00.00									
	high	high	hıgh	hıgh	mod	mod	mod	mod	mod	mod	hıgh	hıgh									
JL	16 15	.00 0	.00.0	24.78		24 34	17 43		1 00 0	36 78	00.0	.00.00									
	hıgh	hıgh	hıgh	high	mod	mod	mod		mod	mod	hıgh	hıgh									
obs-avg tıme	16 21	.00 0	.00 0	24 8	13.92	24 23	17 35	8 535	.00 0	36 8	00.0	.00.0	16 205	24 795	15 6325	16 38	1 00.00	36 795	RF/C	N	N
obs-avg ratng	hıgh	hıgh	hıgh	hıgh	mod	mod	mod		mod	mod	hıgh	hıgh									
Blaır		53.33		19.17		3 83		3.03		16.63		7.23									
		high		mod		low		low		mod		mod									
JL		53.15		18 96		4 09		3.75		15.03		6 05									
		hıgh		mod		low		low		mod		mod									
obs-avg tıme		53.24		19 07		3.96		3 39		15.83		6 64		36 1525		3 675		11 235	P	N	N
obs-avg ratng		hıgh		mod		low		low		mod		mod									
Evans	12.86	1.19	30 45	3 57	2 8	1.36	1.94	3 26	2 02	2.77	2 42	23 51									
	mod	low	mod	low	low		low	mod	low	low	low	mod									
JL	12 59	1.03	30 25	3 59	2.84	1 75	1.81	3.12	0 65	2 28	1 68	23 53									
	mod	low	mod	low	low	low	low	mod	low	low	low	mod									
obs-avg tıme	12 73	1.11	30.35	3.58	2.82	1 555	1.875	3.19	1.335	2.525	2 05	23.52	21 5375	2 345	2 3475	2.3725	1 6925	13 0225	C	N	N
obs-avg ratng	mod	low	mod	low	low		low	mod	low	low	low	mod									
Gandy	2.67	2.19	18 24	17.2	0.82	4 97	3 5	0.67	2 28	14.71	17 98	24 09									
	low	low	mod	hıgh	low	low	low	low	low	mod	mod	mod									
JL	2 75	2 18	18.37	17 34	0 78	5 03	3.4	1 25	1.46	14 62	17 71	24 06									
	low	low	mod	high	low	low	low	low	low	mod	mod	mod									
obs-avg tıme	2.71	2.185	18.31	17.27	0 8	5	3 45	0 96	1.87	14.67	17.85	24.08	10.5075	9 7275	2 125	2 98	9.8575	19.37	P/3R	N	N
obs-avg ratng	low	low	mod	hıgh	low	low	low	low	low	mod	mod	mod									
Perez	31.84	42.92	15.95	38 15	3.18	2.67	3.9	5 45	2 09	47.48	26.43	29.75									
	mod	low	low	mod	low	low	low	low	low	mod	mod	mod									
JL	31.96	42.84	15 59	38.12	2.96	3 64	3.59	5.82	1.5	47.78	26.21	29.65									
	mod	low	low	mod	low	low	low	low	low	mod	mod	mod									

obs-avg time	31.9	42 88	15.77	38 14	3.07	3 155	3 745	5.635	1 795	47.63	26 32	29 7	23.835	40 5075	3 4075	4.395	14 0575	38 665	H/3R	N	N
obs-avg ratng	mod	low	low	mod	low	low	low	low	low	mod	mod	mod									
Gaddis	9.01	00.0	00.0	00 0	2 07	2.05	2 57	3.19	6 09	.00 0	00 0	.00 00									
	low	high	high	high	low	low	low	low	mod	high	high	high									
jL	8 93	00.0	00 0	.00 0	1.96	1 84	2 4	3 21	6.12	.00 0	00 0	00 00									
	low	high	high	high	low	low	low	low	mod	high	high	high									
obs-avg time	8.97	00 0	.00 0	00 0	2 015	1.945	2 485	3 2	6 105	00 0	00 0	00 0	8 97	1 00 00	2.25	2 5725	6 105	1 00 00	2ND	N	N
obs-avg ratng	low	high	high	high	low	low	low	low	mod	high	high	high									
Zaleski	1 00 0	51 84	.00 0	21 45	1.21	2 94	3 72	8 85	00.0	.00.0	20.52	00 00									
	mod	mod	high	mod	low	low	low	low	high	mod	mod	mod									
JL	1.00 0	52 34	00 0	20 9	1 25	2.78	3 71		1.00 0	.00 0	20 31	00 00									
	mod	mod	high	mod	low	low	low	low	high	mod	mod	mod									
obs-avg time	1 00 0	52 09	.00 0	21 18	1 23	2 86	3 715	4.425	00.0	00 0	20 42	00 0	1 00 00	36 6325	2.4725	3 6425	20 415	1 00 00	CF	N	N
obs-avg ratng	mod	mod	high	mod	low	low	low	low	high	mod	mod	mod									
Koop	1.65	2 47	6 05	3 04	4 71	2 05	0 99	1 34	1.17	4.01	2 86	3 98									
	low	low	mod	low	mod	low	low	low	low	mod	low	mod									
JL	1 81	2 65	6 21	3 03	4 9	2 09	1 03	1 31	1 34	3 53	2 46	4 18									
	low	low	mod	low	mod	low	low	low	low	mod	low	mod									
obs-avg time	1 73	2 56	6 13	3 035	4 805	2 07	1 01	1.325	1 255	3.77	2 66	4 08	3 93	2 7975	2 9075	1 6975	1 9575	3 925	LF/RF	N	N
obs-avg ratng	low	low	mod	low	mod	low	low	low	low	mod	low	mod									
Mauldin	24 24	41.44	22 44	48 37	4 98	4 08	1 02	4 08	00 0	00 0	3 98	1 1									
	mod	mod	mod	mod	low	low	low	low	mod	mod	low	low									
JL	24 75	41 25	22 84	48 25	6 35	4 09	1	4 75	00 0	.00 0	3 96	1									
	mod	mod	mod	mod	low	low	low	low	mod	mod	low	low									
obs-avg time	24 5	41.35	22 64	48 31	5 665	4 085	1 01	4 415	00 0	00 0	3 97	1.05	23.5675	44 8275	3 3375	4 25	3 97	1 05	2ND	N	N
obs-avg ratng	mod	mod	mod	mod	low	low	low	low	mod	mod	low	low									
Stout	6 43	7 63	4 87	19 68	2	1 59	3 85	2.58	2 5	25 28	10.96	7.37									
	low	mod	low	mod	low	low	low	low	mod	high	mod	mod									
JL	6 31	7 69	4 83	19 76	2 07	1.36	3	2 47	1 5	25 15	10 81	7 32									
	low	mod	low	mod	low	low	low	low	mod	high	mod	mod									
obs-avg time	6 37	7 66	4 85	19 72	2 035	1.475	3 425	2 525	2	25 22	10.89	7 345	5 61	13 69	2 73	2	6 4425	16 28	P/1ST	N	N
obs-avg ratng	low	mod	low	mod	low	low	low	low	mod	high	mod	mod									

hx	hx	disqual -?	waiver	inj	inj	inj	inj	other	details
ankle	foot		1/8-1/10/0	hip	knee	ankle	foot		
N	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		
Y-B	N	N	Y	N	N	Y-R	N		
N	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		
Y-L	N	N	Y	N	N	Y-R	N		

Y-R	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		
				LEFT					
Y-R	N	Y-R	Y	N	N	N	N		
N	N	N	Y	N	N	Y-L	N		
N	N	N	Y	N	N	N	N		

N	N	N	Y	N	N	N	N		
N	Y-R	N	Y	N	N	N	N		2/25/2001
N	N	N	Y	N	N	N	N	3MC FX	
N	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		
N	N	N	Y	N	N	N	N		

VITA

Julie Lowenberg was born in Arlington, Texas, on November 1, 1973, the daughter of Jim Lowenberg and Mary McDonald. Her high school career was filled with varsity letters in volleyball, soccer, and track and field. She was also a member of the National Honor Society, a chairman of the student council, the Fellowship of Christian Athletes, and the Catholic Youth Organization. After completing her work at L.D. Bell High School, Hurst, Texas, in 1992, she entered the University of Southern Mississippi. At USM she was a varsity volleyball player, a student athletic trainer for various varsity sports, and a tutor for the athletic academic center. She received the degree of Bachelor of Science in Sports Medicine from USM in May, 1997, and was then licensed and nationally certified as an athletic trainer. During the following years she was employed as an athletic trainer at Healthsouth Rehabilitation, working with junior college, university, and various other junior level athletes. In September, 1999 she became a graduate assistant athletic trainer and enrolled in graduate school at Southwest Texas State University, San Marcos, Texas.

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