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Sportmetrics™: The Key to Prevention of Serious Knee Ligament Injuries in Female Athletes

INTRODUCTION

For over three decades, the Cincinnati Sportsmedicine Research and Education Foundation is nationally recognized for performing important research on preventing and treating knee injuries. Over fifteen years ago, Dr. Frank R. Noyes published a research article on the female athlete's high risk for developing knee injuries. The majority of the injuries involve the ACL and occur as non-contact injuries. Dr. Noyes and his research staff

have dedicated years to studying this problem, and have identified several factors which place the female athlete at greater risk than their male counterpart for suffering a devastating knee injury.



THE PROBLEM:

In the female athlete, approximately 70% of serious knee injuries occur during non-contact events such as landing from a jump, or from a twisting/turning movement when a sudden knee imbalance occurs. The athlete must react quickly with control, coordination, and normal muscle strength or a giving way at the knee will occur. Many of the non-contact injuries are preventable, while contact injuries with an opponent are less preventable.

STATISTICS:

Anterior cruciate knee injuries occur 4-6 times more frequently in female athletes than in male athletes. One in every 10 college female athletes, and one in every 100 high school female athletes will sustain a serious knee injury every year. There are over 100,000 anterior cruciate ligament surgeries every year in the United States and approximately more than one million worldwide.

THE CAUSE:

Several theories have been discussed regarding the discrepancy between male and female knee injury rates. The majority of the research has concentrated on the following areas:

STRUCTURAL/ANATOMICAL THEORIES

1. Wider pelvis; Q-angle
2. Joint Laxity
3. Narrow Intercondylar Notch

HORMONAL-ESTROGEN THEORIES

1. Collagen Strength Deficit
2. Joint Laxity

TRAINING DIFFERENCES

1. Strength
2. Technique
3. Coaching

It is more than likely that the cause of increased knee injury incidence in female athletes over male athletes is multi-factorial. First, anatomical differences do exist. The female athlete, with a wider pelvis and greater Q-angle, experiences greater stress at the knee during athletic events. Additionally, the female athlete demonstrates more anterior knee laxity. Secondly, estrogen both directly and indirectly affects the female neuromuscular system. Therefore, estrogen may have an effect on patterning of the neuromuscular system in the female athlete. Finally, differences in training of male and female athletes may contribute to the difference in knee injury rates. Research has documented differences in the biomechanics of landing and lower extremity strength variations between the female and male athlete. The male athlete demonstrates greater use of hamstring and gastrocnemius muscles when landing from a jump. This protects the knee ligaments. The female athlete will most often contract the quadriceps in response to anterior tibial translation. The quadriceps contraction at knee flexion angles between zero and forty degrees significantly increases strain on the ACL. With weaker hamstrings, the female athlete is more vulnerable to anterior translation, and is ineffective in using the hamstrings as an ACL agonist.



coordination is not as common in male athletes. Research at Cincinnati Sportsmedicine in 1996 showed that hamstrings strength and power, jumping ability, and knee control in female athletes were abnormally low in a high percentage of female athletes when compared to their male counterparts. Researchers believed that female athletes did not perform the training and conditioning programs to achieve proper knee balance. After the female athletes participated in specific muscle strengthening and coordination exercises, the researchers determined that the female athletes developed greater leg strength and power. They also developed limb symmetry equivalent to that of male athletes of the same age. This training program later became known as Sportsmetrics™. This research further demonstrated that female athletes decreased knee landing forces while jumping and landing mechanics changed from stiff-legged landings to more controlled knee joint actions which provided stability. These athletes also showed an increase in vertical jump height.

Other researchers have shown that a neuromuscular training program significantly increases hamstrings strength in females, and corrected imbalances in hamstrings to quadriceps strength ratios and dominant versus non-dominant hamstring strength. After training, the female athlete has demonstrated mean hamstrings strength patterns equal to males.

Additionally, Cincinnati Sportsmedicine conducted an epidemiological study that evaluated the effects of training in a “real world” setting. A preseason screening questionnaire was completed by 829 female and 434 male high school soccer and volleyball players. Then, a subgroup of 366 female athletes participated in the Sportsmetrics™ training program for six weeks prior to their season. Athletic trainers submitted weekly team and individual injury reports during a three-month sports season. The report included the number of practice and competition exposures. An injury risk exposure was defined as one athlete participating in one practice or match. The individual injury report included the type of injury, mechanism of injury, and treatment. A serious knee injury was defined as a knee ligament sprain or rupture causing an individual to seek medical care by a trainer or physician, causing a practice or match to be discontinued while resulting in at least five consecutive days of lost time from practice or competition.

THE TREATMENT:

When faced with a potential injury situation in which the female athlete is slightly off-balance or must make a sudden stop or twist, the athlete may not have the coordination or muscle strength to react immediately and avoid a serious knee injury. This problem with muscle

Cincinnati Sportsmedicine's research demonstrated that the female athletes who completed the Sportsmetrics™ program decreased their risk for knee injury by 3-4 fold when compared to the athletes that did not complete the program.

An article published in the Journal of the American Academy of Orthopaedic Surgeons in 2000, stated that there is not a clear understanding of the cause of non-contact ACL injuries. However, prevention programs designed to increase neuromuscular control, improve balance, and teach avoidance strategies for at-risk situations appear to be effective in decreasing injury rates.

THE SPORTSMETRICS™ TRAINING PROGRAM:

The Sportsmetrics™ program has been designed specifically to provide training, coordination, balance, and strength to the lower extremities and knee joint. The training prepares the athlete to react immediately to an injury situation. In order to be an effective neuromuscular training program, Sportsmetrics™ training addresses the major deficiencies that are present in the female athlete.

REACTION FORCE DOMINANCE:

Allowing the ground reaction forces to control the direction of the knee. Reaction force dominance results in high valgus knee moments and high ground reaction forces. Typically during single leg landing, pivoting or deceleration, as often occurs during knee ligament injury, the female athlete will allow the ground reaction force to control the direction of motion of the knee joint. There is an imbalance between neuromuscular and ligamentous control at the knee joint. This lack of dynamic muscular control of the joint leads to high forces and high valgus torques at the knee.

QUADRICEPS DOMINANCE:

Increased quadriceps recruitment and decreased hamstring strength. With quadriceps dominance, there is an imbalance between the quadriceps and hamstrings as well as coordination. The female athlete activates their quadriceps before their hamstrings during sport specific skills to stabilize their knee joint. This dependence on the quadriceps further accentuates and perpetuates strength and coordination imbalances between the quadriceps and hamstrings.

DOMINANT LEG DOMINANCE:

Assessing side-to-side differences in strength, flexibility and coordination. Dominant leg dominance is the imbalance between muscular strength and coordination on opposite legs. Without specific training, the dominant leg often demonstrates greater strength and coordination. Each exercise in the Sportsmetrics™ program was chosen in order to enhance dynamic neuromuscular control of the knee joint. Each exercise is important, and when combined together, the exercises provide the physical therapist with the necessary framework to enhance the athlete's ability to dynamically stabilize the knee joint during competitive sporting events. In the Sportsmetrics™ program, three development phases are implemented to stress a different training focus.

The first phase targets the correction of reaction force dominance by focusing on proper form and technique. Jumping and landing technique is evaluated by the physical therapist with feedback given to the athlete. This is similar to the feedback given to an athlete while learning a specific skill required for a sport. Alterations in training intensity and volume in each phase assists in the correction of quadriceps dominance throughout the Sportsmetrics™ program. For example, the total volume of work is decreased from Phase II to Phase III to allow the athlete to increase intensity and effort. The increased effort during the jump/plyometrics will translate to greater hamstring recruitment during movements that are more multi-directional and sport specific. Feedback regarding technique is important in all three phases in order to stress deep knee flexion to facilitate hamstrings contraction during each jump.

TRAINING TO CORRECT REACTION FORCE DOMINANCE:

In order to correct reaction force dominance, an athlete must learn to control dynamic knee motion in the coronal plane to prevent valgus and varus stress. Additionally, the athlete must recognize the knee as a single-hinge instead of a ball-and-socket joint. Maintaining dynamic control of knee motion in the sagittal plane is achieved through a progression from single plane exercises to multi-planar exercises. This progression includes the following jump plyometrics:

WALL JUMPS:

Also known as ankle bounces, the jump is performed with knees slightly flexed and arms overhead. This jump provides low intensity exercise to warm up joints and muscles. The therapist can begin the analysis of an

athlete's level of reaction force dominance or valgus/varus motion at the knee.

TUCK JUMPS:

The athlete starts in an upright neutral stance and tucks the knees simultaneously to the chest. This jump allows the therapist to assess abnormal coronal plane knee displacement since the athlete usually devotes minimal attention to technique.

BROAD JUMPS:

Starting from an upright neutral stance, the athlete jumps forward as far as possible. Both take off and landing should be on both feet. The athlete must remain in a deep crouch position for 5 seconds. The broad jump allows the therapist to assess the athlete's knee motion while they are progressing forward in the sagittal plane. The ligament-dominant athlete will often display a lack of knee control during takeoff from this jump. The athlete will learn to recognize proper knee positioning and control. This will enhance proprioceptive and kinesthetic abilities.

180-DEGREE JUMPS:

Starting from an upright neutral stance, the athlete jumps straight up into the air and makes a 180-degree turn before landing. This teaches the athlete dynamic body and knee control in a transverse plane. It requires the athlete to recognize and control rotational forces.

BARRIER JUMPS: SIDE/SIDE & FORWARD/BACKWARD

While facing a 6"-8" barrier, the athlete jumps forward and backward or side to side with feet together. This jump directly creates and targets dynamic control of dangerous valgus and varus moments at the knee. It requires the athlete to quickly dampen, decelerate, and redirect ground reaction forces.

SCISSORS JUMP:

Starting in a long lunge position with the front knee bent directly over the ankle, the athlete alternates legs by pushing off the front leg and landing with opposite leg bent in front. This provides transition from generating double leg to generating single leg power and control. It will prepare the athlete for single-leg hop exercises.

SINGLE LEG HOP:

This jump is performed just like a broad jump.

However, both the start and landing is performed on one leg. The athlete lands in a deep crouch position and holds for 5 seconds. This jump can roughly mimic a mechanism of an ACL rupture during a competitive event. The athlete is required to gain and maintain dynamic knee stability over a period of time.

TRAINING TO CORRECT QUADRICEPS DOMINANCE:

In order to decrease the tendency towards quadriceps dominance, exercises have been developed which emphasize co-contraction of the knee flexor/extensor muscles. A difficult part of this program is to develop a more appropriate firing pattern for the knee flexors, while providing exercises that also strongly activate the knee extensors. At angles greater than 45 degrees, the quadriceps becomes an agonist to the ACL. Therefore, it becomes important to use deep knee flexion angles to put the quadriceps into an ACL agonist position. By training an athlete with deep knee flexion jumps, she will learn to increase the amount of knee flexion and decrease the amount of time in a more dangerous straight-legged position. The interaction of all the plyometric jumps are important to increase quadriceps and hamstrings co-contraction. Their cumulative effects provide an increased knee flexor to knee extensor work ratio. The following jumps are more specific for correction of quadriceps dominance.

SQUAT JUMP:

This jump begins in a squat position with the chest and head up and back straight. The hands touch the floor on the outside of the heels. The athlete jumps up reaching as high as possible and then returns to a squat position with the hands reaching to the outside of the heels again. This jump requires increased control of sagittal plane moments. With deep knee flexion angles greater than 90 degrees, the hamstrings are recruited. Here, increased work load of the hamstrings forces muscular adaptation due to decreased mechanical advantage at deep knee flexion angles.

BROAD JUMP & SINGLE-LEG HOP:

Both the broad jump and single leg hop trains the hamstrings to provide stabilization and balance in a high-risk maneuver. Hamstring firing is required early in the landing to prevent anterior tibial shearing force. Also, the hamstrings counteract the quadriceps firing during deceleration from a landing and prevent the dangerous valgus knee motion.



BARRIER JUMP: FRONT TO BACK:

This jump will require repetitive recruitment and co-contraction of the knee flexors and extensors. The jump forces loading of the weaker and less mechanically advantaged hamstrings and gastrocnemius muscles.

TRAINING TO CORRECT DOMINANT LEG DOMINANCE:

The final problem that must be addressed in the female athlete is the correction of dynamic contralateral imbalances. This problem is addressed throughout the entire training protocol. Equal leg-to-leg strength, balance, and foot placement are stressed throughout the plyometrics training. The athlete must continuously place their weaker leg under greater stress to maintain symmetry during the double leg jumps. Correction of dominant leg dominance also requires the athlete to coordinate multiple joint actions and multi-planar movements into power skill movements that can be utilized during competitive play. The progression from a double leg jump to a single leg power jump is necessary for correcting dominant leg imbalances. By incorporating multi-planar jumps, equal use of both lower extremities is necessary. More complex patterns of movement require greater synchronization and coordination in side-to-side performance. This will lead to greater balance in side-to-side muscle recruitment and equalization of leg-to-leg coordination and power. The following jumps are more specific to correction of dominant leg dominance.

TUCK JUMP, SQUAT JUMP, BARRIER JUMP, AND MATTRESS JUMPS:

All of these jumps require the athlete to provide equal force output by each leg to maintain proper position in jumping, landing, and upright body position. The jumps force the weaker leg to work harder to maintain a position with the stronger leg.

SINGLE-LEG HOP, SINGLE-LEG BARRIER HOP, TRIPLE HOP AND HOLD:

All of these jumps will force each leg to work inde-

pendently without compensation by the contralateral lower extremity.

BOUNDING:

This jump begins with the athlete on one leg and opposite leg bent behind. While staying in one place, leg positions are alternated by driving the back leg forward and upward. This involves coordination of multi-planar movements. It requires the athlete to jump with maximum distance in both the vertical and horizontal planes. The weaker leg is repeatedly and quickly exposed to the forces generated by the other leg. Here, the weaker and less coordinated leg is challenged to redirect forces.

JUMP, JUMP, JUMP, VERTICAL JUMP:

Three broad jumps are performed with each take off and landing in a deep crouch position. The jump is completed with a maximum vertical jump and return to a deep crouch position. This requires the athlete to transfer horizontal momentum into vertical movement. It allows for the transfer of movement skills in training to movements in competitive play. One example is the basketball player who is performing a jump stop lay-up while moving at full speed to the basket. Another example is the soccer player moving across the field to out jump the defender to head the ball on goal from a cross kick.

JUMP UP, DOWN, 180, VERTICAL JUMP:

This jump begins with a double foot jump onto a 6"-8" box. The athlete then lands in a deep crouched position and immediately performs a double foot jump down off the box. After landing in a deep crouched position, the athlete immediately performs a 180 degree jump. Upon landing, the jump sequence is completed by jumping into a maximum vertical jump landing back into a deep crouched position. This jump requires coordination of both legs to maintain body alignment and control during a highly complex multi-planar movement.

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