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Female ACL Injury Prevention With a Functional Integration Exercise Model

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summary

A thorough review of the literature reveals that female athletes have a higher incidence of sustaining an anterior cruciate ligament (ACL) tear compared to their male counterparts. This article briefly describes the associated risk factors, anatomy, and etiology of the female ACL tear. More importantly, the primary objective of the article is to present a research driven functional training model designed to prevent ACL tears.

Women's sports have significantly grown in popularity in recent years, beginning with the passing of Title IX and more recently from the success of the women's world-cup soccer team and the Women's National Basketball Association. This success does not apply just to the professional level but also to the college and high-school ranks. More female athletes are participating in sports at a younger age, which translates into a higher skill level acquired by the female athlete. Women's games are games of increasing speed and aggressiveness with the competition level rising each year. Along with this increased level of play comes a potential increase in injuries. The most significant injury that seems to be an epidemic to the female athlete involves the anterior cruciate ligament (ACL). Research on why women are injuring this specific ligament at such an alarming rate when compared with male athletes has been extensive in recent years. A review of statistics, risk factors, the function of the ACL, mechanism of injury, and prevention are all important topics when discussing the high rate of ACL injury in the female athlete.

Risk Factors

The results of comparing statistics of ACL injury rates in male and female athletes are quite alarming. Studies show that women are anywhere from 2 to 8 times more likely to have an ACL injury than are men. A woman injures her ACL most commonly in gymnastics, followed by soccer, basketball, field hockey, volleyball, lacrosse, and then softball (5). Men have the highest ACL injury rates in football and wrestling, neither of which are sports that women participate in frequently.

Many intrinsic and extrinsic factors predispose female athletes to an ACL injury (Table 1). These risk factors include hormonal influences, intercondylar notch width, joint laxity, limb alignment, muscle strength, neuromuscular activation, ligament size, excessive shoe-surface interface friction, sports activity, and training/conditioning level. Despite extensive study, no single cause for the disparity among genders has been singled out. It is not the goal of this article

Table 1
Female Anterior Cruciate Ligament Risk Factors

Intrinsic	Extrinsic
Hormones	Shoe-surface interface friction
Intercondylar notch width	Type of sport
Joint laxity	Training/conditioning level
Lower-limb alignment	Equipment
Muscle strength	
Neuromuscular activation	
Ligament size	

to debate the causative factors in female ACL injury; rather, it is to present a comprehensive prevention program to reduce the occurrence rate.

Basic Anatomy and Etiology of Injury

The ACL is located on the anterior section of the intercondylar area of the tibia and extends superiorly, posteriorly, and laterally to attach to the posterior part of the medial side of the lateral condyle of the femur. The main function of the ACL is to provide knee-joint stability by acting as a static restraint to anterior tibial translation. The ACL's mechanism of injury primarily occurs through noncontact sport activities involving sudden turning, jumping, planting, and pivoting (1, 4). The tear or rupture usually occurs in the midsubstance of the ligament, which is its weakest part. Commonly, the athlete runs, suddenly stops, and then turns, thereby causing a deceleration of the lower limb, a forced hyperextension of the knee, or a forced tibial rotation, resulting in injury to the ACL (7). Other mechanisms include an internal rotary force applied to the femur on a fixed weight-bearing tibia, an external rotation force with a valgus force, or a straight anterior force applied to the back of the leg, forcing the tibia forward relative to the femur.

Ireland (6) explains the mechanism of injury of the ACL in terms of the "position of no return." In this position, the spine is forwardly flexed and rotated to the opposite side, the hips are in adduction and internal rotation, the knee is slightly flexed and has a valgus stress on it, and the tibia is in external rotation. This landing pattern is such that 1 foot is out of control, and the body weight is forward on the balls of the feet. In this position, the hip abductors and extensors have been shut down. This causes the pelvis and hip to be uncontrolled, and the muscles that normally upright the individual cannot perform their function because they are in a position of mechanical disadvantage. This "safety position" is an ideal position to be in during sport movements. This position is where there is a normal lumbar lordosis, and the hips and knees are in a flexed position with neutral rotation. The landing pattern is controlled with the athlete coming down on both feet with the weight of the body in a center-balanced position in mid foot stance.

Recent research (8) has shown that during closed kinetic chain knee extension the arthrokinematics between men and women differ. Specifically, as a woman approaches terminal knee extension, a greater amount of femoral gliding versus rolling occurs compared with men. This relative increased anterior movement of the tibia may strain the ACL. Along with this anterior glide, electromyograph studies show a concomitant decrease in hamstring activity. This combination of events may be a reason for increased ACL tears in women.

Even though the ACL provides a majority of the anterior restraint, a significant amount of stability is attributable to the dynamic action of the hamstrings. The hamstrings reduce anterior tibial translation and internal tibial rotation during knee flexion, therefore acting synergistically with the ACL (9). It is this synergistic relationship between the ACL and the hamstrings that activates to decrease the shear forces at the knee during jumping and pivoting motions (11). In contrast, the quadriceps acts antagonistically to the ACL, encouraging forward displacement of the tibia relative to the femur. The contraction force produced by the quadriceps can produce forces in excess of what the ligament can handle, predisposing a person to ligament tensile failure (4).

Neuromuscular activation of muscles in response to anterior tibial translation differs between men and women. In men, the hamstring is recruited first to stabilize the knee during anterior tibial translation (4). On the other hand, women rely more on the quadriceps and gastrocnemius to resist anterior tibial translation (4). Therefore, a balance of strength between these 2 opposing muscles and proper neuromuscular control is critical to normal knee function.

Proposed Prevention Program

By understanding the mechanism of injury and the risk factors that predispose a female athlete to ACL injury, specialized intervention/prevention programs can be accurately designed to fit the individual. The program needs to address factors that can be modified, such as hamstring strength and power, decreasing landing forces, and teaching proper neuromuscular control during jumping and landing (2–6, 11). Hewett et al. (3) looked at plyometric training in the female athlete to see its results on how it affected the landing forces, strength, and power of the leg muscles. The results showed that plyometric training was effective in reducing the occurrence of ACL injuries in women.

Table 2 Stretching	
Static	**Dynamic**
Hamstrings Quadriceps Piriformis Ilio tibial band Gastroc/sloeus	Figure-8 lunge

All stretches are performed daily before exercise.

Table 3 Plyometrics		
Week 1	**Week 2**	**Week 3**
Squat jumps	Squat jumps	Squat jumps
180 degree jumps	180 degree jumps	Double leg tuck jumps
Split squat jumps	Cycled split squat jumps	Double leg zig-zag hop
Alternate leg bounds	Double leg zig-zag hop	Coumbination bounds
Week 4	**Week 5**	**Week 6**
Double leg tuck jumps	Single leg zig-zag hop	Single leg zig-zag hop
Combination bounds	Standing triple jump	In-depth jump
Double leg zig-zag hops	Single leg vertical power jump	Single leg tuck jump
Double leg vertical power	Jump double leg speed hop	Single leg speed hop

Perform the above exercises on Monday and Thursday. For each exercise, do 2 sets of 5–8 repetitions. Rest 1–2 min between sets.

Considering the risk of ACL injuries in addition to the incidence of patello-femoral pain syndrome, low back injuries, and stress fractures in women, we have incorporated additional protective training strategies into our exercise prescriptions. Our intent is to provide the athlete with a multidimensional, functional exercise model, which is needed to combat an etiology that is multifactorial. For example, throughout the program the athlete will use and demonstrate symmetrical weight shifting, ilio tibial band mobility, hip adductor recruitment, and core stability with a neutral lumbo-pelvic girdle. Additionally, we apply the ACL and patello-femoral protected limits during the closed kinetic chain movements to promote a safer training environment with respect to knee-joint stresses. By doing this, the athlete is in the best position to create efficient movement patterns, which decrease the chance of injury and enhance overall athletic performance.

The focus of this program is to increase the strength and neuromuscular control of the hamstrings through priority

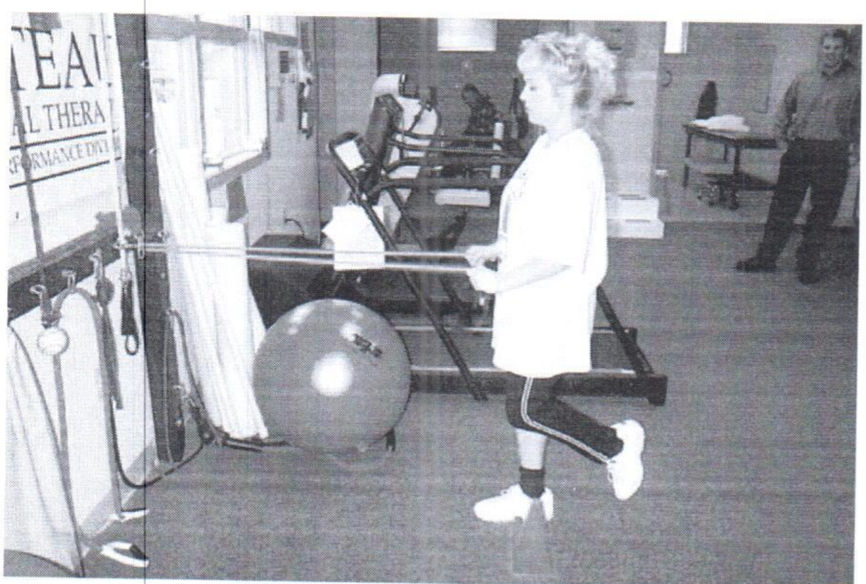

Figure 1. Proprioceptive oscillations with resistance tubing (12).

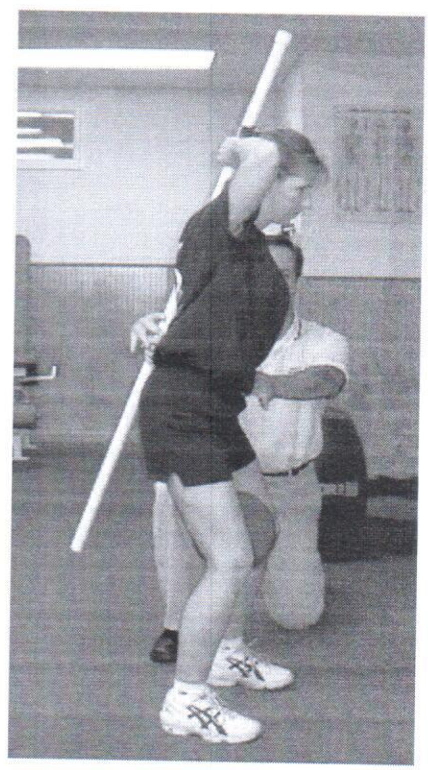

Figure 2. Squat technique.

Table 4
Functional Integration Exercise Model

1. Proprioceptive oscillations with resistance tubing: 30 s 3–5 reps
2. Squat: 2 sets of 15 reps (1 set slow and controlled)
3. Lunge: 2 sets of 15 reps (1 set slow controlled, 1 set fast and quick)
4. Supine stability ball walk-outs: 2 sets of 5–8 reps
5. Prone strider hamstring curl: 2 sets of 15 reps (1 set slow controlled, I set fast and quick)
6. Stiff-leg deadllift: 2 sets of 15 reps

Perform the above exercises on Tuesday and Friday. Rest 2–3 min between sets. Also perform 30 repetitions of abdominal work for 2–3 sets each session. Once proper form is attained, resistance can be added by the use of a barbell or holding dumbbells for squat and lunges. Resistance for prone strider hamstring curl can be achieved by use of leg-curl machine.

training while maintaining the overall development of the leg musculature. Proprioception, core stabilization, and hamstring activation are emphasized as the key components to the routine. The program is designed as an off-season training tool, lasting 6 weeks and ending 2–3 weeks before preseason. Table 2 lists both static and dynamic stretching techniques to be performed before initiation of exercise. The plyometric aspect of the program is aimed at decreasing landing forces and teaching proper neuromuscular control during jumping and landing (Table 3). Proper technique will minimize frontal plane stresses placed on the knee during specific sport movements, thus minimizing the strain on the ACL and assuming the safety position to which Ireland (6) refers. Table 4 lists the 6 functional integration exercises, 5 of which are described below in detail.

Proprioceptive Oscillations With Resistance Tubing

The goal of this exercise is to enhance the athlete's proprioceptive awareness (Figure 1) (12). The exercise technique can be modified accordingly depending on the athlete's skill level by integrating double and single leg stance and multidirectional unstable surfaces. Once the appropriate exercise environment is determined, the athlete is asked to quickly oscillate the resistive tubing. The exercise environment should be safe but challenging. In this particular case, the athlete is performing right single-leg stance with eyes closed. The strength and conditioning professional ensures the right knee is bent slightly to increase cocontraction of the knee musculature and prevents the athlete from attaining lower-limb stability from a joint-locking strategy. In our proposed model, the athlete is facing the wall, which results in an anterior pull. For the athlete to attain right lower-limb stability, she needs to recruit posterior musculature, such as the hamstring and soleus, to facilitate a posterior weight shift. The exercise is performed at 30-second intervals for 3–5 repetitions.

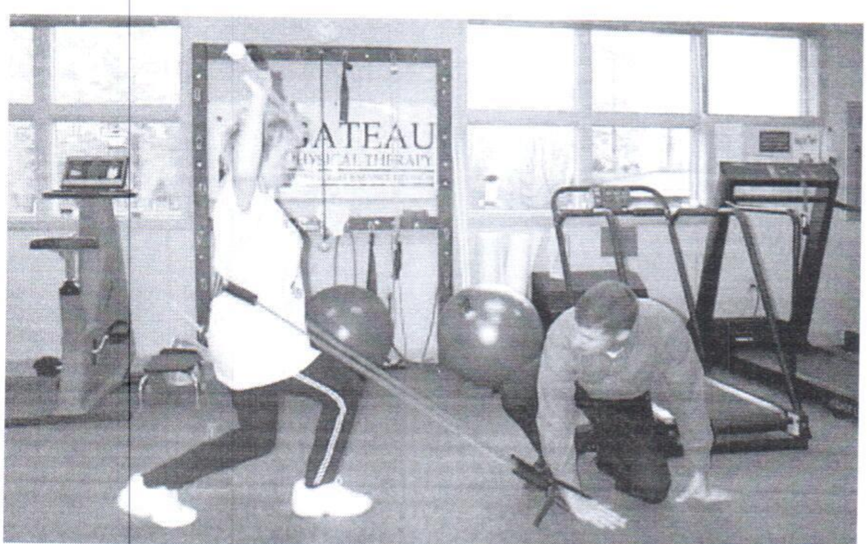

Figure 3. Lunge technique.

Squat Technique

A properly performed squat technique (Figure 2) is certainly a cornerstone of functional training. To maximize the effectiveness of the exercise, we incorporated the use of a medicine ball and wand. The strength and conditioning professional places a medicine ball between the athlete's knees to facilitate symmetrical weight bearing, as well as to increase adductor recruitment. The wand is placed behind the athlete's back to emphasize contacts at the head, midscapular region, and lumbar region. The athlete is instructed to maintain a neutral pelvis and forward trunk inclination of 30 degrees to facilitate core stability and hamstring activation, respectively (10, 13). The squat is performed within the protected limits of 0–30 degrees closed kinetic chain to prevent excessive ACL and patello-femoral stresses (13). The athlete can perform 15 repetitions for 2 sets (1 set performed in a slow and controlled manner, 1 set performed in a quick manner).

Lunge Technique

The lunge (Figure 3) is another cornerstone of functional training. In order to maximize the effectiveness of this training technique, we emphasize the use of

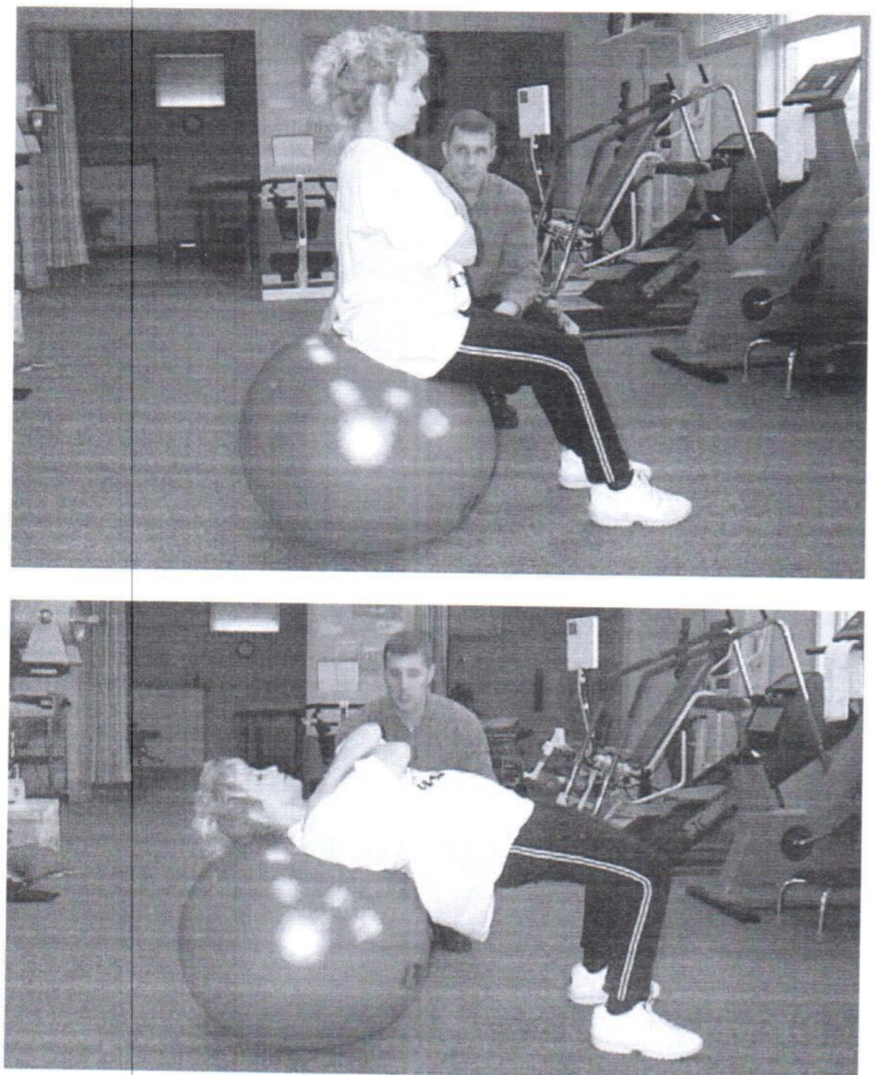

Figure 4 and 5. Supine stability ball walk-outs.

the wand overhead to facilitate dynamic latissimus dorsi and torso flexibility. By crossing one extremity over the other and stepping forward, a tandem stance position is achieved. The tandem lunge will create a more proprioceptively enriched exercise environment. The athlete should maintain a neutral pelvic tilt during the movement to achieve core stabilization (10). The sport-conditioning tube is wrapped around the waist and pulled anteriorly and inferiorly to achieve the desired resistance. The lunge is performed within the protected ACL and patello-femoral limits to decrease stresses on the respective ligaments and joints. The athlete can perform 15 repetitions for 2 sets (1 set performed in a slow and controlled manner, 1 set performed in a quick manner).

Supine Stability Ball Walk-outs

This exercise (Figure 4 and 5) emphasizes core stabilization and reciprocal hamstring firing and can be an integral component to any ACL prevention-training program. First, the athlete attains a neutral spine and pelvis and proper posture during static sitting on the unstable ball (10). Then, the athlete maintains the neutral spine and pelvis while she slowly walks out into a bridging position. The athlete holds the position for 5 seconds with an emphasis on static stability, then slowly walks back to the returning position while maintaining dynamic stability throughout the movement. The exercise is performed for 5–8 repetitions for 2 sets.

Prone Strider Hamstring Curl

One open kinetic chain exercise that is significant regarding an ACL prevention program is a prone strider hamstring curl (Figure 6). We advocate the athlete assuming a prone position with the contralateral leg flexed at the hip and knee over the side of the plinth. This position facilitates a properly locked lumbar spine and resembles a runner's striding posture. In addition, the athlete performs manually resisted hamstring curls to achieve quality eccentric and concentric contractions in this functional running position while the athlete's lumbar spine is stabilized. In this position, the athlete is less likely to compensate and sacrifice lumbar stability. Throughout the exercise, the strength and conditioning professional should monitor proper form. The athlete can perform 15 repetitions for 2 sets (1 set performed in a slow and controlled manner, 1 set performed in a quick manner).

Many factors must be taken into consideration when dealing with female athletes, especially when looking at their susceptibility to ACL injury. The rates at which female athletes are being injured can be minimized if the athletes and trainers understand the mechanism of injury and the risk factors of ACL injury. By performing a thorough evaluation, correcting certain postural deformities, and undertaking a specialized training program,

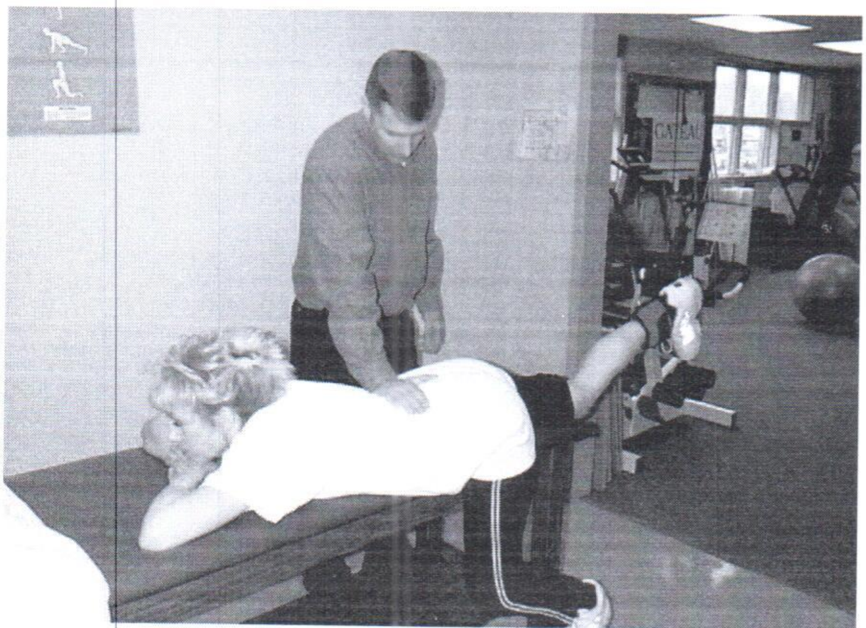

Figure 6. Prone strider hamstring curl.

female athletes can significantly reduce their risk of ACL injury. The overwhelming statistics show that female athletes are more vulnerable to ACL injury, but this problem can be reduced through education and intervention. ♦

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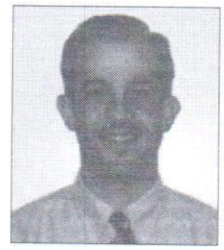

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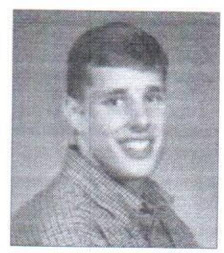

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