Preventing ACL Injuries in Females: What Physical Educators Need to Know

Lisa Toscano
Brianne Carroll

Jumping, landing, cutting, and pivoting are all actions that can contribute to the tear of an anterior cruciate ligament (ACL). The number of female athletes sustaining ACL injuries has grown over the years and has now surpassed the number of injuries sustained by male athletes. Female athletes whose sport involves jumping and cutting are significantly more likely to sustain a serious knee injury than are male athletes participating in the same sports (Hame, 2009; Hewett, 2000). Why is it that women are more susceptible to these injuries than men are? More importantly, can they be prevented? Can physical educators develop a better understanding of joint mechanics to help girls earlier in their development with this widespread problem? Working with girls in physical education class at a younger age may help to correct some biomechanical weaknesses. This article will present physical educators with a practical visual checklist of high-risk behaviors that can lead to ACL injuries when landing. In addition, it will offer some suggestions to help make students stronger while improving the biomechanical weaknesses that can lead to an ACL tear. The goal of this article is to help physical education teachers observe clear signs of biomechanical weakness and encourage the integration of a neuromuscular training program into their physical education curriculum.

Introduction to ACL Injuries

Knee injuries have become a significant problem in sports medicine. In 2006 it was estimated that there are more than 30,000 female ACL tears annually (Boone, 2006), and 70 percent occur without any contact (Sigward & Pollard, 2012). Non-contact ACL tears have been widely publicized for occurring three to eight times more often in women (Elliot, Goldberg, & Kuehl, 2010). These ACL tears are occurring as early as the middle and high school years. A better understanding of the risk factors associated with this injury can help develop interventions to treat and prevent ACL tears (Sward, Kostogiannis, & Roos, 2010).

The rise in ACL injuries affects athletes not only in the short term but in the long term as well, as 50% to 90% of these athletes will develop osteoarthritis in their injured knee due to degenerative joint changes.

Lisa Toscano (lisa.toscano@manhattan.edu) is an associate professor in the Department of Kinesiology at Manhattan College in Riverdale, NY. Brianne Carroll is a third-year physical therapy student in the Department of Physical Therapy at Hunter College in New York, NY.
resulting from their ACL tear (Zebis, Andersen, Bencke, Kjaer, & Aagaard, 2009). The increase in ACL injuries in the female population has led to an intense examination of the causes of this debilitating injury (Hewitt, Ford, Hoogenboom, & Myer, 2010). The Loyola University Health System (2011) attributed part of this rise to early sport specialization — the trend of young athletes competitively playing one sport year-round instead of multiple sports throughout many seasons. Extrinsic factors such as footwear and playing surface and intrinsic factors such as anatomical, hormonal, neuromuscular, and biomechanical gender differences have been suggested as theories for female predisposition to ACL injuries. Other factors, such as quadriceps dominance, single leg dominance, calf tightness, hip instability, hip flexor tightness, and trunk stability (Boone, 2006) have also been found in women and may contribute to this gender bias. These biomechanical and neuromuscular factors during sport-specific tasks are believed to be likely factors for the higher rate of non-contact ACL injuries in women (Hewitt et al., 2010). While anatomical and biological factors (wider hips and female hormones) that contribute to female ACL injuries cannot be changed, it is possible to improve other crucial areas of concern with education and training.

Neuromuscular Interventions

The gender disparity in non-contact ACL injury risk, combined with the evidence that females have deficits in neuromuscular control, have led to the development of neuromuscular interventions. These interventions can help all active females, as well as males, to develop stability for the knee. The objective of neuromuscular training programs is to improve muscle-firing patterns by enhancing unconscious motor responses of the central nervous system. The main goal of these programs is to produce a state of readiness for muscles in response to joint forces, resulting in enhanced motor control and increased dynamic stability. No universal ACL prevention program currently exists; however, existing programs include hip and hamstring training, core stabilization, balance and agility training, and neuromuscular training with video and verbal feedback to modify jumping and landing techniques (Bien, 2011). Many researchers define neuromuscular training as a multi-intervention program that combines strength, balance, plyometric, agility, and sport-specific exercises (Zech et al., 2010). Training these areas in physical education class may help prevent the unsafe joint positions that can result in injury.

A successful physical education neuromuscular-training program can teach all students how to improve the strength, balance, and alignment necessary to control the upper body, trunk, and lower body for maximum postural stability. In addition, the program can help lower students’ center of gravity by increasing hip and knee flexion, which can lead to decreased ground reaction forces in landing (Barber-Westin, Noyes, Smith, & Campbell, 2009). Increasing students’ awareness of their center of gravity and its relationship to postural stability is key to injury prevention.

Hip and Hamstring Training

Many females have unsafe joint positions, harmful muscle firing patterns, and lower extremity muscle-strength ratios — all of which increase the risk of suffering an ACL. According to Myer, Ford, McLean, and Hewitt (2008), the greater risk of ACL injury in females, coupled with the dramatic increase in sport participation (doubling each decade), has led to a significant rise in the number of ACL injuries in female athletes. Evidence suggests that the primary cause of this gender disparity may be neuromuscular in nature (Myer et al., 2008). Strengthening the muscles of the hip and the hamstrings is a critical step toward addressing these concerns. Strong hips and hamstrings can offset some of the inherent biomechanical risk factors in females.

According to Bien (2011), female athletes exhibit greater hip adduction and internal rotation with decreased knee flexion while walking, running, and anticipated and unanticipated cutting and landing. This predisposes women to increased knee valgus compared to men. Knee valgus is the position when the knees angle inward. This angling inward is an unsafe joint position and causes a greater strain on the ACL, especially when landing. Video analysis has demonstrated that women have higher knee valgus than men in cases of non-contact ACL injuries (Boden, Torg, Knowles, & Hewitt, 2009). Since research has identified that knee valgus angles are a primary predictor of ACL injury risk in active females, observing students in physical education class and teaching them to avoid this position may be the first step in prevention.

In order to counteract this valgus position, activation of the hip musculature is needed. The gluteal muscles play an important role in protecting against knee valgus and work together to provide stability to the legs and the hip in weight-bearing activities such as walking, running, and playing sports. The gluteus medius muscle keeps the hip in an abducted position, especially during activities such as landing, cutting, and changing directions. A weak gluteus medius may cause a knee valgus collapse because of the inability of the muscle to keep the hip in an abducted position. The gluteus maximus muscle is a powerful hip external rotator. According to Leetun, Ireland, Willson, Ballantyne, and Davis (2004), the strength of the external rotators have been found to be a reliable predictor for lower-extremity injury risk. Performing a single-leg squat is an easy way to determine weakness in the gluteal muscles. Strengthening the gluteus medius and maximus muscles can help address the knee valgus weakness in female athletes and assist in reducing pathomechanical hip motions and postures that place the knee in a vulnerable position (Bien, 2011). In essence, with increased use of the hip musculature during activity there may be a decreased loading at the knee.

Female hamstring activation also plays a role in the ACL injury rate of women versus men. Hamstring activation is needed to control the valgus postures demonstrated by females, yet women’s hamstring muscles are usually underdeveloped and relatively weak compared to the quadriceps. This strength deficit places excessive stress on the ACL ligament. Quadriceps dominance is described...
by Myer, Brent, and Ford (2011) as an imbalance in the strength of the knee extensors and flexors, recruitment, and coordination. Quadriceps dominance results in female athletes landing with the knee nearly in full extension, which is a recipe for ACL injury. Unlike men, women do not increase hamstring-to-quadriceps torque ratios at velocities that approach those of functional activities, and actually decrease hamstring-to-quadriceps ratios in sporting maneuvers (Myer et al., 2008). Both Hurd, Chmielewski, and Snyder-Mackler (2006) and Zebis et al. (2009) found that training the hamstrings helped dynamic valgus control and decreased the quadriceps patterns found in women. In most non-contact ACL tears captured on film, researchers have identified a position of eccentric contraction of the quadriceps in landing, planted foot with internally rotated hip, valgus knee at almost full extension, and upright trunk position. The upright trunk position found in landing is a result of quadriceps dominance (Myer et al., 2011).

Improvements in hamstring strength and activation may allow an increased knee flexion in landing, subsequently decreasing ACL sprains. Physical education classes that focus on hamstring and hip strength training will help address the issue of quadriceps dominance in girls and women. Hamstring and hip strength should be emphasized in physical education classes in order to bring awareness to students of its importance in injury prevention.

Core Training

Regardless of the sport, a strong core allows participants to maximize energy transfer as well as correct and enhance postural control. Dynamic neuromuscular core stability is not achieved by strength alone but rather through precise coordination of the muscles of the abdominals, spinal extensors, and the gluteal muscles (Oliver & Adams-Blair, 2010). Using state-of-the-art 3D motion-analysis technology, researchers at the Cincinnati Children’s Sports Medicine Biodynamic Center observed that females with ACL injuries do not steady their upper body when they jump or change directions. This places enormous pressure on their planted knee and overloads the ACL. Without a strong core, the body will often collapse at the knee joint, causing it to wobble from one side to another (Cincinnati Children’s Blog, 2012). Based on this data, it appears that incorporating core-stability training has the potential to limit ACL injury.

Single-plane exercises such as the sit-up are not enough to functionally strengthen the core. Training the core in multiplanar activities is critical for an athlete’s performance. According to Oliver and Adams-Blair (2010), one should begin with isometric exercises and awareness of the pelvis in the neutral position. Pelvic neutral can be obtained by hollowing in the belly button. This exercise is taught first because all other exercises should start from this position. The ability to maintain a stable core allows for adaptation to postural changes that occur from support movements (Oliver & Adams-Blair, 2010). Electromyography studies indicate that prone trunk extensions with the upper body and lower extremity lifted (“Superman” exercise), planks, and power wheel (roll outs) all improved the efficiency of core muscles to stabilize the trunk in multiple planes (Bien, 2011). Strengthening the core muscles will provide support and control for joints and posture and can be done routinely in physical education classes as a warm-up activity. Front planks, side planks, walking lunges with torso rotations, and twist curls are other examples of exercises used to condition the core. Oliver and Adams-Blair (2010) provided weekly progressions of core-strength activities that can be followed in any physical education class. In addition, Pilates is an activity that can be introduced in physical education classes that focuses on core strength and provides a good foundation for any kind of movement activity.

Balance and Agility Training

Several studies have reported a significant reduction in ACL-injury risk factors by using balance and proprioceptive training (Bien, 2011). Exercises that require balance improve relative quadriceps-to-hamstring ratios as well as hamstring and calf activation timing. This improved timing produces more muscular stability. Since females are quadriceps dominant, activating the hamstring quicker will potentially decrease strain to the ACL. In physical education class challenges to balance can consist of single-leg stances used to condition the core. Oliver and Adams-Blair (2010) used partner manual perturbations (disruptions in balance), closing eyes to decrease visual feedback, and sport-specific dynamic balance challenges, which have all been found to improve dynamic balance in healthy individuals. Yoga is a good addition to any physical education class because it integrates balance, strength, and flexibility. Yoga also exposes neuromuscular weaknesses and imbalances that need attention. Physical educators can add yoga to their curriculum or combine it with their usual strength-training classes in order to improve muscular stability and possibly prevent injury.
Calf Training

In addition to the hamstrings, the muscles of the calf (gastrocnemius and soleus) are critical in lower-body stabilization. Calf training may also be an important element in limiting injury risk. Fatigue at the ankle joint was found to contribute to losses in postural control and overall lower-body stability (Reimer & Wikstrom, 2010). Strong ankle and calf muscles help stabilize the knee when decelerating by providing more stability from the ankle joint. According to the National Institute of Health (2008), when the calf muscles are not helping to absorb the force when landing, and the knee is not in the proper position, the knee will buckle and possibly tear the ACL. When the gastrocnemius muscle that spans across the knee joint is strong, it provides structural support to the knee. Training the calf muscles to improve strength and endurance can be routinely accomplished using single-leg calf raises with weighted or elastic-band resistance. Single-toe raises will also strengthen the calf muscles and increase balance. These are two desired results when preventing ACL injuries. Calf-strengthening activities can be done as part of a physical education warm-up and requires little or no equipment.

Tuck-jump Assessment and Training

While it might not be feasible to perform video analysis with verbal feedback with all students in a physical education class, it is still possible to identify ACL risk factors in students more easily. The tuck jump is a clinical-friendly assessment and training technique to help identify high-risk female athletes who may be predisposed to an ACL injury. Myer et al. (2008) created the tuck-jump analysis, which involves a series of successive jumps over a 10-second period that helps identify common mistakes. For example, does the athlete exhibit lower-extremity valgus at landing? Are the thighs not equal in flight or parallel at the peak of the jump (weakness in core muscles)? Is there excessive landing contact noise (quadriceps dominance)? Landing with little flexion in the knee demonstrates characteristics of being quadriceps dominant and will probably result in excessive noise in the landing phase (Myer et al., 2011).

Tuck jumps are used to increase lower-body power, but can also be used as an assessment to identify and to monitor improvement in technique. The tuck jump with its defined checklist of biomechanical flaws may assist the physical education instructor in identifying injury risk. Flawed technique should be the focus of the teacher’s feedback. After learning landing techniques, students can pair up and do peer assessments of their partner’s tuck jump. This will also focus on the awareness needed to correct their own safe landing positions during activity. According to Blackburn and Padua (2009), non-contact ACL injuries occur immediately after landing, leaving little time for prevention or correction once the student has landed. These body positions are trainable and have become the foundation of most ACL prevention programs. Physical educators who are aware of the ACL epidemic can build their students’ awareness of vulnerable joint positions and then provide direction for treatment in class or in connection with local-community strength and conditioning clinics and programs. The complete and ready-to-use assessment checklist can be found in the Journal of Strength and Conditioning (Myer et al., 2011) and would be very beneficial in aiding the physical educator to prepare for class.

Importance of Physical Education

As physical educators, it is not always possible to implement a full ACL prevention program in a lesson plan, but it is possible to use the research to identify students who are at a greater risk for a non-contact ACL injury and to correct these imbalances. This research also supports the importance of keeping physical education in schools. By keeping physical education mandatory for everyone, physical educators can help reduce the muscle imbalance caused by sport specialization and contribute to ACL injury prevention. Educating students on the importance of safe joint positions, as well as implementing training techniques in every class, may help reduce injuries in active females, whether they are competitive or recreational participants. Teaching a curriculum based on lifelong fitness activities will also give sport-specialized athletes new experiences and will help to address their muscle imbalance.

Safe joint positions in females are critical for the stability and absorption of landing forces. The photos and descriptions in Table 1 can serve as a reference for physical educators and students to check for proper body alignment in an activity. Practicing these

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>Checklist for Proper Alignment in ACL Injury Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-body Proper Landing (front view)</td>
<td>With symmetrical knee bend and core engaged, the hips and hamstrings are equally activated. Keeping the arms out for balance supports a proper landing.</td>
</tr>
<tr>
<td>Table 1. Continued</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Full-body Proper Landing (side view)</strong></td>
<td></td>
</tr>
<tr>
<td>Teaching proper landing technique will absorb stress and help activate the hamstrings to avoid injury. With symmetrical knee bend and core engaged, the hips and hamstrings are equally activated. Keeping the arms out for balance supports a proper landing.</td>
<td></td>
</tr>
<tr>
<td><strong>Lower-body Proper Landing (knee alignment)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lower-body Proper Landing (side view)</strong></td>
<td></td>
</tr>
<tr>
<td>Knee in alignment with big toe activates the hamstrings and gluteus muscles to avoid injury.</td>
<td></td>
</tr>
<tr>
<td><strong>Full-body Improper Landing (front view)</strong></td>
<td></td>
</tr>
<tr>
<td>Upright trunk and straight leg landing.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1. Continued

<table>
<thead>
<tr>
<th>Description</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full-body Improper Landing</strong> (side view)</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>Upright trunk and straight leg landing. Quadriceps dominance present.</td>
<td></td>
</tr>
<tr>
<td><strong>Lower-body Improper Landing — Staggered Landing</strong></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>Avoid one-step landing.</td>
<td></td>
</tr>
<tr>
<td><strong>Lower-body Improper Landing — Knee Valgus</strong> (knee turned inward)</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>Females tend to display a knee valgus in landing. The turning of the knee inward can produce shearing forces on the ACL that will result in tearing.</td>
<td></td>
</tr>
<tr>
<td><strong>Lower-body Improper Landing</strong> (side view)</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>Knees fall over big toe. Shearing effect on the ACL.</td>
<td></td>
</tr>
</tbody>
</table>
landing techniques may help to prevent a future ACL injury. Injuries are inherent to sport, and some injuries are unavoidable. However, by dedicating classes to introduce females to safe joint positions (especially when landing); core stabilization exercises; hip, hamstring, and calf strengthening; and balance and agility activities, physical educators may help reduce the widespread epidemic of female ACL injuries.

There are a number of reliable, well-known training programs that offer advice in gaining dynamic neuromuscular control of the lower body, including the Duke Sports Medicine Clinic ACL prevention program (www.dukesportsmedicine.com), the Santa Monica Sports Medicine Foundation’s PEP program (www.smssmf.org), and the Cincinnati Children’s Hospital ACL prevention program (www.childrenshospital.org). These programs often offer short warm-up activities that replace traditional warm-ups and concentrate on hamstrings and gluteal strength, dynamic joint-stability training, and jumping training. Nordic hamstring curls, side-lying leg lifts, progressions of single-leg stances (eyes closed, balance mats, and wobbly boards), lunges, step-ups in all directions, slide boards, proper squatting with progressions, hops and jumps in various directions, star excursion balance activities, and shuttle runs are all activities used to expose and increase lower-extremity strength and proper joint mechanics. The video clips found on clinic web sites are extremely helpful in teaching these activities to physical educators. Additionally, by adding a unit plan focusing on the neuromuscular interventions described earlier, physical educators can help develop strong, healthy individuals who can engage safely in lifelong activity.

Conclusion

In summary, in order to prevent ACL injuries, physical educators should observe the following:

1. Notice the joint positions of your students when running, jumping, cutting, and landing. Identify high-risk students early.
2. Demonstrate and have students practice proper landing techniques.
3. Teach activities that increase the strength of the hamstrings and gluteal muscles. The hamstrings and gluteal muscles are the ACL’s best friend.
4. Focus on core stabilization training.
5. Incorporate balance and agility activities in class warm-ups. Utilizing the photo checklist (Table 1) can help guide teachers and students in proper landing techniques and help increase the performance and the safety of physical education students and athletes.

Knowledge of safe joint positions and core strength and stabilization is critical for educators to recognize and correct biomechanical deficits. Prevention is possible if students and educators are aware of the risk factors and know how to address them.

References


