Review Article

# Anterior Cruciate Ligament Rupture: Differences Between Males and Females

Karen M. Sutton, MD

James Montgomery Bullock, MD

## Abstract

The rate of anterior cruciate ligament (ACL) rupture is three times higher in female athletes than in male athletes. Intrinsic factors such as increased quadriceps angle and increased posterior tibial slope may predispose girls and women to ACL injury. Compared with males, females have smaller notch widths and smaller ACL cross-sectional area; however, no conclusive correlation between ACL size and notch dimension exists, especially in relation to risk of ACL injury. Female athletes who land with the knees in inadequate flexion and in greater-than-normal valgus and external rotation are at increased risk of ACL injury. No conclusive link has been made between ACL injury and the menstrual cycle. Neuromuscular intervention protocols have been shown to reduce the rate of injury in girls and women. Females are more likely than males to have a narrow A-shaped intercondylar notch, and special surgical considerations are required in such cases. Following ACL reconstruction, female athletes are more likely than male athletes to rupture the contralateral ACL; however, males and females are equally likely to rupture the reconstructed knee. Although self-reported outcomes in the first 2 years following reconstruction are worse for females than for males, longer-term studies demonstrate no difference between males and females.

From the Department of Orthopaedics and Rehabilitation, Yale University, New Haven, CT.

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## Epidemiology

Female athletes are two to eight times more likely than male athletes to sustain anterior cruciate ligament (ACL) injury.[1,2] A recent meta-analysis indicated that ACL injury is approximately three times higher in females than in males in soccer and basketball.[3] That analysis demonstrated a female-to-male injury ratio of 2.67 in soccer, 3.5 in basketball, 4.05 in wrestling, and 1.00 in alpine skiing. The number of girls and women participating in sports continues to increase, and it is important to understand the sex difference in rates of ACL injury, risk factors, prevention strategies, and treatment in order to optimize care.

Most ACL injuries occur in persons in their late teens and early 20s; however, the divergence in ACL injury rates by sex is evident immediately after the commencement of puberty, with a disproportionate increase in females.[4] The risk of ACL injury in female collegiate year-round high-level soccer and basketball players is approximately 4.4% to 5% per year,[3,5] compared with 1.7% for males.[3]

The annual incidence of ACL injuries is estimated to be 100,000 to 250,000, with a healthcare cost of $1 to $2 billion.[6,7] In addition to the burdens of pain and an extensive recovery course (average, 6 to 9 months), ACL injury is associated with lost productivity, lost competition, and lost scholarship opportunities. Associated injuries and earlier onset of arthritic changes are concerns in the affected knee.[7]

## Etiology

Approximately 70% of ACL injuries are noncontact injuries, and the remaining 30% are contact injuries.[8] A deceleration event and a sudden change in direction with a planted foot (ie, cutting maneuver) is the most common mechanism of noncontact ACL injury.[9]

## Extrinsic Risk Factors

Female sports participation increased considerably after the passage of Title IX of the Education Amendments of 1972.[10] Lack of experience was initially proposed as a contributing factor in increased injury rates in females. However, the increased participation of girls and women in organized participation did not lead to a reduction in ACL injury rates. National Collegiate Athletic Association injury surveillance data demonstrated no significant change in rate of ACL injury in male or female athletes over a 15-year period (1989 through 2004).[11]

A Norwegian study of handball players demonstrated that the risk of ACL injury in female players was 2.4 times higher on artificial floors than on natural wood floors.[12] No difference in rate of ACL injury by floor type was found in males. Most studies of extrinsic factors have not demonstrated or examined the effects of sexual dimorphism on ACL injury. Extrinsic factors that can increase ACL injury in a non–sex-specific manner are shoe–playing surface interfaces that cause increased friction. More cleats, larger cleats, a turf surface, and a dry climate have been shown to contribute to higher torsional forces at the shoe–playing surface interface.[6,11]

## Intrinsic Risk Factors

ACL rupture is thought to occur when muscle activity fails to appropriately stabilize the joint, causing increased loads on and failure of the passive restraints.[13] Thus, treating surgeons must understand the static and dynamic anatomy of the knee joint.

### Quadriceps Angle

The quadriceps angle (Q angle) has been shown to be 2.7° to 5.8° greater in females than in males when measured supine and 3.4° to 4.9° greater in females when measured in a standing position.[14] This larger Q angle leads to a more laterally directed pull of the quadriceps at the knee, which may place the ACL in a position in which it is more prone to rupture.[6]

### Intercondylar Notch

Many researchers have tried to find a link between the geometry of the intercondylar notch and the risk of ACL injury. There are contradictory findings regarding sex differences in notch width indices, a measure that attempts to standardize notch width relative to overall distal femoral width. A study of 213 Division I athletes demonstrated that athletes with intercondylar notch stenosis were at increased risk of noncontact ACL injuries.[15] However, no statistically significant difference was found between the sex of the athlete and notch width indices or rate of ACL tears. The notch width index may not be the ideal measure because as subjects grow taller, the femoral condylar width increases disproportionately compared with the intercondylar notch width.[16]

The A-shaped notch narrows from the base to the midsection and apex (Figure 1). In contrast, in U-shaped notches, the midsection does not taper from the base. The W-shaped notch differs from the U-shaped notch in that it has two apices instead of a classic flat roof. A study of 294 radiographs of ACL-injured and control patients indicated a higher proportion of A-shaped notches in women than in men.[17] Although persons with ACL injury had smaller notch widths and notch width indices, notch shape and sex did not correlate with injury status.

### ACL Size

When standardized for body weight, the ACL is smaller in females than in males.[6] Efforts have been made to standardize the way in which ACL size is compared between the sexes to ensure that similar subjects are compared. In an MRI study, Dienst et al[18] found that smaller intercondylar notch size correlated with a smaller ACL midsubstance cross-sectional area. In a comparison of males and females of similar height, females were found to have a thinner ACL midsubstance. Other authors have contradicted these findings, however. Anderson et al[19] found that the notch width increases in taller males but not in females; however, they found no correlation between notch size and ACL size.

### Tibial Slope

Recently, much emphasis has been placed on the geometry of the proximal tibia and its effect on ACL function and failure. An increase in posterior tibial slope (PTS) places the tibia more anterior relative to the fe-

**Figure 1**

A B C

Arthroscopic images of right knees demonstrating different notch shapes. **A,** A-shaped notch, which narrows from the base through the midsection to the apex. **B,** U-shaped notch, with no tapering from the base to the midsection. **C,** W-shaped notch, with characteristics of a U-shaped notch but with two apparent apices rather than a classic flat roof. (Reproduced with permission from van Eck CF, Martins CA, Vyas SM, Celentano U, van Dijk CN, Fu FH: Femoral intercondylar notch shape and dimensions in ACL-injured patients. *Knee Surg Sports Traumatol Arthrosc* 2010;18[9]:1257-1262.)

mur during quadriceps contraction, which may result in increased strain on the ACL (Figure 2). Hohmann et al[20] found that the PTS of the medial plateau was higher in ACL-injured females than in the control group and that females with ACL injury had a higher PTS than did males with ACL injury. In a cadaver biomechanical study of 10 male and 10 female height- and weight-matched specimens, Lipps et al[21] found higher peak ACL strain in female knees than male knees under simulated pivot-landing test conditions ($P$ = 0.004). They found significantly smaller ACL cross-sectional area ($P$ = 0.015) and greater lateral tibial slope ($P$ = 0.016) to be significant factors in knees with higher peak anteromedial ACL strain, irrespective of sex. The difference in female and male ACL strain could not be explained by a non-significant trend to increased posterior slope of the lateral and medial tibia.

Terauchi et al[22] found that medial tibial plateau posterior slope was significantly larger in the ACL-deficient females than in the negative control group (10.9° and 8.2°, respectively; $P$ = 0.003). No significant difference was demonstrated in ACL-deficient males compared with negative controls. Brandon et al[23] measured the posterior slope of the medial tibial plateau in 100 ACL-insufficient male and female patients and in 100 negative control subjects with patellofemoral pain. Both male and female patients with ACL insufficiency had significantly greater PTS than did their negative control counterparts ($P$ < 0.001 for each). However, there was no statistically significant difference between female and male patients with ACL deficiency. In another study, the difference in medial tibial plateau slope between patients with noncontact ACL injuries and those with no history of ACL injury was statistically significant only for the female subjects (9.8° versus 8.20°; $P$ = 0.002).[24]

Hashemi et al[25] used MRI to measure the medial tibial slope (MTS), lateral tibial slope (LTS), and coronal tibial slope as well as the medial tibial depth of concavity in 55 uninjured control subjects (33 women, 22 men) and 49 subjects with ACL injury (27 women, 22 men). All injured patients had more posteriorly sloped LTSs and MTSs, as well as more shallow medial tibial depths compared with the uninjured control subjects. Compared with female control subjects, women with ACL injury had greater LTS and lesser medial tibial depth but not greater MTS. Uninjured women had significantly greater MTS and LTS, as well as shallower but not significant medial tibial depth compared with uninjured men. There was no statistically significant difference in any of the measured variables between men and women with ACL injury. However, the presence of a high posterior LTS combined with a shallow medial tibia was seen in 75% of the combined injury population. Hashemi et al[25] noted that although there was no significant difference in measurements between men and women with ACL injury, good population-based studies are needed to determine the

Figure 2

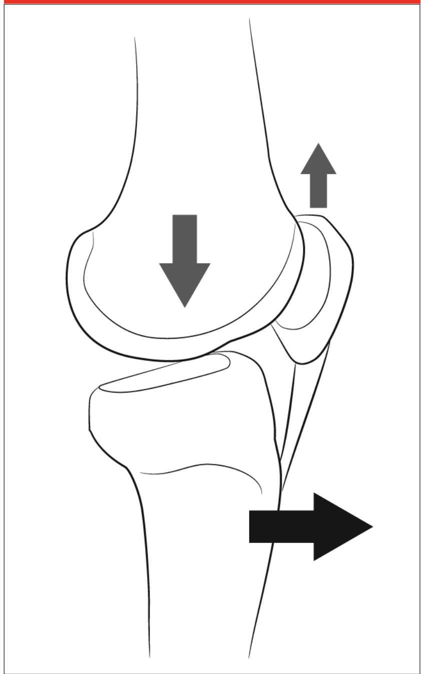

Illustration of the biomechanical consequences of posterior tibial slope. In the knee with posterior tibial slope, the effect of the tibiofemoral compressive load (down arrow) and the force of the quadriceps muscle (up arrow) results in an anteriorly directed shear force, which causes anterior translation of the tibia relative to the femur (right-facing arrow).

effect of such differences on ACL injury in female athletes.

Four of the aforementioned studies on MTS demonstrated significantly greater posterior MTS in injured females compared with uninjured females. In two of three studies that commented specifically on injured males versus injured females, no significant difference in measurements was reported. It may be that risk of ACL injury in relation to tibial slope has more to do with a particular threshold measure than with a particular sex.

Future studies must account for the effect of not only PTS but meniscal slope on the risk of ACL injury; a decreased lateral meniscal slope may have protective effects against ACL rupture.[26] Efforts should also be made to standardize the measurement methods used (eg, tibial axis, sides of the plateau, radiographic modalities) to characterize tibial plateau slope so as to make it easier to compare studies.

## Biomechanical and Neuromuscular Factors

Although the Q angle and other static measures have been used to predict knee injury,[27] more dynamic measures better simulate and predict knee alignment in injury scenarios. Females have a higher quadriceps-to–hamstring mass ratio and a higher ratio of quadriceps-to-hamstring recruitment.[28]

The hamstring should respond to a stretch reflex in the ACL; thus, in females, quadriceps deficiency may result in an increased risk of injury. The lateral hamstring and quadriceps have a greater recruitment pattern in females, which may lead to greater abduction.

Video analysis of landing positions in female athletes confirms this asymmetry. Compared with males, females land with a more erect posture, which subjects the knees to forces that put them at risk of anterior tibial translation. The position of external rotation is also theorized to place persons at risk of ACL injury because of the increased knee laxity. This position is seen to a greater degree in females than in males. Thus, in the at-risk position, female knees have the potential for more perturbations in position, thereby predisposing them to higher rates of ACL injury (Figure 3).

The position of the foot and ankle in cutting and landing maneuvers has not been conclusively linked to risk of ACL injury.

The lower extremities are part of a kinetic chain that includes core musculature. Core stability should optimally position the trunk and upper body to help the lower extremity function efficiently[29] and, in particular, improve knee joint stability to reduce the risk of injury.[30] In a study of 277 collegiate athletes, weakness in the core, measured by deficits in active proprioceptive repositioning of the trunk, predicted subsequent knee injury with 90% sensitivity and 56% specificity in female athletes but not male athletes at 3-year follow-up.[31] The study was not adequately powered to comment specifically on the risk of ACL injury, however.

### Kinematics/kinetics

In a study of 205 female athletes in high-risk sports, Hewett et al[5] performed preseason joint angle and moment analysis for jump-landing tasks. Nine athletes went on to have ACL injuries during the season—seven in soccer and two in basketball. Comparison of the preseason data on the ACL-injured athletes and the uninjured athletes showed that the injured athletes had knee abduction angles that were 8.4° greater at initial contact and 7.6° greater at maximum displacement and that they had 2.5 times greater knee abduction moments, 20% higher ground reaction forces, and 16% shorter stance time. Athletes with ACL injuries had increased angular motion, which took place at a faster pace and with higher forces than in noninjured athletes. This study demonstrated that preseason knee abduction moment results could predict which female athletes were at higher risk of ACL injury (73% sensitivity, 78% specificity).

The differences in knee abduction moments between females and males arise after pubertal growth spurts. One study demonstrated no sex-related difference in pubertal sub-

Figure 3

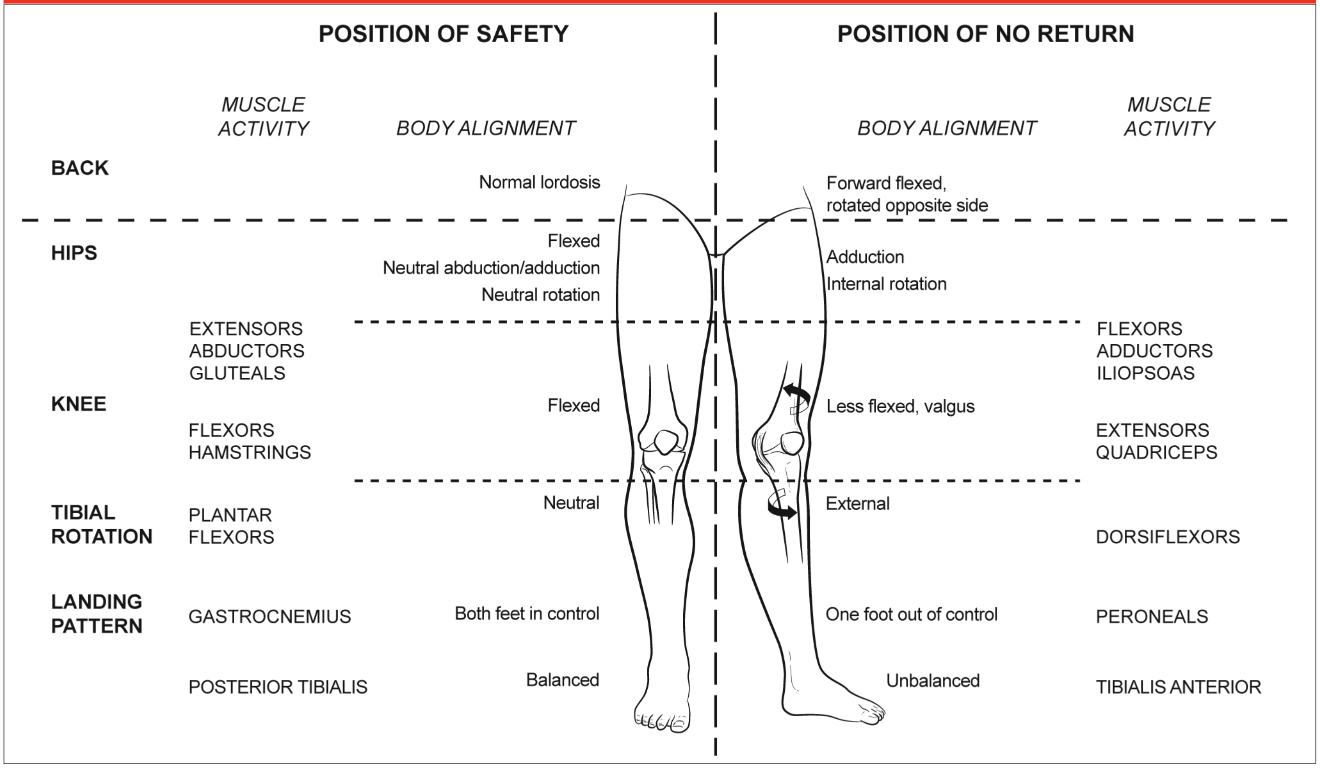


Illustration demonstrating two landing positions: the safe position, with the knee flexed, and the compromised landing position, which is associated with increased risk of anterior cruciate ligament injury in girls and women. (Adapted with permission from Ireland ML: The female ACL: Why is it more prone to injury? *Orthop Clin North Am* 2002;33[4]:637-651.)

jects.[4] However, the peak abduction angles increased in girls from year 1 to year 2 of the study; no such increase was shown in boys. This study did not directly examine ACL injury. However, given that a disproportionate increase in female injury rates occurs around the growth spurt, this pubertal phase may be a key point at which the various factors combine to affect sex differences in ACL injury.

## Genetic Predisposition

In a Canadian study, patients with ACL tears were found to be approximately twice as likely as noninjured control subjects to have a family member with ACL injury.[32] However, this study was subject to recall bias, and it lacked information regarding sports exposure of family members and the sex of injured family members. A small study on female twins suggested that a familial predisposition, which manifests with neuromuscular imbalance and decreased dynamic stability of the knee, might be partly responsible for ACL injury.[33]

Recent studies examining collagen genotypes—specifically, COL5A1, which encodes for the α1 chain of type V collagen—in ACL-injured and -uninjured participants have shown under-representation of the CC genotype of the COL5A1 BstUI RFLP in women with ACL injury but not in men. The TT genotype was overrepresented in all female participants with reported family history of ligament injuries.[34] However, it would be premature to attempt to link these findings directly to risk of ACL rupture in female athletes without further data regarding confounding factors.

## Hormonal Factors

Estrogen receptors are present on ACL fibroblasts, but findings are contradictory regarding their effect on collagen synthesis, knee laxity, and the strength of supporting muscles about the knee.[6] Using immunohistochemical analysis, Liu et al[35] demonstrated that estrogen and progesterone receptors were localized to synoviocytes, fibroblasts in the ACL stroma, and cells in the blood vessel walls of the ligament. Furthermore, Hamlet et al[36] found androgen receptors in ACL specimens from men aged 18 to 24 years, which indicates a potential role for male sex hormones in protecting young men from ACL injury. In an in vitro study published in 2001, Yu et al[37] demonstrated that estrogen had a negative and more dominant effect on fibroblast proliferation and collagen synthesis, whereas progesterone attenuated those effects.

The hormonal effects on clinical findings have been investigated, as well. The menstrual cycle is divided into three phases: follicular (days 1 through 9, low progesterone and estrogen), ovulatory (days 10 through 14, preceded by an estrogen surge), and luteal (days 15 through 28, rise in progesterone and a later rise in relaxin).[38]

A meta-analysis of nine studies found that anterior knee laxity was greater in the ovulatory phase than in the luteal phase and was lowest in the follicular phase.[39] However, more injuries were encountered in the follicular phase. In a case-control study of 91 skiers, Beynnon et al[40] showed that female skiers were 3.22 times more likely to sustain an ACL injury in the preovulatory phase than in the postovulatory phase. Hormone levels were measured based on serum progesterone concentrations.

Saliva samples, menstrual cycle self-reporting, and urine samples are some of the various measures that have been used in an attempt to stratify the cycle. As a result of the array of methods employed to better understand and accurately phase cyclical hormonal changes, it is often difficult to make precise comparisons across studies. The Hunt Valley II meeting consensus agrees that evidence is inconclusive regarding the interplay of the menstrual cycle and the incidence of noncontact ACL injury but notes that injuries are more likely to occur in the early and late follicular phases.[41] Large-scale studies that track hormone levels in female subjects, measure various markers of laxity throughout the menstrual cycle, and collect injury data would be best to elucidate this important yet difficult question regarding the effect of the menstrual cycle on ACL injury. Currently, the data are insufficient to make any conclusive statement regarding the effects of the menstrual cycle on knee laxity and on the rate of ACL injury in girls and women.

## Prevention Strategies

A program of neuromuscular and proprioceptive training in teenaged female soccer players resulted in an 88% reduction in ACL injury in the first year of implementation and a 74% reduction in the second year.[38] In a meta-analysis of neuromuscular interventions aimed at reducing ACL injuries in females, three of six studies reviewed indicated significant reductions in the incidence of ACL injury.[42] Hewett et al[42] noted a 72% reduction in noncontact ACL injury in trained female athletes who underwent a preseason neuromuscular training program ($P \leq 0.05$), Mandelbaum et al[38] reported significantly fewer injuries in their intervention group than in the control group (0.05 and 0.47 incidences of ACL injury per 1,000 exposures, respectively; $P < 0.001$), and Mykelbust et al[43] noted a significant reduction in injury rates in elite athletes only ($P = 0.01$). The combined data from all six studies demonstrated a significant effect of neuromuscular programs on the incidence of ACL injury ($P < 0.0001$).

A more recent meta-analysis of nine studies was done,[44] with some overlap with the study by Mandelbaum et al.[38] Sadoghi et al[44] reported a 62% reduction in the risk of ACL rupture in athletes in the ACL prevention programs compared with those in the control groups. When results were stratified by sex, female athletes were found to have a risk reduction of only 52%, compared with 85% in male athletes. In our opinion, this finding does not mean that prevention programs are more useful or successful in reducing injury in males than in females because none of the studies directly compared the same interventions in males and females. The study by Hewett et al[45] came the closest to making a direct comparison, in that they had a female intervention and a female control group and a male control group; however, they did not have a male intervention group. The 366 female athletes who underwent training sustained significantly fewer noncontact injuries than did the 463 female athletes who did not train ($P = 0.01$), but there was no significant difference between the female athletes who underwent training and the 434 male athletes who did not train.

Although many prevention studies have demonstrated a reduction in the risk of ACL injury in girls and women, we are unaware of any study that employed reduction techniques in males and females and showed a significantly greater reduction in the number of female injuries than male injuries. Theoretically, it seems reasonable to think that if there were some innate or intrinsic discrepancy in female risk factors that were addressed by proprioceptive training protocols, then there would be greater potential for increased reduction in injuries in females than in males.

## Ideal Components of a Successful Prevention Protocol

Definitive conclusions from the meta-analysis by Sadoghi et al[44] were limited by the heterogeneity of the studies included. However, the analysis did indicate that doing the injury prevention exercises for ≥10 minutes three times per week with a focus on neuromuscular training is an essential minimum criterion of a successful program (Table 1). The program should last ≥8 weeks to allow sufficient time for neuromuscular changes and performance training effects.[46] Preseason protocols are likely to be most effective, and continuation throughout the season and perhaps the athlete's entire career may be most effective. Studies have shown that deconditioning can occur within 2 to 8 weeks.[41]

The International Olympic Committee statement on noncontact ACL injuries indicates that use of protocols designed to alter dynamic loading of the knee joint through neuromuscular and proprioceptive training are effective in reducing the risk of ACL injury in female athletes.[9] Strength and power exercises, neuromuscular training, plyometric exercises, and agility exercises should be incorporated into the program, along with regular warm-up (Figure 4). The knee-over-toe position should be emphasized when cutting or landing in a position of knee and hip flexion from a jump on two feet.[9] Preenrollment drop vertical tests should be administered to identify at-risk athletes. In this test, the athlete begins by standing on a box (31 cm above ground) with the feet positioned 35 cm apart, then drops directly down off the box and immediately performs a maximum vertical jump, raising both arms as if jumping for a basketball rebound.[5] Details about the athlete's knee kinematics can be analyzed from this test.

Poor compliance has been a problem, with dropout rates near 50% even among elite athletes.[43] Efficient, low-cost protocols with some exercise variability over time to maintain athlete interest are integral to continued participation of players and coaches and to overall program success. Factors that remain unknown include the age at which these exercises should be begun, program duration, the intensity of maintenance programs, sport-specific needs, and how best to identify which athletes may need more individual intensive prevention protocols.

**Table 1**

| Components of an Ideal Anterior Cruciate Ligament Injury Prevention Protocol |
|---|
| 10 min, 3 times/wk for approximately 8 wk |
| Preseason implementation for neuromuscular adaptation |
| Perform as a warm-up to avoid neuromuscular fatigue |
| Maintenance recommended to avoid deconditioning, which can occur at 2 to 8 wk |
| Must include neuromuscular and proprioceptive training, plyometrics, agility drills, functional balance, and core strengthening |
| Low cost and easy to implement |
| Identify at-risk players who need more intensive intervention (eg, drop vertical test) |
| Encourage compliance (eg, varied workouts, correlate training with improved sport/muscular performance, risk awareness education/training) |

## Surgical Management

Females are more likely than males to have an A-shaped intercondylar notch (Figure 1, A). In the patient with an A-shaped notch, the surgeon should place the arthroscope in the anteromedial portal and drill the

**Figure 4**

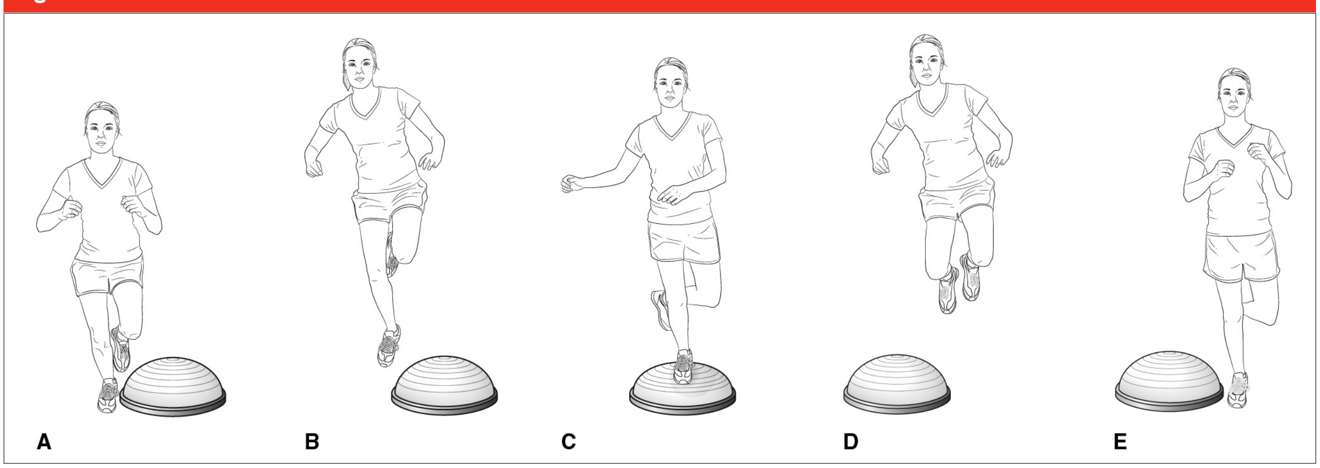


Illustration of a woman performing the both sides up (BOSU) lateral hop. This advanced exercise demonstrates single-limb stance support on surfaces of varying stability. The athlete must hold each position for 3 seconds (**A**, **C**, and **E**) before hopping to the next stance position (**B** and **D**). Deep knee flexion is stressed when performing this exercise.

femoral tunnel through an accessory medial portal to improve visualization and create an anatomic femoral tunnel.[47] Given that A-shaped notches are narrower than U- and W-shaped notches and given the propensity for females to have A-shaped notches, the surgeon may encounter a greater number of female than male patients in whom double-bundle ACL reconstruction either cannot be performed or is more challenging to perform.

## Graft Selection

Graft mismatch may be a matter of concern in quadrupled hamstring autograft techniques. The average hamstring graft diameter is significantly smaller in females than in males. Ma et al[48] found that females had significantly smaller-diameter grafts than males (7.5 and 8.1 mm, respectively). In females, preoperative variables such as height and body mass index were not predictive of graft diameter. In a study of 235 Chinese patients, Xie et al[49] found that females had significantly smaller-diameter and shorter gracilis tendon and semitendinosus tendon size than did males. Unlike Ma et al,[48] Xie et al[49] found that height, weight, and body mass index could be used to predict graft size.

In a French study involving 298 athletes, the reinjury rate was slightly higher following hamstring tendon autograft than following patellar tendon autograft, but this difference did not achieve statistical significance.[50] Age and sex did not significantly influence the reinjury rate. However, the females in the patellar tendon repair group had no reinjury, whereas five reinjuries were reported in the hamstring tendon group. In a Swedish study of 244 patients, no significant differences were found in clinical outcomes or functional scores between male and female patients 2 years after ACL reconstruction with hamstring autografts.[51]

Debate continues with regard to whether bone–patellar tendon–bone autograft, hamstring autograft, or bone–patellar tendon–bone allograft is the best treatment option. Biomechanical data indicate that smaller grafts experience larger strain;[21] thus, one might be concerned that hamstring autografts in active young females would be more susceptible to failure. However, we are unaware of any studies confirming significantly higher ACL reconstruction failure in female patients than male patients following hamstring autograft reconstruction.

## Associated Issues at the Time of Surgery

A ramp lesion is a repairable meniscal lesion involving the peripheral attachment of the posterior horn of the medial meniscus, and it can be associated with ACL rupture. One study demonstrated a significantly lower occurrence of ramp lesions in female patients than in their male counterparts (11.97% and 18.56%, respectively; $P = 0.017$).[52] Full-thickness articular cartilage defects were noted more frequently in male patients at the time of ACL reconstruction. A cohort study of 15,783 primary unilateral ACL reconstructions registered in the Swedish National Knee Ligament Registry and the Norwegian National Knee Ligament Registry from 2005 through 2008 found that male patients had an increased odds ratio of full-thickness cartilage lesions (ie, 1.22).[53]

## Surgical Outcomes

A cohort study of 4,438 patients registered in the Swedish National Knee Ligament Registry demonstrated worse outcomes in females than males at 1 and 2 years following ACL reconstruction.[54] Outcomes were measured based on the Function, Sports, and Recreational Activities subscale of the Knee Injury and Osteoarthritis Outcomes Score (KOOS). Over time, these differences equilibrated, and at follow-up >2 years, no difference was seen in KOOS values.

Females are more likely than males to suffer a subsequent ACL injury following ACL reconstruction, and that injury is most likely to occur in the contralateral knee. Shelbourne et al[55] prospectively followed 1,415 patients for ≥5 years after ACL reconstruction. One hundred thirty-six patients incurred a subsequent ACL injury to either knee (9.6%). Females had a higher rate of subsequent ACL injuries compared with men (12.5% and 7.8%, respectively; $P = 0.004$). Women were more likely than men to suffer an injury to the contralateral normal knee (7.8% and 3.7%, respectively; $P < 0.001$). Both sexes had an equal chance of re-rupture of the reconstructed knee, with 4.3% in males and 4.1% in females.

## Summary

Female athletes experience a higher incidence of ACL ruptures than male athletes across multiple sports. The idea that the higher injury rate among females is the result of lack of experience in the given sports has been disproved. Unique anatomic factors in females, such as a greater Q angle, smaller ACL size, narrower intercondylar notch, and increased medial PTS, are some of the possible static contributors to higher injury rates in females. Neuromuscular and proprioceptive preseason protocols designed to train female athletes to avoid placing their knees in at-risk positions on landing or in cutting maneuvers have been successful in reducing the incidence of injury in various sports.

Although females initially have worse outcomes than males following ACL reconstruction, the results are equivalent at >2-year follow-up. Female patients are at greater risk than male patients of rupturing the contralateral ACL in subsequent activity following an index injury. Further study is needed to better understand the factors involved and determine which ones can be addressed to reduce the sex disparity in ACL injury rates.

## References

*Evidence-based Medicine:* Levels of evidence are described in the table of contents. In this article, references 4, 5, 11, 15, 16, 26, 29-31, 33, 38, 39, 42, 44, 45, 48, 49, 51, and 53-55 are level II studies. References 8, 9, 12, 17, 19, 20, 22-25, 27, 32, 34, 40, 46, 47, 50, and 52 are level III studies. Reference 3 is a level IV study. References 1, 2, 6, 7, and 41 are level V expert opinion.

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