Micheli and Kocher

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Chapter 12

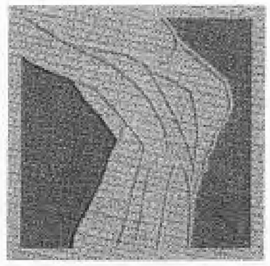
Special Concerns in the Female Athlete

Mary Lloyd Ireland • Susan M. Ott

Young female athletes have a disturbingly high rate of anterior cruciate ligament (ACL) tears and anterior knee pain complaints. These gender differences are real and multifactorial. Anterior knee pain is a very common problem in repetitive training sports such as cheerleading, dance, and cross-country running. ACL tears are the plague of female adolescent basketball and soccer players. However, other conditions are more common in males, including Osgood-Schlatter disease and Sinding-Larsen-Johansson syndrome. Osteochondritis dissecans is 3–4 times more common in males than in females.[1] Salter-Harris fractures of distal femur, proximal tibia, and tibial tubercle apophyseal injuries and tibial eminence fractures are more common in males than in females. ACL tears and anterior knee pain will be the focus of this chapter. The female athlete triad will be defined to increase awareness of this diagnosis, which is often made too late to provide a cure.

Every year, more males and females participate in organized sports at the high school and college levels.[2,3] According to the National Federation of State High School Associations, for the 2002–2003 season, 3,988,738 males and 2,856,358 females participated in high school athletics. Coed participation totaled 19,289 athletes. The progressive increase in sport participation by high school girls compared to boys is shown from the years 1971 to 2003[2] (Figure 12–1). In the 1971–1972 school year, athletes at the high school level were made up of 3,666,917 boys and 294,015 girls. By the 1980-1981 school year, boys made up 3,500,124 of the athletes and girls rose to 1,853,789. The ratio of boys to girls was 1.4:1 in 1999–2000. Between 1971 and 1994, the number of girls participating in high school sports compared to female students rose from 1 in 27 to 1 in 3.[4,5]

The National Collegiate Athletic Association (NCAA) in the three divisions of colleges for the years 2000–2001, reported 157,740 female and 217,115 male participants.[6] The years from 1989 to 2001 are shown in groups of females, males with football, and males excluding football (Figure 12–2).



Ratios of males to females participating at the collegiate level in all divisions is 1.4:1. Since the passage of Title IX in 1972, there has been a progressive trend toward equalization of men and women at federally funded colleges. With football eliminated, the ratio comparing males and females competing in college is equal.[3]

Unfortunately, the number of knee injuries is also on the rise. At the high school level, Powell et al.[3] reported the number of injuries over a 3-year period and serious knee injuries as the percentage of athletes undergoing knee surgery divided by the number of participants in their respective sports. The top two sports necessitating knee surgeries were girls' basketball, followed by girls' soccer. For knee surgeries the percentage of girls compared to boys in basketball was 4% and 2%, respectively; in soccer, 3.9% and 2%, respectively. In male-only sports the percentage of reported knee surgery cases was 2.4% in football and 2% in wrestling.

The numbers and relative risk of knee-injured males and females were analyzed at Kentucky Sports Medicine (KSM) over a 13-year period (personal communication, unpublished). Genders were compared for three conditions, all knee diagnoses inclusive, plica syndrome, and ACL tears. The three diagnoses were evaluated in four age groups: younger than 15 years, high school age, college age, and older than age 23. Relative risk was calculated as the ratio of percentages of females to males in each of the four age groups. The relative risk was higher in females, younger than age 15, for all categories: plica (1.6), ACL injury (2.0), and all (1.4) (Table 12–1). Athletes undergoing ACL reconstruction at KSM were analyzed for relative risk. The ratios of females to males were 7:1 in younger than age 15 and 1.8:1 in high school age, 0.96 in college age, and 0.16 older than age 23.

Athletes undergoing ACL reconstruction who were playing basketball and soccer when injured were further analyzed. For ACL reconstruction the relative risk in

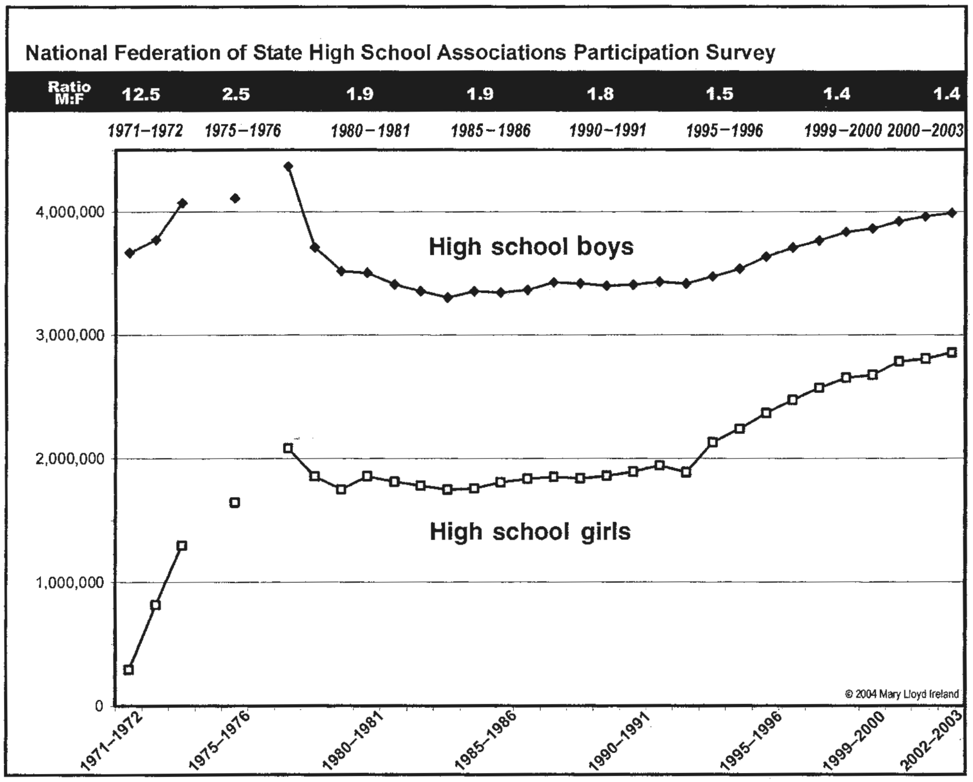
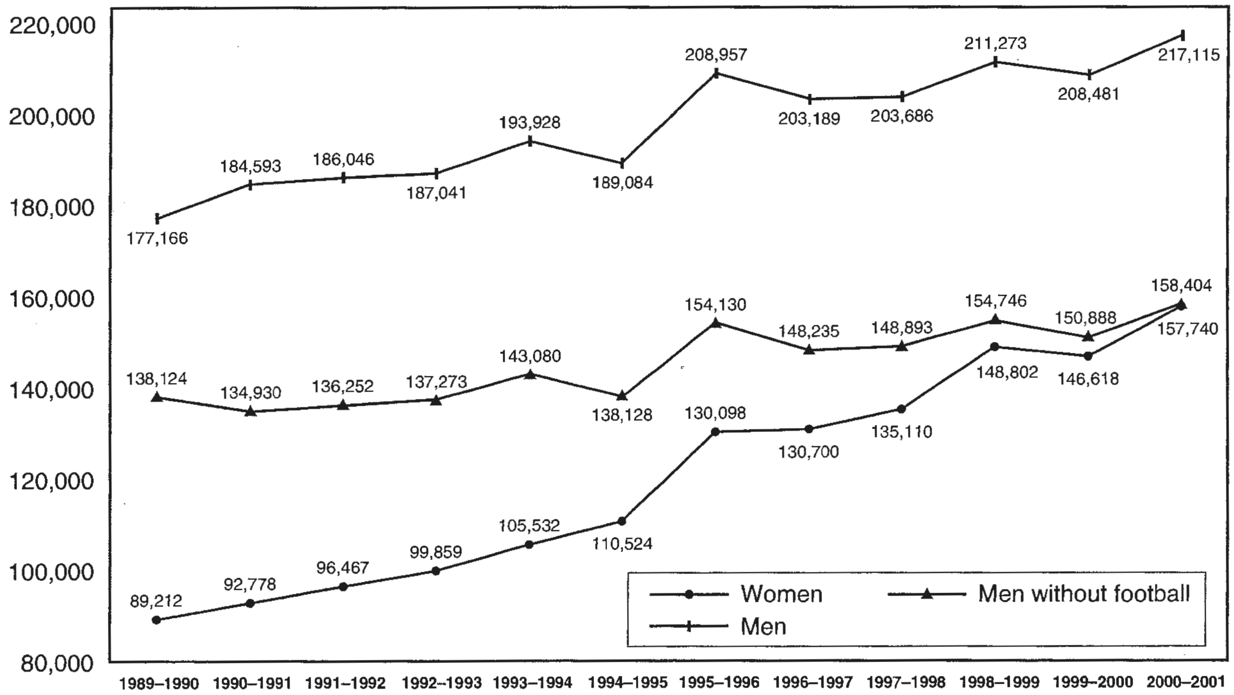


Figure 12–1 High school athletics participation survey, 1971–2003.

	1989–1990	1990–1991	1991–1992	1992–1993	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001
Ratio M:W	1.99	1.99	1.93	1.87	1.84	1.71	1.61	1.55	1.51	1.42	1.42	1.38
Ratio (M–Football):W	1.55	1.45	1.41	1.37	1.36	1.25	1.18	1.13	1.10	1.04	1.03	1.00
Ratio (%) W:M	50.4%	50.3%	51.9%	53.4%	54.4%	58.5%	62.3%	64.3%	66.3%	70.4%	70.3%	72.7%
Ratio (%) W:(M–Football)	64.6%	68.8%	70.8%	72.7%	73.8%	80.0%	84.4%	88.2%	90.7%	96.2%	97.2%	99.6%



	1989–1990	1990–1991	1991–1992	1992–1993	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001
Men as % of total	66.5%	66.6%	65.9%	65.2%	64.8%	63.1%	61.6%	60.9%	60.1%	58.7%	58.7%	57.9%
Women as % of total	33.5%	33.4%	34.1%	34.8%	35.2%	36.9%	38.4%	39.1%	39.9%	41.3%	41.3%	42.1%

Figure 12–2 Ratios of men to women in college sports, 1989–2001. (Data from National Collegiate Athletic Association [NCAA] Injury Surveillance System.)

Table 12–1 Kentucky Sports Medicine Experience

	PLICA					ACL Diagnoses					All Knee Diagnoses				
	Females	**Males**	**Total**	**Ratio F:M**	**Relative Risk**	**Females**	**Males**	**Total**	**Ratio F:M**	**Relative Risk**	**Females**	**Males**	**Total**	**Ratio F:M**	**Relative Risk**
Under 15	381	181	562	2.10	1.6	65	56	121	1.16	2.0	510	499	1009	1.02	1.4
High School	628	423	1051	1.48	1.1	370	444	814	0.83	1.5	952	1345	2297	0.71	1.0
College	276	221	497	1.25	1.0	166	303	469	0.55	1.0	480	756	1236	0.63	0.9
Over 23	1328	1182	2510	1.12	0.9	474	1068	1542	0.44	0.8	2482	3586	6068	0.69	1.0
	2613	2007	4620	1.30		1075	1871	2946	0.57		4424	6186	10610	0.72	

Notes:

1. Age of each patient was determined as of the time the patient was originally diagnosed.
2. "High School" age group is ≥15 and <19 years of age at the time a patient was first diagnosed.
3. "College" age group is ≥19 and <23 years of age.
4. Data from Kentucky Sports Medicine billing system, January 1, 1990 through August 11, 2003.
5. "Relative Risk" shows the ratio of percentages of females to males for each age group.

basketball athletes (females:males) was 6.5:1 in those younger than age 15; the ratio for high school age was 1.63:1, and college age fell to 0.88:1 (Table 12–2). Of the ACL reconstructions performed in female basketball players, 65% were high school age and less than 14% were younger than age 15. In male basketball players, 2% were performed on those younger than age 15, 40% were high school age, 17% were college age, and 41% were older than age 23 (see Table 12–2). In soccer, ACL reconstructions were performed, but relative risk (female:male) ratios were 1.9:1 in high school age players, dropping to 0.75:1 in college age players (see Table 12–2). The true rates of knee injuries of pediatric and adolescent ages are unknown. Funded prospective studies in this age group comparing the sexes and sports are needed. Documentation of hours of participation, numbers of participants, numbers and types of surgeries, and exact diagnosis must be done to determine injury rates.

KEY POINTS

1. High-school age soccer and basketball female athletes are the most vulnerable to ACL injury.
2. In the 2000–2001 school year, females competing at the collegiate level numbered 157,740, comprising 42% of the total number of athletes.
3. In the 2002–2003 school year, high school female athletes numbered 2,856,358, comprising 42% of the total number of high school athletes.
4. Girls' basketball leads as the sport that causes most ACL injuries in the high-school and college-age athlete.

Growth and Development

There are inherent differences between the sexes physiologically, anatomically, and psychologically. Prepubertal girls and boys have the same body composition, motor skills, strength, and endurance, and are essentially comparable in physical condition and can compete against each other in sports until between the ages of 10 and 12.[7] Compared to the past, children today are heavier and taller and undergo puberty at an earlier age.[7] The exception is gymnasts, who are shorter than gymnasts of 20 years ago.[5] Until puberty, the genders differ little in strength, body fat, motor skills, endurance, physical condition, and injury risk.[7]

The effects of estrogen on females at puberty increases their percentage of body fat and lessens lean muscle mass compared to the androgen influence on males.[8] Upper body strength in females, even with training, remains 30–50% that of males, and lower extremity strength remains 70% that of males.[7] Despite these differences, women show the same physiological response to training as males, with significant increases in strength, power, and endurance.[9]

In females, growth is essentially complete by 2 years' postmenarche. Females reach physiological and skeletal maturity and achieve peak height velocity before males.[10] The peak height velocity in females with idiopathic scoliosis by clinical measurements documents growth peak and predicts cessation of growth reliably.[11] Peak height velocity occurs at a median of 6 months before menarche and 8 months before median Risser 1, and 3.5 years before median Risser 5.[11] Peak limb growth occurs 6 months earlier than spinal growth.[12,13] Spinal growth occurs after limb growth has ceased.[14] The peak height occurs a month after menarche, with a rate of 9 cm per year. Sports training has not been shown to have any impact on height peak, height velocity, or the rate of increase in height during adolescence.[11]

Knee Growth

Sixty-five percent of the growth of the lower extremity occurs at the knee—37% distal femoral physis and 28% proximal tibial physis.[13,15,16] The appearance of the physeal plate radiographically with anteroposterior (AP), lateral, and notch views is helpful. Central physeal closure and "blurred" physis indicate skeletal knee maturity.[17] Growth measurements should be repeated for each clinic visit and include growth velocity of standing height, sitting height, lower limb, and growth remaining for different segments.[13] Although charts and diagrams of growth are only templates, they outline evolution of growth. Wrist films for skeletal age is a suggested method to assess skeletal maturity.[18]

The estimates of remaining growth at the knee in boys and girls are shown in Figure 12–3[19] (Carl Stanitski, personal

Table 12–2 Kentucky Sports Medicine Experience Basketball Athlete and Soccer Athlete ACL Reconstructions

	Kentucky Sports Medicine Data, 1990–2003											
	Basketball						Soccer					
	Females		Males		Ratios F:M		Females		Males		Ratios F:M	
Age Group	N	%	N	%	N	Risk	N	%	N	%	N	Risk
Under 15 (n = 24)	21	14%	3	2%	7.00	6.48	6	10%	0	0%		
High School (n = 149)	95	65%	54	40%	1.76	1.63	38	66%	20	45%	1.90	1.44
College (n = 45)	22	15%	23	17%	0.96	0.88	9	16%	12	27%	0.75	0.57
Over 23 (n = 65)	9	6%	56	41%	0.16	0.15	5	9%	12	27%	0.42	0.32
	147	100%	136	100%	1.08	1.00	58	100%	44	100%	1.32	1.00

College: ≥19 and <23.
High School: ≥15 and <19.

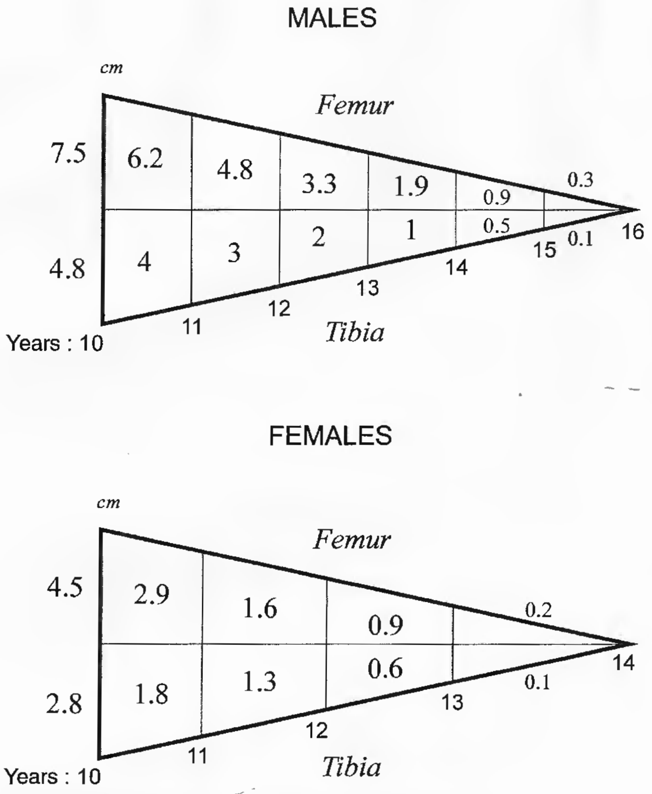


Figure 12–3 The remaining growth at the knee in males and females, in centimeters, is shown in yearly average increments. (Data from Morrissy RT, Weinstein S: Lovell and Winter's Pediatric Orthopaedics, 5th ed., Vol 1. Philadelphia: Lippincott, Williams & Wilkins, 2001, p 47.)

communication). In boys at age 10, distal femoral growth is 7.5 cm and proximal tibial growth is 4.8 cm compared with girls, (4.5 cm distal femoral and 2.8 proximal tibia). The remaining growth in centimeters is shown until age 14 in females and 16 in males. A good analogy is a car approaching a stop sign. The engine is running, but the vehicle is slowing down, such that the risk of an accident is less at that time remaining to get to the stop sign. Physes work the same way. The physiological response and appearance of the physical plate, wide open versus partially closed, reflects the dynamics of growth (Carl Stanitski, personal communication).

Most female athletes who sustain an ACL tear are skeletally mature enough to perform bony procedures across the plate. However, in girls who are immature, the physician should know the Tanner stages.

KEY POINTS

1. Ages of growth patterns and peak velocity of knee growth differ in males and females.
2. Tanner staging and radiological appearance of growth plates about the knee are important in deciding the timing, type of graft, and fixation of ACL reconstruction.
3. Peak height velocity occurs 6 months before menarche.
4. Estimates of remaining growth about the knee help to counsel patients on injury patterns and the safety of ACL reconstructions.

Puberty is assessed by Tanner stages, which are reported by the athlete.[20] Although Tanner 3 stage patients can be treated as adults, Tanner 1 and Tanner 2 stages require soft tissue tunnel grafts and fixation coming from the epiphyseal plate.

To preserve articular cartilage and the menisci, ACL reconstruction should be performed earlier rather than later. Parents and patient should be informed of all potential risks of ACL reconstruction.

Lower Extremity Alignment

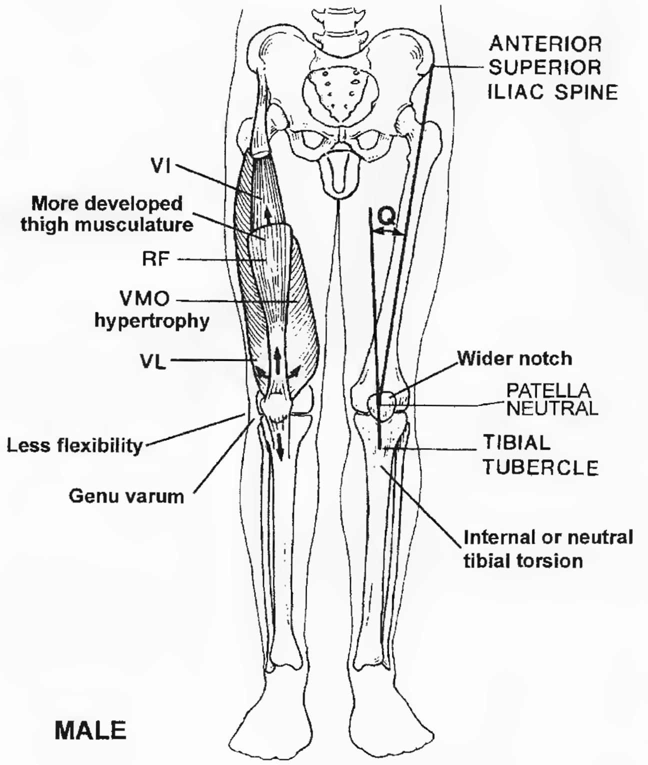
Normal male alignment is shown in Figure 12–4, A. The hips are directly over the knees, which are over the ankles—no significant rotation. In females, rotational and valgus alignment create the forces responsible for anterior knee pain and patellar instability. Miserable malalignment syndrome is defined as excessive knee valgus, femoral anteversion, tibial external rotation, and forefoot pronation (Figure 12–4, B). This malalignment syndrome creates valgus moments at the knee, internal femoral rotation, and laterally directed patellar forces. Commonly seen in cheerleaders, gymnasts, dancers, and track athletes, miserable malalignment syndrome is evident in the swimmer pictured in Figure 12–4, C.

Lower extremity alignment differences are more obvious to patient and examiner during active movements. While the patient is standing on a small step-up, ask him or her to do a simple mini-squat on one leg (Figure 12–5). The male (Figure 12–5, A) flexes more at the hip and knee without rotation, keeping the hip over knee over ankle. The female typically acquires a more upright posture and greater knee valgus position. Her hip is adducted, internally rotated, and the tibia is externally rotated and forefoot pronated. Viewed from the side, the male demonstrates a flat back and posteriorly rotated position of the pelvis, while the female has an anteriorly rotated pelvis position with increased lumbar lordosis[21] (Figure 12–5, B). This lower extremity position of femoral internal rotation and adduction places the knee in the high-risk position predisposing to ACL tears and patellofemoral dislocation.

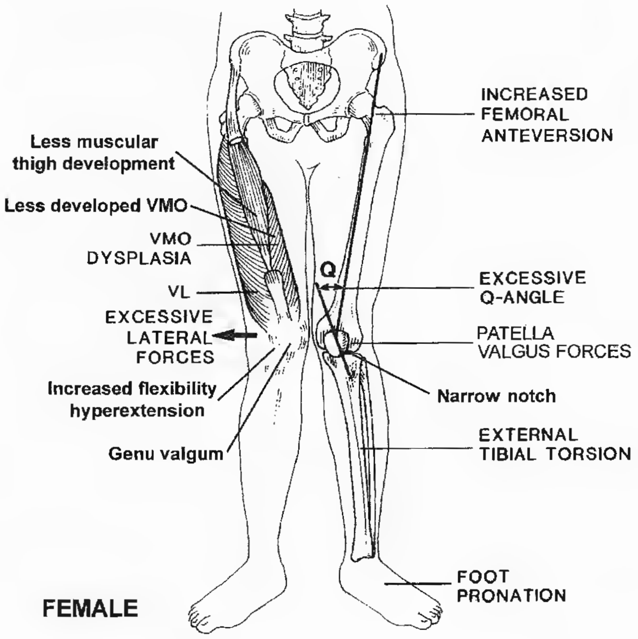
It is the dynamic, not static, anatomical measurements that predict knee problems. It has been believed that females have a larger Q-angle measurement; however, the difference between males and females is not significant and no relationship between Q-angle and knee injury rates has been proved. Clinical

KEY POINTS

1. Dynamic, not static, alignment predicts movement in sport and knee injury patterns.
2. Mini-squat movement patterns differ in males and females.
   a. The male stays straighter and the lumbar spine is flatter, resulting in knee and tibia in neutral rotation.
   b. The female knee goes into excessive valgus with the femur internally rotated.
   c. Proximally excessive lumbar lordosis and distally excessive tibia external rotation and forefoot pronation create abnormal rotational forces at the knee.

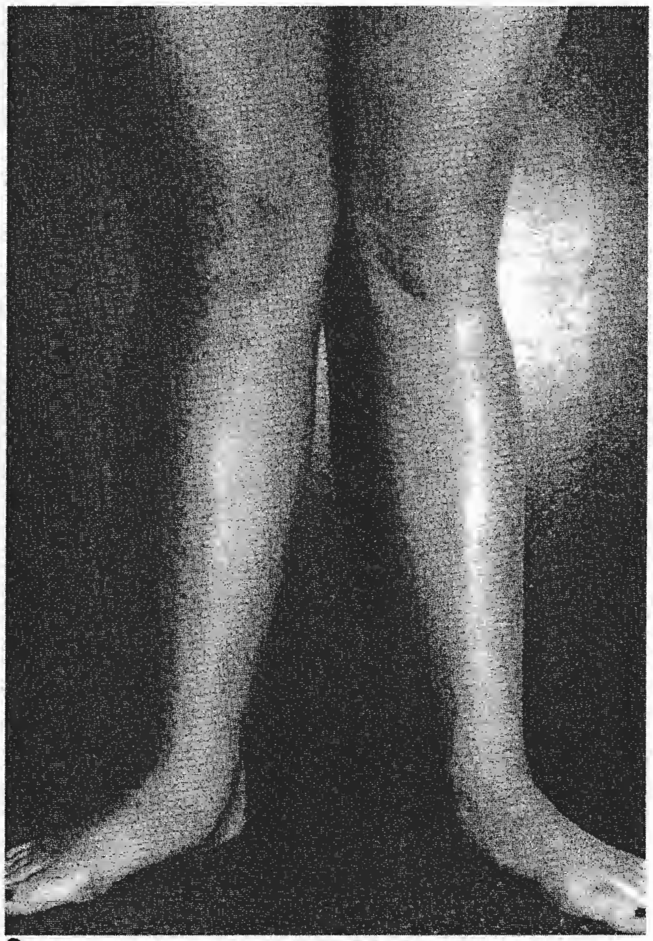


A



B

Figure 12–4 Valgus and rotational forces at the knee create a higher incidence of patellofemoral disorders and ACL injuries in females. **A** and **B**, Compared with males, females have anatomical differences of increased femoral anteversion, increased Q-angle, increased genu valgum and narrower intercondylar notch, external tibial torsion, and forefoot pronation. Developmentally, females also have a less-developed thigh musculature and higher rate of vastus medialis obliquus (VMO) hypoplasia than males. (Copyright 2003 ML Ireland.)



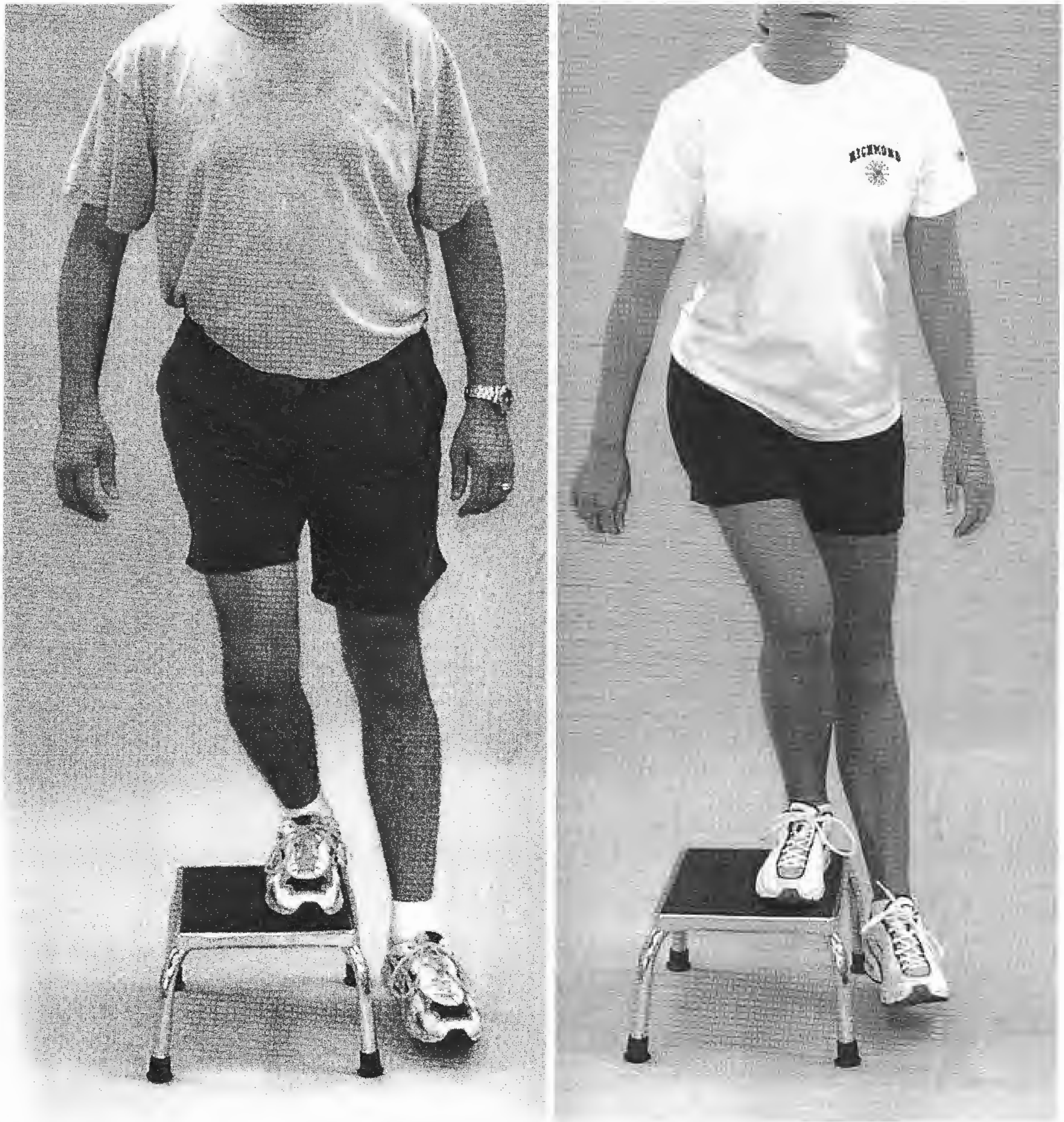
C

Figure 12–4—cont'd **C**, Clinical example of a collegiate swimmer from the front, showing 20 degrees genu valgum, external tibial torsion, hypoplastic VMO, heel valgus, and pes planus with forefoot pronation. This is termed *miserable malalignment syndrome*. (Reprinted with permission from Fu FH [ed]: Sports Injuries: Mechanisms, Prevention, Treatment. Philadelphia: Williams & Wilkins, 1994.)

measurements were recorded in a series of 50 males and 50 females. The Q-angle was 15.8 ± 4.5 degrees in females and 11.2 ± 3.0 degrees in males.[22] Females have a narrower pelvis than males.[22,23] The mean femoral lengths were greater by 1.5 cm in males compared to females.[23] Q-angles in these two studies were slightly but not significantly greater in females compared to males. Ratios of pelvic width to femoral length may provide more injury-predictive information than absolute widths or lengths.[21] Pelvic shape is determined by genetics, culture, and environment.[24]

Anterior Knee Pain

Anterior knee pain is a common complaint in females. Only when the specific diagnosis is made can sport and gender injury rates be determined. The differential diagnosis categories are lengthy[25] (Table 12–3) and include inflammatory (bursitis, tendinitis, arthritis), mechanical (subluxation, dislocation, patellofemoral stress syndrome, plica), and miscellaneous (other) classifications. A specific primary



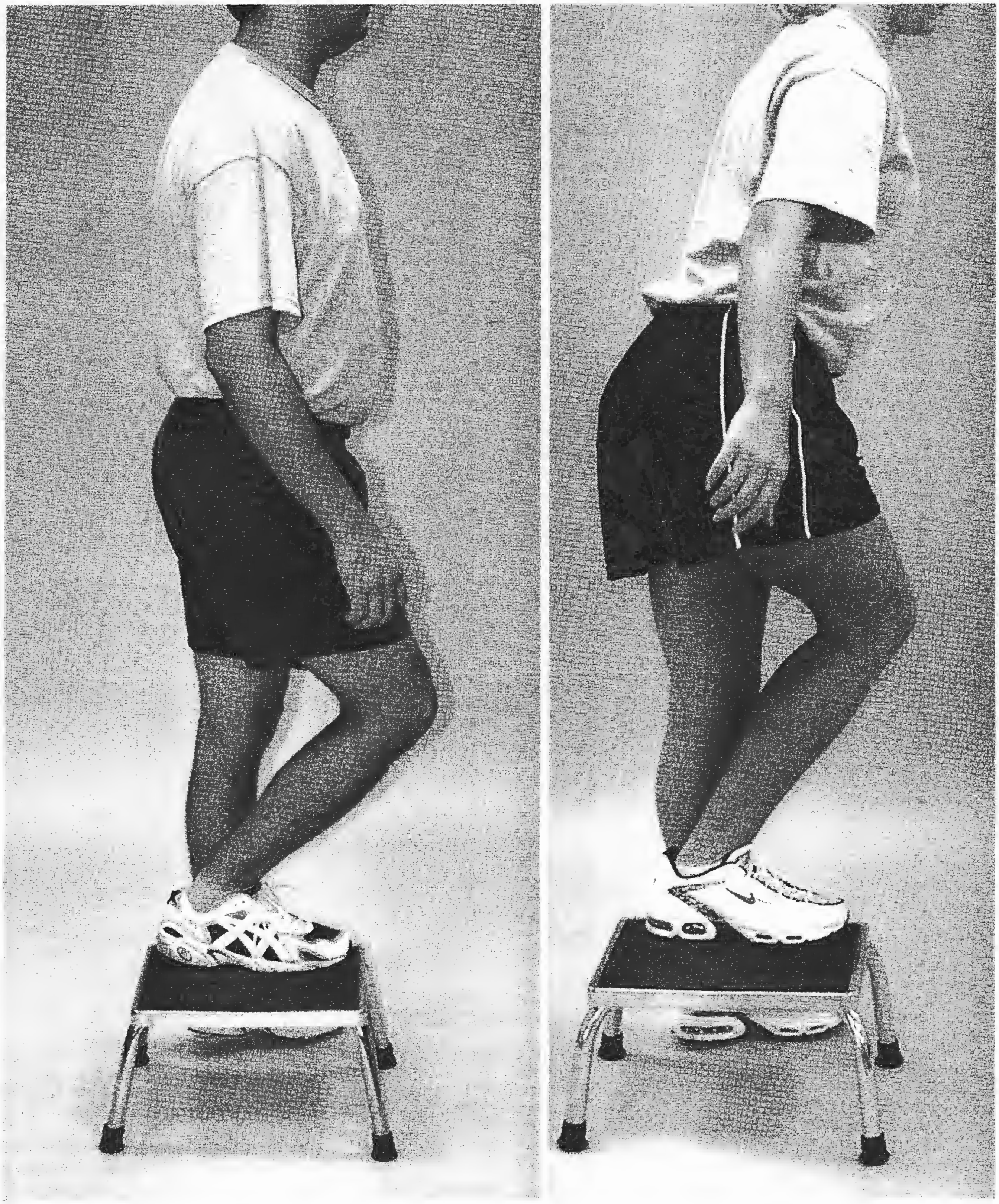
A

Figure 12–5 **A,** When instructed to do a mini-squat, the male *(left)* demonstrates hip over knee over ankle alignment; the female *(right)* demonstrates femoral adduction and internal rotation and subsequent valgus of the knee, tibial external rotation, and forefoot pronation.

Continued

diagnosis should be made. An algorithm for anterior knee pain has been developed.[25,26] The four categories combine clinical examination and plain radiographs. The term *chondromalacia* is a pathological, not clinical, diagnosis. Clinically, the use of the term *patellofemoral stress syndrome (PFSS)* is suggested.

Most patellofemoral disorders are best treated nonoperatively. Core strengthening including back and hip exercises is important. Avoid knee extension machines and full squats. Surgical intervention should be a last consideration for treatment of PFSS or miserable malalignment syndrome.[27]



B

Figure 12–5—cont'd **B,** Seen from the side view, the female *(right)* has an anteriorly rotated pelvis, forward head, and forward trunk position. The male *(left)* has a straight upright posture with less lumbar lordosis and a more posteriorly directed pelvis. The anterior pelvis position creates lower extremity rotational compensation patterns. (Copyright 2001 ML Ireland.)

Table 12-3 Differential Diagnosis: Anterior Knee Pain

Mechanical	Inflammatory	Other
Repetitive Microtraumatic	***Bursitis***	***Referred Pain***
• Patella	• Prepatellar	• Lumbar disc herniation
Stability	• Retropatellar	• Others
Subluxation	Semimembranosus	***Regional Pain Syndrome (Reflex Sympathetic Dystrophy)***
Dislocation	Pes anserinus	
Tilt		
Rotation	***Tendinitis***	***Tumors***
Malalignment	• Quadriceps patella	• Benign
Fracture	• Pes anserinus	• Malignant
Stress	• Semimembranosus	
Bipartite	• Patella tendonitis	***Pigmented Villonodular Synovitis***
Fibrous union		
Acute fracture	***Neuromata/Retinacular Pain***	
• Pathologic medial plica		
• Patellofemoral stress syndrome	***Arthritis***	
• Osteochondral fracture	• Osteo	
Trochlear groove	• Rheumatoid	
Patella	• Psoriatic	
• Loose bodies	• Others	
Cartilaginous		
Osteochondral	***Syndromes***	
• Osteochondritis dissecans	• Reiter's	
Patella	• Others	
Trochlear groove		
• Skeletally immature		
Osgood-Schlatter's disease		
Sinding-Larsen-Johansson syndrome		
Acute Macrotraumatic Injury		
• Extensor mechanism disruption		
Quadriceps rupture		
Patellar tendon rupture		
Inferior avulsion fracture		
Interstitial		
Skeletally immature		
Tibial tubercle fracture		
• Patellar fracture		
Transverse		
Displaced/nondisplaced		
Comminuted		
Status post ACL reconstruction with central third patellar tendon bone		

Symptomatic medial plica is a real diagnosis and is common in the teenage female athlete. The thickness of the intraarticular synovial fold is best palpated in extension. The plica may become thick enough to create a snapping sensation as it moves over the medial femoral condyle with flexion. Resist the temptation for arthroscopic excision of the plica for a year. Understand the female athlete's relationship in the family dynamics: her goals and ability/desire to comply with rehabilitation before surgery.[28]

Females have a higher incidence of vastus medialis obliquus (VMO) hypoplasia, and lower muscular strength than males, thus increasing the female's risk of patellar instability.[29] In the injured knee, quadriceps weakness is reflected by VMO atrophy. The VMO, with its thin fascia, reflects knee function of the entire quadriceps. A weak VMO predisposes to lateral patellar subluxation.[30] The VMO hypoplasia and internal femoral rotation predisposed the runner in Figure 12–6, *A*, to patellar instability and anterior knee pain. As she flexes her knee, the femur further adducts (Figure 12–6, *B*). With a valgus force on the patella, the train (patella) easily jumps off the track (femur), which has already been medialized. Physical examination should include open chain resistance on the tibia, watching for patellar tracking (Figure 12–7, *A*) The J side occurs when the patella laterally jumps at 20 degrees as a result of valgus forces, patella alta, or trochlear groove hypoplasia (Figure 12–7, *B*).

Routine views include the following positions: standing posterior anterior (PA), lateral, femoral notch, and bilateral patellar sunrise. Attention should be paid to patella tendon length, position of the patella, and anatomy of the trochlear groove. In a study screening for patellar subluxation, only 45% of controls had normal radiographs.[31] Dynamic imaging can be useful in assessing tracking abnormalities.[32] Static imaging can assess articular cartilage damage and delineate anatomy of the trochlea and patella.[33] Radiographic measurements include length of a patella-to-patella tendon; the ratio less than 0.8:1 is termed *patella alta* and greater than 0.8:1 is termed *patella infera* on lateral views. The basketball athlete in

Figure 12–6 Anterior knee pain patients usually have underdeveloped musculature and malrotation of the femur and tibia. **A,** Although the alignment appears rather straight—no excessive genu valgum or valgus—there is significant internal rotation of the femora, indicating femoral anteversion. The patellae are pointing toward one another. **B,** This is accentuated when the individual gets in a flexed position: the femur goes into further adduction and internal rotation, worsening the rotation and medializing the femur, thus lateralizing the patella. (Copyright 2002 ML Ireland.)

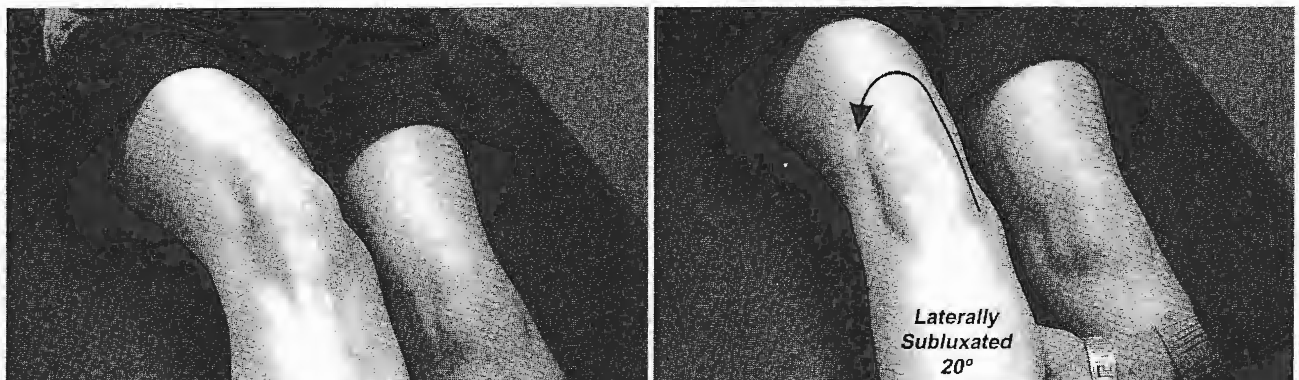


Figure 12–7 **A,** A positive "J" sign is demonstrated as the patient's patella is at 40 degrees of flexion and subluxes laterally at 20 degrees of flexion **(B)**. Asking the patient to straighten the leg against the examiner's resistance can demonstrate this sign of lateral patellar instability. (Copyright 2002 ML Ireland.)

Figure 12–8, *A* and *B*, complained of anterior pain and swelling of her knee. Patella alta is demonstrated on AP and lateral views. The patella:patella tendon ratio is 0.5, and the Hughston patellar view shows lateral subluxation and shallow trochlear groove (Figure 12–8, C). Following a quadriceps and core strengthening program, and with the use of a neoprene sleeve with lateral pad, this patient was able to successfully return to competition.

Patella instability has long been thought to be a condition that predominantly affected females. However, in a review of the literature, Arendt et al.[34] found that patella dislocation and subluxation are more common in males than females. Much of the literature on patellofemoral dislocations was dated and retrospective. Although the surgical treatment of patella dislocations has improved, there is currently no consensus on treatment.[34] If patellofemoral ligaments are injured from bony attachments, arthroscopically aided repairs should be considered. Lateral release is indicated for tight lateral retinaculum and is not indicated as a single procedure for lateral patellar instability.

KEY POINTS

1. Make a definitive diagnosis in the patient who grabs her patella and says the front of her knee hurts.
2. Conservative management of patellofemoral disorders predictably improves anterior knee pain.
3. If the patient will not do a rehabilitation program before surgery, she will not do one after surgery. All involved will be miserable, including the surgeon.

ACL Injuries

The NCAA's Injury Surveillance System records and publishes surveys of 16% of member institutions.[3] Athletic trainers complete the survey. Injury categories for the knee are collateral, ACL, meniscus, patella, patellar tendon, and other. The NCAA has recorded injury rates as numbers of injuries divided by exposure hours. Males and females similarly play soccer and basketball and, hence, injury rates can be compared. ACL rates are 3.5 times higher in women's basketball than men's and 2.8 times higher in soccer.[35,36] Rule and competition differences do not allow comparison of gender injuries in gymnastics, ice hockey, and lacrosse. The NCAA does not record injury statistics in cheerleading. ACL injury rates in basketball games were 4.3 times greater in females compared to males and 2.4 times greater in practices. Knee injury rates in females were higher in all categories.[3,35]

Females who tear their ACL are generally younger than males who do. Ott et al. found in a series of ACL reconstructions that females were 5 years younger than their injured male counterparts.[37] High school athletes who played soccer and/or basketball were studied for mechanism of injury, onset of swelling, and intraarticular injuries associated with ACL tears.[38] Mechanisms of injury were similar in males and females—that of noncontact jumping activities. Compared to males, female soccer athletes had fewer medial meniscus tears. Female basketball players had fewer medial femoral condyle (MFC) injuries. The conclusion was that if such intraarticular injuries prove to be a significant risk factor for poor long-term outcome, women may enjoy a better prognosis after reconstruction.

Soccer studies on injured young players give us cause for concern. In a study of indoor soccer players, females were 5.75 times more likely to sustain a serious knee injury than males.[39] In Sweden, knee injuries were compared in two groups: soccer athletes younger than age 16 who play with senior teams, and those senior teams whose ages are equal to or older than age 19. Thirty-eight percent of the players had been injured before they were 16. Of these, 39% were injured while playing on senior teams. When playing on senior teams, 59% of the players younger than 16 and 44% of the players 16 years or older sustained ACL injuries during contact situations.[40] It was recommended that those who were younger than 16 practice, but not play games, with the seniors.

Surgical Treatment

Treatment of the ACL-injured female athlete should not differ from that of the male athlete.[37,41,42] The decision of graft choice—bone-patellar tendon-bone (B-PT-B), hamstring, or allograft—should be made based on surgeon and patient preference, not gender.[43] Pinczewski compared the ACL-reconstructed hamstrings patellar tendons of men and women. Hamstring reconstruction in females was looser at 2 years post-reconstruction but normalized by 3 years.

Barrett et al.[42] compared female patients undergoing bone patellar tendon and hamstring ACL reconstructions. Although failure rates were equal, short- and medium-range follow-up patients in the hamstring group did not return to pre-injury level and had an increased anterior tibial translation.[44,45] More men returned to preinjury level of activities than women.[45]

Most gender comparisons following ACL reconstructions have been done in the adult age group. Barber-Westin et al.[41] reviewed surgical outcomes in males and females after autogenous B-PT-B ACL reconstruction. Twenty-six months postoperatively there were no significant differences for complications or outcomes. Males had a higher rate of patellofemoral crepitus than females (i.e., 15% and 7%, respectively).[41]

Ott et al. reported the outcomes of male and females after ACL reconstruction with ipsilateral B-PT-B grafts.[37] The study required a minimum 2-year follow-up. Results were an average of 5-year follow-up. Females tore their ACLs at a significantly younger age than males. Outcome instruments of the Cincinnati Scale, the ACL Quality of Life Scale, and the Tegner activity rating scale were used.[46–48] There were no differences comparing gender in the ACL Quality of Life Scale. In the Tegner scale, females had a significantly higher activity level. Females showed an average of 5.7 points lower than females measured on the Cincinnati Scale. There was a trend toward lower scores in females between ages 12 and 18 and older than age 24. Following ACL reconstruction with B-PT-B, there was no difference between males and females for complaints of anterior knee pain.[37]

Ferrari et al.[42] reported on ACL reconstruction comparing men and women with bone patellar tendon bone grafts using objective, subjective, and functional assessments with the Tegner, Lysholm, Modified Hospital Special Surgery, and Cincinnati scales. There were no differences in donor site pain, patellofemoral crepitus, stair climbing, stability, functional assessment, and rating scale scores. Men and women had similar satisfaction rates and the same knee scale scores. They concluded there was no basis for inclusion of gender as

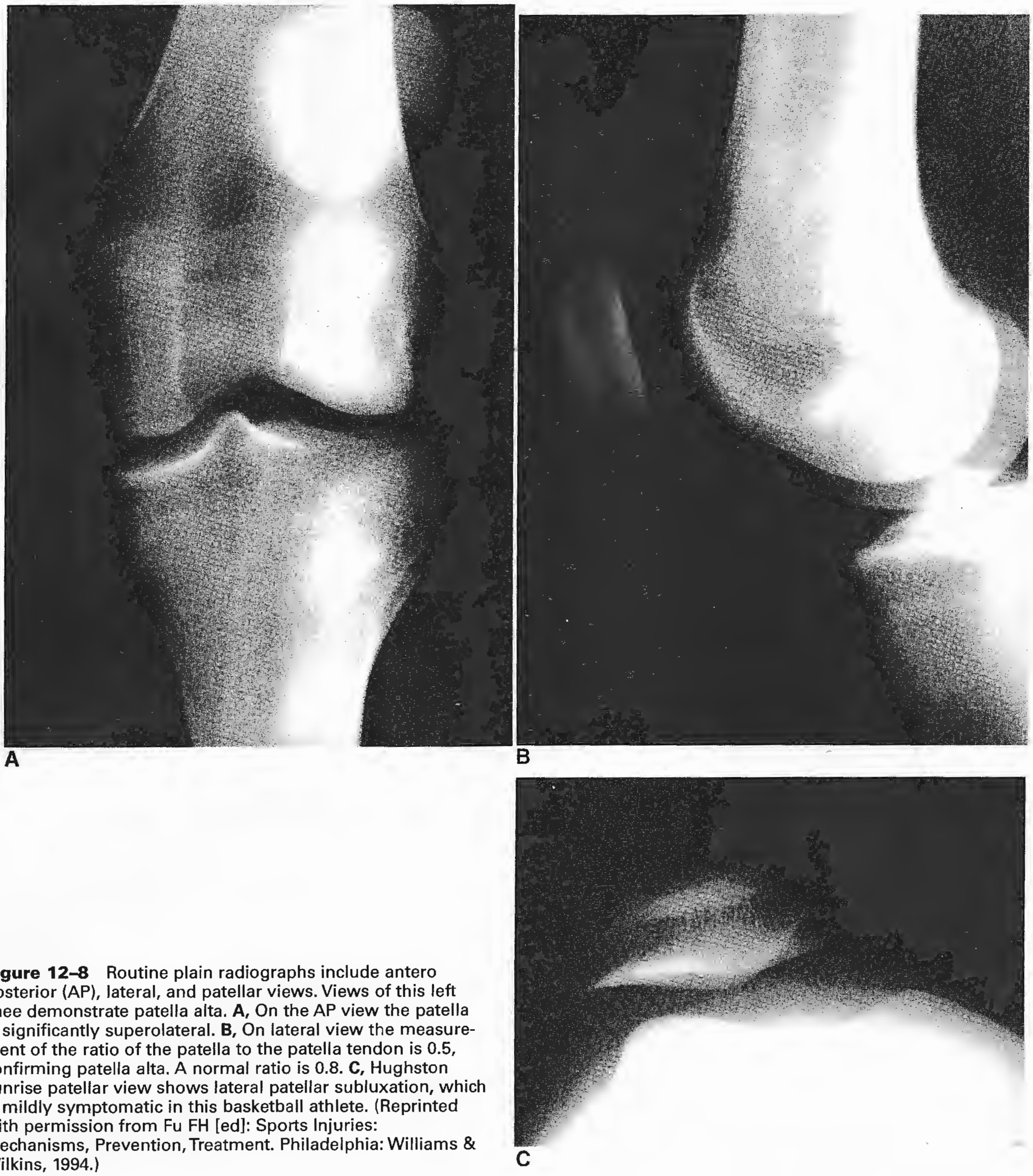


Figure 12–8 Routine plain radiographs include antero posterior (AP), lateral, and patellar views. Views of this left knee demonstrate patella alta. **A,** On the AP view the patella is significantly superolateral. **B,** On lateral view the measurement of the ratio of the patella to the patella tendon is 0.5, confirming patella alta. A normal ratio is 0.8. **C,** Hughston sunrise patellar view shows lateral patellar subluxation, which is mildly symptomatic in this basketball athlete. (Reprinted with permission from Fu FH [ed]: Sports Injuries: Mechanisms, Prevention, Treatment. Philadelphia: Williams & Wilkins, 1994.)

a determining factor regarding the decision to perform ACL reconstruction with bone-patellar tendon-bone.[42]

Mechanism of Injury

ACL injuries typically occur rapidly, with the patient upright and with an awkward stop in anticipation of lateral movement.[21] In basketball players these injuries often occur after an awkward landing trying to land, shoot, rebound, or prevent a ball from going out of bounds. Compared to males, females tend to land more in the so-called position of no return.[49] Video analysis has allowed the description of the position of no return, from which the outcome is a torn ACL.[21] The basketball athlete pictured in Figure 12–9 is in a relatively upright position with less knee and hip flexion, relatively straight back, momentum forward, and excessive

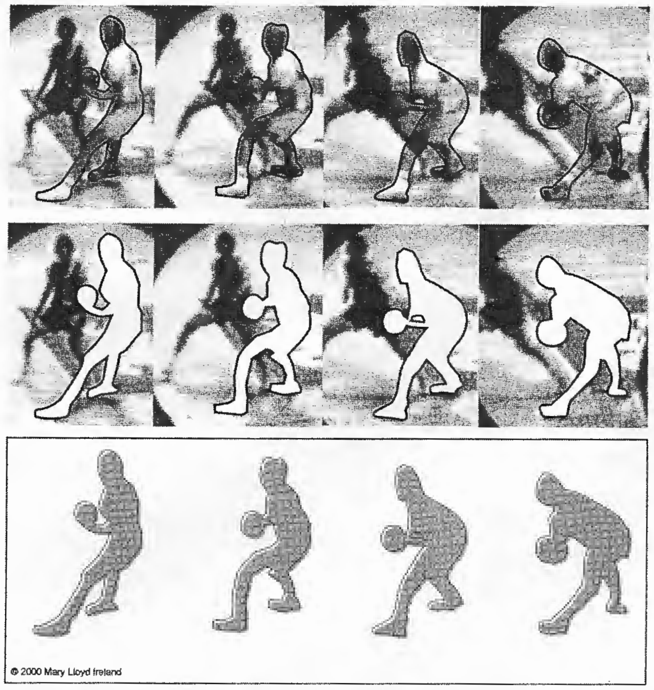


Figure 12–9 The mechanism of ACL tear is captured on video. Injury to the left knee is observed from the back and left side of the athlete. She has just rebounded and stops to change direction to avoid the defending player. She lands in an upright position with less knee and hip flexion and a forward flexed lumbar spine. After the ACL fails, she falls forward and knee valgus rotation and flexion increase. She is unable to upright herself and regain pelvic control to avoid ACL injury. (Copyright 2000, ML Ireland.)

knee valgus.[21] Males tend to land with more hip and knee flexion with hip over knee over ankle, with less knee valgus and less foot pronation. Landing in a safe position of greater hip and knee flexion, allowing agonist muscles to protect the ACL, is the goal (Figure 12–10).

KEY POINTS

1. In organized sports such as basketball and soccer, girls tend to sustain ACL injuries more often at a younger age.
2. The decision to perform any type of ACL reconstruction should not differ in males and females. The rate of anterior knee pain after ACL reconstruction is the same in males and females.

Factors Predisposing to ACL Injuries

Why do females tear their ACLs more frequently than males? The reason is multifactorial. Three areas have been studied: neuromuscular, hormonal, and anatomical. These categories can be divided into intrinsic (not changeable), extrinsic (changeable), and combination (possibly changeable) (Table 12–4). Possible anatomical predispositions to ACL injury include notch width, pelvic size and shape, and quadriceps angle (Q-angle).

In June 1999, a panel of experts on ACL injuries met in Hunt Valley, Maryland, to discuss ACL injuries in the female athlete.[50] The panel evaluated risk factors and prevention strategies. The following conclusions were made. There is no consensus as to the role of notch size and ACL injury. There are insufficient data to relate lower extremity alignment and ACL injury. There is no evidence that knee braces prevent ACL injuries. Shoe-surface friction may improve performance but increase risk of injury. This is a modifiable risk that should be studied. There is no consensus regarding the role sex hormones may play in risk of ACL injury. Hormonal intervention or modification of participation is not justified for prevention of ACL injury at this time. The trunk, hip, and pelvis may contribute to ACL injury at the knee. Neuromuscular factors are significant and may be the most important risk factor in ACL injuries in female athletes. Strong quadriceps activation with eccentric contraction is a major factor in ACL injury. Male and female athletes in the same sport may need different training and conditioning programs. Training programs that improve body control reduce ACL injury rates and may increase performance.[29]

Laxity and Hyperextension

Generalized laxity and knee hyperextension are two different factors that often may coexist in females. The female athlete in Figure 12–11, *A*, demonstrates passive hyperextension. She underwent ACL reconstruction on the right knee, and loss of this 30-degree physiological hyperextension is shown when she is standing (Figure 12–11, *B*). Although laxity has been listed as an intrinsic risk for ACL injuries, Snyder-Mackler found no difference in laxity comparing 20 patients with ACL deficient knees, 10 who were compensators and 10 who were noncompensators.[51] There is no established relationship between laxity and risk of ACL injury.

Femoral Notch

Notch size, notch volume, and notch width indices have been studied extensively with varying results.[52–57] Regardless of gender, smaller notches have been associated with increased rate of ACL tear.[52,53] The question remains: Does a smaller notch result in a smaller ACL? If so, is a smaller ACL therefore weaker and predisposed to tearing? How does the height and weight of the athlete relate to notch size and ligament size and strength? Using magnetic resonance imaging, Anderson et al.[55] reported that girls had smaller ACLs and notches than boys.[58] Notch assessment by plain films has been reported. Regardless of gender, a small notch-width ratio is associated with increased rate of ACL tear. Shelbourne et al.[52] studied the relationship of notch width and incidence of ACL tear and found no significant differences in notch width between height groups for males and females. With height and weight as covariates, females had statistically significant smaller notches than males. Patients, both males and females, with smaller notches had an increased incidence of contralateral ACL injury.

In a series of analyses of notch radiographs of 108 ACL injured and 186 normal individuals, the shape, width of femur, and notch and ratios were measured.[53] Notch measurements are significantly influenced by patient position and knee flexion. Standardization of patient position by description and goniometer measurement for notch view should be done. Therefore, comparisons of notch measurement cannot be done from one clinic to another.

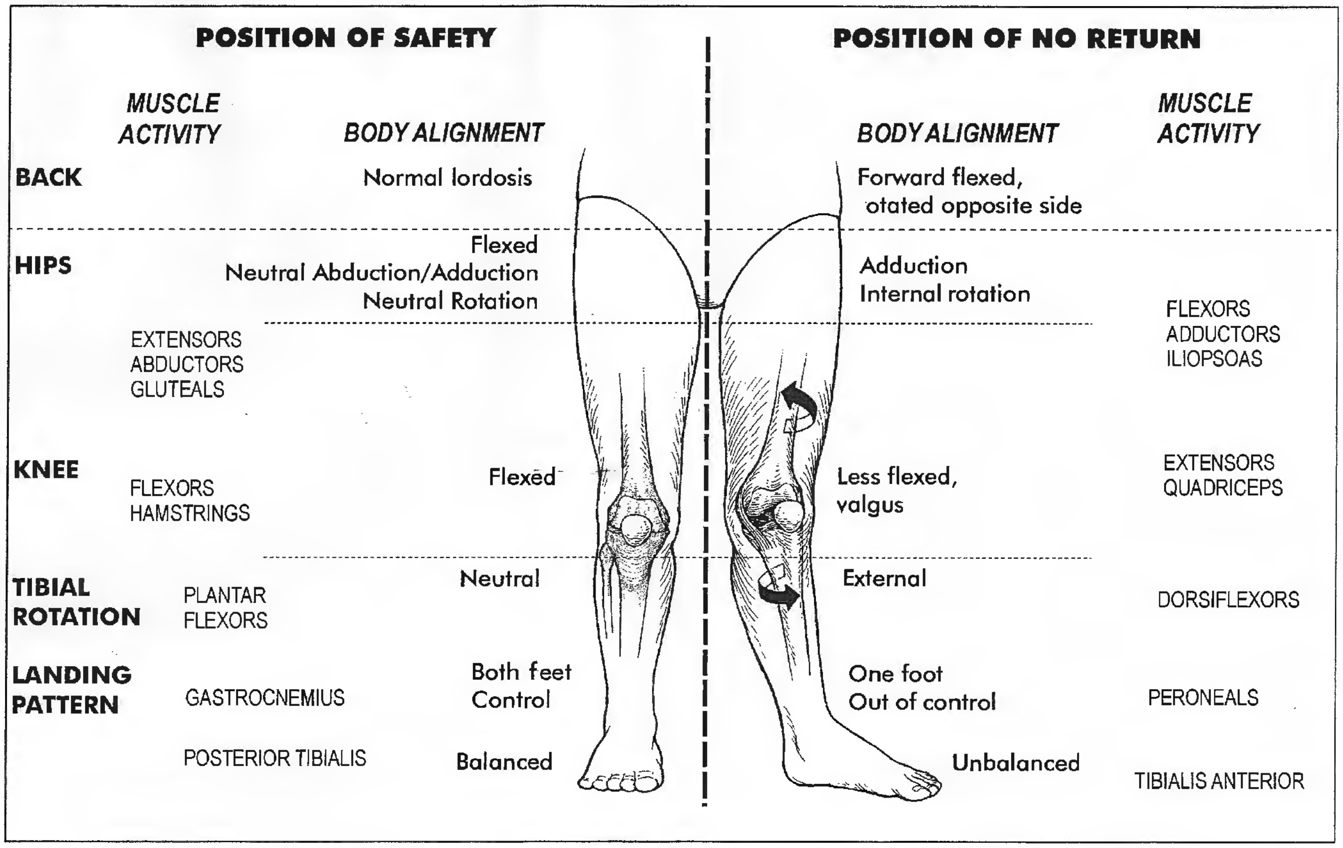


Figure 12–10 This diagram shows the "position of no return." This term refers to an awkward out-of-control landing with the leg pronated in valgus angulation, the body more upright and the leg in pronation and rotation, and the knee in valgus angulation, which places the ACL at risk of tearing. The safety position is more flexed, with the body over the legs, and more balanced. (Copyright 2002 ML Ireland.)

Table 12-4 Factors Contributing to ACL Injuries

Intrinsic	Extrinsic	Combined (Potentially Changeable)
Alignment	Strength	Proprioception
Hyperextension	Conditioning	Position Sense/Balance
Physiologic Rotatory laxity	Shoes	Neuromuscular Patterns
ACL size	Motivation	Order of firing
Notch size/Shape		Acquired skills
Hormonal influences		
Inherited skills/ Coordination		

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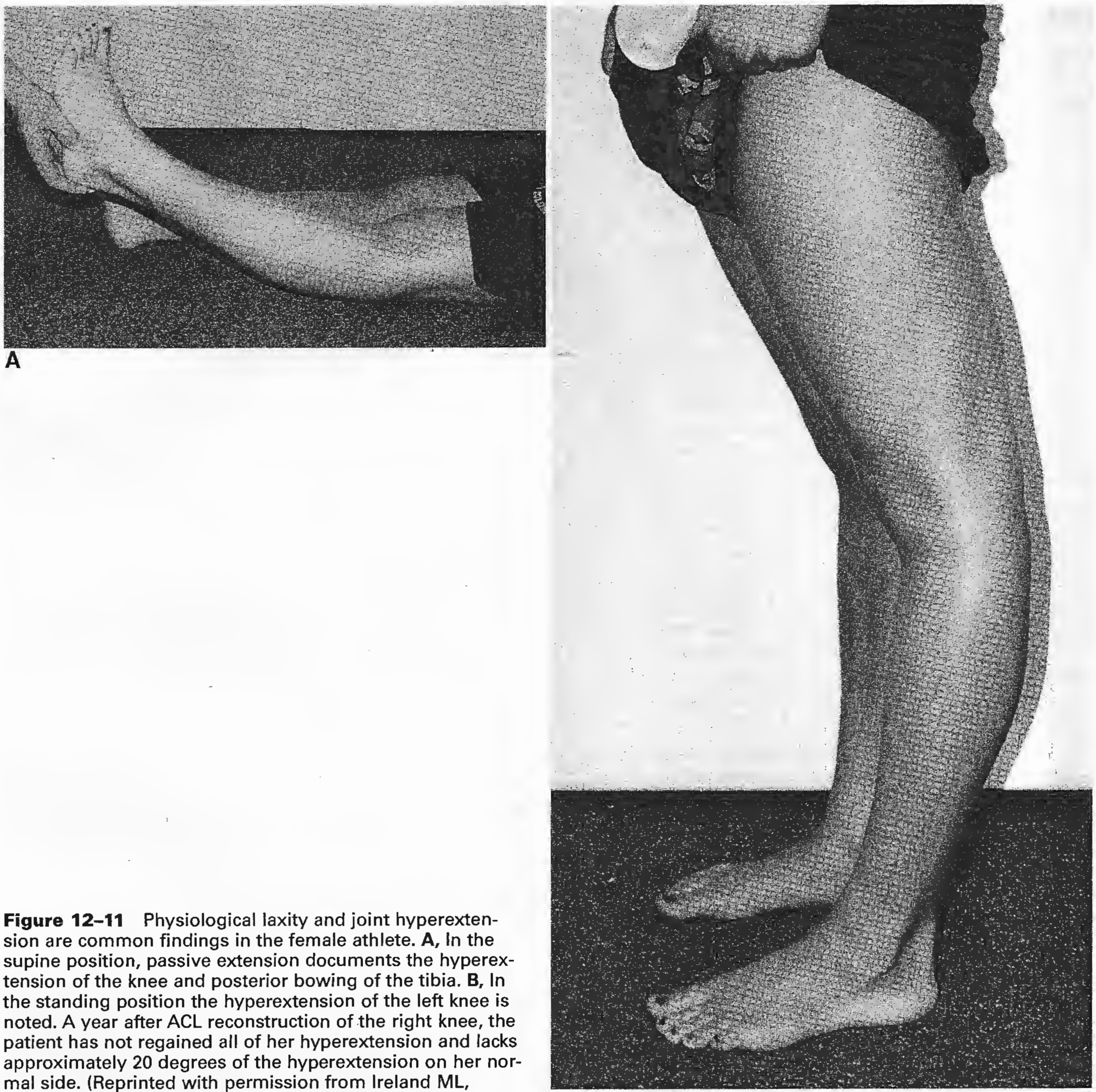
Sex Hormones

Sex hormones have effects on numerous end organs, which is most obvious during menarche. However, the influence of sex hormones (specifically estrogen) on ACL injury rates has not been proved. Researchers have reported increased rates of injuries in all phases of menses. Wojtys et al.[59] reported that ACL injury rates were higher in the ovulatory phase, reported as a 4-day phase (days 10–14), and less in the follicular phase days 1–9. Repeated statistical analysis found the results were not statistically significant but only showed a trend.[60] In a second study, Wojtys et al.[61] reported on 69 females with acute ACL injuries. Urinary hormone levels were obtained within 24 hours of injury, and menstrual cycle history was obtained. This study observed a significantly increased incidence of ACL injury during the ovulatory phase and fewer than expected injuries during the luteal or follicular phases.[61] Arendt et al. reported less ACL injuries occurred during the ovulatory phase.[36] Myklebust et al. reported higher injury rates 1 week premenses and just after menses.[62] In 2000, Slauterbeck and Hardy reported higher injury rates just before and after menses.[63] The cyclic phases and hormonal level measurements (blood, urine, saliva) should be standardized. History of subjects regarding oral contraceptive (OCP) use and menses must be documented. The study design must be critically reviewed by investigators with experience in hormonal research.

Estrogen and relaxin receptors are present on the human ACL, as determined by histochemical analysis and bioassay.[64,65] The unanswered question is: What effect does the rapidly fluctuating hormone level have on the biomechanical characteristics of the ACL? In a sheep study, Strickland et al.[66] concluded that estrogen and estrogen receptor agonists at the physiological level do not lead to decreased ligament strength. Other injury patterns have not been related to cycle hormonal influences. Ankle sprains, lumbar strains, neck injuries, shoulder instability, shoulder



A

B

Figure 12–11 Physiological laxity and joint hyperextension are common findings in the female athlete. **A,** In the supine position, passive extension documents the hyperextension of the knee and posterior bowing of the tibia. **B,** In the standing position the hyperextension of the left knee is noted. A year after ACL reconstruction of the right knee, the patient has not regained all of her hyperextension and lacks approximately 20 degrees of the hyperextension on her normal side. (Reprinted with permission from Ireland ML, Nattiv A: The female athlete, Elsevier Science, 2003.)

dislocations, and other musculoskeletal disorders do not appear to be under cyclic influence. Even though hormone receptors are present, what is the clinical significance?

There are estrogen receptors on the ACL, and estrogen may effect the amount of ligament and joint laxity. Estrogen inhibits type I procollagen synthesis and proliferation of fibroblasts in vitro at physiological estradiol concentrations.[64] However, the in vivo effects of estrogen and estradiol have yet to be determined. Heitz et al.[67] studied knee joint laxity during the menstrual cycle in uninjured females. Hormone levels were determined by blood radioimmunoassay and knee laxity by KT-2000 arthrometry. Knee joint laxity was found to be greatest during the luteal phase; however, the sample size was small (seven participants). The question remains: Does anterior tibial translation place the ACL at risk? There is no consensus in the scientific community as to the role hormones play in ACL injuries in female athletes.[50] There is evidence to warrant continued study. No one is recommending hormonal prescription or a change in practice schedule based on phase of cycle for female athletes.

Female sex hormones also affect the neuromuscular system. Sawar et al. reported increased quadriceps strength and significant slowing of muscular relaxation time during the ovulatory phase.[68] Estrogen also affects the central nervous system, which may affect motor skills during different phases of the menstrual cycle.[69,70] The influence of hormones on other organ systems should also be considered a factor in ACL injuries.

Neuromuscular

Differences between males and females in neuromuscular activation and muscle recruitment have been reported to contribute to ACL injury. In general, compared to males, females are more "ligament dominant" with less muscular development.[71] Males are better at stiffening their knees through muscle activation. An increase in knee stiffness was 473% in males compared to 217% in females in muscle contracted states ($p = .003$).[72]

Wojtys, Huston, and coworkers have done excellent research comparing gender differences and neuromuscular performance.[67,73,74] Female athletes recruit their quadriceps first, have a slower time to peak hamstring torque in the unfatigued and fatigued state, and have greater anterior tibial laxity.

In a 6-week program, Wojtys et al.[74] showed that females were able to improve their muscle reaction time by agility training but not with isokinetic and isotonic strengthening programs. Hewett[75] showed a reduction in impact forces, increased hamstring torque, and reduced adduction/abduction movement after a plyometrics training program in females. Rozzi et al.[76] showed that in healthy collegiate soccer and basketball athletes, women had greater joint laxity and longer time to detect joint motion as the knee extended. This combination of anterior tibial translation in reduced response time in an extension arc allows the quadriceps to become a more active antagonist against the agonist hamstring effect with the ACL. Chappell et al.[77] compared male and female kinematics during three jumping tasks and found females to have a greater knee extension and valgus moment, increasing the peak proximal tibial anterior shear force during stop. Fatigue has also been shown to affect muscle response time and hip and knee flexion angles.[73,76,78]

ACL Injury Prevention

Prevention programs show encouraging results for reduction of ACL injuries, moreso in females than males. Instructions give players clues and immediate feedback on safe landing positions, jump training, and sports-specific programs. Hewett et al.[75] used a 6-week flexibility and plyometric training program at the high school level and reduced the rate of knee injuries significantly in the untrained female. Mandelbaum has reported an 88% reduction in rates of ACL tears in a 14- to 18-year-old female soccer athlete group, with implementation of the prevention injury in enhanced performance program.[79] A monograph that describes the current principles and programs of prevention of ACL injuries is available.[80] Although implemented for ACL prevention, these programs would be of benefit for females with anterior knee pain, stress fractures, and other lower extremity disorders.

KEY POINTS

1. ACL injuries are caused by multiple factors.
2. By understanding the injury landing pattern (position of no return), coaches and researchers can implement safe landing positions—flat back and flexed hips and knees.
3. ACL prevention programs appear to be successful.

Female Athlete Triad

If you treat female athletes, you should understand the triad and definition and serious consequences. Early diagnosis is the only hope.

The female athlete triad is defined as amenorrhea, disordered eating, and osteoporosis. These three components are interrelated in their etiology, pathogenesis, and health consequences.[81–83] The female with the triad is at increased risk for stress fractures and recurrent injuries, but not knee injuries. The athlete at risk is prepubertal in body type, strives for perfection, wears revealing clothing and outfits for competition, and is subjectively judged.[84] The true prevalence of the female athlete triad is unknown. Young athletes approaching puberty also appear to be at increased risk. If the female athlete triad is diagnosed, treatment is multidisciplinary, including a physician, a psychiatrist, a psychologist, and a nutritionist.[85]

Eating disorders range from anorexia nervosa, bulimia, and restrictive eating behaviors to poor nutritional habits. Athletes with disordered eating patterns are at risk for certain endocrine, skeletal, and psychiatric problems.[86] Eating disorders are 10 times more prevalent in women than men. The exact prevalence in athletes is unknown and ranges from 15–62% of athletes, depending on the sport. The prevalence of eating disorders in nonathletes is estimated between 1% and 3%. There is an incidence (62–74%) of pathological weight control among college gymnasts. The incidence of anorexia is 19.0–25.7% in ballet dancers. The incidence of pathological weight control among swimmers aged 9–18 is 15.4% and nearly 70% among elite swimmers.[5] The prognosis for eating disorders is dismal. In nonathletes, 50% do well and 30% struggle and relapse, and there is a 10–20% mortality rate. Many of these athletes with eating disorders continue to struggle with their weight and body image throughout their lifetime.[87]

The prevalence of amenorrhea in the general population is 2–6%, jumping to 3.4–66.0% in athletic populations.[88] Athletic amenorrhea has a hypothalamic origin resulting in decreased ovarian hormone production and hypoestrogenemia similar to menopause.[88]

Although stress fractures around the knee are relatively uncommon, if diagnosed, a complete musculoskeletal and medical evaluation should be undertaken. Athletes with stress fractures often have menstrual irregularity.[82,89,90]

The significance of athletic amenorrhea is the observed skeletal demineralization and early osteoporosis.[91] The danger is that these women are losing bone when they should be accruing it, thus never achieving peak bone mass.[88] After ruling out other causes of amenorrhea, treatment of athletic amenorrhea in a woman who has been menstruating for less than 3 years is to decrease exercise intensity and improve nutrition.[92] In an athlete more than 3 years postmenarche, treatment is with low-dose oral contraceptives.[88]

Osteoporosis is characterized by low bone mass and microarchitechtural deterioration, leading to increased skeletal fragility and risk of fracture. Women are four times more likely to develop osteoporosis than men.[93] Weight-bearing exercise may reduce the rate of bone loss in adult women; however, it will not produce a large increase.[93] In the face of athletic amenorrhea, the positive effects of weight-bearing exercise are negated. Bone densitometry should be ordered in those athletes suspected of suffering from these serious disorders. Early diagnosis and treatment of the female athlete triad is her only hope for survival. Asking the tough questions and taking time to listen can only help her.

KEY POINTS

1. Recognize the athlete with an eating disorder and female athlete triad.
2. The earlier the diagnosis of female athlete triad is made, the better chance that intervention and treatment will succeed.

Summary

Female athletes have made much progress in skill acquisition and opportunity to compete in team and individual sports. However, there are disturbing differences in the rates of ACL tears in basketball and soccer in females compared to males. The risk factors responsible for ACL injuries in females must be determined and ranked in order of importance. It has not been determined what the intervention programs are actually changing. The programs all emphasize proper landing techniques and single-leg proprioception. To continue competition in these high-risk sports, athletes (male and female) should have an ACL reconstruction performed to reduce chance of injury to the menisci and articular cartilage—the latter two are presently more difficult to treat than stabilization.

A specific diagnosis should be made in the female with anterior knee pain. Arthroscopy should be considered only after failure of the rehabilitation program and understanding of patient and family dynamics. The positive benefits of being an athlete and acquiring the skills to stay healthy for life outweigh the risks of knee injury. The concern for and treatment of the female knee should not differ from that of the male knee. Keep her on the playing field and active for life!

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