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Knee Injuries in Female Athletes

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Summary

Female athletes are at increased risk for certain sports-related injuries, particularly those involving the knee. Factors that contribute to this increased risk are the differences in sports undertaken and in gender anatomy and structure. Gender differences include baseline level of conditioning, lower extremity alignment, physiological laxity, pelvis width, tibial rotation and foot alignment. Sports like gymnastics and cheerleading create a noncontact environment, but can result in significant knee injuries. In quick stopping and cutting sports, females have an increased incidence of anterior cruciate ligament (ACL) injury by noncontact mechanisms. Patellofemoral (PF) disorders are also very common in female athletes.

Awareness of these facts helps the sports medicine professional make an accurate diagnosis and institute earlier treatment-focused rehabilitation with or without surgery. Further prospective and retrospective research is needed in areas of epidemiology, mechanisms, severity and types of knee injuries. The goal is to lessen the severity of certain knee injuries and to prevent others.

Women have participated in sports for more than a thousand years. However, compared with men, the total number of female participants has been relatively small. In the US, the enactment and enforcement of the Title IX Educational Assistance Act of 1972 heralded an expansion of opportunities for women in sports. Title IX mandated that all institutions receiving federal funds provide equal opportunities for women for all programmes, including athletics. With added accessibility, encouragement and the increased focus on fitness over the past 2 decades, women's participation in organised and recreational sports has increased dramatically.

A proportional increase in the incidence of sport-related injuries in women has also been noted.[1-4] The increase, however, is not explained solely by the increasing number of female participants. Instead, it has been demonstrated that compared with males, females have an increased risk for certain types of knee injuries.[5,6]

In the US, the National Collegiate Athletics Association (NCAA)[7] has recorded and averaged knee injury rates by number per athlete exposure over 3 collegiate seasons (1990 through 1993) (see table I). A survey of 15% of the 828 schools in all divisions is done yearly by the NCAA. Comparison is possible by rates shown as number per 1000 athletic exposures. Injury categories include:
- overall knee
- anterior cruciate ligament (ACL)
- collateral ligament (medial and lateral)
- torn cartilage (meniscus)
- posterior cruciate ligament (PCL)
- patella and/or patella tendon.

The exact mechanisms of injury – contact versus noncontact, deceleration or rotation – were not recorded. Gender-comparable sports are soccer and basketball. Lacrosse and gymnastics statistics are somewhat comparable, but the sport rules and apparatuses are different for males and females. Surveillance statistics for male sports are kept for spring football, football, wrestling, ice hockey, baseball, gymnastics, basketball, soccer and lacrosse. Female sports statistics are recorded in gymnastics, basketball, soccer, lacrosse, field hockey, volleyball and softball. Injuries in other sports, including cheerleading, are not recorded by the NCAA. The injury rates for all categories for the 16 sports are given in table I.

The knee injury rate was highest for men's spring football (total rate 2.04), followed by women's gymnastics (1.85), women's soccer (1.76), men's wrestling (1.68), men's soccer (1.34), men's football (1.31) and women's basketball (1.12). Women's gymnastics led to the highest number of ACL tears (0.52) and meniscal tears (0.45). Patella or patella tendon injuries were highest in women's soccer (0.30), followed by women's gymnastics (0.28). Collateral ligament sprain rates in men, in order of frequency, were: spring football (1.06), wrestling (0.89) and football (0.67). Other diagnoses of ACL tears, torn cartilage, PCL injuries, and patella and/or patella tendon injuries are compared in table I.

The exact reason for gender variation in injuries is not known, but factors include gender differences in coaching, conditioning, strength training, structure, hormones and specific sport biomechanics, and the contact nature of some sports. Additional research is needed to determine the reasons for this increased incidence of noncontact knee injuries in females.

The purpose of this review is to increase awareness within the sports medicine community of gender-specific knee injuries. The ultimate goals of this awareness are to assure accurate diagnosis, and institution of earlier focused and sport-specific rehabilitation, with or without surgery. With improved and earlier care and further prospective research projects, the incidence and severity of knee injuries, especially involving the ACL, can be reduced or, hopefully, prevented.

1. Conditioning

Poor conditioning is related to an increased incidence of injury. When an athlete has not achieved the proper level of conditioning, the overall risk of injury increases. For most women, this baseline level of conditioning is significantly less than that of their male counterpart.[8-12] The relationship between poor conditioning and increased incidence of injury has been documented, in particular in relation to the knees of female athletes.[13,14] Adequate conditioning, in turn, improves performance and reduces the risk of injury.[15-17]

Stress-related injuries have also been associated with the poorly conditioned athlete. In a random review of 74 female and 74 male cadets, an increased

Table I. National Collegiate Athletics Association (NCAA) knee injury rates by sport, 1990-93 (after National Collegiate Athletic Association).[7] All data are shown as rate per 1000 athletic exposures, and are averaged for the 3 academic years[a]

Sport	Total no. of exposures	Total no. of injuries	Total rate	Site of injury				
				anterior cruciate ligament	collateral ligament	torn cartilage (meniscus)	posterior cruciate ligament	patella and/or patella tendon
Comparable sports								
Gymnastics								
females	89 752	166	1.85	0.52	0.31	0.45	0.03	0.28
males	30 231	22	0.73	0.17	0.23	0.17	0.03	0.07
Soccer								
females	148 563	262	1.76	0.31	0.57	0.34	0.02	0.30
males	326 561	439	1.34	0.13	0.56	0.20	0.05	0.24
Basketball								
females	306 095	343	1.12	0.23	0.27	0.23	0.02	0.22
males	480 937	355	0.74	0.06	0.18	0.12	0.01	0.27
Lacrosse								
females	109 731	75	0.68	0.15	0.10	0.10	0.00	0.22
males	208 606	180	0.86	0.19	0.24	0.17	0.00	0.15
Noncomparable sports								
Males only								
Spring football	130 171	265	2.04	0.23	1.06	0.31	0.06	0.18
Football	1 804 042	2361	1.31	0.19	0.67	0.22	0.04	0.11
Wrestling	238 108	400	1.68	0.11	0.89	0.37	0.03	0.17
Ice hockey	576 934	124	0.21	0.02	0.06	0.05	0.00	0.06
Females only								
Field hockey	109 788	86	0.78	0.15	0.16	0.17	0.00	0.19
Volleyball	298 531	202	0.68	0.11	0.12	0.17	0.01	0.18
Softball	234 498	127	0.54	0.10	0.13	0.12	0.01	0.14

a Conclusions drawn from, or recommendations based on, the data provided by the NCAA are those of the author, based on analyses/evaluations by the author, and do not represent the views of the officers, staff or membership of the NCAA.

incidence of stress fractures was found in women.[18,19] In other studies conducted at the US Naval Academy, stress-related injuries were seen more frequently in women; however, as the women became acclimatised to the rigours of training, similar numbers of serious injuries were reported for males and females.[4,20]

2. Structure and Size

Anatomic and structural differences between males and females play a significant role in the incidence and type of knee injuries. In contact sports, the probability of injury increases with the bodyweight of the participants.[21] Since women tend to weigh less than men,[8,22] the likelihood of serious injury when those of the same gender and size compete is somewhat diminished. However, in contact sports with participants of mismatched size, the smaller or less skilled participant is more likely to be injured. Female athletes are, therefore, at increased risk of injury when participating in contact sports against males.

2.1 Hormonal and Ligamentous Laxity Effects

Female athletes tend to have increased ligamentous laxity and flexibility compared with their male counterparts. This laxity may contribute to the increased incidence of patellar subluxations and ligament sprains seen in female athletes.[23,24] The cyclic hormonal effects on soft tissues are not well understood and require further research. Nonetheless, the hormone relaxin (found only in females during pregnancy) is ultimately associated with ligamentous relaxation that enables the pubis and pelvis to accommodate the size of the fetus and passage during birth. The effect of relaxin is systemic and increases the risks of ankle sprains and ligamentous injuries during pregnancy.[25]

Ligamentous laxity may be as much a function of conditioning as of inheritance or genetics.[5] Athletic females have less laxity than nonathletic females.[26] Indeed, some studies have shown no relationship between knee laxity and injury.[26,27] Other studies have found an increased likelihood of knee ligament injury in loose-jointed athletes. In football, the likelihood of ligament injury was greater in loose-jointed players, whereas muscle tears were more common in tight-jointed athletes.[28]

2.2 Anatomic Differences Between Women and Men

2.2.1 Lower Extremity Alignment

Lower extremity alignment contributes directly to the forces and strain on the knee compartments, ligaments and musculotendinous structures. Alignment differences increase the chance of development of patellofemoral (PF) disorders. Most females have a lower centre of gravity, wider pelvis, shorter legs and greater genu valgus than males.[13,14] In addition, females often have increased femoral anteversion, less development of the vastus medialis obliquus (VMO), increased flexibility and differences in notch shape and width compared to males. Biomechanically, balanced offset of forces occurs with wider pelvis and genu valgum. However, the factors of genu valgum, VMO hypoplasia and femoral anteversion increase the laterally directed forces on the PF joint and increase stresses on the medial compartment and the medial collateral ligament.[29]

The normal valgus alignment of the lower extremity creates a natural tendency for the mobile structures crossing the knee joint to be displaced laterally during gait.[5,30,31] The Q-angle – a measurement of the angle created by the line from the anterior-superior iliac spine and the patella and the line from the patella to the tibial tubercle – is normally less than 12° (fig. 1, left). With increased Q-angle, excessive lateral forces on the quadriceps mechanism occur. Association of patella alta and rotatory limb malalignment contribute to the patellar tracking and miserable malalignment syndrome (fig. 1, right). Retropatellar pain is often seen in women who have femoral anteversion, genu valgum and forefoot pronation, and external tibial torsion can further contribute to maltracking patellae and anterior knee pain. Due to these differences in alignment and stresses on the PF joint, females more commonly experience anterior knee pain.

2.2.2 Lower Extremity Development: Muscularity, Flexibility, Torsion

Specific differences between males and females exist in terms of:

- lower extremity alignment
- muscularity
- femoral anteversion
- torsion
- ankle varus and valgus
- subtalar motion
- foot pronation and supination
- pes cavus and planus.

Females have a wider pelvis, increased femoral anteversion, less muscular development, increased flexibility and knee hyperextension, genu valgum, narrow femoral notch and external tibial torsion (fig. 2, left). Males have a more narrow pelvis, more developed lower extremity musculature, VMO hypertrophy, less flexibility, less knee hyperextension, genu varum, wider femoral notch, and internal and/or neutral tibial torsion (fig. 2, right).

Femoral Notch Size and Shape

There is an epidemic of noncontact ACL injuries. Structurally, specific gender differences in both intercondylar notch shape and width as well as ACL size may place female athletes at increased risk of injury of this ligament.[32]

Compared with the male, the female knee and ACL tends to be smaller, implying that there is less tissue to restrain anterior and displacement forces. In addition, a decreased femoral notch to width ratio can be seen. In these individuals, a smaller

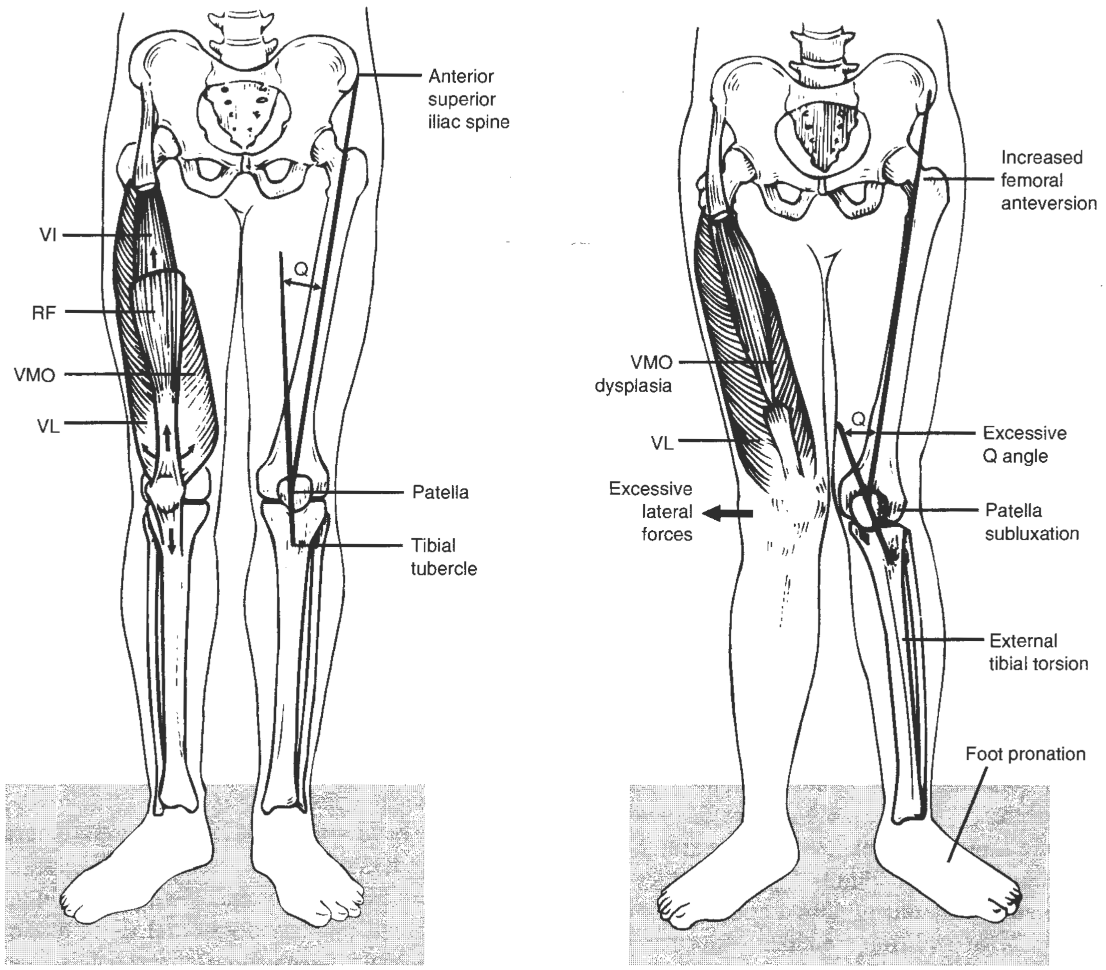

Fig. 1. Diagram showing: (**left**) normal alignment and Q-angle (an angle created by the line from the anterior-superior iliac spine and the patella and the line from the patella to the tibial tubercle) less than 12°; and (**right**) miserable malalignment syndrome. In the latter, the increased femoral anteversion, VMO dysplasia, excessive Q-angle, external tibial torsion and forefoot pronation can be seen, all of which cause excessive laterally directed forces on the patella. *Abbreviations:* RF = rectus femoris; VI = vastus intermedius; VL = vastus lateralis; VMO = vastus medialis obliquus.

ACL and less notch space available for the ACL combine to increase injury risk.[12,19] In noncontact injuries, an increased risk of ACL injury with reduced notch size has been noted.[33,34]

The actual shape of the notch may also vary with gender and contribute to the incidence of ACL injury (fig. 3). A small, A-shaped notch may not actually be pinching a normal-sized ACL, but rather is a sign of a congenitally smaller ACL. Radiographic findings of a decreased notch to width ratio and an A-shaped notch may place female athletes at increased risk for a noncontact mechanism ACL injury.

3. Specific Knee Injuries in Female Athletes

As mentioned in sections 1 and 2, females are more likely to sustain noncontact injuries for many reasons, including the biomechanics of specific sports, anatomy and conditioning. More specifically, females are vulnerable to overuse syndromes and noncontact ACL sprains of the knee.[5] Male athletes sustain more injuries by contact mechanism, which is directly related to the nature of the sport (e.g. football and ice hockey). According to NCAA statistics, at the US collegiate level, the order of frequency of collateral ligament injury were: men's spring football (1.06), men's wrestling (0.89), men's football (0.67), women's soccer (0.57) and men's soccer (0.56) [see table I]. Although mechanisms are not recorded, most collateral ligament injuries are contact-induced.

In collegiate athletes, the ranking of PF or patellar tendon problems was: women's soccer (0.30), women's gymnastics (0.28), men's basketball (0.27), men's soccer (0.24), women's basketball (0.22) and women's lacrosse (0.22). Meniscal injury ranks were: women's gymnastics (0.45), men's wrestling (0.37), women's soccer (0.34), men's spring football (0.31), women's basketball (0.23), men's football (0.22) and men's soccer (0.20). Recording of injury types and mechanisms should be done at many levels – adolescent, college, recreational.

At the high school level, knee injury rates were similar for males and females, but females sustained more major injuries, such as ACL tears, during games.[32] An additional cause for the increased number of injuries in females in all sports is a relative lack of fundamental motor skills. Poor training experience in the developmental years and inaccessibility to good coaching and equipment has

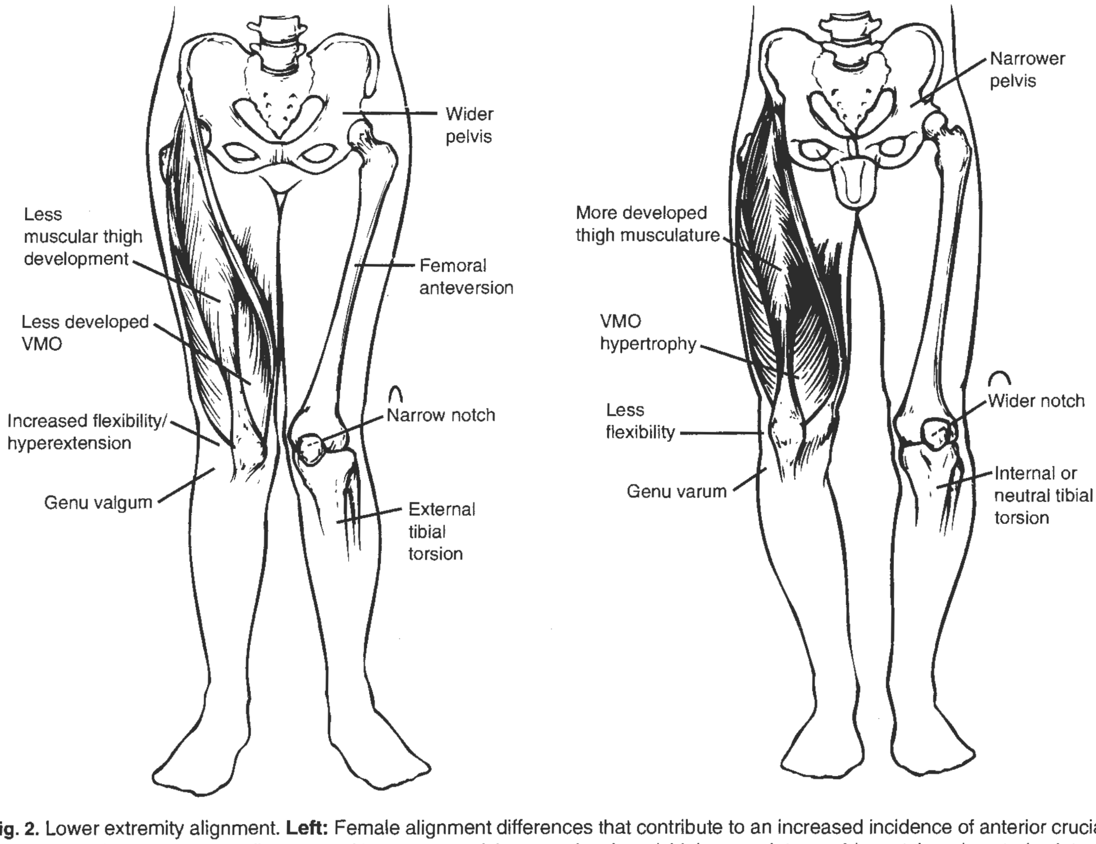

Fig. 2. Lower extremity alignment. **Left:** Female alignment differences that contribute to an increased incidence of anterior cruciate ligament injuries. **Right:** Male alignment, with narrower pelvis, more developed thigh musculature, wider notch and neutral or internal tibial torsion. *Abbreviation:* VMO = vastus medialis obliquus.

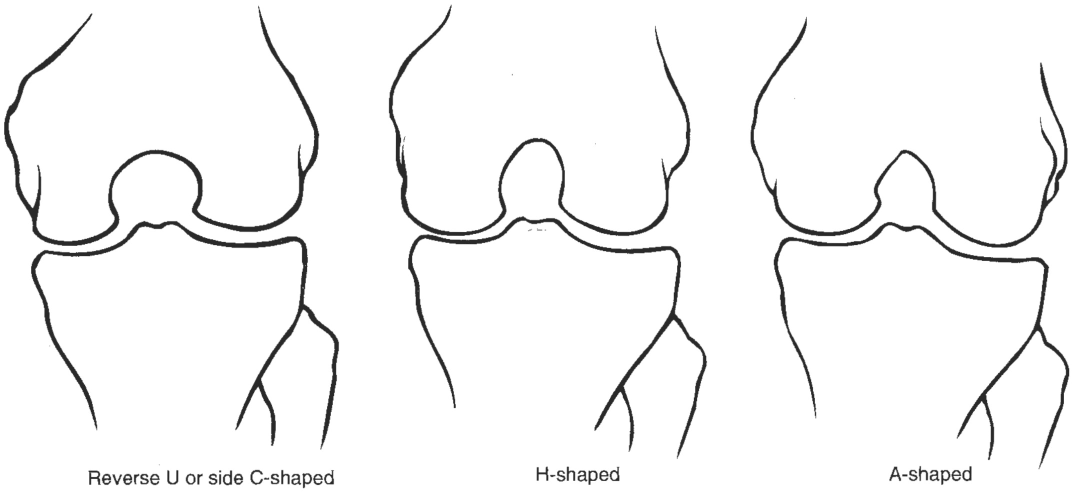

Fig. 3. The femoral notch shape.[35]

been related to the increased incidence of injuries sustained by female athletes.[5]

3.1 Patellofemoral Stress Syndrome

Differences in structure, anatomy and conditioning compared with males contribute significantly to the increased incidence of anterior knee pain in female athletes.[14] In the female athlete's knee, the PF joint is the most common compartment injured.[5,11,36,37] Anterior knee pain can be placed into 3 categories: (i) inflammatory; (ii) mechanical; and (iii) miscellaneous.[38] As shown in table II, there are multiple causes of anterior knee pain.[39]

Since there are numerous causes of anterior knee pain, a specific diagnosis should be made in the patient who complains of such pain. PF stress syndrome is a clinical diagnosis and can include such pathologic processes as chondromalacia patella, symptomatic plica, lateral subluxation of the patella and early degenerative disease. With detailed history and complete physical examination the primary diagnosis can be made.

Symptomatic plicae are more common in females. The plica is an intra-articular redundant synovial fold.[40,41] The synovial tissue can enlarge, become inflamed and impinge on the medial femoral condyle. Fortunately, most patients with PF syndrome improve on a regimen of nonsteroidal anti-inflammatory medications, hamstring stretching and quadriceps strengthening emphasising the VMO.

3.2 Patellofemoral Instability

Recurrent patella instability tends to occur predominantly in females.[42] This gender difference may not apply as consistently to acute dislocations where studies have ranged from Hughston's findings of a 70% male preponderance to Larsen's findings of a 62% female preponderance.[43-49] Fortunately, major malalignment, VMO dysplasia and recurrent lateral patellar dislocations are uncommon in female athletes. Open realignment procedures are indicated in patients with these disorders.

For the competitive athlete, lateral patellar subluxation episodes are best treated nonoperatively with rehabilitation. Arthroscopy is sometimes indicated, but lateral release is rarely required. Rehabilitation and alternative sport suggestions are the mainstay of treatment.

The VMO is a primary compensating factor for lateral patellar instability. This is the only structure that provides an active medial vector to counterbalance the valgus force. As assessed by electromyographic (EMG) analysis, the VMO is twice as active as the rest of the quadriceps throughout the motion. In individuals with and without symptoms related to patellar alignment, VMO activity measured by EMG showed no significant change.[50] In patients with patellar subluxation, however, VMO activity is decreased.[51] Due to less fascial thickness and vector forces, the VMO is the first part of the quadriceps to demonstrate atrophy in the injured knee and the last to return to full function during a rehabilitation programme.[5,52] Female athletes tend to be particularly susceptible to VMO dysfunction after injury or surgery. In addition, the clinical syndrome of VMO hypoplasia is more common in females and may have a genetic component. For female athletes with an injured knee, rehabilitation of the quadriceps emphasising the VMO is necessary.

Table II. Differential diagnosis of anterior knee pain

Mechanical
Patella
subluxation
dislocation
fracture
stress
acute (transverse)
bipartite
fibrous nonunion
acute fracture
Quadriceps rupture
Patella tendon rupture
inferior avulsion
interstitial
Patellofemoral stress syndrome
Pathologic plica
Osteochondral fracture
trochlear groove
patella
Loose bodies
Osteochondritis dissecans
Inflammatory
Bursitis
prepatellar
Retropatellar
semimembranosus
Tendinitis
patellar
pes anserinus
semimembranosus
Synovitis
Arthritis
Other
Reflex sympathetic dystrophy
Tumour

3.3 Anterior Cruciate Ligament Tears

Certain ACL injuries and injury patterns are more frequently seen in females. Most injuries, however, are sport- and not gender-specific.[35] Although PF disorders are numerically more common, ACL ruptures are more significant and require surgery to create a stable knee, a dedicated rehabilitation programme and adjustment of sport activities. According to the NCAA Surveillance Survey[50] females are at increased risk of ACL injury in a variety of sports including gymnastics, soccer and basketball (table III). As shown in the table, statistics compiled from 1990 to 1993 show that females had ACL injuries at 3.83 times the rate of males in basketball, 3.06 times the rate of males in gymnastics and 2.38 times the rate of males in soccer.

In basketball, comparison between different competitions of noncontact ACL injuries showed a statistically significant greater frequent of injuries in females compared with males.[53] The Atlantic Coast, Big Ten and Pacific Ten Conference data analysis showed that females were 8 times more likely to sustain an ACL tear than males.[53] Of 44 professional men and women basketball players, females sustained an ACL injury at 10 times the rate of the male athletes.[37] Comparing 1988 US Olympic Basketball Trials participants, females sustained more knee injuries and required surgery more often than the males. These trial participants were chosen as the elite in US and hence are a comparable group. Of 80 males involved in the trials, 11 received knee injuries, of which 3 were ACL injuries (see table IV). In comparison, 34 of 64 female trial participants had knee injuries and 13 of these were ACL injuries. All 3 males and 8 of 13 females with ACL injuries underwent ACL reconstruction. The surgical findings of the 6 males and

Table III. Anterior cruciate ligament rate per 1000 athletic exposures (1990 to 1993)[50]

Sport	Injury rate per 1000 exposures		Female/male ratio of injuries
	females	males	
Gymnastics	0.52	0.17	3.17
Soccer	0.31	0.13	2.30
Basketball	0.23	0.06	3.72
Lacrosse	0.15	0.19	0.76
Field hockey	0.15		
Volleyball	0.11		
Softball	0.10		
Spring football		0.23	
Football		0.19	
Wrestling		0.11	
Ice hockey		0.08	
Baseball		0.02	

20 females who underwent surgical procedures are shown in table V.

A prospective study comparing injury patterns in junior college individuals, found that the risk of ACL tears could be reduced by modifying play technique for the 3 most common mechanisms of injury.[54] Plant-and-cut, straight leg landing and 1-step stop were the most common injury mechanisms, and were replaced with rounding turns, flexed landing and 3-step stop. Coaches are happy to cooperate with these changes.[55]

The female knee may, in general, be more cruciate-dependent than the male knee.[56] Secondary restraints, especially the hamstrings and posterior capsule, can, at reduced loads, compensate for a knee with a positive Lachman but negative pivot shift. However, female athletes tend to have increased recurvatum, implying laxity in the posterior capsule, and reduced muscle mass (including that of the hamstring and quadriceps) compared with male athletes. If a cruciate-dependent individual sustains a cruciate ligament injury, nonsurgical treatment is more likely to fail. Unlike a musucloteninous dominant male football lineman with anterolateral rotatory instability, the ligamentous lax and dependent female gymnast would not be as likely to depend on her rehabilitated hamstrings, tight posterior capsule and flexed knee position to maintain stability. Surgical reconstructions are often the best alternative to returning the ligament-dominant individual back to sport.

Prospective studies are underway to investigate ACL injury, and there are multicentre efforts to identify females at risk of this type of injury. Factors include analysis of alignment, gait, skills, EMG parameters, force plate and strength.

3.4 Osgood-Schlatter's Disease and Jumper's Knee

Fortunately, some knee disorders are less common or severe in females. Both Osgood-Schlatter's disease (tibial tubercle apophysitis) and jumper's knee (patellar tendinitis) are milder and are seen less frequently in females. The reduced incidence of Osgood-Schlatter's disease is probably related to sport, intensity of participation, growth phases and the relative earlier maturation and physeal closure in females. The decreased incidence of jumper's knee may be sport-specific and be associated with the reduced torque production at the knee created by females compared with males.

3.5 Stress Fractures

Females, especially those who are unconditioned, are at increased risk of sustaining overuse injuries including stress fractures.[19] The endurance training that military recruits undertake places females at increased risk of overuse injuries like

Table IV. Injuries sustained during 1988 Olympic basketball trial

Parameter	Males	Females	Total
Number of participants	80	64	144
Athletes with knee injuries	11*	34	45
ACL injuries	3	13	16
Number of athletes requiring surgery	6**	20	26
Number of procedures	6	25	31
Type of procedure			
Arthroscopy	3	17	20
ACL reconstruction	3	8	11

a Statistically significant $p < 0.0001$.

b Statistically significant $p < 0.0007$.

Abbreviations and symbols: ACL = anterior cruciate ligament; *,** indicate a statistically significant difference between male and female athletes (* = $p < 0.0001$; ** $p < 0.0007$).

Table V. Arthroscopic diagnosis of injuries sustained during 1988 Olympic basketball trials

Parameter	Males	Females
Isolated meniscal tears	3	6
medial	1	4
lateral	2	2
ACL tears	3	13
isolated complete	3	3
isolated partial		2
complete ACL with meniscal tear		3
partial ACL with meniscal tear		2
complete ACL with MCL tear		2
complete ACL/PCL/MCL		1
Articular cartilage/loose body/patella		5
Normal		1
Diagnosis totals	**6**	**25**

Abbreviations: ACL = anterior cruciate ligament; MCL = medial cruciate ligament; PCL = posterior cruciate ligament.

stress fractures.[20] The major factor in the development of these injuries is the rapid onset of the training, which does not allow for a progressive exposure to stress and the development of tolerance. A staged progression of training may avoid many of these injuries. Indeed, studies have shown that, as female recruits became more acclimatised to the rigours of training, the incidence of injuries declined.[18]

Females are also at increased risk of stress fracture secondary to a relatively lower bone density, amenorrhoea and poor nutrition.[57-61] The risk is particularly great in female runners with menstrual irregularities[62] or ballerinas with poor nutrition and menstrual irregularities.[57] A detailed nutritional and gynaecological history must be obtained. Cyclic estrogen replacement may reduce the incidence of stress fractures. Identification of nutritional deficiencies or eating disorders may provide an avenue for early treatment of these disorders in the hope of preventing possible serious consequences.

4. Female Knee Injuries in Specific Sports

Knee disorders are the most common type of injury for both males and females in all sports. However, females tend to have a higher concentration of injuries about the knee than their male counterparts.[32,63]

In basketball at the high school level, girls had more game-play major injuries than boys.[32] These injuries involved the knee 58% of the time. Females receive knee injuries more often in softball than males, while the knee injury rate for women and men involved in track-and-field events is similar.[64] In women's flag football (noncontact American style), 16% of all injuries involved the knee.[8] The stress fracture rate in track-and-field has been shown to be greater in female than in males.[65] In volleyball, knee injury risk rate has been similar in both genders.[66]

In a retrospective study of injury patterns at 2 colleges, half of the injuries involved the lower extremity, 24% knees and 15% ankles.[67] Contact sports had twice the overall injury rate of noncontact sports, except for female gymnastics which had the highest injury rate of all teams. Cheerleading injuries have not been well reported, yet may have the greatest time loss from injury of all sports.[68] A retrospective review of cheerleaders showed that half of all injuries involved the knee, 34% of the knee injuries were sprains, 31% were plica and 26% were patellar subluxations or dislocations.[69]

In ballet and dance, the incidence of knee and lower extremity injury remains high. 40% of all injuries in a review of classic ballet involved the hip or knee.[70] 60% of injuries in aerobic dance were lower extremity,[71] and 9.2% of injuries in aerobic injuries involved the knee.

Swimming injury patterns showed breaststroker's knee due to medial patellar facet problems was more common in females, whereas injury tended to be due to medial collateral ligament sprain in males.[72] The total risk injury in swimming was found to be similar when comparing genders.[73]

In the NCAA Surveillance Survey, female sports of gymnastics, soccer and basketball have the greatest incidence of knee injury and ACL involvement of all women's sports (table III).[7] In

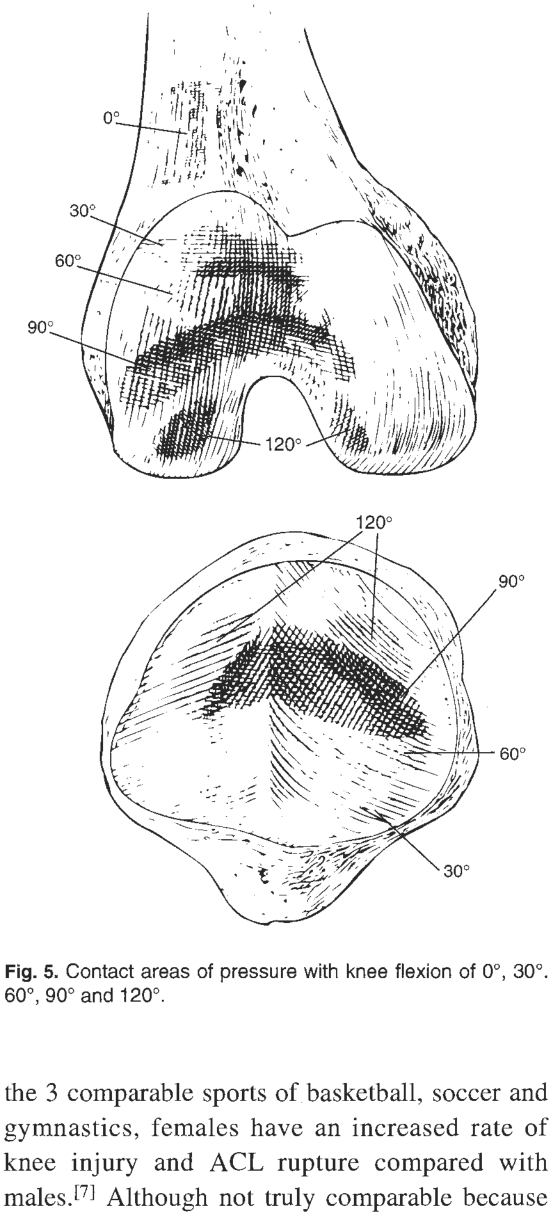

Fig. 5. Contact areas of pressure with knee flexion of 0°, 30°. 60°, 90° and 120°.

the 3 comparable sports of basketball, soccer and gymnastics, females have an increased rate of knee injury and ACL rupture compared with males.[7] Although not truly comparable because lacrosse is a contact sport for males and a non-contact sport for females, lacrosse was the only NCAA comparable sport in which males had a higher rate of ACL injuries.[7] Ranking of the 3 most injured joints by NCAA statistics shows the knee to be the most common in sports in females and males.

5. Modifications in Rehabilitation Techniques for Female Athletes

Compared with males, the average female athlete has less experience in sports and less access to good coaching, athletic trainers and facilities.[5] Female athletes may not have access to or previous experience in the weight room. The coach, physician, physical therapist or athletic trainer, therefore, should provide instruction on the proper techniques of exercise and weight training. An athlete with little previous experience in rehabilitation should, at first, be monitored closely while they acclimatise to the equipment and the protocols.

Certain exercises may exacerbate problems in the knee. Avoidance of high resistance exercises of the quadriceps in extremes of arc of motion in patients who have PF disorders has been suggested.[74,75] With increasing knee flexion, the PF contact areas increase (fig. 4).[75] When the athlete flexes her knee to 90°, the increased surface area of contact and elevated posteriorly directed forces can exacerbate pre-existing anterior knee pain and decrease the effectiveness of the exercise.

The knee extension exercise machine can create additional pain in patients with PF disorders.[76-78] Forces on the anterior tibia and increases in flexion range create excessive PF joint pressures. For patients with anterior knee pain, quadriceps strengthening should be with a close kinetic chain mechanism. The forces on the natural padding of the foot, not the anterior tibia, produces less PF force and are more sport-specific. Research has shown that loading the PF joint from above, as in squats, and from the foot, as in leg presses, rather than loading anterior to the distal tibia, produces less patellofemoral joint reaction force.[39] However, squats or leg presses with flexion to 90° or down to parallel should be avoided because the PF joint reaction forces are again maximal.[78]

A more focused approach of quadriceps rehabilitation in a patient at risk of or with PF syndrome would include straight leg raising and mini-squats or mini-leg presses in a painless arc of motion while limiting flexion. Squats with feet apart to shoulder width and avoiding flexion beyond 90°

Fig. 5. Squats with feet (**left**) in neutral and (**right**) in external rotation, which aids vastus medialis obliquus strengthening.

minimises PF forces, creates a closed kinetic chain mechanism and improves quadriceps strength (fig. 5). External rotation of the feet may accelerate VMO stimulation (fig. 5). Leg press in a painless arc of motion also helps to restore quadriceps function (fig. 6). Proper body mechanics in the performance of full or mini-squats, and power clean and dead lifts are essential. Performance of proper lifting technique is critical to optimally improve quadriceps strength and to prevent injury. Partial squats with low load, limited flexion and high repetition may reduce the incidence of retropatellar pain.[13] Closed kinetic chain strengthening and sports-specific skills should be emphasised. Stationary bicycling, with moderate resistance and a high seat, and swimming are also usually well tolerated.[79]

Selective VMO strengthening improves patellar tracking. Unfortunately, simple straight leg raising or terminal extension exercises are not the optimal way to rehabilitate the VMO.[80] The femur should be externally rotated to decrease the lateral pull of the tensor fascia lata and stretch the VMO. Hip adduction should be performed with the knee extension to optimise the firing of the VMO which partially originates from the adductor magnus. Electric stimulation of the VMO, modalities or biofeedback may also be of benefit.

6. Conclusions

In the past, primarily due to their greater numbers and dominance in the highly visible sports, the focus of research has been on male athletes. With

Fig. 6. Leg press machine.

the increasing trend of women participating in competitive and recreational sports, more research is being done on females. Studies have found that compared with males, females are at an increased risk for ACL injuries and PF disorders. Intrinsic and extrinsic factors contribute to this risk. Prospective and retrospective studies are needed in this area.

Understanding the unique aspect of certain sports and injury patterns can enhance the care of the knee in female athletes. Proper rehabilitation techniques and use of equipment will enable the athlete to have a quicker and safer return to sport. Appreciation of gender differences in sport and injury patterns is important. Based on an accurate diagnosis, institution of appropriate treatment by the sports medicine team will ensure the optimal care for female athletes.

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