16 Prevention and Management of Common Musculoskeletal Injuries in the Adult Female Athlete

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Abstract

As the female athlete transitions into an adult, her body is again under a multitude of changes, primarily from the effects of estrogen. This sex-specific hormone causes the change in body composition, muscular strength, neuromuscular firing, and bone composition. This bodily alteration opens the female athlete up to face different musculoskeletal injuries, with overuse trauma being the most common. However, injury to the knee in general and anterior cruciate ligament in particular is more of a concern for young adult female athletes, with tear rates exceeding male athletes several fold, especially for those participating in soccer and basketball. Current research continues to focus on ACL injury in females, looking at a wide array of potential contributing factors. Prevention of musculoskeletal trauma is crucial in keeping the female athlete healthy, and proper training/conditioning programs can help to reduce injury risk.

Keywords

Estrogen • Sex-specific hormones • Anterior cruciate ligament • Soccer and basketball • ACL injury in females • Training/conditioning programs

16.1 Learning Objectives

After completion of this chapter, you should have an understanding of:

- The fundamental differences in the anatomy, physiology, and body composition between adolescent and adult females in terms of the musculoskeletal system
- The relative similarities and pertinent differences between adult males and females concerning the anatomy, body composition, and biomechanics of the musculoskeletal system

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- Various more common types of orthopaedic injuries sustained by adult females involved in certain athletic activities
- Several measures for prevention of musculoskeletal injuries incurred by adult female athletes
- Different modes of treatment for orthopaedic injuries sustained by adult females participating in certain sporting activities

16.2 Introduction

As growth proceeds from childhood through adolescence then finally culminates into adulthood, the developing female body carries along with it a multitude of changes. Not only does a mature woman have to face morphologic challenges, she must also adapt to structural, hormonal, and metabolic alterations as well. Indeed, the musculoskeletal system is certainly no exception to this growing rule throughout the different life stages. Although it is healthy to be engaged in a regular exercise program, participating in multiple athletic competitions and sporting activities can leave the adult female more vulnerable to orthopaedic injuries; especially if she is not sufficiently fit to perform her best in extremely demanding levels of physical play.

This chapter focuses on several anatomical features unique to the adult female athlete; different types of musculoskeletal trauma which tend to be more common for women participating in sports, along with methods of injury prevention and how to go about treating these orthopaedic issues once they do occur.

16.3 Research Findings and Contemporary Understanding of the Issues

16.3.1 The Fundamental Differences in Anatomy, Physiology, and Body Composition Between Adolescent and Adult Females in Terms of the Musculoskeletal System

To recap some of the similarities and differences between young females and adult women, the following anatomical changes are found to be fairly consistent: breast tissue development, fat deposition around the hips, thighs, and buttocks, plus broadening of the pelvis, all of which herald the onset of puberty under the influence of the female sex hormone, estrogen [1, 2] (Fig. 16.1).

This transition stage usually occurs between the ages of 12 and 14. Estrogen also brings about longitudinal skeletal growth, with the final bone length achieved between 2 and 4 years after pubescence. A woman's body composition continues to fluctuate during the teenage years, then at some point in the mid-20s, more adipose tissue is accumulated and muscle mass starts to decline, at a rate of about 3 kg per decade (greater than ½ pound per year). The rise in total body fat along with loss in the quantity of fat free mass is due to lower levels of physical activity, relative lack of testosterone, and consuming the same quantity of caloric intake [2]. In terms of skeletal density and therefore bony integrity, calcium, among other essential minerals, continues to be deposited into

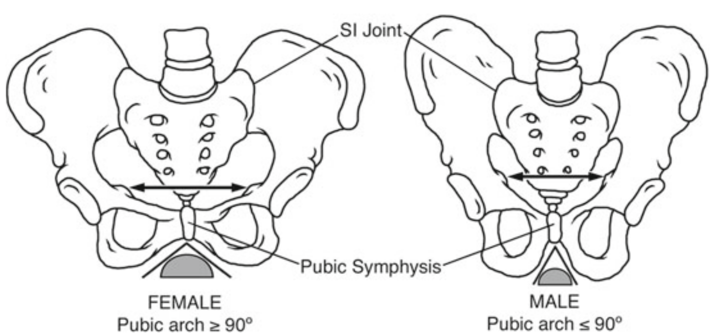

Fig. 16.1 Pelvis morphology

the skeleton to build up bone as the body is steadily growing. This process of calcium deposition into the bone bank thus increasing the quantity of bone gained, becomes accelerated during the adolescent growth spurt of puberty spanning the teenage years, and then reaches its peak in terms of bone mass acquisition in the early 20s. After this period of very rapid bone deposition, bone loss begins to occur gradually during the late 20s or early 30s depending on both nutritional and hormonal status, along with the amount of mechanical stimuli applied [3] (see Chap. 7) (Fig. 16.2).

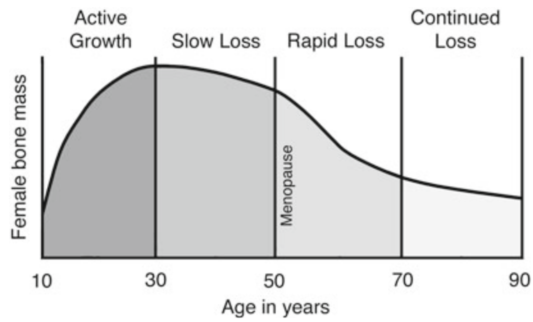

Fig. 16.2 Rate of bone loss through a woman's lifetime

16.3.2 The Relative Similarities and Pertinent Differences Between Adult Males and Females Concerning the Anatomy, Body Composition, and Biomechanics of the Musculoskeletal System

Up until the onset of puberty, anatomical structure and body composition between males and females are fairly similar in terms of height, weight, girth, bone width, and subcutaneous fat. The body build, shape, and size of both sexes begin to diverge once the endocrine system starts to undergo changes. Two sex-specific hormones, estrogen and testosterone, begin to take over to influence the development of adolescent features, separating teenage girls and boys in terms of anatomy as well as functions of the musculoskeletal system [1, 2]. During the adolescent growth spurt females tend to deposit more fat around the breasts, hips and thighs. This gender related adipose tissue deposition, in addition to that surrounding internal organs, is termed essential fat. Essential fat in females composes about 9–12 % of total body weight, as compared to only 3 % in males. The other type of adipose tissue is storage fat, which is comparable in both sexes, comprising about 15 % of body weight [2, 4–6]. At physiological maturation, the average adult female non-athlete carries between 18 and 26 % of adipose tissue, whereas mature men only contain about 12–16 % body fat on average [4, 5]. However, for female athletes engaged in excessive exercise, especially long distance runners who train and compete over 100 miles per week, their percentage of body fat can be reduced to well below 10 % [4, 6]. In fact, some elite endurance athletes can eventually attain body fat of only around 6–8 %. It is estimated that body fat below 11 % in women is enough to cause amenorrhea [2].

Males tend to carry more adipose tissue in the abdomen/flank and upper body versus females, who store fat mostly around their hips and lower body [2]. The different body fat distribution in men and women tends to affect athletic performance. For example, because females have greater fat content they have increased buoyancy in water. This is deemed advantageous by decreasing drag and lowering energy expenditure by 20 %. However, the higher fat percentage is thought to hinder physical performance in many endurance sports from having to carry the excess body weight (though hard evidence is somewhat lacking) [4–6].

Generally speaking, between 11 and 12 years of age, girls are about 90 % as strong as boys. By the time they are 15–16 years old, females are about 75 % as strong as males [4, 6]. When adjustments are made for body mass, men are at least one-third stronger than women [5]. Specifically, females are only 50 % as strong in the upper and 75 % in the lower body as males [6]. When muscle mass is taken into account, relative leg strength is similar in both sexes, but upper extremity strength in females still lags behind that of males [1, 4, 6]. This is due to men having more muscle mass relative to body weight than women, 40 % as compared to 23 %.

The lack of muscle strength stems from women having decreased fiber size (15–40 % less), making the cross sectional area about 60–85 % smaller as well [4, 6]. In fact, this relative difference in fat free mass tends to be lower in females from age 7 until 25 years of age. After the mid-20s, lean muscle mass begins to decline in both sexes, at a rate of ¼ to ½ pound yearly [2]. In correlation to a greater amount of lean muscle mass in men, the skeletal framework in males is larger as well; they also mature later and attain more final height (taller) and weight (heavier) than females from undergoing a longer period of growth [6]. However, under estrogen's effect, growth rate of the female skeleton is greatly accelerated, culminating in the final bone length to be achieved earlier only a few years after the onset of puberty. In other words, females cease to grow faster—their body and bones reach a plateau after 2–4 years of fairly rapid growth. Therefore, men reach final skeletal maturity about 21 or 22 years old, rather than 17–19 years of age in women [2].

In terms of bony and articular differences, females' bones are smaller as well and therefore their joints have less surface area. Women have shorter and smaller limbs relative to body length as compared to men. The length of lower extremities in women is 51.2 % of total height versus 56 % in men [7]. Additionally, men have broader shoulders, larger chests, and narrower hips; women, on the other hand, have wider pelves, more varus hip, and higher knee valgus angles (Fig. 16.3).

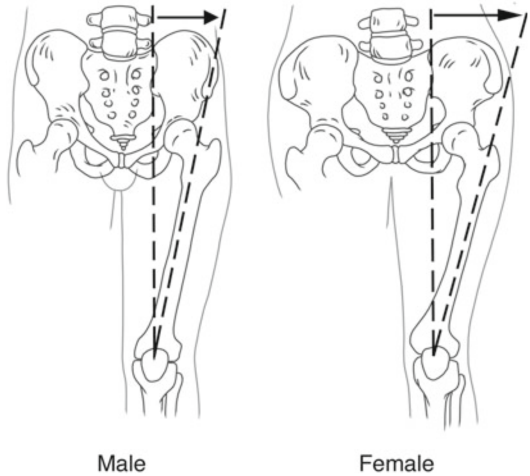

Fig. 16.3 Hip–knee angular difference

This anatomical difference, combined with an overall smaller stature and wider pelvis, gives women a lower center of gravity. The increased angular inclination in the lower limbs of females causes an asymmetrical force distribution/transmission through the extremity's overall alignment from the hips to the ankle, and subsequently can contribute to a myriad of overuse type of musculoskeletal injuries [1, 2, 4–6].

Neuromuscular recruitment, primarily in the lower extremities in women, differs from that of men after puberty, especially during landing tasks [4, 8–12]. This altered neuromuscular recruitment has been linked to increased risk for injury during athletic activities. Women also have increased joint laxity, which is partially attributed to less lean muscle mass that can restrain excessive joint motion [13]. Joint laxity differences are most profound in the knee, ankle and elbow joints. Studies have shown this increase in joint laxity along with differential neuromuscular recruitment may be responsible for the greater incidence of ACL injury in females compared to males [12] (Fig. 16.4).

16.3.3 Various More Common Types of Orthopaedic Injuries Sustained by Adult Females Involved in Certain Athletic Activities

The involvement of women in athletic activities, ranging from mild exercise to elite performance, has skyrocketed over the past 100 years. This comes from a change in social norms and attitudes towards women as well as legislature ensuring equal opportunity for females. Subsequently, over the past 30 years, the role of women in athletic competition has been revolutionized, from sitting in the stands to standing on the sidelines, and of course playing in sporting events. Alongside the tremendous rise in female sports participation, comes with that visible gender

Fig. 16.4 Risky versus safe landing positions

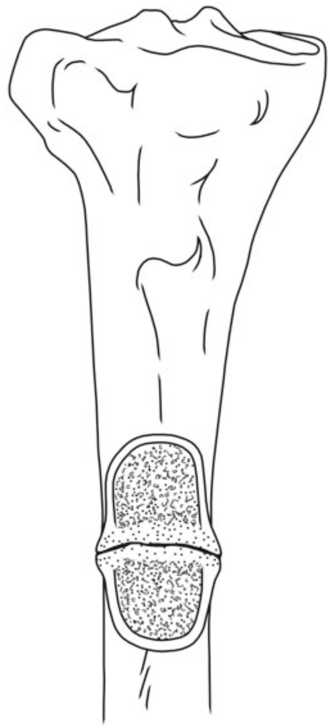

Fig. 16.5 Tibial stress fracture

differences between men and women, especially in the different types of musculoskeletal injuries incurred among other unique orthopaedic issues occurring in athletics [3–6, 14–16].

The following depicts musculoskeletal conditions more commonly seen in female athletes that may vary in types and incidence according to different sporting activities. Even recreational events such as running can bring about 25–65 % of injuries severe enough to keep women away from training. In fact, about half of these female runners must seek medical care for their musculoskeletal problems. Other modes of physical activity, which portend a similar rate of injury risk, include group exercise participants, soccer players, basketball players, and handball players [14].

As discussed in Chap. 15, overuse injuries are extremely common in the female athlete. The rise in overuse injuries can be contributed to the relative rise in the number of females involved in athletics as well as an increase in intensity along with year-round participation. Stress fractures are seen in both men and women, with the most common bone fractured being the tibia (33–55 %) (Fig. 16.5).

However, fractures to the femoral neck, tarsal navicular, metatarsal, and pelvic area are more commonly seen in the female athlete [17]. Specific sites of stress fracture are also dependent on the type of sport; for example, high jumpers most commonly fracture their medial malleolus and tarsal navicular [18]. Associated risk factors can be due to internal body structure/function, including muscle imbalance, limb malalignment, and fluctuating hormones; or attributed to external factors such as the type of footwear, running style, and training errors (i.e., exercise mode/frequency/intensity/volume). Additional contributors to the increased risk of stress fractures can involve psychological and medical issues, including inadequate/inappropriate nutrition, disordered eating, osteopenia, and hormonal irregularity [1, 4, 5, 8, 19]. The presence of stress fracture shows itself as gradual onset of pain induced by activity as well as tenderness to the bony site when palpated. Radiographic imaging should be utilized to determine if a stress fracture is present. General treatment for a stress fracture

Fig. 16.6 ACL (anterior cruciate ligament) tear

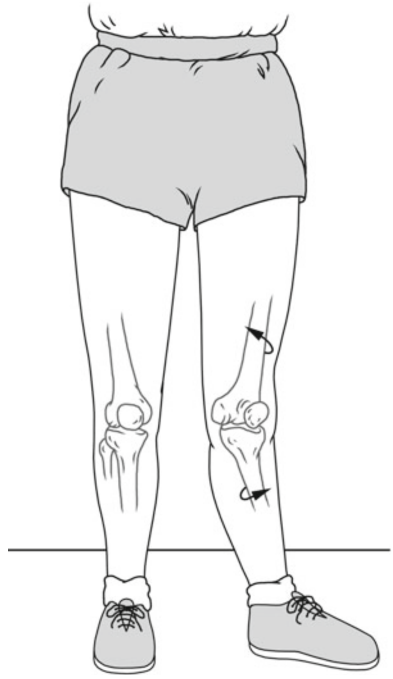

Fig. 16.7 Risky limb landing attitude

is reduction in activity and relative rest; however, if the stress fracture does not respond to resting or casting, a surgical procedure to fix the problem may be necessary. Non-impact exercise can be beneficial during the "rest" period to help maintain cardiovascular fitness. For example, cross-training such as swimming, water running, and bicycling can also be beneficial as well [17–19].

One of the most common injuries in female athletes is trauma to the anterior cruciate ligament (ACL). The incidence of injury in women competitors can range anywhere from two to ten times higher than male athletes [3–6, 8, 12–14] (Fig. 16.6).

Specific sports portend different rates of ACL tear/injury. For example, collegiate female soccer players are 2.6 times more likely to sustain an ACL injury as compared to males, whereas basketball players are 5.75 times more likely to have an ACL tear [20]. Injuries to the ACL are also commonly seen in gymnastics, downhill skiing, field hockey, team handball, and lacrosse. While it has not been clearly defined as to why there is an increased risk in ACL injury in women, the etiology of this gender specific phenomenon is theorized to be multifactorial, including anatomical, hormonal, biomechanical, neuromuscular, and environmental. Other contributing factors may include skill level, physical condition, imbalanced thigh musculature (especially hamstring weakness as compared to the quadriceps), increased flexibility, and decreased proprioceptive capability [4, 5, 9]. Risky positions when landing have been previously alluded to and usually involve an off-balance body position especially on one limb. Injury in women occurs most often in response to a valgus load with hip internal rotation and external tibial rotation as seen in cutting maneuvers, and can be exacerbated if an external lateral force is applied to the knee [20, 21]. The other, less common mechanism for ACL injuries occurs during knee hyperextension with external tibial rotation while landing, which tend to be more predominant in basketball and gymnastics [20] (Fig. 16.7).

Joint stiffness and stability can be maintained by active contractile soft tissues. Stiffness is the resistance of bodily structures in response to a force, and active joint stability can be controlled by voluntary muscle contraction. Wojtys et al. measured anterior tibial translation and muscular contraction to an externally applied stress, finding that translation was decreased with increased muscular co-contraction. However, they found that women naturally have decreased joint stiffness, indicating a reduced ability to protect the knee from external forces [21].

Recent studies have looked into the possibility of joint laxity due to fluctuating hormones during the menstrual cycle. It has been proposed that the rate of ACL injury increases during the initial and late follicular phase, accompanied by a surge in estrogen (see Chap. 7) [22]. However, there has been no consensus as to whether hormonal changes during menses directly cause the increased risk of ACL injury; thus more research needs to be conducted. As discussed previously, the timing of neuromuscular firing is different in women during landing tasks and can be linked to ACL injury. Huston and Wojtys found female athletes initially activate their quadriceps for knee stabilization, whereas males recruit their hamstrings first. They also found female athletes took longer to generate maximum hamstring muscle torque as compared to males [23]. More recently, research trends have shifted from looking at hamstring and quadriceps to analyzing the effect of activation and strength of hip musculature in relation to ACL injuries. When the knee is loaded, biomechanically, the hip abductors and external rotators are activated preventing hip adduction and internal rotation, which causes a valgus force at the knee [24]. Failure of the hip abductors and external rotators to fire causes an increase in the Q-angle which subsequently adds more load to the knee joint [25]. Brent et al. found a decrease in hip abduction strength in females during cutting maneuvers, suggesting a decrease in muscular contraction at the hip can lead to an ACL injury at the knee [26].

Contributing factors to anterior knee pain and dysfunction stem from static structural misalignment from the pelvis to the feet, dynamic imbalance of limb muscular strength, excessive soft tissue pliability or extreme stiffness, or a combination thereof [8]. Specifically speaking, this

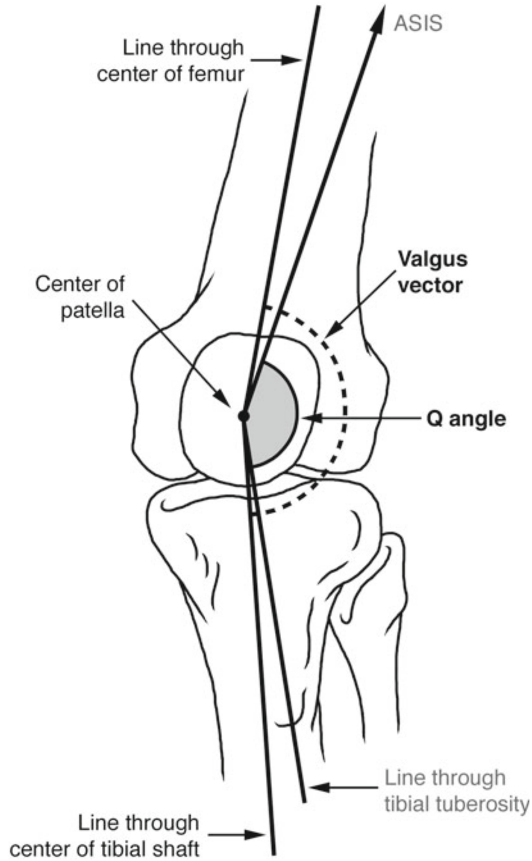

Fig. 16.8 "Miserable malalignment syndrome"

entity is often named the "Miserable Malalignment Syndrome," associated with an increase in hip external rotation and femoral anteversion coupled with a higher Q-angle, genu valgum, tibia vara, and a hypermobile patella [1, 4, 6, 16] (Fig. 16.8).

The body, as an attempt to center the knee under the hips and above the ankle, compensates by internally rotating the femur, along with externally rotating the tibia and pronating the foot, all of which asymmetrically loads the patellofemoral joint [25, 27].

Patellofemoral pain syndrome (PFPS) is very common in female athletes, especially runners, occurring in 20 % of females as compared to 7.4 % in males [28]. The higher rates of PFPS in women are thought to be due to structural alignment as well as biomechanical and hormonal differences. However, the exact mechanism for the

Fig. 16.9 Patellofemoral joint incongruency

injury and pain is still unclear and seems to vary between athletes. Three major factors contributing to the development of PFPS are lower extremity and/or patellofemoral malalignment, quadriceps muscle imbalance and/or weakness, plus physical overload of the patellofemoral joint [27]. Malalignment can be caused by increased pressure from excessive tightness of the lateral patellar retinaculum (soft tissue restraint) or from a shallow trochlear grove of the distal femur and/or high or low riding patella, all of which can contribute to PFPS and anterior knee pain [1, 6, 16] (Fig. 16.9).

Furthermore, as females flex their knees from full extension to about 30°, the femoral condyles do not fully support the patella, contributing to a more lateral riding position. Sports such cycling or running on hills, or those involving repeated strikes to the anterior knee region (volleyball) tend to place more stress across the patellofemoral joint, in turn causing an increased incidence of experiencing painful knee symptoms [4]. Malalignment can also contribute to increased risk for subluxation or frank dislocation of the patella. A common mechanism of patellar dislocation stems from internal rotation of the femur with a fixed foot causing the quadriceps to pull the patella laterally which may be a result of an acute, traumatic episode or from chronic, repetitive type of activity [1, 4, 20]. The dislocated patella, in general, usually spontaneously reduces; however if it doesn't reduce, slow extension of the knee with medial force on the lateral patella will cause patellar reduction [20].

Iliotibial band syndrome (ITBS) is one of the most common overuse injuries in female athletes. The incidence of ITBS are sports dependent and most commonly seen in long distance runners at a rate of 4.3–7.5 %. Iliotibial band syndrome is a result of inflammation and irritation of the distal attachment of the iliotibial band that runs alongside the lateral femoral condyle. Inflammation is exacerbated with repetitive flexion and extension motions, as seen in running and bicycling. Anatomical factors that are thought to increase the risk of developing ITBS are excessive tibial internal rotation, genu varum, and increased foot pronation. It has also been suggested that weakness in the hip abductor muscles can also contribute to the development of ITBS. Treatment of ITBS is generally conservative and consists of rest, heat and ice to decrease inflammation, stretching of the hamstrings, quadriceps, and ITB, along with physical therapy for strengthening. In extreme intractable cases, surgical intervention to increase the length of or partially release the tendinous band might be required [4, 16].

Other lower extremity conditions more prevalent in athletic females involve the foot, especially if special shoe wear is deemed necessary for sports participation. The other factor playing a contributory role toward female foot problems lies in the type of sports consisting of frequent starts, decelerations, and sudden stops such as basketball, causing excessive forward and backward movements of the foot inside the shoe and friction around the lesser toes. Again, this overuse condition is exacerbated by wearing athletic shoes originally designed for males, not taking into account that a female's foot is shaped wider in front (forefoot) and narrower in the back (hindfoot) [1, 4, 6]. Bunion (or hallux valgus) formation results from bursitis overlying the first metatarsal head of the great toe. Bunions are commonly seen in female athletes and in fact exceed the incidence in males by about nine times. More than half the women in the USA have a bunion. This condition is due to a wide forefoot shape combined with wearing a narrow shoe toe box, causing excessive pressure and therefore more frictional wear, resulting in inflammation and pain. This inflammatory entity is aggravated by midfoot pronation or flat arches and wearing high heels [1, 4, 16]. Treatment for bunion pain is first and foremost properly fitting shoes. Shoes designed with a wide toe box are ideal for women suffering from bunions. Orthotics can also be worn to alleviate pain and provide extra comfort, support, and

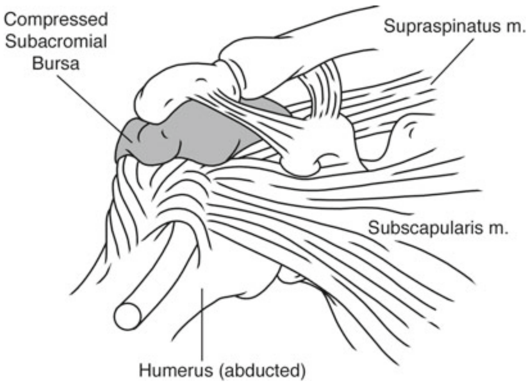

Fig. 16.10 Impingement syndrome

protection. Other modalities for pain relief are bunion shields, splints, and bandages. However, if the pain becomes unbearable, a surgical procedure can be performed to correct the bony protuberance. Bunionectomy will remove the bony outgrowth plus realign the bones and soft tissues [16].

The shoulder girdle joint seems to be more susceptible in females in terms of orthopaedic injuries, especially when engaging in higher risk athletic activities such as gymnastics, swimming, diving, throwing/pitching maneuvers, tennis, and volleyball. Again, etiology of this upper limb trauma could also be acute or chronic, with anatomical malalignment, structural imbalance, poor posture, muscular weakness, soft tissue inflexibility or excessive laxity, all contributing to the incidence and severity of injury. Biomechanically speaking, female athletes performing in sports requiring overhead activities tend to place undue stress on the soft tissue stabilizers (both static *and* dynamic) surrounding the shoulder girdle articulations, resulting in bursitis and rotator cuff tendinosis, leading to inflammation and pain (impingement syndrome) (Fig. 16.10).

For example, female swimmers, since their bodies and arm lengths are generally shorter; they must utilize more strokes across the water to cover the same distance as men, increasing the number of repetitive insults placed across the shoulder joint. Another cause of shoulder problems in overhead female athletes is due to increased laxity of the joint capsule, allowing the humeral head to "ride" out and back in over the glenoid, making the dynamic stabilizers such as the rotator cuff muscles work that much harder to keep the "ball" centered in the "socket", again causing painful symptoms [1, 4, 6] (Fig. 16.11).

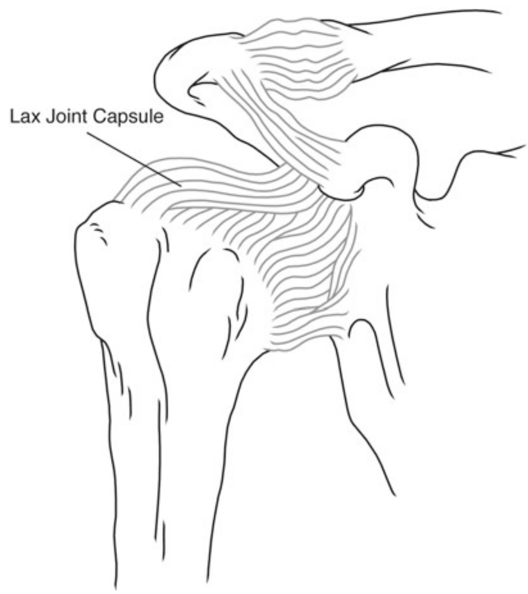

Fig. 16.11 Shoulder instability

Similarly for throwing mechanics, since humeral length is less in women but forearm length is the same as men, along with having narrower shoulder girdles, the lever arm is shorter as well, making overhead winding motions more difficult, placing differential forces on the surrounding supportive musculature [6].

The elbow is also more susceptible to "wear and tear" in females, with an incidence of 10 % versus 1–5 % in males primarily between 42 and 46 years of age. Lateral epicondylitis, also known as tendinosis or tennis elbow, is degeneration of the tendons attaching to the lateral humeral epicondyle. This overuse condition is due to repetitive forearm rotation affecting the extensor muscle(s). Symptoms consist of pain and tenderness to touch at the lateral epicondyle and treatment is very limited. Generally, rest, ice, and bracing are recommended initially, then steroid injections, with surgery in only recalcitrant cases [4].

Spondylolysis is a common back injury seen in female athletes, particularly affecting the fourth and fifth lumbar vertebrae (L4–L5). Injury usually occurs at the junction between the superior and inferior process or pars interarticularis. Injury rates are higher in women participating in gymnastics, skating, and dance. The presenting symptom is unilateral lower back pain, exacerbated by lumbar extension. Confirmation of this type of stress fracture is obtained through X-ray, although sometimes radiographs cannot pick up the injury site. In these cases, other imaging modalities such as an MRI may be ordered to reveal the damaged area. Treatment for spondylolysis is conservative, primarily with rest and/or bracing, with surgery only in extremely rare cases [1, 4, 6].

16.3.4 Several Measures for Prevention of Musculoskeletal Injuries Incurred by Adult Female Athletes

As previously stated, as compared to males, both intrinsic and extrinsic factors contribute to the increased incidence and varied types of orthopaedic injuries incurred and musculoskeletal conditions occurring in adult female athletes. Intrinsic factors include sex specific changes in musculoskeletal anatomy and physiology affecting relative limb length, lower extremity alignment; body composition, muscle mass/strength, and neurological recruitment. Extrinsic factors involve physical fitness, proprioception, playing level, competitive environmental conditions, sporting equipment, athletic wear, especially shoes, along with interaction/friction between footwear and ground surfaces [1, 2, 5, 6, 29]. Generally speaking, altering intrinsic conditions is virtually impossible because this is inherent within the athlete. However, neuromuscular control can be modified through training and conditioning to affect the manner by which muscles are recruited and the force they produce. This can affect the way the athlete lands during certain athletic activities, thus potentially decreasing the risk of lower extremity injury. Additionally, strengthening exercises for the hip (gluteus extensors/abductors/adductors), thigh (quadriceps/hamstrings), and leg (gastrocsoleus) muscles can be instituted to help support key joints of the lower limb (hip–knee–ankle), respectively. The importance of physical training lies in balancing the anterior and posterior musculature to optimize muscular contraction with neurological activation while playing sports. Furthermore, other aspects of the workout program should be considered, such as stretching for flexibility, ipsilateral stance exercises for balance/proprioception, core conditioning for trunk stabilization, plyometrics for anaerobic power, and agility drills for speed/coordination. As discussed in Chap. 15, the different types of warm-up, in particular static stretching, to potentially prevent injury and enhance performance, is being highly debated. Trends are now moving towards actively recruiting muscles as opposed to passively stretching them in preparation for activity [6].

To be extremely effective, training programs must be at least 6 weeks long, and sessions must be more frequent than once a week [5, 6, 30, 31]. Sports specific exercises should also be integrated into the workout regimen to ensure that correct and strict technique is maintained. Similar conditioning programs can also be applied to the upper body, enhancing physical fitness ability and minimizing injurious mechanisms. The training program needs to focus on deficits in range of motion and strength of the shoulder girdle region, especially the rotator cuff muscles. Other musculotendinous units surrounding this upper limb articulation, such as the pectorals (major and minor), latissimus dorsi, deltoids, triceps, and biceps brachii, should also be strengthened for added limb support [1, 4, 6].

Control of external factors can contribute to the prevention of injury. Modification of environmental conditions can be done to a certain extent, ensuring that playing equipment is adjusted to body size, and making sure that athletic gear, especially shoes, are well padded/fitted to the foot will also decrease risk of trauma. As far as prevention of stress injury is concerned, avoidance of excessive, repeated bouts of impact activity will help to reduce this and other types of overuse orthopaedic conditions. Cling to the principle of gradual moderation when increasing training intensity, duration, and frequency in order to optimize athletic performance and minimize musculoskeletal injury [1, 6, 14, 16].

In short, the majority of extrinsic factors contributing to adult female musculoskeletal conditions can be modified to decrease the incidence of orthopaedic injury. The mainstay of this prevention strategy lies in physical conditioning programs, training women athletes to keep their body in balance as far as strength, flexibility, and proprioception, along with optimizing other factors such as speed/agility, coordination, and power. However, the exercise regimen must be individualized to match the female athlete's fitness profile and progression should be gradual in order to minimize overtraining, attrition, and injury rates [5, 29, 30, 32].

16.3.5 Different Modes of Treatment for Orthopaedic Injuries Sustained by Adult Females Participating in Certain Sporting Activities

Proper management of a musculoskeletal injury should be done in order for optimal recovery in a timely manner. The following general principles (PRICE) hold when addressing orthopaedic issues: *P*rotection from further harm to the injured extremity; relative *R*est for the affected limb(s) to maintain range of motion (ROM) to minimize stiffness; *I*ce to aid in soft tissue inflammation; even/equal distribution *C*ompression wrap (not to tight) to help with edema; and *E*levation above heart level as much as possible to control swelling. In other words, utilize appropriate first aid measures initially to hopefully halt the progression of the injurious process and reduce painful symptoms. As far as treatment for specific injuries is concerned, tendon strains, muscle "pulls," and ligament sprains, dependent upon the degree, will usually respond to avoidance of provocative maneuvers and first aid treatment initially [31].

Administration of medications may help with pain and speed up recovery. Over-the-counter nonsteroidal anti-inflammatory drugs (NSAID) can be used for inflammation and pain; however, caution needs to be taken as not to remove the body's natural protective mechanism by masking symptoms. Another consideration is the medication's potential toward a delayed healing response due to blunting of the body's natural process of inflammation. Administration of vitamin C has been shown to provide a strong anti-inflammatory effect and aids in the process of bone formation and scar tissue healing. Vitamin C is also an antioxidant, which also aids in the repair of tissues. However, results are contradictory as far as the role of vitamin C in terms of helping with exercise recovery. Similarly, other studies have shown anti-inflammatory as well as anabolic affects of omega-3 fatty acids, particularly seen in fish oil. Like NSAIDs, however, caution needs to be taken when consuming these minerals as not to remove the body's natural inflammatory response and subsequent tissue healing [6].

Along the same line, electrical stimulation devices may also be used, but only as an adjunct to neuromuscular retraining. In terms of orthotics for the feet, the custom molded ones tend to be better than those off the shelf as far as helping to distribute load more evenly inside the shoe [4, 16]. As for bracing of the limbs, use these judiciously as well, since muscles can become deconditioned if braces are worn too frequently, and no studies thus far have shown conclusive evidence that they can prophylactically prevent knee injuries [1, 6, 16]. Moreover, recent studies have found that improper bracing can, in fact, increase the risk of injury because lack of motion in one joint will cause load transfer to be distributed to the adjacent joint. Therefore, caution needs to be taken when using limb braces as protective or preventative measures. Similarly, athletic taping, although helpful in terms of joint stability, tends to take away the protective proprioceptive capability of soft tissues surrounding the joint. In addition, the tape loosens within about 20 min of play, rendering taping completely ineffective after that length of time [4, 6, 16].

Extreme trauma to the limb warrants absolute immediate immobilization plus radiologic studies are definitely needed to quickly rule out displaced fractures. Musculoskeletal insults of this severity require an orthopaedic consultation and could culminate eventually in surgical fixation if the injury is severe enough [5, 29]. As far as nonoperative management of musculoskeletal conditions in the adult female is concerned, as soon as the athlete has a pain free extremity and joint ROM is regained, progression of activities should be instituted to include therapeutic rehabilitation exercises. The rehab program should encompass conditioning workouts previously outlined to include strength, flexibility, power, speed, and agility. In addition, other elements including coordination, balancing/proprioception should also be integrated as part of the physical training regimen. Furthermore, faulty body biomechanics should be adjusted when engaging in movement/motion to minimize physical stress as part of the kinetic chain adding insult to the already injured limb. Finally, sports specific drills need to be added once prior physical milestones have been mastered. From this point on, functional exercises are emphasized in this phase of recovery in order to return the athlete to her pre-injury physical status and level of play [5, 6, 14, 29, 32].

16.4 Future Directions and Concluding Remarks

In summary, the adult female athlete, through the growing years of development into more mature stages in life, has to face not only morphologic changes of the entire musculoskeletal system, but she also has to deal with sex-specific hormonal alterations influencing body composition as well. Prior to the early 1970s, involvement of women in sports was sparse until congress intervened, mandating equality for females participating in academic/athletic competitions. Paralleling the exponential rise in female sporting events, the rate of orthopaedic injuries/conditions also became much more prevalent and exceeding the incidence in males, affecting especially the knee joint and namely the ACL. Different factors, both intrinsic and extrinsic, contribute to the increased occurrence of musculoskeletal injury in athletic women. What appears to be fairly effective in preventing certain orthopaedic conditions in female athletes consists of engaging in physical conditioning programs to institute strength, flexibility, agility, speed, proprioception, coordination, plyometrics, and power. Once musculoskeletal injuries have occurred, however, it is prudent to recognize/diagnose the offending problem early in order to protect the affected athlete from further harm. In addition, initial first-aid type measures can be instituted to help decrease symptoms plus enhance healing and recovery. Physical rehabilitation exercises with individualized gradual progression as tolerated can be added once the athlete responds to these first-line modalities. However, if the injury becomes recalcitrant to conservative management, orthopaedic consultation should be sought for further evaluation and treatment. The ultimate goal for any injured athlete is to provide aid promptly and hasten rapid recovery as much as possible in order to return her to play, whether it is in elite competitions or recreational sports.

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