Special Concerns of the Female Athlete

Mary Lloyd Ireland

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11 / SPECIAL CONCERNS OF THE FEMALE ATHLETE

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Introduction

Physiologic, anatomic, and psychologic differences in females and males create certain unique patterns of illness and injury. Enhanced appreciation of these special situations will enable the practitioner to sharpen diagnostic skills and improve treatment of the female athlete. Unique illnesses are related to nutritional and hormonal balance. These illnesses include anorexia nervosa, bulimia, athletic amenorrhea, iron deficiency anemia, hormonal imbalance, pregnancy, and postmenopausal osteoporosis (1–4).

The majority of injuries are related to participation in the sport rather than the gender of the athlete (5–10). Anatomic differences in lower extremity alignment, less upper extremity strength, hormonal imbalance, and nutritional disorders increase chances for certain overuse injuries with intense training in females. Stress fractures in amenorrheic runners and upper extremity injuries in underdeveloped prepubertal gymnasts are common. There is an increased incidence of patellofemoral (PF) disorders and anterior cruciate ligament (ACL) injuries in females (11). Differences shown diagrammatically are the female's wider pelvis, increased flexibility, less developed musculature, less developed vastus medialis obliquus (VMO), narrower femoral notch and genu valgum, and external tibial torsion (Fig. 11.1). In the male, extremity alignment includes a narrower pelvis, more developed thigh musculature, VMO hypertrophy, less flexibility, wider femoral notch, genu varum, and internal or neutral tibia torsion (Fig. 11.2). Why do these overuse and ACL injuries occur? The reasons are multifactorial. In the past, studies were done on males only. More research is desperately needed in women's sports. Concerns over lasting injury and illness exist. Follow-up of a women's collegiate gymnastics team showed half of the athletes had less than fully recovered from their injuries three years after stopping competition (12).

With the increased awareness in the importance of fitness and the passage of Title IX ensuring equal rights for male and female athletes in federally supported institutions, the numbers of females participating in structured competitive and recreational athletics has skyrocketed during the past several decades. The history of competition of women at various levels—local, national, and international—is fascinating (13, 14). With this dramatic increase in participation, injury rates and patterns emerge. More research is needed in areas of female sport participation.

Sports of Participation

National Collegiate Athletic Association (NCAA) and United States Olympic Committee (USOC) recognize sports that are male and female combined, male only, and female only (Table 11.1). In NCAA competition, female-only sports are field hockey and softball. Male-only NCAA sports are water polo, baseball, football, ice hockey, and wrestling. Olympic sports that are female only are rhythmic gymnastics and synchronized swimming. Male-only Olympic sports are baseball, bobsled, boxing, ice hockey, modern pentathlon, ski jumping, nordic combined skiing, soccer, water polo, weight lifting, and wrestling. Sport biomechanics of the male- or female-only sports create uniquely different patterns and different incidence of injury.

Injury Rates

Since 1982, the NCAA Injury Surveillance System has been published with detailed injury information in 16 sports. The 4 comparable sports for men and women are gymnastics, basketball, soccer, and lacrosse. Female-only sports are softball and field hockey. Male-only sports are spring football, football, wrestling, ice hockey, and baseball.

For women, the highest overall injury rate in collegiate sports is gymnastics, followed by soccer, basket-

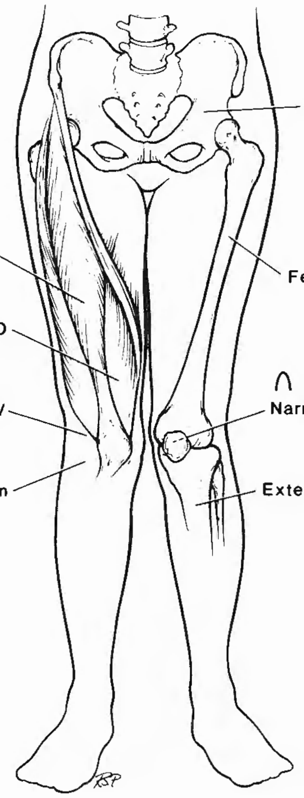


Figure 11.1 Diagram shows the lower extremity alignment that may predispose to certain overuse problems involving the hips and knees and especially ACL and patellofemoral injuries. Females have a wider pelvis, increased flexibility, less developed musculature, hypoplastic vastus medialis obliquus, narrow femoral notch, genu valgum, and external tibial torsion.

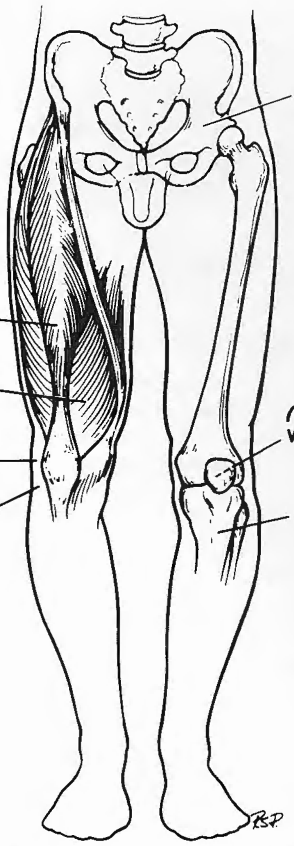


Figure 11.2 Males have a narrower pelvis, more developed thigh musculature, vastus medialis obliquus hypertrophy, less flexibility, wider femoral notch, more tendency toward a genu varum, and internal or neutral tibial torsion.

ball, field hockey, volleyball, lacrosse, and softball. The men's sports of spring football and wrestling had the highest injury rates (10) (Table 11.2). Equal occurrence of injury in practice and games were women's and men's soccer, lacrosse, field hockey, softball, and baseball. In gymnastics, about 80% of injuries occurred in practice (Table 11.2). Knowledge of injury rate and timing of occurrence allows the practitioner to plan coverage.

The type of injury for each of the 16 NCAA sports was analyzed (Table 11.3). The categories analyzed included contusion, tendinitis, incomplete ligament sprain, incomplete muscle tendon strain, complete muscle tendon strain, fracture and stress fracture, concussion, heat exhaustion, and inflammation. For completeness, the sixteen sports and all categories are included. The incidence of incomplete sprains was highest in spring football (Table 11.3) followed by women's gymnastics, wrestling, and men's soccer. Women's gymnastics lead the diagnoses of complete sprain, incomplete strain, and tendinitis. Concussion and heat exhaustion rarely occurred.

The rate at which a particular body part was injured was also analyzed (Table 11.4). The ankle was the most commonly injured joint. Women's gymnastics had the highest rates of lower back and foot injuries. The injured body parts for all sixteen sports are shown for comparison in this table.

There are many studies comparing male and female incidence of injury in similar sports (7, 8, 15). Using the National Athletic Injury Illness Reporting System, Whiteside (8) reported the order of highest to lowest incidence of injuries was basketball, gymnastics, softball in women (compared to basketball) gymnastics, and baseball in men. Men's and women's basketball had the highest relative injury frequency. Women had a relatively higher frequency rate of ankle injuries and fractures in basketball and gymnastics.

Injury type and rate were compared to six varsity sports at Indiana University during the 1977 to 1978 season (15). The highest injury rate was gymnastics (40%) with the most injuries occurring during practice, in tumbling, and in younger women. Most of the basketball injuries occurred on defense while guarding.

The ankle is the most commonly injured joint in many series (6, 8, 9, 15). In 19 female collegiate sports, injury rates were most common in basketball, followed by volleyball, field hockey, gymnastics, and track and field (16). In this survey of 361 colleges and universities, the injury-contributing factors in order were improper

Table 11.1.
Sports by Gender

Olympic Sports: Male / Female	Olympic Sports: Male Only	Olympic Sports: Female Only
Archery	Baseball	Rhythmic gymnastics
Athletics	Bobsled	Synchronized swimming
Basketball	Boxing	
Biathlon	Ice hockey	
Canoe / kayak	Modern pentathlon	
Cycling	Ski jumping	
Diving	Nordic combined skiing	
Equestrian	Soccer	
Fencing	Water polo	
Gymnastics, artistic	Weight lifting	
Field hockey	Wrestling	
Judo		
Luge		
Rowing		
Shooting		
Figure skating		
Speed skating		
Alpine skating		
Nordic skiing		
Swimming		
Team handball		
Tennis		
Table tennis		
Volleyball		
Yachting		

NCAA Sports: Combined	Male / Female	Male Only	Female Only
Fencing	Gymnastics	Water polo	Field hockey
Rifle	Volleyball	Baseball	Softball
Skiing	Basketball	Football	
	Cross country	Ice hockey	
	Lacrosse	Wrestling	
	Soccer		
	Swimming / diving		
	Tennis		
	Indoor / outdoor track		
	Golf		

training methods, inadequate facilities, and poor coaching techniques.

Sport Differences

Differences in sport biomechanics and training create certain specific injury patterns. The repetitive maneuvers of ballet, gymnastics, cheerleading, dance, and ice skating create circumstances for unique injuries. Gymnastic balance beam maneuvers may cause unusual injuries due to the apparatus (Fig. 11.3). In this collegiate gymnast, repetitive landings on the balance beam caused recurrent medial dislocations, one of which was open, of the left great toe from landing with the beam between the great and second toe causing the first metatarsophalangeal (MTP) dislocation. Medial stress views show severe instability of the left first MTP joint (Fig. 11.4*A*). Following a season of buddy taping of the toes, surgical reconstruction of the joint was performed. Intraoperative stress testing shows severe lateral instability of the left first metatarsophalangeal joint (Fig. 11.4*B*). There are reports of profiles and injuries in specific sports which include women rowers (17), professional ballerinas (18), and swimmers (19). Summarization of physiologic profiles provide excellent information (20–22).

Gender Differences

The diagnosis and treatment of the athletic female has been reviewed in detail. (4, 23). Excellent comparative studies of the genders have been done in the military setting (20, 24–26). Athletic women in the Navy were found to have more success than nonathletes in areas of stamina, strength, and self-discipline (26). Compared to males, women were found to be capable of equal efficiency and aerobic metabolism at the United States Military Academy (20). In a random review of 74 female and 74 male cadets, an increased incidence of stress fractures were found in females (24). Eleven fe-

Table 11.2.
Injury Rates per 1000 and Percentage in Practice and Games[a]

	Women				Men			
	Injury Rate per 1000	Total Injuries	Practice	Game	Injury Rate per 1000	Total Injuries	Practice	Game
Gymnastics	8.59	1634	78%	22%	5.06	415	81%	19%
Lacrosse	4.25	871	68%	32%	6.05	2554	54%	46%
Basketball	5.13	281	61%	39%	5.61	3386	65%	35%
Soccer	7.90	2540	51%	49%	7.87	5194	47%	53%
Volleyball	4.76	2823	65%	35%	x	x	x	x
Field Hockey	5.00	1526	59%	41%	x	x	x	x
Softball	3.90	1788	52%	48%	x	x	x	x
Spring Football	x	x	x	x	9.59	2129	94%	6%
Wrestling	x	x	x	x	9.41	4992	66%	34%
Football	x	x	x	x	6.57	29217	58%	42%
Baseball	x	x	x	x	3.37	3837	44%	56%
Ice Hockey	x	x	x	x	5.61	2908	32%	68%

[a]All data are shown as rate per 1000 athletic exposures for 1992–1993
Source: NCAA Injury Surveillance System, No. 9044–11/92

Table 11.3.
NCAA Injury Rate by Type of Injury[a]

	Contusion	Tendinitis	Ligament Sprain (incomplete tear)	Ligament Sprain (complete tear)	Muscle-tendon Strain (incomplete tear)	Muscle-tendon Strain (complete tear)	Fracture	Stress Fracture	Concussion	Heat Exhaustion	Inflammation
Gymnastics-W	0.98	0.30	2.73	0.46	2.43	0.03	0.30	0.30	0.19	0.00	0.25
Gymnastics-M	0.60	0.20	1.59	0.00	1.00	0.00	0.40	0.00	0.00	0.00	0.30
Basketball-W	0.50	0.21	1.79	0.21	0.78	0.03	0.28	0.20	0.17	0.00	0.18
Basketball-M	0.80	0.20	2.23	0.09	1.06	0.03	0.39	0.07	0.10	0.00	0.15
Soccer-W	0.92	0.33	2.12	0.23	2.20	0.07	0.44	0.25	0.23	0.04	0.32
Soccer-M	1.75	0.19	2.24	0.20	1.98	0.01	0.47	0.03	0.30	0.03	0.20
Lacrosse-W	0.18	0.18	1.08	0.12	1.83	0.00	0.09	0.33	0.09	0.00	0.33
Lacrosse-M	1.15	0.30	1.51	0.15	1.24	0.01	0.35	0.06	0.15	0.00	0.11
Field Hockey-W	0.84	0.33	0.88	0.12	1.10	0.02	0.33	0.10	0.08	0.08	0.18
Volleyball-W	0.23	0.23	1.51	0.05	1.02	0.02	0.13	0.04	0.05	0.02	0.15
Softball-W	0.51	0.30	0.55	0.11	0.86	0.03	0.34	0.01	0.10	0.00	0.06
Spring Football-M	1.25	0.18	3.23	0.25	1.98	0.03	0.55	0.03	0.20	0.00	0.13
Wrestling-M	0.69	0.06	2.46	0.14	1.63	0.04	0.27	0.03	0.31	0.03	0.08
Football-M	0.86	0.08	1.95	0.23	1.29	0.03	0.34	0.03	0.30	0.12	0.10
Ice Hockey-M	1.04	0.02	1.14	0.10	0.79	0.01	0.35	0.01	0.30	0.00	0.01
Baseball-M	0.44	0.28	0.59	0.06	1.15	0.01	0.25	0.02	0.05	0.00	0.05

[a]All data are shown as rate per 1000 athletic exposures in 1991–1992
Source: NCAA Injury Surveillance System, No. 9044–11/92

Table 11.4.
NCAA Injury Rate by Body Part[a]

	Neck	Shoulder	Wrist	Hand	Lower Back	Hips, Groin	Upper Leg	Knee	Patella	Lower Leg	Ankle	Foot
Gymnastics-W	0.22	0.41	0.30	0.05	0.96	0.25	0.46	1.48	0.03	0.49	1.91	0.71
Gymnastics-M	0.00	0.50	1.00	0.10	0.50	0.00	0.00	0.10	0.00	0.40	1.00	0.20
Basketball-W	0.02	0.21	0.05	0.09	0.33	0.21	0.25	0.92	0.10	0.24	1.38	0.27
Basketball-M	0.07	0.14	0.07	0.06	0.40	0.35	0.34	0.78	0.14	0.19	1.83	0.30
Soccer-W	0.32	0.25	0.07	0.01	0.27	0.37	1.45	1.27	0.08	0.71	1.76	0.41
Soccer-M	0.40	0.19	0.11	0.03	0.25	0.46	1.39	1.39	0.09	0.54	1.75	0.46
Lacrosse-W	0.00	0.03	0.03	0.03	0.21	0.45	0.69	0.63	0.06	0.66	0.84	0.27
Lacrosse-M	0.08	0.56	0.07	0.06	0.23	0.38	0.82	0.90	0.04	0.28	0.99	0.10
Field Hockey-W	0.02	0.12	0.04	0.10	0.16	0.14	0.73	0.47	0.22	0.35	0.69	0.24
Volleyball-W	0.02	0.40	0.01	0.07	0.38	0.12	0.27	0.52	0.15	0.15	1.17	0.11
Softball-W	0.03	0.63	0.08	0.15	0.24	0.08	0.22	0.45	0.06	0.13	0.39	0.08
Spring Football-M	0.53	1.33	0.08	0.05	0.35	0.28	1.28	1.80	0.20	0.30	1.70	0.18
Wrestling-M	0.60	1.18	0.09	0.10	0.38	0.14	0.22	1.66	0.11	0.17	0.75	0.06
Football-M	0.28	0.83	0.06	0.10	0.29	0.34	0.57	1.26	0.08	0.21	0.97	0.16
Ice Hockey-M	0.07	0.82	0.13	0.06	0.20	0.42	0.47	0.89	0.04	0.13	0.26	0.13
Baseball-M	0.02	0.80	0.09	0.08	0.07	0.10	0.33	0.29	0.04	0.11	0.32	0.05

[a]All data are shown as rate per 1000 athletic exposures for 1991–1992
Source: NCAA Injury Surveillance System, No. 9044–11/92

males and no males sustained stress fractures. Women had double the incidence of men's lower extremity injuries. However, men required an extra week to resolve their lower extremity injuries and required twice as much time to reach maximal improvement from back injuries as compared to women. Physiologic differences in men compared to women occur in aerobic fitness and resistive training. Compared to men, women midshipmen improved their fitness level more rapidly, and the disparities were often societal (27). Stress-related injuries were seen more often in women. As the women acclimated to the Naval Academy, similar numbers of serious injuries were seen. There is a comprehensive review of data comparing male and female athletes in areas of body composition and physique, muscle characteristics, strength, and cardiovascular endurance capacity (22). After age 10 to 12, there are significant differences in all aspects of physical performance. In the 18 to 22 year olds, body fat for females is 22% to 26% and males is 12% to 16%. In males, androgens create greater lean body weight. In females, estrogens contribute to the greater amount of fat weight. Detailed summaries of different sports comparing the genders include body composition, somatotype, muscle fiber, strength and cardiovascular endurance capacity, and O_2 max. Similarities in highly trained male and female athletes are lower-body strength (per unit of body weight), cardiovascular endurance capacity, body composition, and muscle fiber type. In females, a sedentary lifestyle after puberty may significantly contribute to the differences physiologically (22).

Gender differences in body composition and structural variables have been studied (21). Differences are similar in athletic females compared to males and nonathletic females compared to males. Total lean body mass is greater in males. Similar male and female ranking for fatness and leanness were reported with the lowest in runners and gymnasts and highest in basketball, volleyball and field events.

Work capacity studies show that, compared to men, women have more fat and less muscle, but only slight differences in the $\dot{V}_{O_2max}$ when expressed relative to body size and composition (28). Males have greater hemoglobin and higher red blood cell levels. In general, females are highly trainable and demonstrate the same physiologic training changes as males. The effects of aerobic exercises on training in symptomatic women with mitral valve prolapse were reviewed (29). Aerobic exercise was found to be a positive influence in the management of symptomatic women with mitral valve prolapse.

Women, like men, can experience significant increases in strength, power, and muscular endurance (30). Although upper body strength and development are less in females compared to males, sound strength training principles can decrease these differences as based on ratios to body weight. However, upper body strength in women, even with training, has, in some studies, remained only 30 to 50% of their male counterparts. Lower body strength comes much closer to parity.

The development of strength is usually the weakest link in the physiologic profile of the female athlete (22).

Orthopaedic Considerations

Specific Joints

Knee

Injury Rates. Compared to males, PF disorders and ACL injuries are more common in females (9, 31–33). The knee is often injured in collegiate sports. The injuries can be matched to the sport (Table 11.5). The knee injury rates were categorized into the structures involved: ligaments (collateral, anterior cruciate, posterior cruciate), torn cartilage (meniscus), patella or patellar tendon. The collateral ligaments were most frequently injured in spring football, wrestling, football, and ice hockey. In comparable sports, the athletic exposure rate per 1000 ACL in the female involved more

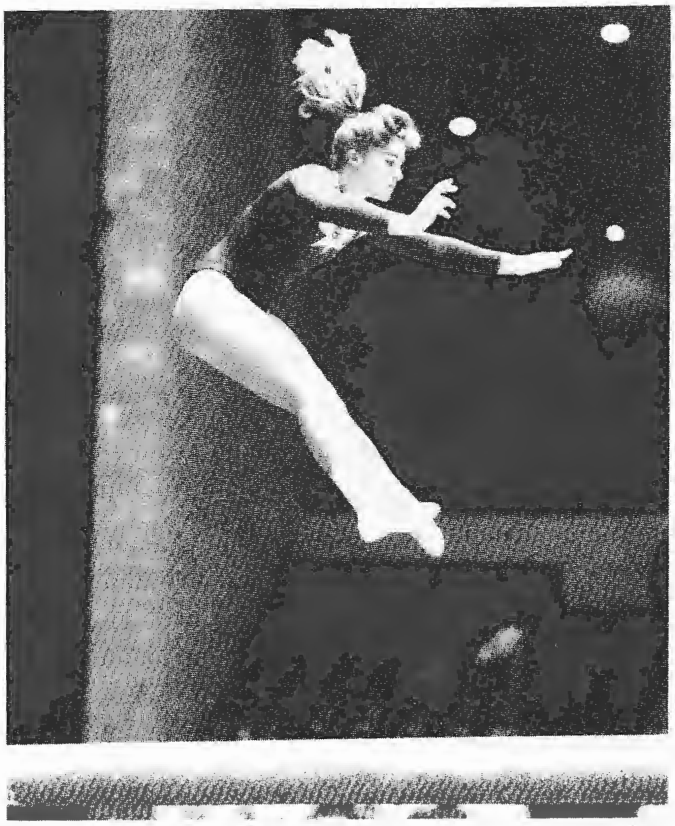


Figure 11.3 Gymnastic apparatus of the balance beam, which is unique in female sports, can result in certain unusual injuries.

Figure 11.4 Collegiate gymnast sustained several injuries when landing on the beam. The force between her great toe and second toe on the left caused several medial dislocations, one of which was open. **(A)** Medial stress radiographs of both great toes medially show the severe medial instability without fracture. **(B)** Clinical stress test immediately prior to surgery. Note the previous scar from open dislocation *(arrow)*. She required reconstruction of the lateral structures of her left great toe.

Table 11.5.
NCAA Knee Injury Rate by Sport[a]

	Total # of Exposures	Collateral	Anterior Cruciate	Posterior Cruciate	Torn Cartillage (Meniscus)	Patella and/or Patella Tendon
Gymnastics-W	36,570	0.41	0.44	0.05	0.36	0.16
Gymnastics-M	10,048	0.10	0.00	0.00	0.00	0.00
Basketball-W	150,617	0.32	0.25	0.03	0.28	0.19
Basketball-M	175,023	0.21	0.07	0.01	0.14	0.24
Soccer-W	75,064	0.39	0.27	0.04	0.29	0.17
Soccer-M	148,959	0.53	0.13	0.08	0.19	0.23
Lacrosse-W	33,315	0.15	0.12	0.00	0.09	0.18
Lacrosse-M	71,032	0.32	0.21	0.00	0.13	0.11
Field Hockey-W	50,971	0.08	0.08	0.00	0.06	0.14
Volleyball-W	120,258	0.12	0.11	0.01	0.14	0.20
Softball-W	71,179	0.11	0.13	0.00	0.08	0.11
Spring Football-M	39,894	1.03	0.18	0.10	0.18	0.28
Wrestling-M	108,990	0.86	0.11	0.01	0.29	0.19
Football-M	744,698	0.69	0.21	0.03	0.25	0.14
Ice Hockey-M	99,863	0.69	0.08	0.01	0.03	0.06
Baseball-M	176,702	0.08	0.03	0.01	0.06	0.07

[a]All data are shown as rate per 1000 athletic exposures for 1991–1992
Source: NCAA Injury Surveillance System, No. 9044–11/92

Table 11.6.
Differential Diagnosis of Anterior Knee Pain

Inflammatory	Mechanical	Miscellaneous
Bursitis	Hypermobility	Reflex sympathetic dystrophy
Prepatellar	Subluxation	Ostechondritis dissecans
Retropatellar	Dislocation	Fat pad syndrome
Pes anserinus	Patellofemoral stress syndrome	Systemic arthritides
Tendinitis	Pathologic plica syndrome	Muscle Strain
Pes anserinus	Osteochondral arthrosis	Stress fracture
Semimembranosus		Meniscal tear
Patellar		Iliotibial band syndrome
Synovitis		

often in gymnastics (0.44 to 0.00), basketball (0.25 to 0.07) and soccer (0.27 to 0.13). In lacrosse, the male more frequently injured the ACL (0.21 to 0.12). In sports, female gymnasts have the highest rate of knee injury. Women's gymnastics lead other women sports with involvement of the ACL, collateral ligament, and cartilage. The uniqueness of the sport and its apparatus, biomechanics, as well as the gymnast's body habitus, strength, ligamentous laxity and alignment are all factors which contribute to this increased injury rate.

Patellofemoral Stress Syndrome and Alignment. Anterior knee pain is common in females. The differential diagnosis is lengthy (Table 11.6). Categories include inflammatory (bursitis, tendinitis, synovitis), mechanical (subluxation, dislocation, patellofemoral stress syndrome, plica), and miscellaneous. The term chondromalacia, or softening of the articular cartilage, is a pathologic diagnosis; clinically, the use of PF (patellofemoral) stress syndrome is suggested. Excellent reviews of chondromalacia exist (34, 35).

PF stress syndrome is commonly seen in females who have microtraumatic forces, alignment abnormalities, forefoot pronation and tibial torsion. For comparison, normal alignment is shown (Fig. 11.5*A*). Abnormal alignment or miserable malalignment syndrome creates excessive lateral forces subluxing the patella. These include Q angle exceeding 15°, increased femoral anteversion, hypoplastic vastus medialis obliquus, external tibial torsion, forefoot pronation, and heel valgus (Fig. 11.5*B*). This malalignment is commonly seen in cheerleaders, gymnasts, dancers, and track athletes. A swimmer exhibits miserable malalignment syndrome as seen on front (Fig 11.5*C*) and side (Fig. 1.5*D*) clinical views. PF disorders are best treated with quadriceps strengthening, avoidance of knee extension machines and full squats, knee sleeves with pads, orthotics for weight bearing sports, and nonsteroidal anti-inflammatory medications. Surgical intervention should be a last consideration in PR stress syndrome and miserable malalignment syndrome.

Anatomically, the articular surface of the patella is the thickest of all and consists of medial, lateral, superior and inferior nonarticulating facet (Fig. 11.6). Great variability in the size and shape of patellar facets, the depth of the trochlear groove, and dynamic muscle forces result in clinical PF disorders. The contact areas and facets of the PF joint have been well identified. Aglietti (36) determined the contact areas based on the degree of flexion (Fig. 11.7). The greatest contact area and pressure occurs at 90° flexion. Patellar tracking is dependent on bony anatomy, alignment, muscular development, and on the type of loading with machines or sport.

Patellar Instability: Radiographic and Clinical Assessment. Because PF disorders and ACL injuries are more common in females, attention to specific radiographic views is key. Routine views are anterior posterior (AP), lateral, femoral notch, and bilateral patellar sunrise. Radiographic measurements and reviews of

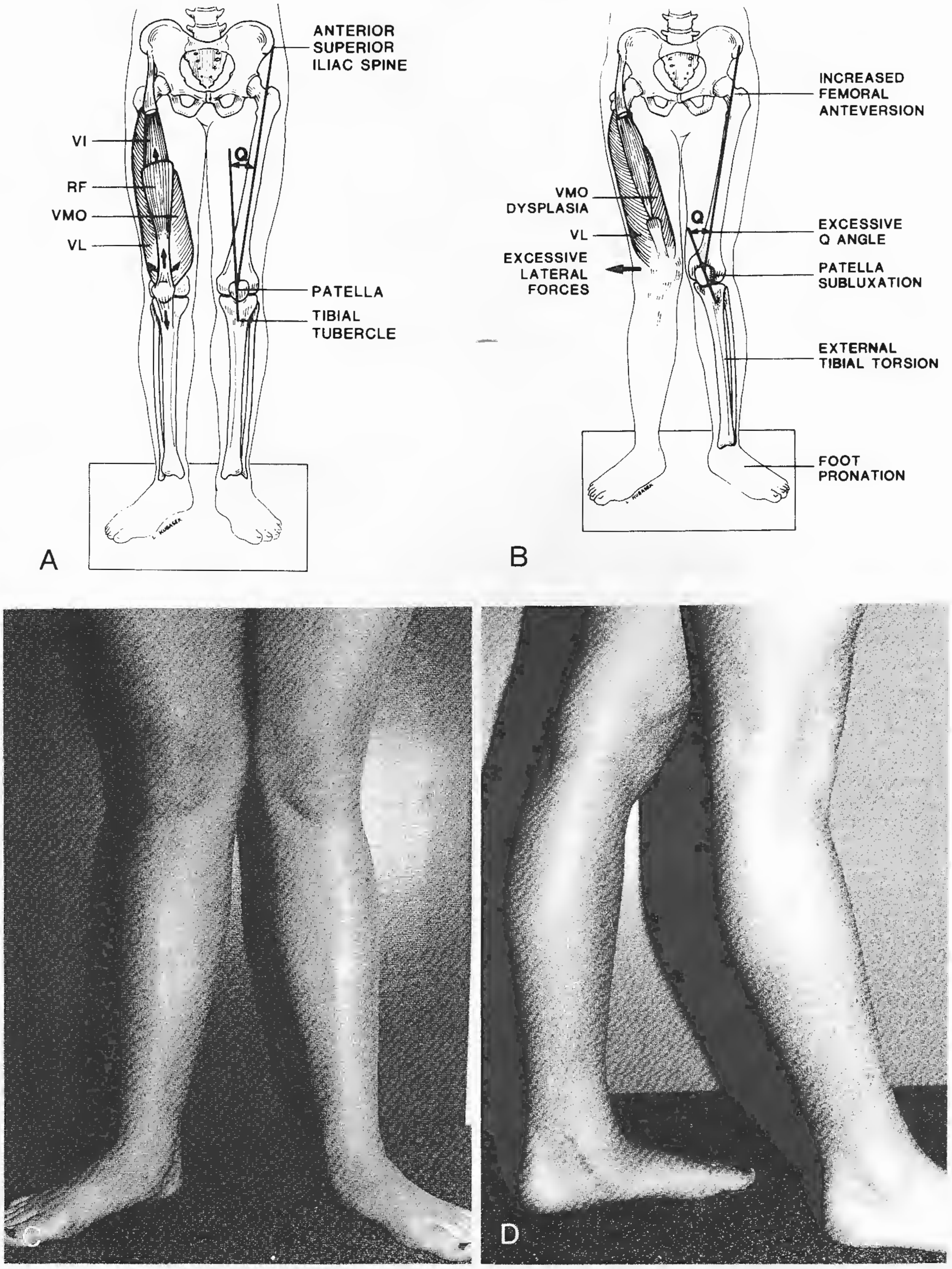


Figure 11.5 Patellofemoral disorders are common in females. **(A)** Normal alignment with normal Q angle measured from anterosuperior iliac spine central portion of the patella, patella to tibial tubercle of less than 15°, and normal musculature of developed vastus medialis obliquus, create forces that centralize the patella resulting in normal patellofemoral tracking. **(B)** Miserable malalignment syndrome consists of increased femoral anteversion, excessive Q angle, external tibial torsion, and foot pronation. All of these factors cause lateral patellar subluxation. This miserable malalignment syndrome is frequently seen in females. Clinical example of collegiate swimmer from the front **(C)** showing 20° genu valgum, external tibial torsion, hypoplastic vastus medialis obliquus, heel valgus, and pes planus with forefoot pronation. **(D)** Hyperflexibility of 20° hyperextension is seen from the side in a clinical view.

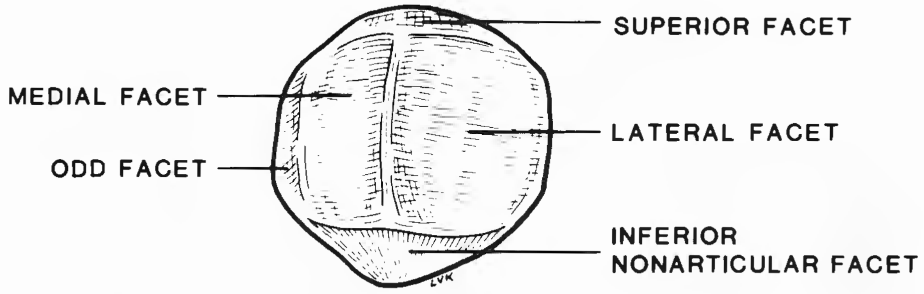


Figure 11.6 Articular surface of the patella demonstrates the anatomy of mediolateral odd patellar facets and the nonarticulating inferior and superior faces. Anatomy can be quite variable in size of the medial and lateral patellar facets.

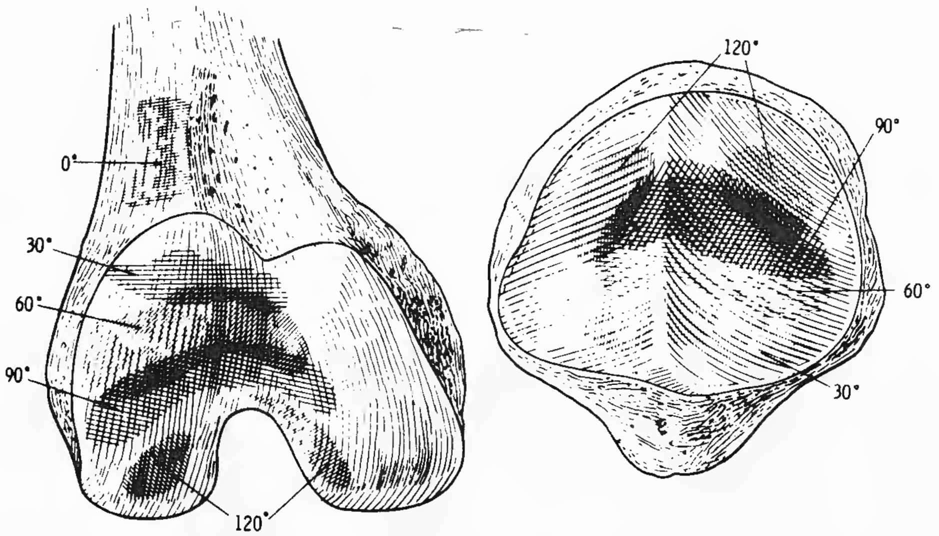


Figure 11.7 Patellofemoral contact areas are shaded at 0°, 30°, 60°, 90°, and 120° flexion in this right knee diagram. Femur *(lateral* to the *left* and *medial* to the *right)* and patella *(lateral* to the *right* and *medial* to the *left)* are shown. Reprinted with permission from Aglietti P, Insall JN, Walker PS, A New Patellar Prosthesis, Clin Ortho 1975;107:175.

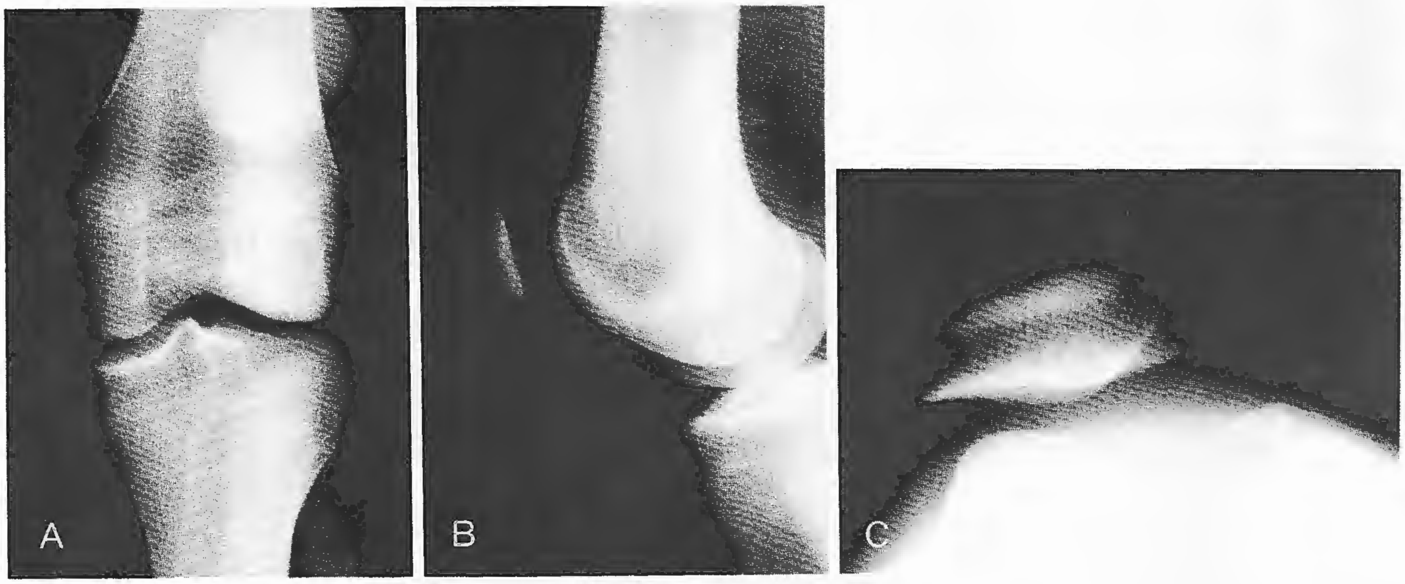


Figure 11.8 Routine plain radiographs include AP, lateral, and patellar view. Views of this left knee demonstrate patella alta. **(A)** On the AP view, the patella is significantly superolateral. **(B)** On lateral view, the measurement of the ratio of the patella to the patellar tendon is 0.5, confirming patella alta. Normal ratio is 0.8. **(C)** Hughston sunrise patellar view shows the lateral patellar subluxation, which is mildly symptomatic in this basketball athlete.

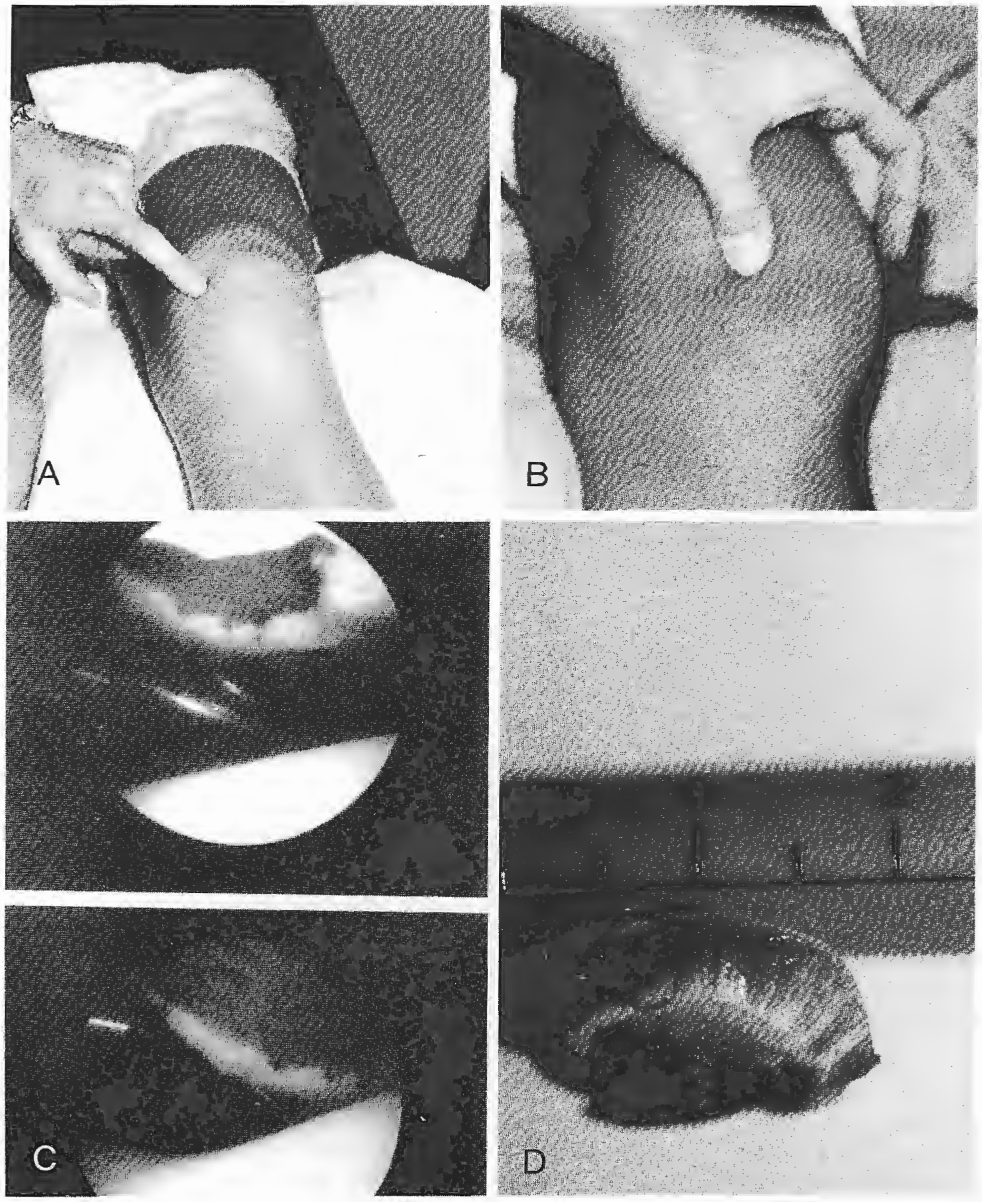


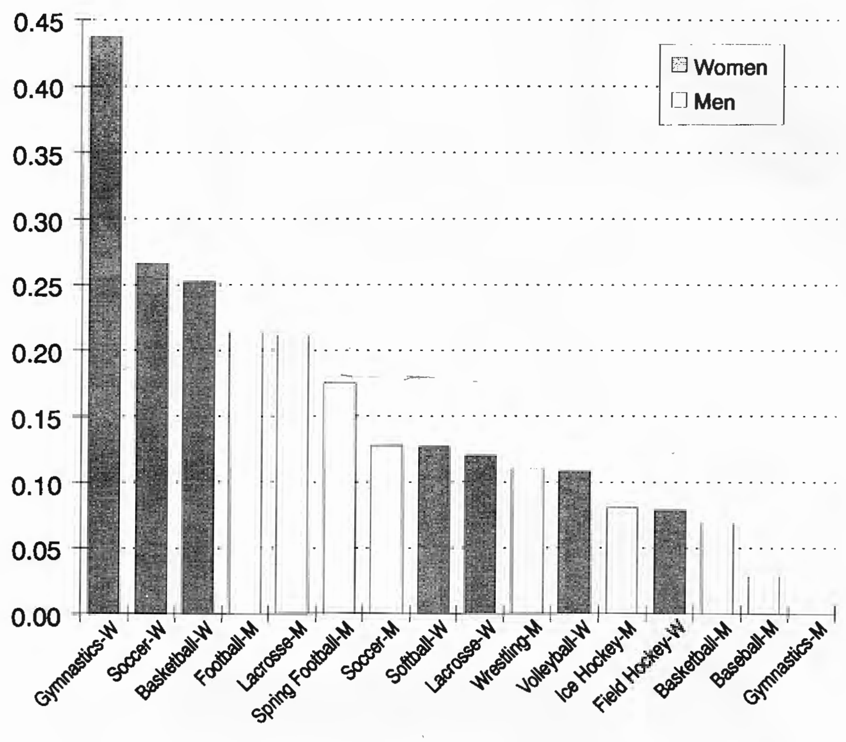
Figure 11.9 Clinical view of a swimmer who laterally dislocated her patella while walking down a stairwell. **(A)** Examiner points to the area of maximal tenderness. Note tense hemarthrosis. **(B)** Intraoperative exam documents lateral patellar instability. **(C)** Arthroscopic exam shows the debrided patellar above and normal trochlear groove below. **(D)** Excised loose patellar fragment is shown. Notice the very thick articular cartilage.

chondromalacia are important in the understanding of PF disorders (34). Measurement of length of a patella-to-patella tendon less than 0.8 is termed patella alta and greater than 0.8 is termed patella infera. This basketball athlete complained of anterior pain and swelling of her knee. Patella alta is demonstrated on AP and lateral views (Fig. 11.8*A*). Patella-to-patella tendon ratio is 0.5 and the Hughston patellar view shows lateral subluxation (Fig. 11.8*B*). The subject of these views returned successfully to competition with a quadriceps strengthening program and use of a neoprene sleeve with lateral pad.

An acute lateral patellar dislocation can be associated with an osteochondral fracture of the patella. This medial patellar facet fracture may not be seen on AP or lateral view. A Hughston patellar view including as much of the distal femur as possible is necessary. This patient with a severely swollen knee and pain over the medial retinaculum (Fig. 11.9*A*) sustained an acute lateral patella dislocation with medial osteochondral fracture. The intraoperative exam demonstrates lateral patellar instability (Fig. 11.9*B*). The arthroscopic view is of debrided patella and normal trochlear groove (Fig. 11.9*C*). The loose patellar fragment was removed arthroscopically. (Fig. 11.9*D*). The very thick articular cartilage and small amount of cancellous bone are well shown.

ACL Injury Rates. The four sports in which men and women compete are gymnastics, soccer, basketball, and lacrosse. The ACL was injured in females 3.5 times more often in basketball, 2.0 times more often in soccer as measured by rates per athletic exposure (9) (Table 11.7). In females, the highest rate of ACL injury was 0.44, whereas no male gymnast sustained an ACL injury. In lacrosse, males sustained ACL injuries 1.75 times more often than females.

Table 11.7.
NCAA ACL Injury Rate by Sport[a]



[a]All data is shown as rate per 1000 athletic exposures for 1991–1992
Source: NCAA Injury Surveillance System, No. 9044–11/92

Male and female basketball injuries at the professional level were compared (33). Compared to men, women were found to sustain more injuries, more sprains, and to have increased knee and thigh injuries. The most common injury involved the ankle. Women's injury frequency was 1.6 times greater than men.

An epidemiology survey of athletes invited to the U.S. Basketball Olympic Trials in 1988 showed that knee injuries ($P < .0001$) occurred more often in females compared to males and that females required surgery ($P < .0007$) more often than males (30). Of the 64 females, 17 required arthroscopy and 8 sustained an injury to the ACL. Of the 80 males, 3 sustained an injury to the ACL, while 3 required arthroscopy only. Factors contributing to this increased incidence of injury at the professional level (33) include differences in training, strengthening, weight lifting, shoes, floor, lower extremity alignment. Further investigation and prospective studies to determine why knee injuries involving the ACL are so common in females are needed.

ACL Research Projects. Some prospective studies have been done, but more research is needed. Studies analyzing differences in noninjured female volleyball and basketball athletes showed only one statistically significant difference in isokinetic strength testing and no differences in ligamentous laxity (37). This difference was with greater peak extension and higher hamstring-to-quadricep peak torque ratio in trail leg at 60° per sec in volleyball players. KT 1000 (Medmetric Company, San Diego, CA) testing showed no statistically significant anterior displacement comparing legs or sports. Further investigation with high speed video, taping, force plate analysis, and electromyography of lower extremity musculature is needed. Differences can be easily observed in volleyball and basketball. Cutting, one-footed positions, changing direction in basketball are shown in Figure 11.10. In volleyball, the position is more two-footed, straight ahead with less cutting and changing of direction (Fig. 11.11).

ACL Injuries: Radiographic and Clinical Assessment. Intraoperative view of a swollen right knee in a female basketball athlete undergoing ACL reconstruction is shown (Fig. 11.12). Notice the scar with severe keloid formation from her previous ACL reconstruction on the left. The elastin and collagen tissue in females may contribute to completeness of ACL tears and scar formation.

Femoral notch views are good for outlining the size, shape and contour of the notch and the articular surface. Narrow notch shape and size has been suggested as a contributing factor to ACL injuries. Letters can be used to classify notch shape (Fig. 11.13). The A-shaped notch on the right is commonly seen in ACL injuries. Other shapes are H, reverse U, or C shape (Fig. 11.13). Ratios of notch-to-femoral width can predict ACL injuries and incidence of bilaterality (38).

This high school basketball athlete was injured on offense while changing directions with the ball in a

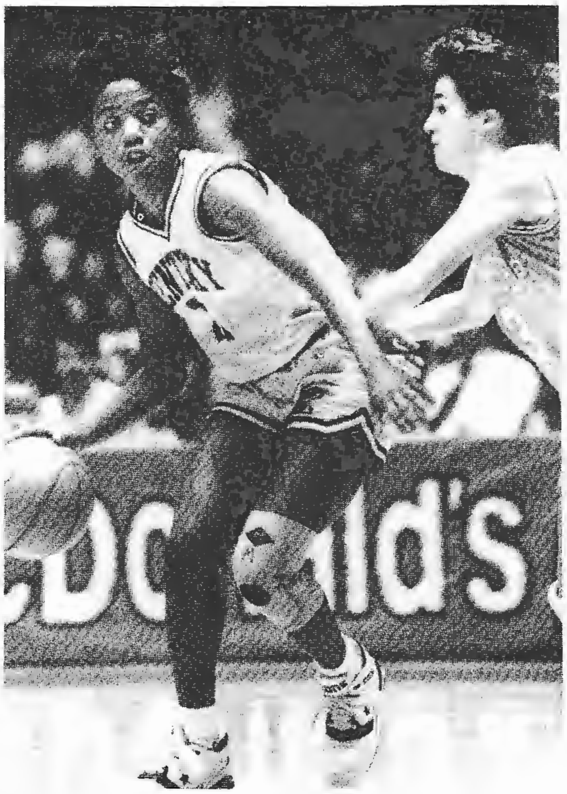


Figure 11.10 Although women's basketball is played similarly to men's, there are unique injury patterns most significantly involving the knee of increased incidence of knee injuries and anterior cruciate ligament tears. A collegiate basketball athlete is shown in one-footed position, eyes attempting to fake the opponent, and pivoting while making a drive for the basket.

Figure 11.11 In volleyball, most injuries are from overuse and involve patellofemoral joint. A collegiate volleyball athlete is shown serving the ball with her eyes set straight forward and with positioning on both feet without rotation.

noncontact mechanism. She had a narrow A-shaped notch view (Fig. 11.14*A*). MRI scan shows abnormal ACL signal, narrow notch, and bone bruise of the lateral femoral condyle (Fig. 11.14*B*). Arthroscopy confirmed the MRI results of a mop-end ACL tear (Fig. 11.14*C top*) and osteochondral femoral condyle defect (Fig. 11.14*C bottom*). Due to their less muscular development and their lower extremity alignment differences, females rely more on the ACL and less on hamstring control. Ligamentous reconstruction should be considered in the ACL-dominant female who is at high risk for significant meniscal and articular surface injury.

Foot and Ankle

Tibiotalar impingement syndrome results from repetitive axial loading sports. Osteophyte formation of the distal tibia and dorsal talar neck causes loss of dorsiflexion range and anterior pain (Fig. 11.15*A*). Arthroscopic removal of osteophytes and partial synovectomy allow a return to sport with improved motion (Fig. 11.15*B*).

In ballet athletes, posterior impingement of the os trigonum can result in local pressure on the flexor hal-

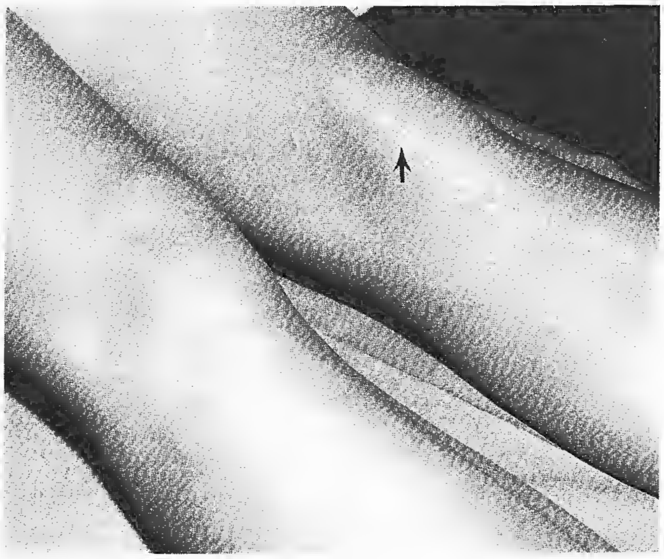


Figure 11.12 Photograph on the operating table of a collegiate female basketball athlete who will undergo right anterior cruciate ligament reconstruction. Note the right knee intra-articular swelling. Also note the keloid scar consistent with elastin stretching on her three-year-old left anterior cruciate ligament reconstruction *(arrow)*.

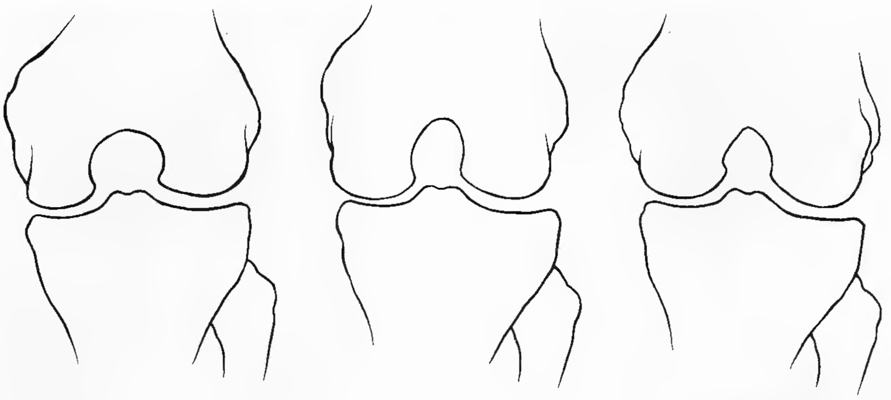


Figure 11.13 A proposed contributing factor to anterior cruciate ligament tears is the uniqueness of notch shapes. These have been seen as reverse C or U, H, and A in shape. The more narrow A shape and a low notch to femur ratio on notch views are common with ACL tears.

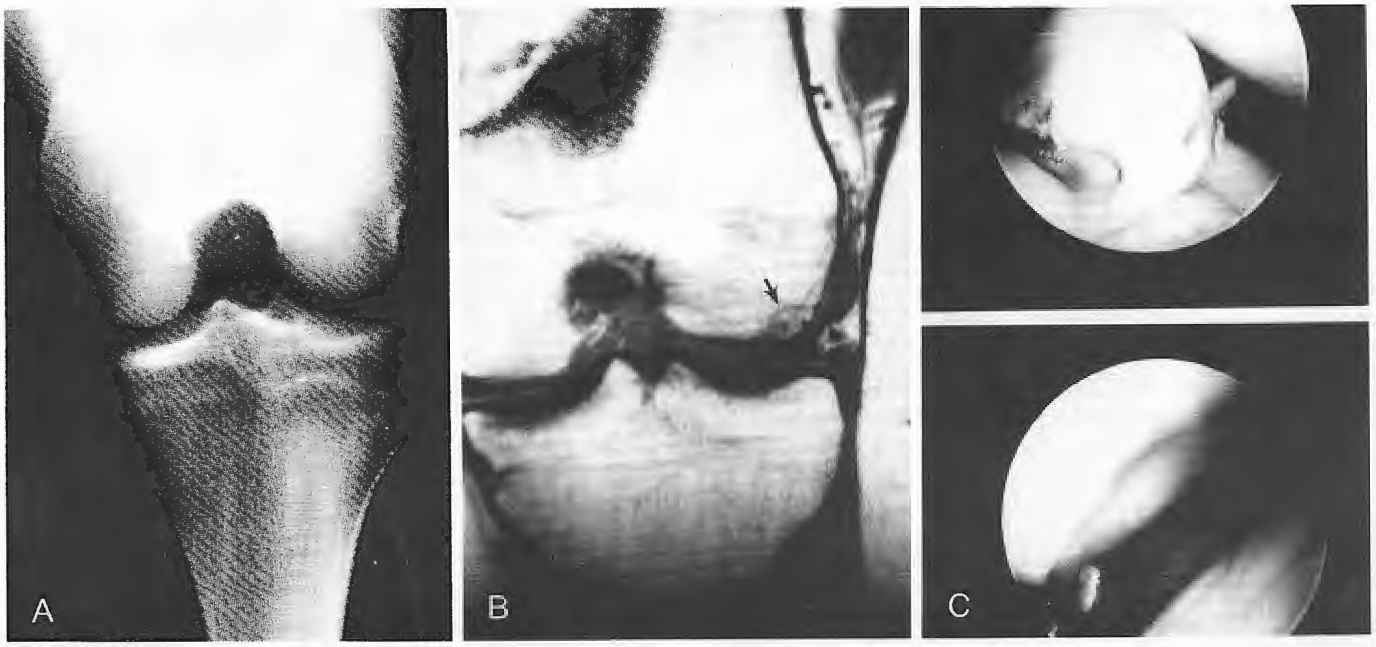


Figure 11.14 Female basketball athlete sustained an acute ACL tear. **(A)** The notch is A-shaped and narrow. **(B)** MRI scan shows on this AP view the narrowed notch and lack of signal in the notch consistent with an ACL tear. Osteochondral change in density of the lateral aspect of the femur is shown *(arrow)*. **(C)** Arthroscopic findings show mop end tear of the ACL *(top)* and probe pointing to osteochondral defect *(bottom)* seen on MRI view.

lucis longus. Pain in the posterior ankle is elicited by resistive testing of great toe plantar flexion. A cone lateral view before (Fig. 11.16*A*) and after (Fig. 11.16*B*) os trigonum excision is shown. Pain-free resumption of ballet activities was possible after surgery.

Tendon problems of the foot are common in females. Posterior tibial tendinitis is seen commonly in dance athletes with pes planus. Tendon problems are more common with the cavus foot. Accessory ossicles may be symptomatic at tendon insertions. This condition caused pain on eversion in this soccer athlete. A peroneus brevis accessory ossicle can be symptomatic. This os versalianum (Fig. 11.17), as shown preoperatively, required excision due to persistent pain.

Stress fractures should also be considered when evaluating soft tissue problems. In dance athletes, a second metatarsal stress fracture can occur at the Lisfranc joint (39).

A high ankle sprain was the working diagnosis in this basketball athlete who complained of continued pain. Radiographs revealed a fibula stress fracture, shown at diagnosis in Figure 11.18*A* and when healed four months later in Figure 11.18*B*.

Bunions (hallux valgus) are commonly encountered in the female athletes. Correction for cosmetic reasons should not be performed because a painful, although straight, great toe may result. Modification of the type of shoe worn is the mainstay of treatment (40). Severe clinical bunion abnormalities are commonly seen, but are usually asymptomatic. A Morton's foot with a short first metatarsal can result in a severe but painless hallux valgus, as in this dancer. (Fig. 11.19). Symptomatic stress fractures of the tibial (medial) sesamoid can mimic bunion pain. A work-up with plain films in this track athlete showed diffuse radiolucency on dorsiflexion sunrise sesamoid views (Fig. 11.20*A*). Increased activity on bone scan (Fig. 11.20*B*) confirmed the diagnosis.

Shoulder

With generalized laxity, sport dependent problems involving the shoulder occur. The vicious cycle of physiologic instability, rotator cuff weakness, pain, posterior tightness, and further imbalance results in persistent pain and dysfunction in overhead activities or in extremes of range of motion (Fig. 11.21). In younger females, joint laxity and decreased strength can cause shoulder problems. Restoration of normal range of motion and strength with proper sport biomechanics is the goal.

In swimmers, increasing joint distraction and repetitive microtrauma, "impingement syndrome," and pain are common (41). The exact diagnosis should be documented by noting the structure involved, severity, and acuteness. Treatment is strengthening, relative rest, and evaluation of biomechanics.

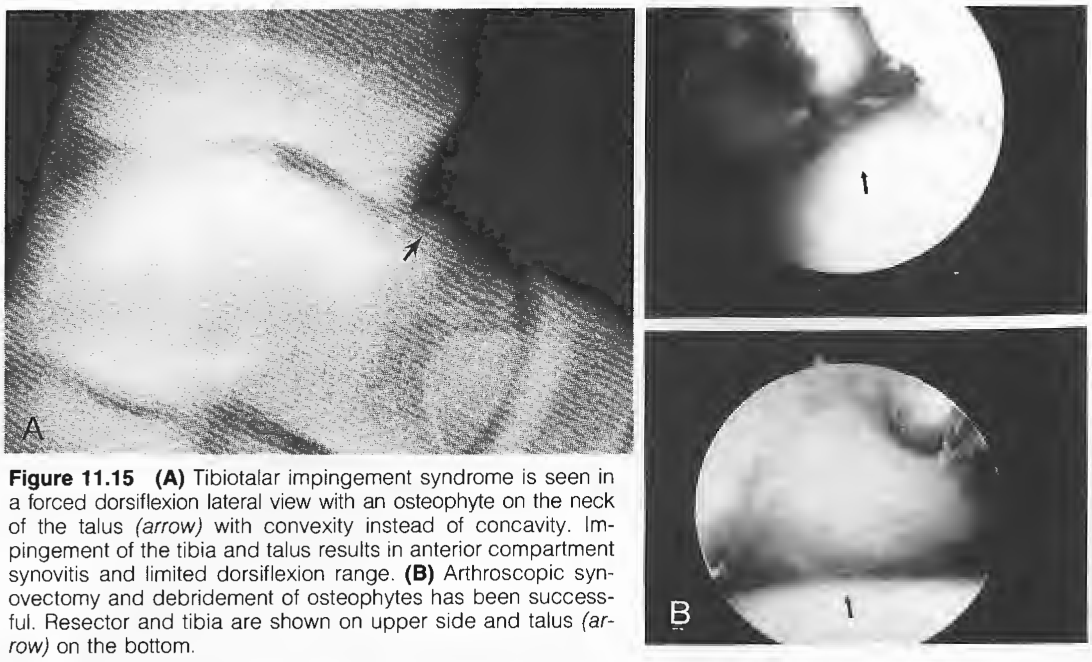


Figure 11.15 **(A)** Tibiotalar impingement syndrome is seen in a forced dorsiflexion lateral view with an osteophyte on the neck of the talus *(arrow)* with convexity instead of concavity. Impingement of the tibia and talus results in anterior compartment synovitis and limited dorsiflexion range. **(B)** Arthroscopic synovectomy and debridement of osteophytes has been successful. Resector and tibia are shown on upper side and talus *(arrow)* on the bottom.

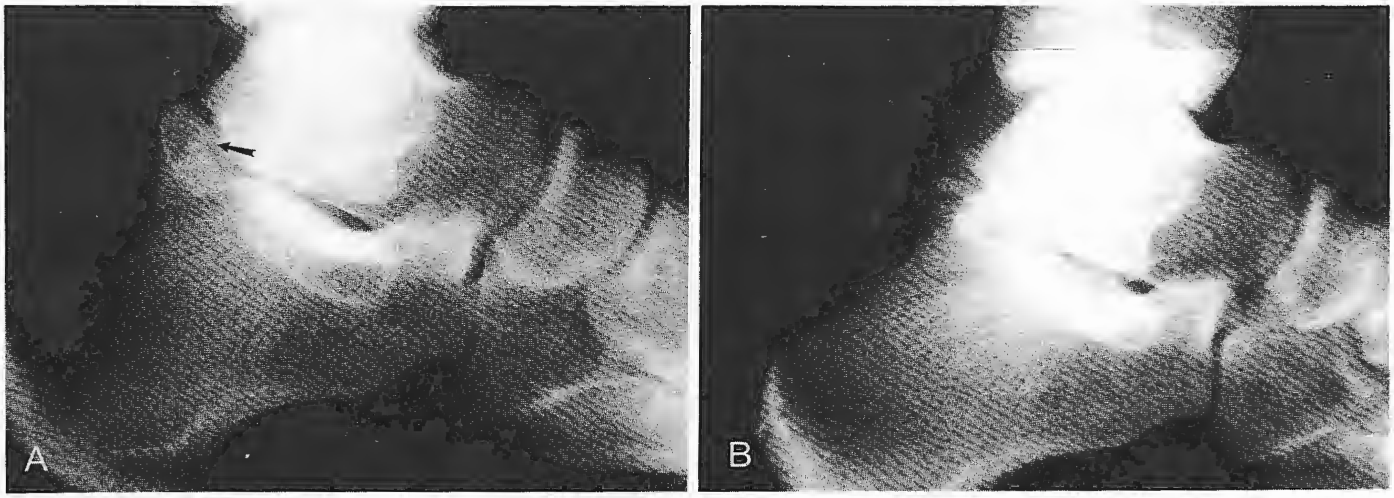


Figure 11.16 Ballet athletes who complain of posterior ankle and great toe pain can have a symptomatic os trigonum fracture. **(A)** A large os trigonum is seen in this ballet athlete who is having difficulty in doing repetitive en pointe maneuvers *(arrow)*. Nonunion and pressure on flexor hallucis longus result in posterior ankle pain and great toe flexion weakness. **(B)** Surgical excision of this lesion, as shown by postoperative lateral radiograph, resulted in a complete cure.

This synchronized swimmer with habitual posterior subluxation was able to compete at highly competitive levels. Note the prominent posterior contour with arm forward flexed and humeral head posteriorly subluxed (Fig. 11.22*A*). The patient smilingly feels the reduction as the examiner pushes forward (Fig. 11.22*B*). Associated generalized laxity and multidirectional instability are common. Operative results are inconsistent.

Figure 11.17 Symptomatic secondary ossification center at the base of the fifth metatarsal in this soccer athlete required excision. Os versalianum *(arrow)* was excised with uneventful return to full activities.

In competitive diving, the forces involving axial loading on water entry and extreme ranges of motion during the gymnastic portion of diving maneuvers result in combined rotator cuff and instability problems. Use of the shoulder as a weight bearing joint can lead to long-term dysfunction. In gymnastics, the shoulder is commonly injured (6, 9, 42). Sport specific strengthening program may prevent significant injuries.

Elbow

The female has an increased valgus carrying angle and ligamentous laxity compared to the male. Due to the increased lateral pressures and less upper extremity strength, repetitive axial loading activities are common.

Osteochondritis dissecans with resultant loose body formation should be considered in axial loading sports. This fourteen-year-old gymnast complained of locking of her elbow. Lateral plain radiograph (Fig. 11.23*A*) and CT scan (Fig. 39.23*B*) confirmed two osteocartilaginous loose bodies in the anterior compartment. Arthroscopic removal of loose bodies (Fig. 11.23*C*) fragments and debridement of the capitellum allowed return to her sport. The largest loose body is shown at time of arthroscopic removal (Fig. 11.23*D*). Posterior compartment loose bodies may also occur. Two large osteochondral fragments are well seen by plain radiographs (Fig. 11.24*A*) and CT scan (Fig. 11.24*B*). An elbow arthroscopy and loose body removal by small arthrotomy of the posterior compartment were done. Resolution of pain, return of full extension, and resumption of gymnastics were possible in this case.

Severe injuries can occur in cheerleading. This young female sustained an elbow dislocation when she landed

Figure 11.18 Fibula stress fractures can also cause problems with ankle pain as shown in this basketball athlete who had been having pain for several months. **(A)** A stress fracture of the fibula *(arrow)* is seen well above the ankle; this was confused for a high ankle sprain 4 months following a decrease in her activities. **(B)** Fibula fracture is asymptomatic clinically and healed radiographically.

Figure 11.19 Bunions or hallux valgus are quite common in females, especially dance athletes. Standing AP views of both feet show hallux valgus, lateral subluxation of great toe and sesamoids, and short first metatarsal.

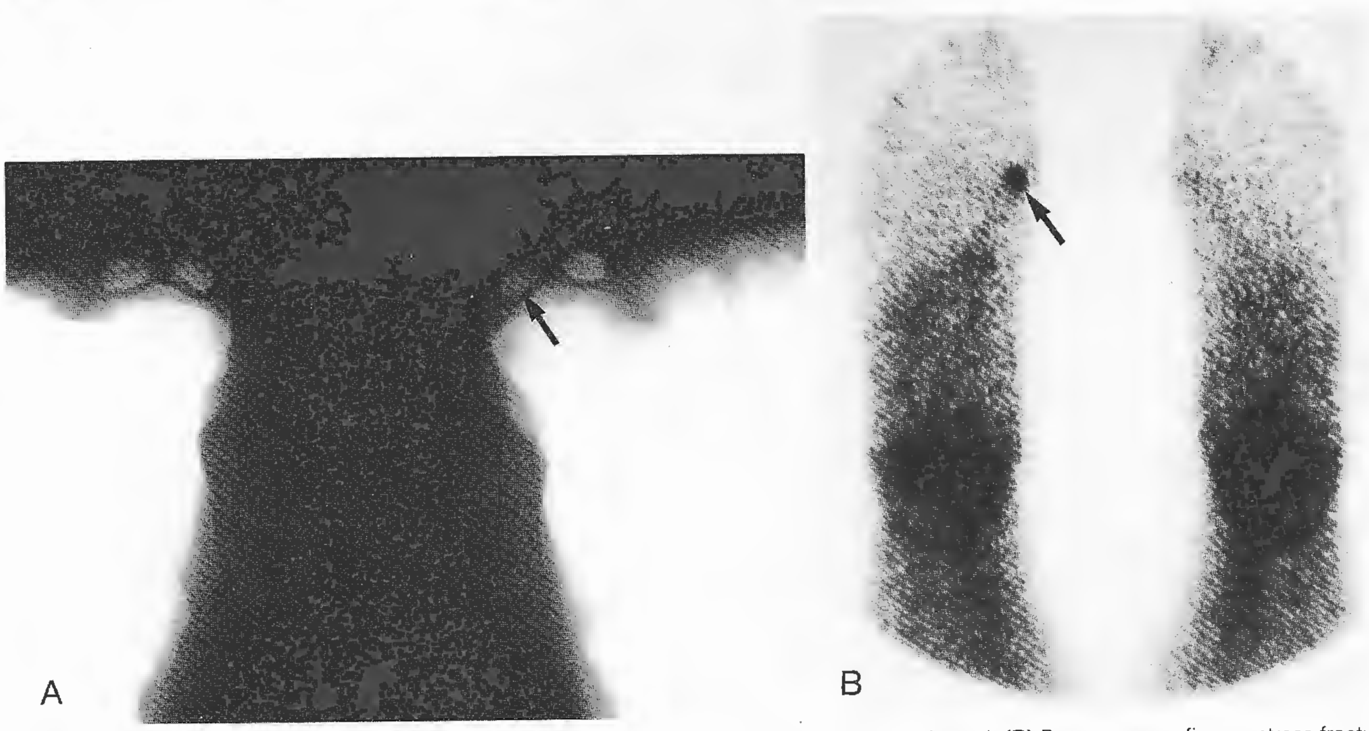


Figure 11.20 In runners, great toe pain, especially with pain on the plantar aspect, can be a sesamoid fracture. **(A)** Sunrise views show radiolucency of tibial *(medial)* sesamoid compared to fibular sesamoid *(lateral)* on right foot *(arrow)*. **(B)** Bone scan confirms a stress fracture of the sesamoid left foot. This was treated with padding, avoidance of running; healing occurred at 8 months clinically.

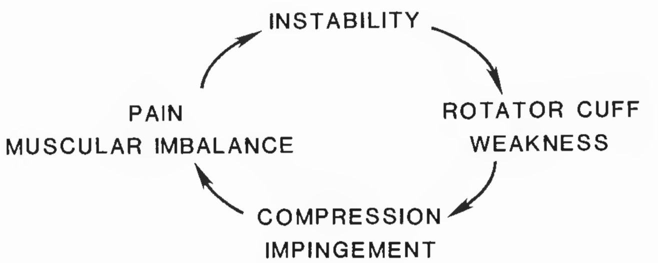


Figure 11.21 Vicious cycle of shoulder pain occurs especially in females when there is a physiologic instability that may be multi-directional, with rotator cuff weakness, subsequent pain, posterior tightness, and further weakness, and muscular imbalance.

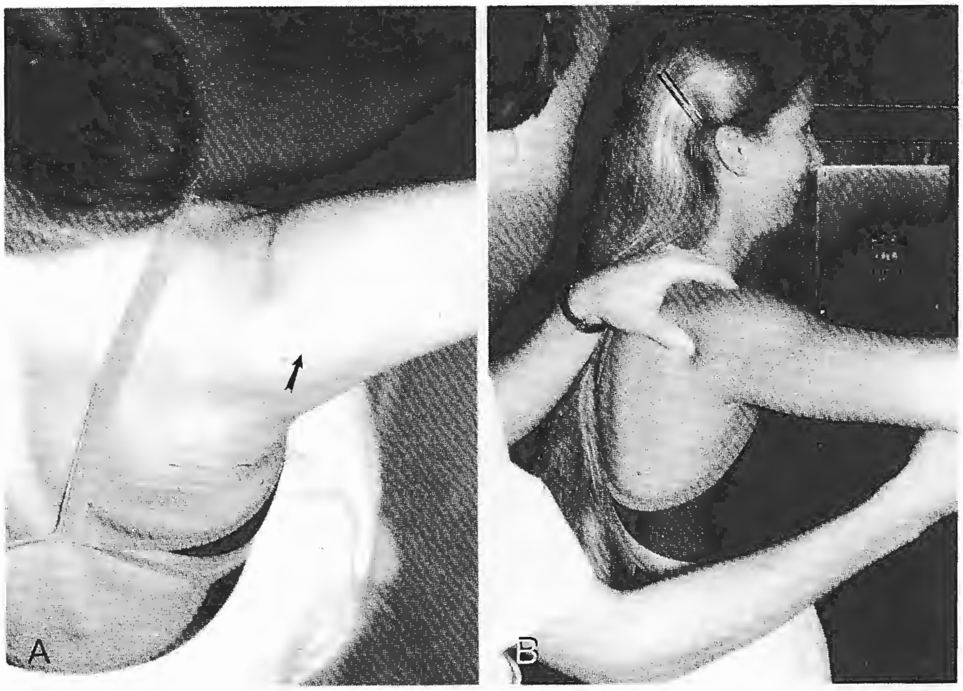


Figure 11.22 (A) This synchronized swimmer shows habitual posterior subluxation. She can voluntarily sublux posteriorly by moving arm anterior to axis of body and internally rotating. Notice the prominence of the subluxed posterior humeral head *(arrow)*. **(B)** Patient's dislocation is easily and painlessly reduced by posteriorly moving the arm and placing direct pressure by the examiner's thumb on the now reduced humeral head.

short from a double-back stunt. Attempted reduction by personnel at practice was not successful. AP and lateral elbow radiographs showed a posterolateral dislocation (Fig. 11.25*A*). A physical exam revealed absent radial pulse and pain, an ecchymotic area medially, and severe elbow swelling (Fig. 11.25*B*). Emergency arteriogram (Fig. 11.25*C*) showed absent filling of the brachial artery, although collateral filling was present. The hand was viable. Surgical exploration revealed an entrapped brachial artery. A cephalic vein patch to the brachial artery was required to restore normal vascularity.

Stress Fractures

In the military population, stress fractures were found to be more common in female cadets compared to males (25). The association of menstrual irregularity and stress fractures in collegiate female distance runners has been established (43). Several series report increased incidence of stress fractures in females (44–48). The association of stress fractures with low bone density, amenorrhea, and poor nutrition has been established (23, 33, 34). The association of nutritional habits and the incidence of stress fractures in ballet dancers was reviewed (49). Specific health concerns of female runners has been addressed (23, 50).

A detailed nutritional and gynecologic history must be obtained. Reviews of treatment by diet modification and hormonal replacement offer excellent guidelines (1, 3, 23, 51).

First Rib

First rib fractures are most commonly associated with major trauma. Stress fractures of the first rib have been reported in female rowers (52). In this ballet athlete, a delayed union (Fig. 11.26) occurred. The only mechanism of injury was repetitive lifting by her partner. Treatment was directed toward improvement of the dancer's nutrition and her hormonal status with avoidance of the specific lifting maneuvers that led to the injury. Resumption of full activities occurred at eight months following injury.

Wrist Injuries

Distal Radius Epiphyseal Fractures. Young gymnasts have been reported to have stress changes of the distal epiphysis (53). Repetitive axial compression forces on the distal radius can cause epiphyseal reactions or fracture. A Salter I distal radius occurred in the right wrist (Fig. 11.27*B*) in this gymnast. The normal distal radius epiphyseal plate is shown in comparison view on the left (Fig. 11.27*A*). This Salter type I fracture healed uneventfully. However, radial growth arrest with subsequent ulnar overgrowth can occur. Clinical and radiographic exams should be done until skeletal maturity is reached.

Even in the skeletally immature, navicular fractures occur. This gymnast complained of right wrist pain for three weeks. She had tenderness in the anatomic snuffbox, not distal radial. Radiographs showed a midwaist navicular fracture (Fig. 11.28).

This collegiate gymnast complained of wrist pain for three months. A work-up with normal plain views marked at the area of maximal tenderness (Fig. 11.29*A*), tomograms (Fig. 11.29*B*), and a bone scan (Fig. 11.29*C*) made the diagnosis of distal radius stress fracture with localized cyst. Successful treatment included dorsal taping blocking full dorsiflexion and relative rest.

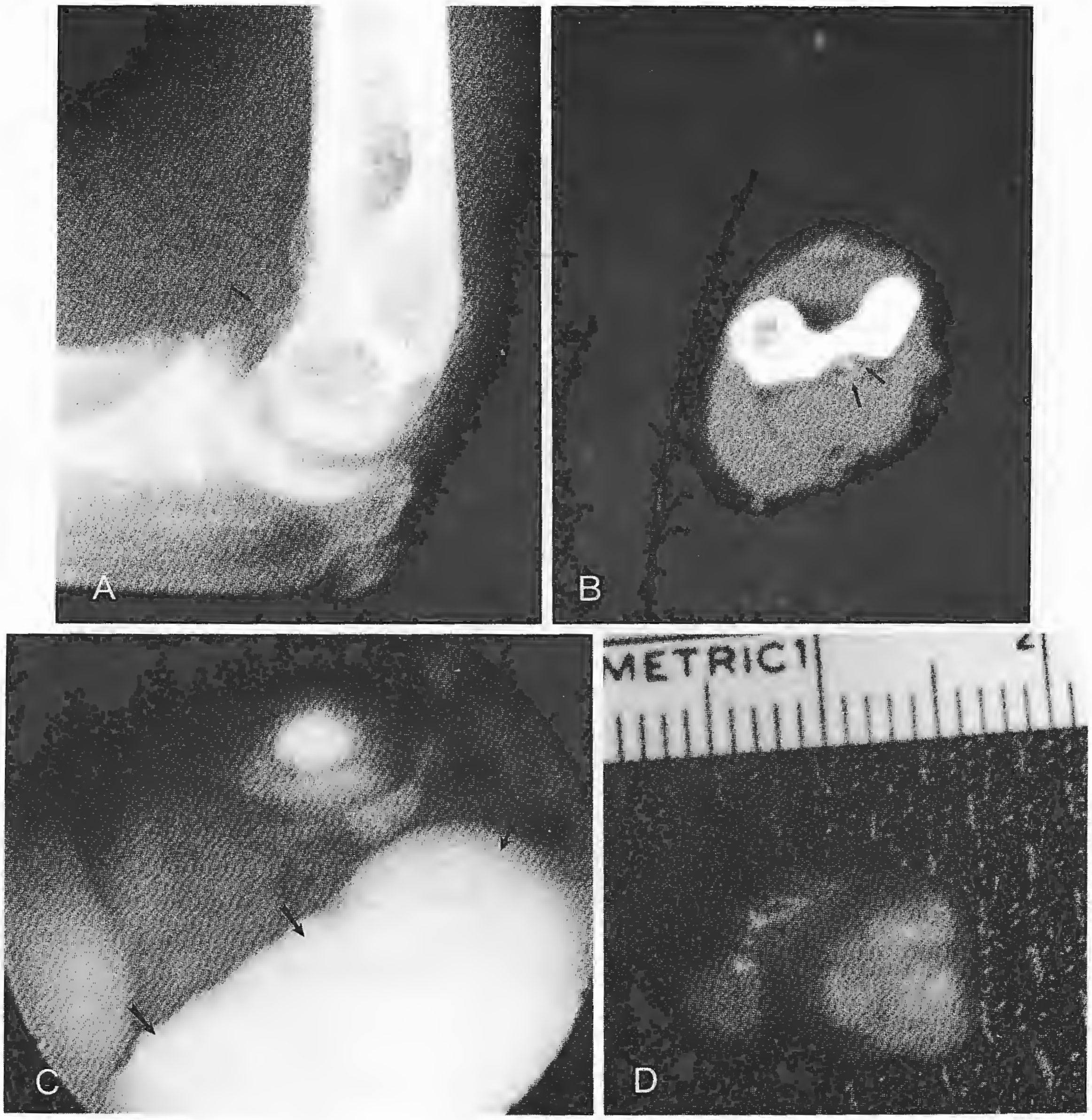


Figure 11.23 Fourteen-year-old gymnast complained of locking of her elbow. **(A)** Lateral plain radiographs show a large radiolucency in the anterior compartment. AP and oblique views did not show any significant area of osteochondral fracture. There was some flattening of the capitellum consistent with an osteochondritis dissecans. **(B)** A CT scan confirmed two osteocartilaginous loose bodies in the anterior compartment *(arrows)*. **(C)** Anterior loose body *(arrows)* is seen at time of arthroscopy. Anterior capsule and motorized resector are at the top. Arthroscopic removal of the loose bodies was successful. **(D)** Largest loose body is shown measuring 1.5 × 1.2 × 1.5 cm.

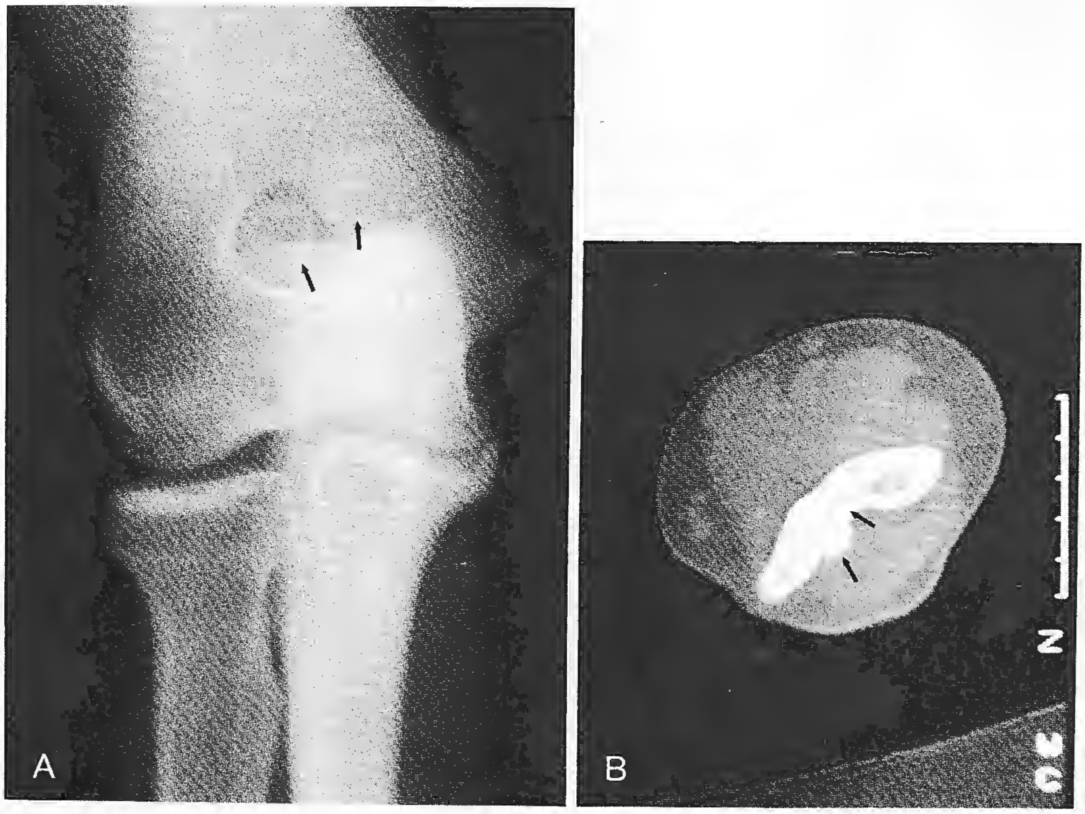


Figure 11.24 A collegiate gymnast complained of pain in her elbow posteriorly, when doing axial loading activities. She had a 10° flexion contracture and pain on bounce home passive extension testing. **(A)** AP radiographs of the elbow showed two large loose bodies in the posterior compartment *(arrows)*. **(B)** The location, size, and number of these were confirmed by CT scan showing the two large loose bodies in the posterior compartment of the olecranon fossa *(arrows)*. Arthroscopy and miniarthrotomy posteriorly resulted in full and painless range of motion.

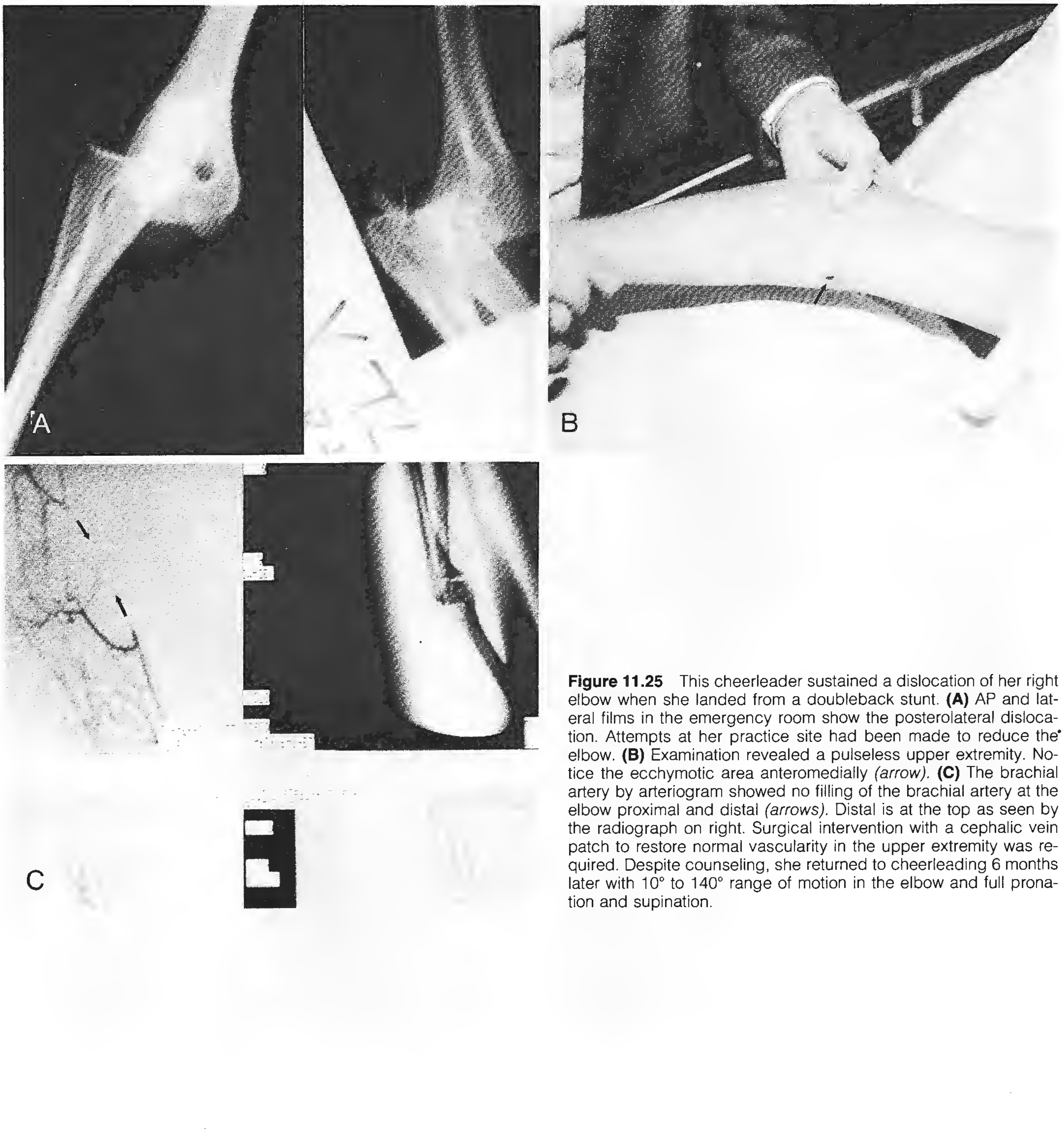


Figure 11.25 This cheerleader sustained a dislocation of her right elbow when she landed from a doubleback stunt. **(A)** AP and lateral films in the emergency room show the posterolateral dislocation. Attempts at her practice site had been made to reduce the elbow. **(B)** Examination revealed a pulseless upper extremity. Notice the ecchymotic area anteromedially *(arrow)*. **(C)** The brachial artery by arteriogram showed no filling of the brachial artery at the elbow proximal and distal *(arrows)*. Distal is at the top as seen by the radiograph on right. Surgical intervention with a cephalic vein patch to restore normal vascularity in the upper extremity was required. Despite counseling, she returned to cheerleading 6 months later with 10° to 140° range of motion in the elbow and full pronation and supination.

Figure 11.26 A ballet athlete sustained a left first rib fracture that went on to a delayed union. Notice the rounded edges of the proximal fragment *(arrow)*.

Figure 11.27 **(A)** A normal undulating epiphyseal plate on comparison view of the left wrist and **(B)** a widened epiphyseal plate on the right. This is a Salter I fracture of the distal radius in this gymnast.

Figure 11.28 Acute midwaist navicular fracture is seen in this skeletally immature right wrist of a gymnast *(arrow).*

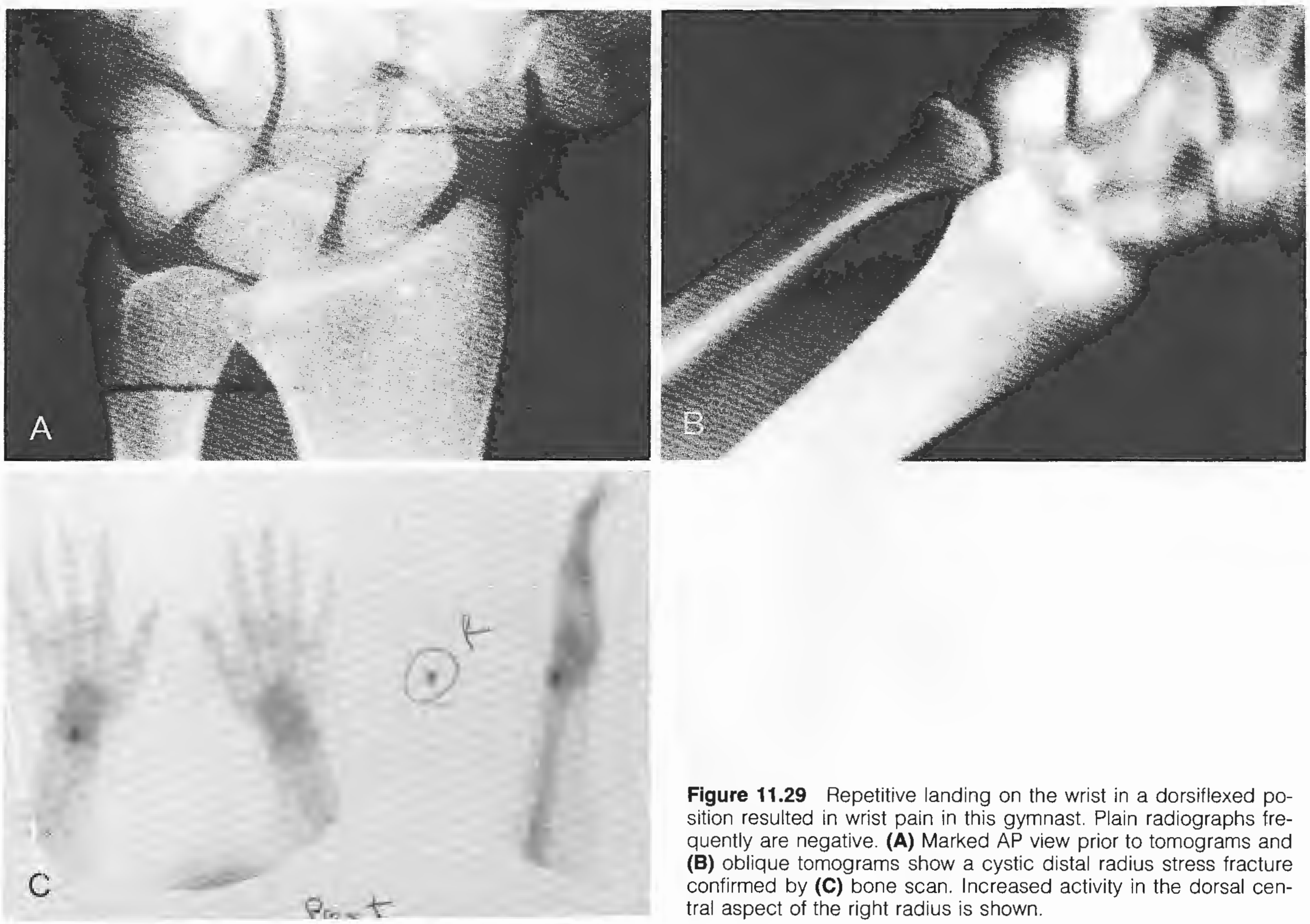


Figure 11.29 Repetitive landing on the wrist in a dorsiflexed position resulted in wrist pain in this gymnast. Plain radiographs frequently are negative. **(A)** Marked AP view prior to tomograms and **(B)** oblique tomograms show a cystic distal radius stress fracture confirmed by **(C)** bone scan. Increased activity in the dorsal central aspect of the right radius is shown.

Femoral Neck

There should be a high index of suspicion for fracture in track athletes with persistent groin pain. Iliopsoas or adductor strain could really be a femoral neck stress fracture. This middle distance and cross country track athlete complained of left hip pain for one month. She was amenorrheic and did not eat meat or drink milk. AP and lateral radiographs showed cortical reaction of the inferior (Fig. 11.30) and posterior (Fig. 11.30) femoral neck. An initial bone scan showed increased activity (Fig. 11.30). This compression side fracture was treated conservatively with nonweight bearing, swimming, nutritional counseling, and oral contraceptives. The fractures healed in six months clinically and radiographically as shown on AP view (Fig. 11.31). On the compression side, femoral neck stress fractures can be treated nonoperatively. If the fracture is on the superior or tensile side, percutaneous pinning before fracture displacement is recommended.

Tibial Fracture

The tibia is a common site for stress fractures. Use of marked views over the area of maximal tenderness to look for periosteal reactions is helpful. If plain films

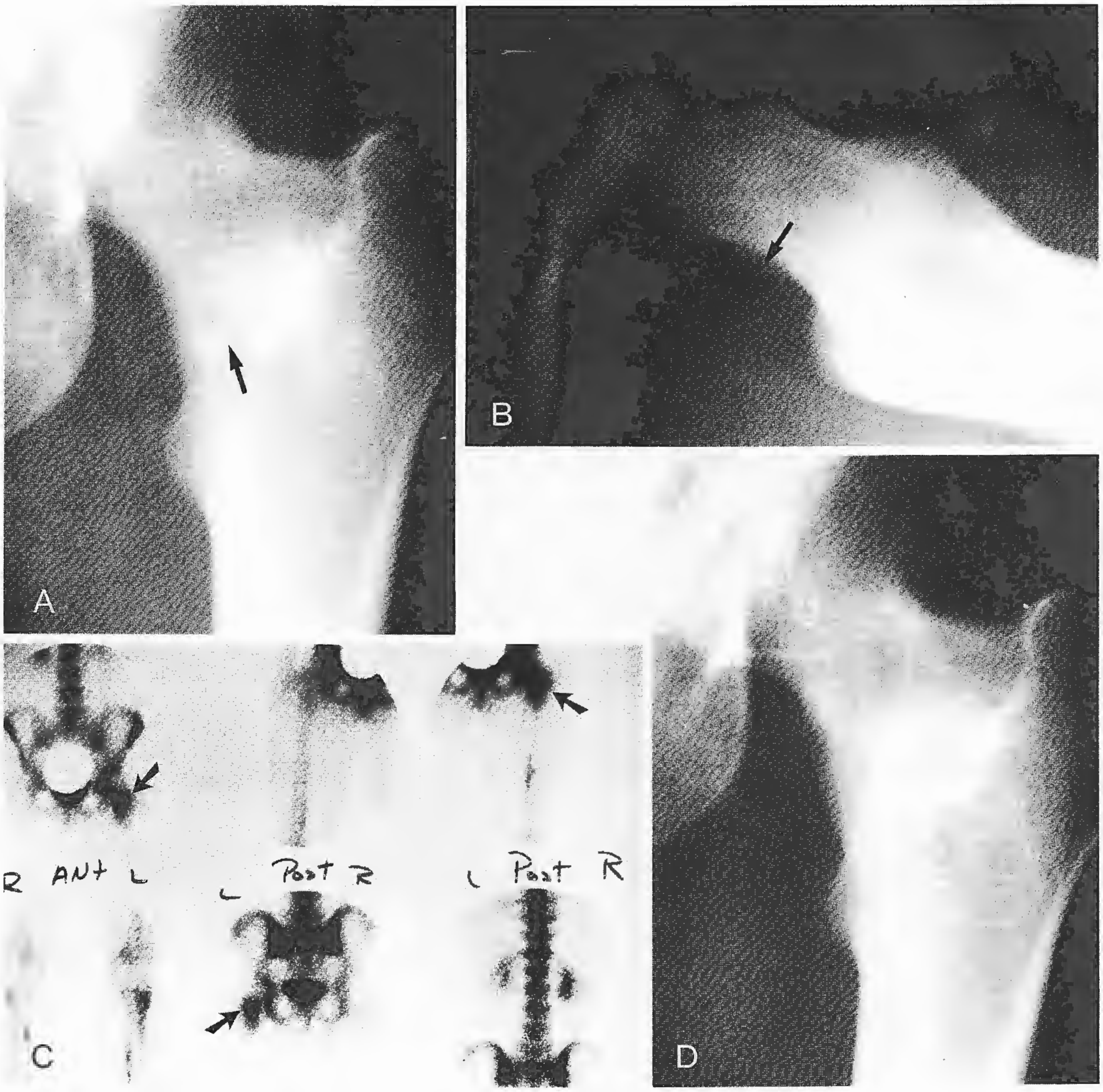


Figure 11.30 A collegiate middle distance and cross country track athlete had pain in her left hip for 1 month. Plain radiographs showed **(A)** an AP view with thickened medial cortex and radiolucency *(arrow)* and **(B)** a lateral view with periosteal reaction posteriorly *(arrow)*. The stress fracture on the compression side inferiorly can be treated nonoperatively. Tension or superior femoral neck fractures should be more aggressively treated with pinning prior to displacement. **(C)** A bone scan showed significant increase in activity in the inferior neck *(arrows)*. **(D)** Follow-up radiographs 6 months following documentation of the fracture showed femoral neck periosteal reaction.

Figure 11.31 Tibial stress fractures are common at the proximal midthird junction and distal third junction. If plain radiographs are negative, a bone scan is helpful. Intensely increased activity of the medial proximal midthird junction is seen. Plain and marked views at area of maximal tenderness were negative in this soccer athlete.

are negative, a bone scan will confirm the diagnosis, as in this soccer athlete with midproximal third junction tibial stress fracture (Fig. 11.31) who had had normal radiographs.

The midthird anterior cortex stress fractures is important to recognize. Clinically, point tenderness and anterior tibial bow suggest this unique stress fracture. Plain radiographs of AP (Fig. 11.32*A*), lateral (Fig. 11.32*B*), and cone-marked lateral view at point of maximum tenderness (Fig. 11.32*C*) confirm the diagnosis. This is commonly seen in basketball athletes with varus and anterior bow of the tibia. Conservative management usually results in healing, as in this patient after six months. However, electrical stimulation or operative management has also been suggested (54).

Fibular Fractures

Repetitive loading such as tumbling, floor routines, cheerleading, and gymnastic maneuvers may result in fibular stress fractures. Pain localization to the lateral fibula and radiographs showing significant increased cortical thickness and a very small medullary cavity are the usual findings in athletes with fibular stress fractures. Tibiofibular views with the marker at the area of maximal tenderness suggest a fracture (Fig. 11.33*A*). Note the prior, now asymptomatic, healed fibular stress fracture just proximal to marked level in this collegiate cheerleader. A bone scan revealed intensely increased activity at the level of maximal tenderness (Fig. 11.33*B*). Successful treatment included compressive support and avoidance of tumbling activities for three months.

Metatarsal Fractures

The most common metatarsal stress fracture is the second, followed by the third. This track athlete was seen after callus formation was present on plain radiographs (Fig. 11.34). With localized swelling and tenderness over the diaphysis and callus on plain radiographs, the diagnosis was easily established.

Back Conditions and Fractures

Scoliosis

Scoliosis is more common in females than males. This skeletally immature eleven-year-old cheerleader has a 20° typical right thoracic curve with apex at thoracic level 8 shown on posteroanterior (PA) view (Fig. 11.35*A*). The lateral view (Fig. 11.35*B*) shows no thoracic kyphosis associated with flat back appearance. This cheerleader demonstrates a more acute 21° left upper lumbar curve on this PA view with apex at lumbar level 1 (Fig. 11.36).

Spondylolysis

Repetitive flexion extension activities result in stress fractures of the pars interarticularis or spondylolysis. The work-up of persistent back pain and a positive hyperextension test should include radiographs of AP, standing lateral, and obliques. The radiolucent defect in the pars interarticularis is best seen on oblique view (Fig. 11.37*A*). Increased activity on oblique view bone scan at the third lumbar level confirms the diagnosis of spondylolysis (Fig. 11.37*B*). Acquired spondylolysis will not progress to spondylolisthesis. In these athletes, spondylolysis and sciatica can occur simultaneously in a single patient. If there is nonunion of the pars interarticularis, posterior spinal fusion successfully eliminates pain. (Micheli LJ, personal communication 1984).

Spondylolisthesis

Standing lateral views are necessary to assess posterior spinal stability for spondylolisthesis. This colle-

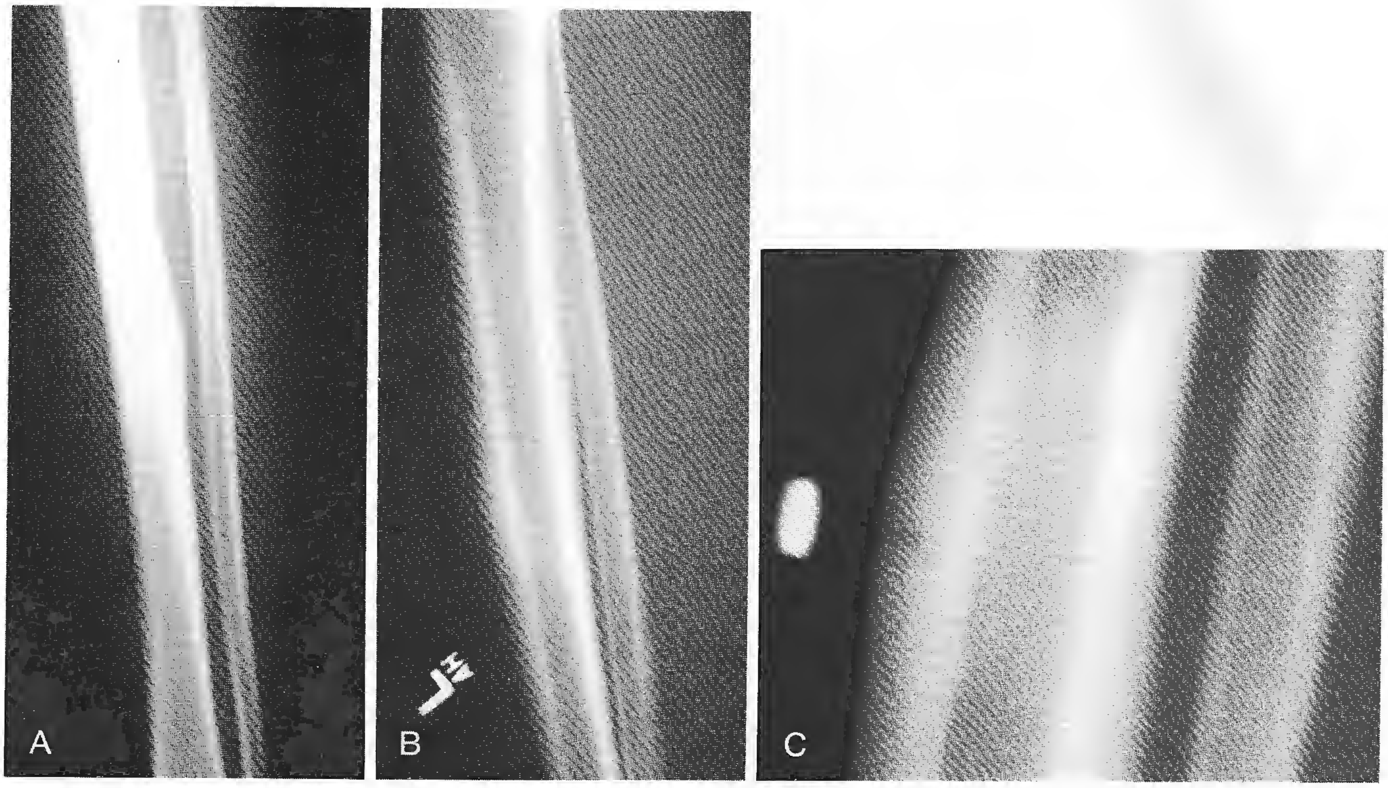


Figure 11.32 This female basketball athlete sustained a stress fracture in the midthird anterior cortex of the left tibia. **(A)** AP and **(B)** lateral view show the healing fracture now four months after onset of symptoms. **(C)** A metallic marker on lateral view at point of maximum tenderness helps confirm that the radiolucency seen is at the level of patient's pain. Conservative management in this patient resulted in complete healing.

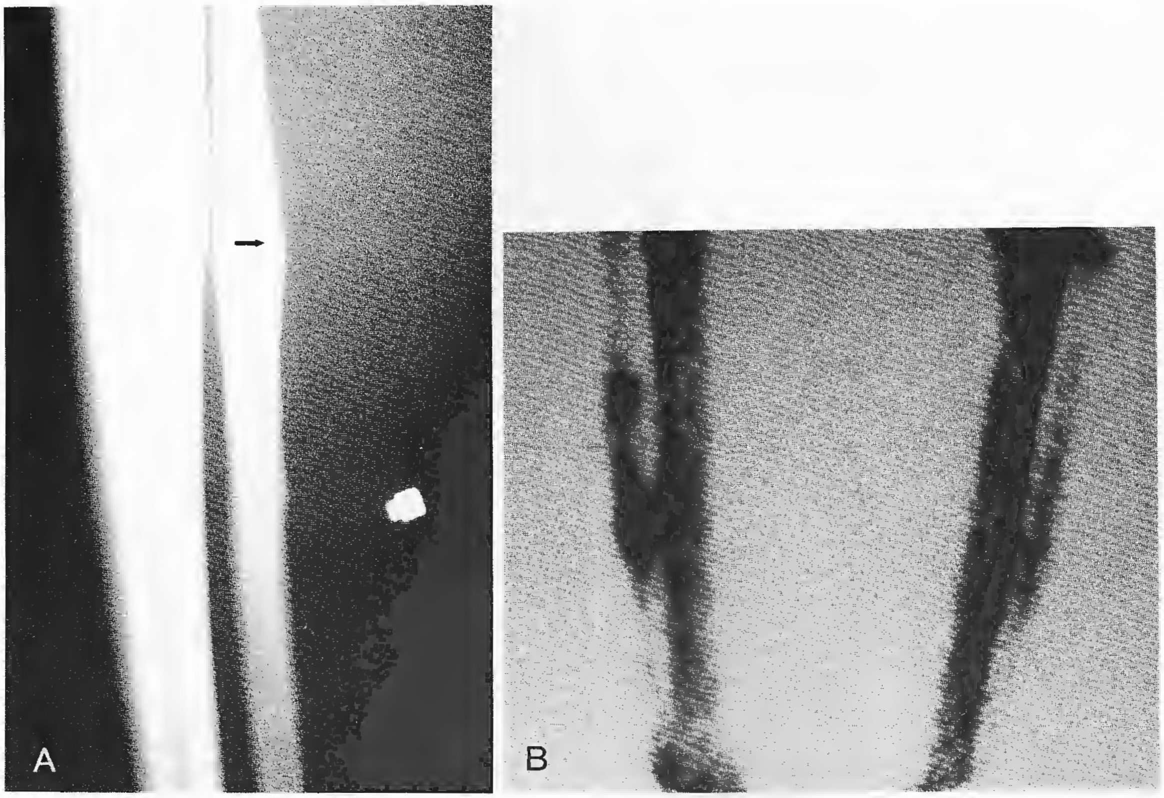


Figure 11.33 This collegiate cheerleader was evaluated for pain in the lateral calf. **(A)** A marked view revealed periosteal reaction at the midthird of the fibula. Notice the periosteal reaction just superior to level of symptoms *(arrow)*. The patient had a documented stress fracture of the fibula at this level 6 months prior to her new onset of symptoms. Notice the narrow intramedullary cavity. **(B)** A bone scan showed increased activity more intensely at the distal fracture level shown on the left as compared with the normal lower extremity on the right.

Figure 11.34 A callus is seen in this healing second metatarsal stress fracture in a female track athlete. On plain films, radiolucency of the fracture line *(arrow)* can be seen with abundant callus, which was palpable and painful over the second metatarsal diaphysis.

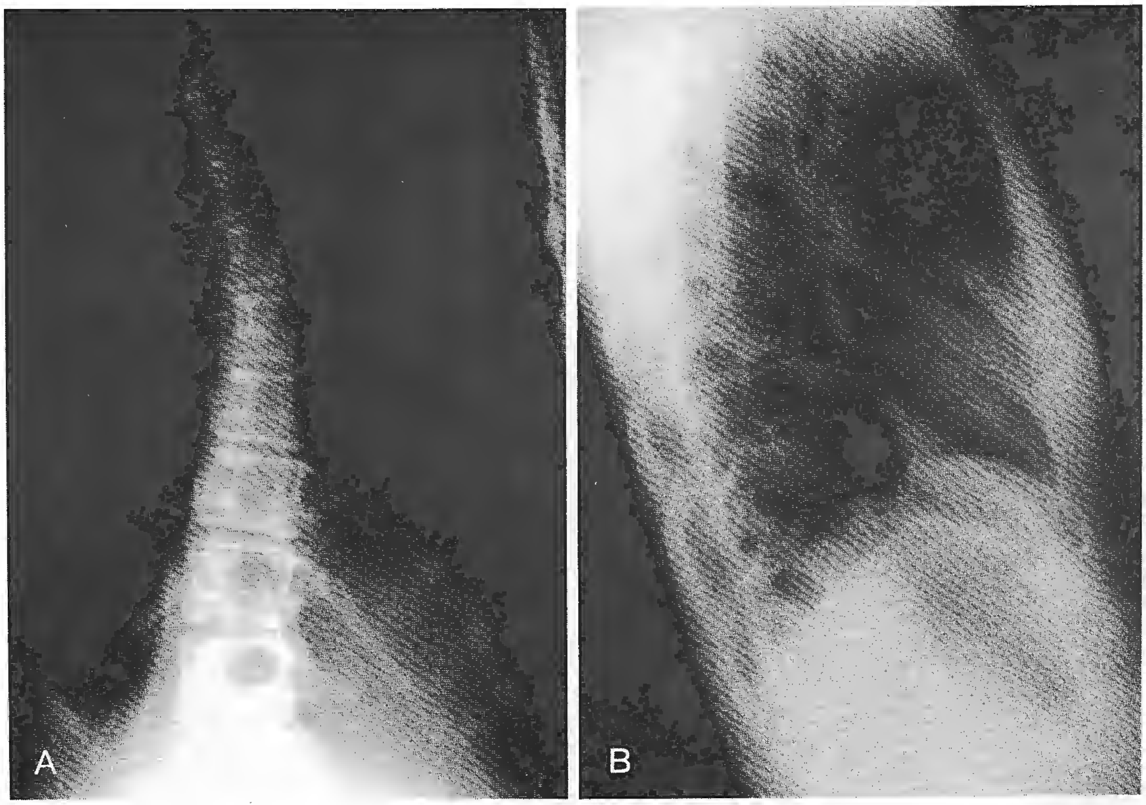


Figure 11.35 **(A)** Standing PA and **(B)** lateral views show a typical right 20° thoracic curve with apex at thoracic L-8 and no thoracic kyphosis in a skeletally immature 11-year-old basketball athlete.

Figure 11.36 This cheerleader demonstrates a more unusual left upper lumbar curve measuring 21° with apex at L1.

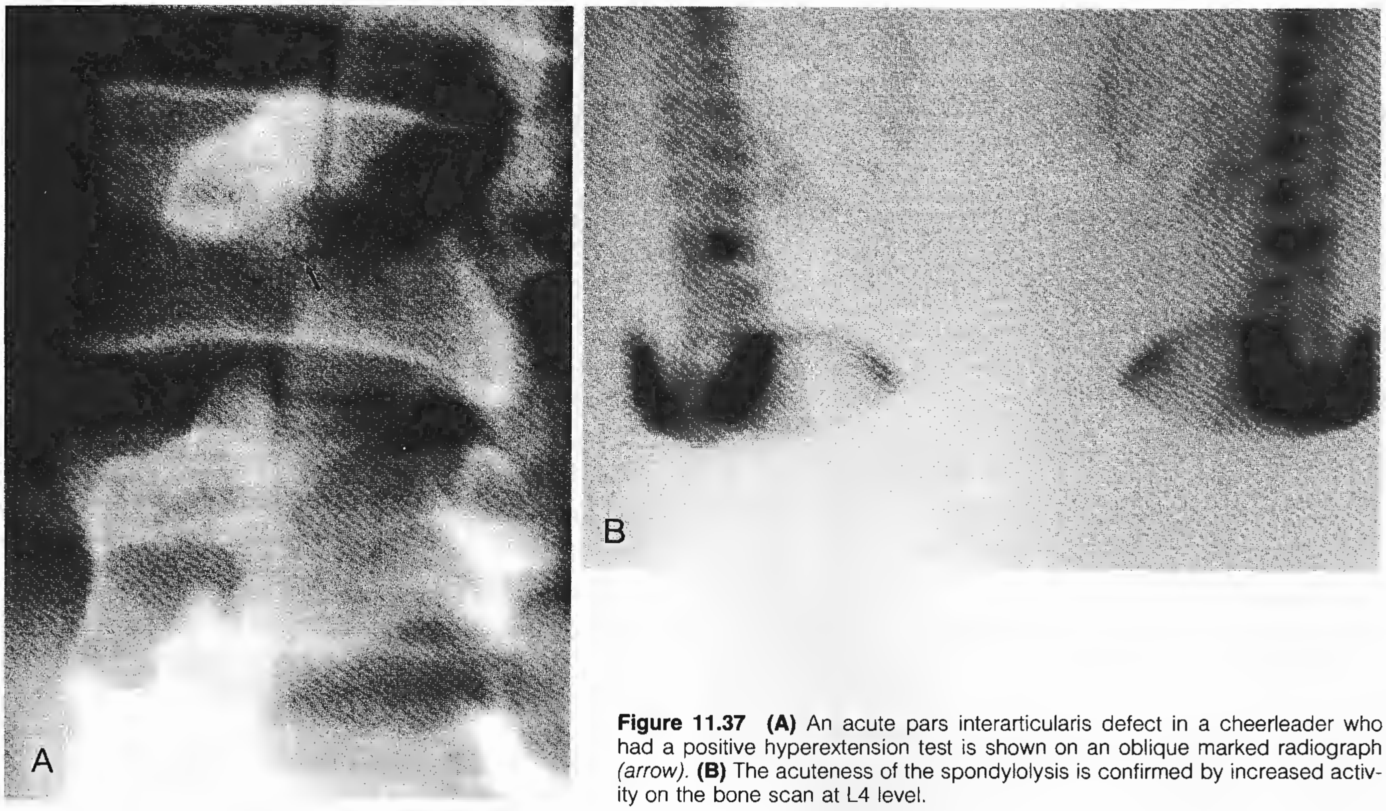


Figure 11.37 **(A)** An acute pars interarticularis defect in a cheerleader who had a positive hyperextension test is shown on an oblique marked radiograph *(arrow)*. **(B)** The acuteness of the spondylolysis is confirmed by increased activity on the bone scan at L4 level.

giate gymnast had a five-year history of occasional back pain. Standing lateral view showed L5-S1 grade IV spondylolisthesis, indicated by dotted lines (Fig. 11.38*A*). Oblique views showed two old radiolucencies in the pars interarticularis at L5 (Fig. 11.38*B*). This gymnast had previous back problems but none at the time of presentation. Her complaints were limited to lateral calf pain. A bone scan showed increased activity in fibula (Fig. 11.38*C*) but no increased activity in the lumbar spine (Fig. 11.38*D*).

Spondylolysis at different levels from a spondylolisthesis may also occur. In this cheerleader, an acute spondylolysis is shown in this oblique marked view (Fig. 11.39*A*). A bone scan showed increased activity at the marked level of pain but not at L5-S1 level. An old grade I spondylolisthesis is shown two levels lower than her level of pain (Fig. 11.39*B*).

Other Fractures

A vertebral body fracture at L5 occurred when this collegiate gymnast fell in a hyperflexed position from the top of the uneven parallel bars. A cone view better shows the fracture, which showed increased activity by bone scan (Fig. 11.40*A*). Anatomic variants or a limbus vertebra may look similar. Bone scan is helpful to establish the diagnosis and better counsel the athlete on the timing of a return to sport. A standing lateral view showed marked lordosis one month after injury (Fig. 11.40*B*).

Pedicle stress fracture has been reported in a ballet athlete (55) and documented by computed tomography (CT) scan (Fig. 11.41*A*). Lateral views showed radiolucency in posterior elements. The CT scan confirmed this diagnosis (Fig. 11.41*B*).

Psychologic

Young female participants in athletics improve self-confidence and overall performance, and enhancement of confidence with positive reinforcement is possible when females actively engage in sports (23, 56, 57). Young women who understand their motives for being involved in sports relate rewarding experiences. However, when maturity occurs, these goals may change and priorities are modified in some female athletes (56). Participating and excelling in athletics can be used as a springboard for dealing with stresses, competition, and challenges in both professional and personal spheres of life (32).

Nutrition

Adequate nutrition is of paramount importance for the athlete's health and successful performance. Reviews of nutritional concerns in the adolescent female (58) and older athlete (59) have been addressed. Particularly in the female athlete, diets are often imbalanced or contain inadequate nutritional components (23, 60–62). Studies comparing males and females in similar sports have emphasized major differences in caloric intake and diet type. Collegiate basketball players were compared, showing that males had twice the caloric intake. Nutritional supplements had a significant effect

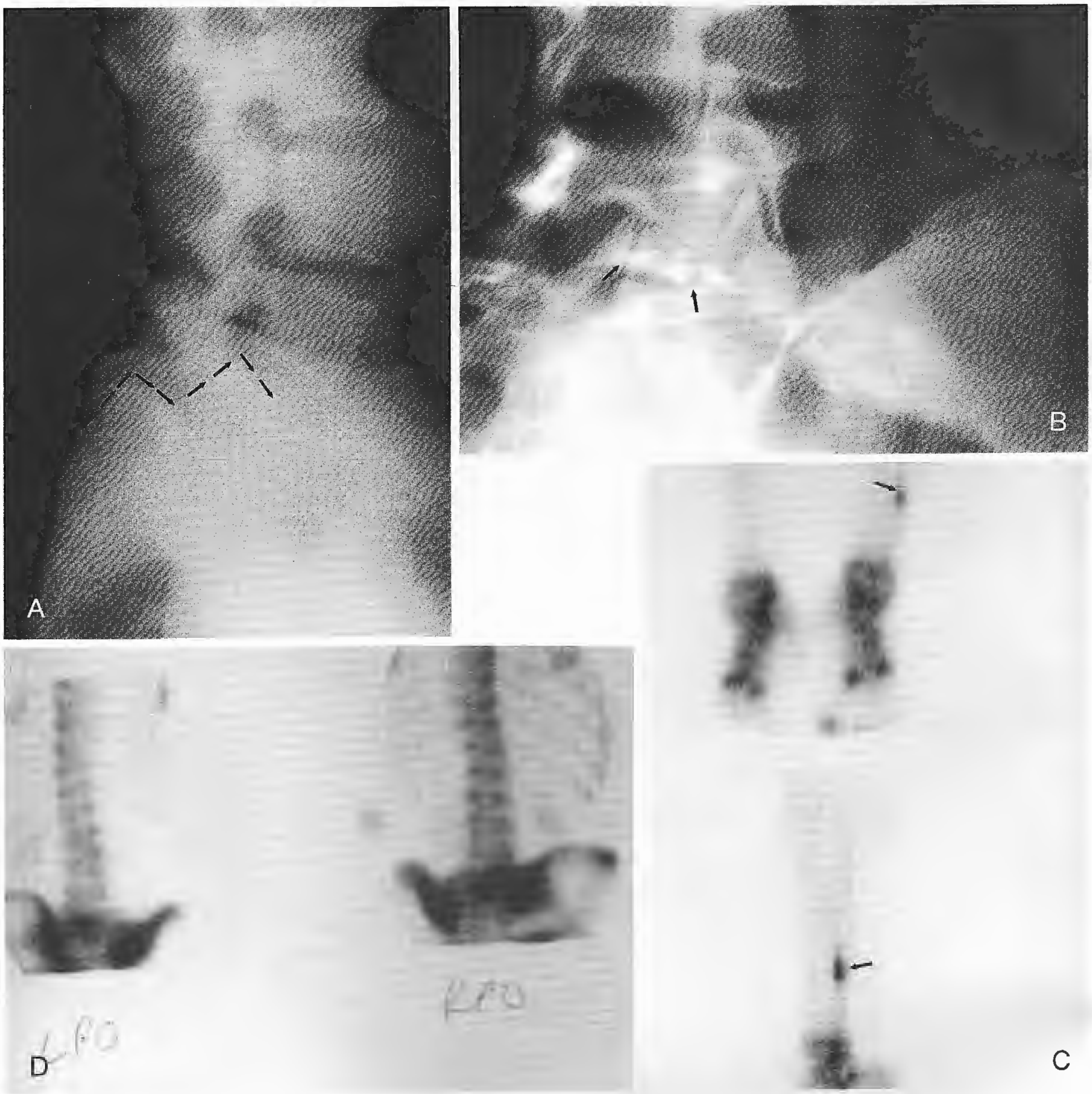


Figure 11.38 Standing lateral views are necessary to assess posterior spinal stability. **(A)** Standing lateral view of this collegiate level gymnast shows a grade IV spondylolysis L5-S1 level *(linear arrows)*. **(B)** Oblique view shows two levels of pars defect at the L5 level *(arrows)*. Patient was evaluated for pain in her fibula. She mentioned prior history of back problems and lateral radiograph was obtained. The patient was disqualified from continued collegiate competition due to subsequent low back pain and neurologic complaints. **(C)** The bone scan shows increased activity in the fibula consistent with a stress fracture *(arrows)* and **(D)** no increase in activity in the lumbar spine.

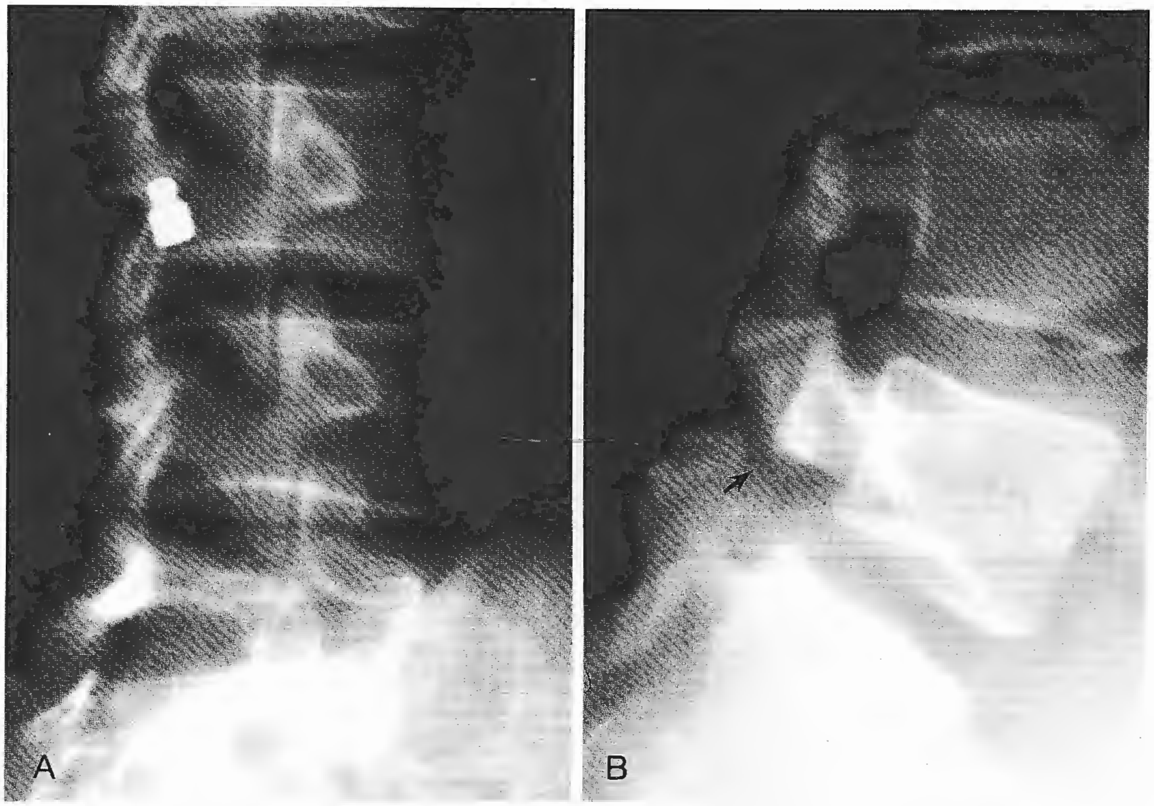


Figure 11.39 An old spondylolisthesis can be seen at a different level from an acute spondylolysis. **(A)** A marked oblique view at the level of pain is two levels above an old symptomatic grade I L5–S1 spondylolisthesis seen on **(B)** lateral view level. Note the radiolucency of posterior elements L5—S1 without significant slippage *(arrows).*

on the total nutrient intake in the women (60). Compared to males, female skiers and marathoners consume fewer calories and have less intake of vitamins, proteins, and carbohydrates (63).

Poor diet can result in deficiency in the intake of carbohydrates, iron, calcium, zinc. Low calcium intake is associated with low bone density, stress fractures, and subsequent problems with osteoporosis (63, 64). Carbohydrate deficiency can result in glycogen depletion and increased onset of muscular fatigue. Zinc deficiency can result in increased injuries from microtrauma as well as changes in immune function. Iron deficiency can contribute to anemia and to poor thermal regulation, especially during exposure to cold.

Common nutritional problems contributing to poor performance are inadequate intake of fluids (65), carbohydrates (66), and excess fat intake (23, 65–68). Nutritional counseling for female athletes to stress the importance of proper ratios of food groups and other nutrients is needed. Nutritional educational programs are essential for improvement of the food choices and overall health in the female athlete (63, 65).

Fluid Intake

Fluid loss of only 1% of body weight during activity is a state of dehydration. Fluid depletion can occur in a very short period of time—in as little as 30 minutes (69). Simple weighing of athletes before and after activity to determine fluid loss is necessary. To maintain physiologic hydration, 16 ounces of fluid must be consumed for every pound lost in excess of body weight multiplied by .03 (69). Fluid intake schedules and discussions of the best hydration fluids have been published (63, 65, 66, 68, 69).

Diet Composition

Meals high in complex carbohydrates, such as starches of bread, whole grain cereals, pasta, legumes, and vegetables like potatoes are required to support all sports activity. The carbohydrate is a primary fuel for anaerobic work and the limiting fuel for aerobic endurance work (66). Many female athletes harbor the belief that starchy foods cause obesity (65). These athletes deprive themselves of starches, then suffer from increased injury and are prone to binge on high sugar, high fat snacks. High carbohydrate menu patterns of 60% carbohydrates are available for the athlete (63, 65, 66, 70).

Iron and calcium ingestion are of particular importance in female athletes. Calcium intake may need to be increased in athletes with amenorrhea. Iron deficiency anemia is very prevalent in females due to inadequate intake associated with normal menstruation (71, 72). Recognition of iron deficiency anemia and treatment with supplements and dietary counseling are necessary (73).

Screening for anemia in all athletes is recommended. In adolescent athletes with a serious commitment to exercise performance, screening of serum ferritin levels to

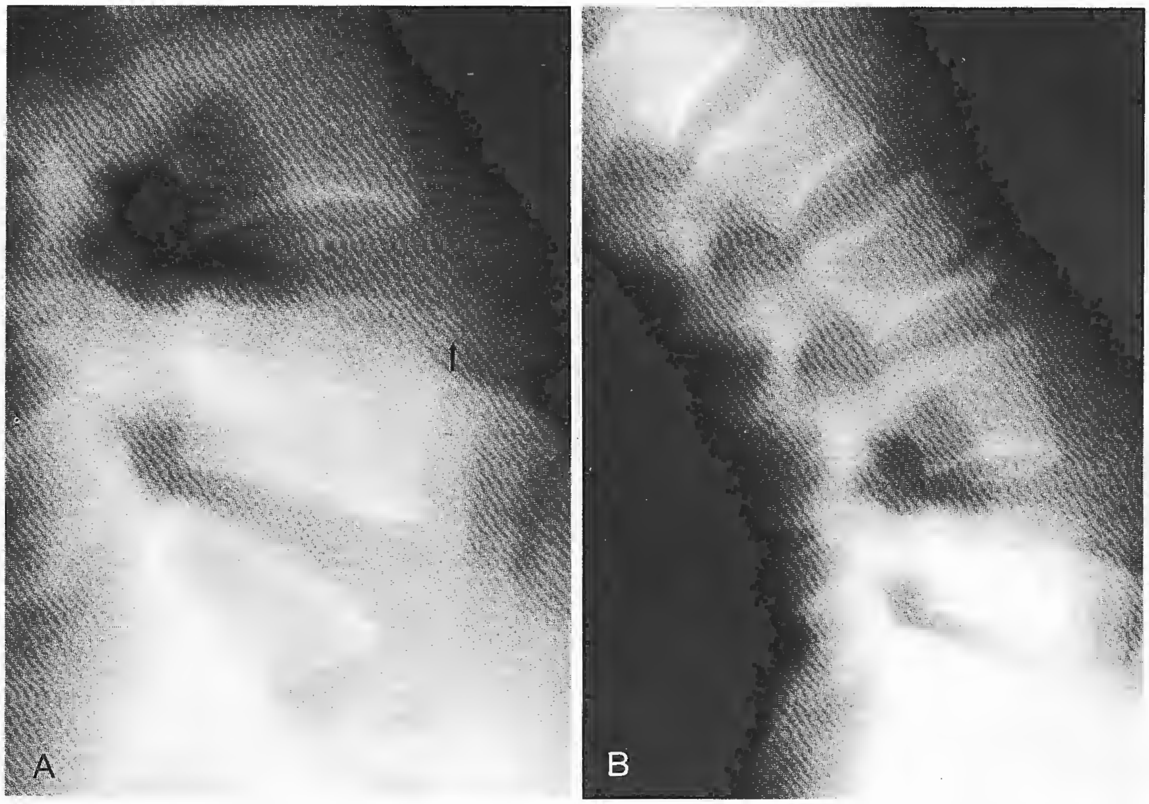


Figure 11.40 An acute avulsion at L5 occurred in this collegiate gymnast who fell from a top uneven parallel bar in a hyperflexion mechanism. **(A)** A cone view shows a superior vertebral body fracture *(arrow)*. **(B)** A standing lateral view 1 month following the injury shows excessive lordosis and healing of the L5 fracture.

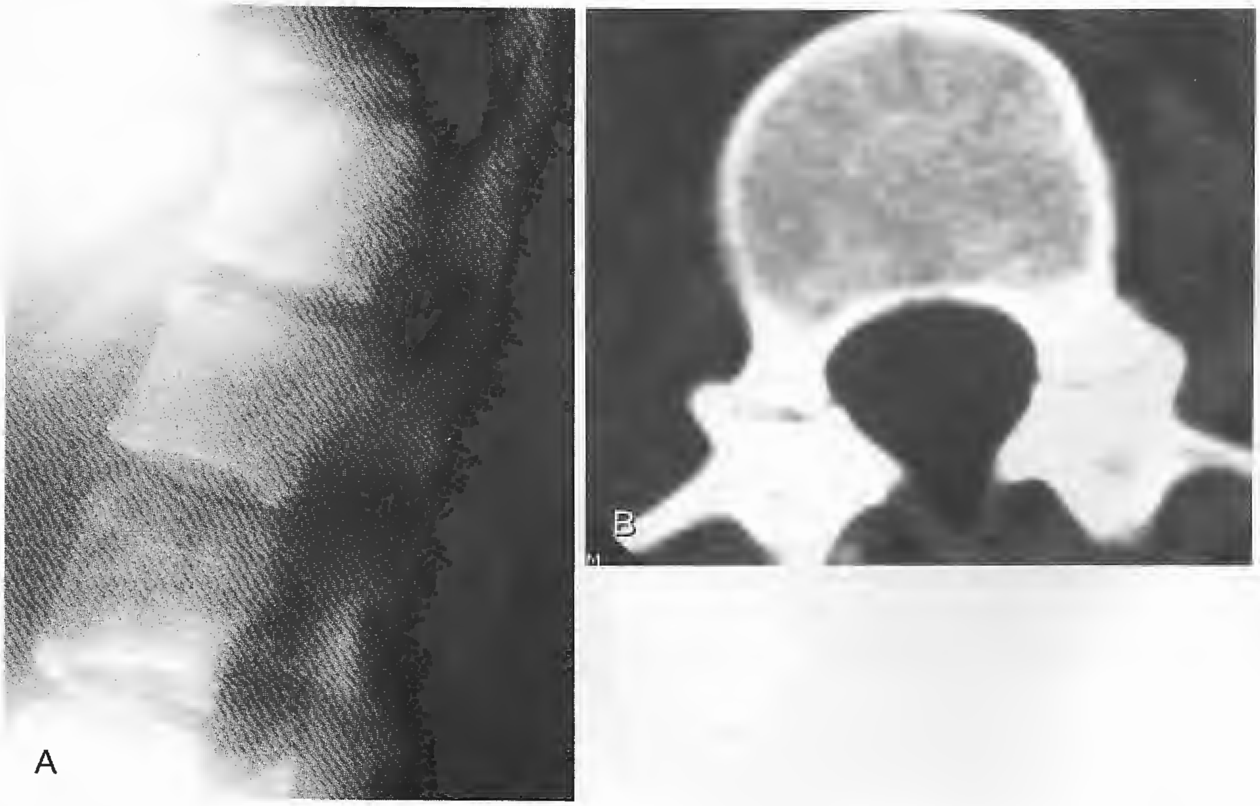


Figure 11.41 A pedicle stress fracture occurred in this ballet athlete. **(A)** A standing lateral view shows posterior element radiolucency *(arrow)*. **(B)** a CT scan confirmed the pedicle fracture.

determine a preanemic iron deficiency has been suggested (73).

Weight, body fat standards, height and weight standards are used as training goals for athletes. The coaching and medical staff must be aware of the proper methods to assess ideal body weight. It is best to employ standards that determine progress toward improved percentage of body fat. Methods for assessing body fat and guidelines for setting standards can be found in nutritional sports references (69, 74). (See Chapter 2.) Athletes carry more lean mass per height than the general population. Weight for height standards can be misleading (65). The athlete should be performing at ideal body weight. Contribution to compromised performance and behavior or to the eating disorders of anorexia nervosa and bulimia occurs when unrealistic body weights and body fat percentages are given by an uneducated member of the coaching or medical staff. Education of the athlete, the coaches, and the medical staff on athletic nutritional needs is mandatory. Consultation with dieticians familiar with needs of a particular sport can result in significant improvements in performance and decreases in injury and illness rates. We are what we eat!

Eating Disorders

Eating disorders are underdiagnosed and exist in epidemic proportions in female athletes. Estimates are that anorexia and bulimia affect as many as one-third of athletic females (75). The athlete, family, coaches, and medical staff should be aware of the very high incidence of eating disorders and nutritional misconceptions among young adolescent females. According to the American Psychiatric Association's definition, eating disorders are gross disturbances in eating behavior, typically beginning in adolescence or early adult life (76). Bulimia is fear of fatness but weight does not decrease below normal weight. Episodes of binge eating and vomiting are common in bulimia. Anorexia nervosa is a disorder with features of refusal to maintain body weight over minimal normal weight for age and height, intense fear of gaining weight or becoming fat, a distorted body image and amenorrhea. Anorexia is a misnomer since loss of appetite is rare. Bulimia and anorexia nervosa can both exist in a single patient.

In the athletic setting, frequent body weight measurements and teammate observation will help identify underlying problems. Denial of eating disorders is common. Cures are rare, so that early diagnosis of eating disorders is critical to hopes of reestablishing a nutritionally sound and normal patient.

Osteoporosis

Hormonal replacement and weight bearing exercise in the premenopausal stages reduces bone loss. Weight bearing activities in postmenopausal women appears to increase mineral content of bone (77). Weight bearing exercise will increase or maintain bone mass, but will not produce a large increase in bone mass (78). Regularly maintained athletic programs for adult women may reduce the rate of bone mass loss that occurs with age and especially postmenopausally (79–82). Patients with anorexia nervosa have reduced bone density that may be permanent. Bone density and mineral content in amenorrheic and eumenorrheic athletes and nonathletes have been quantitated. Further work on bone density is being done to develop normal values for single as well as dual photon densitometry normal values.

Gynecologic/Obstetric

Introduction

Hormonal balance, menarche, menstrual disorders, and menopause are unique considerations in the female athlete.

Normal Menarche

Puberty is the transition period between the juvenile state and adulthood, when the adolescent growth spurt occurs and when secondary sexual characteristics appear. Fertility is achieved and profound psychologic changes take place. It is also the time when many young athletes are initiating or finding their skills. In both males and females, there has been a trend toward early onset of puberty over the last 150 years. This is thought to result from improvement in socioeconomic conditions, nutrition, and general health. Although general trends vary, the average age of menarche in the United States is approximately 12.3 years. It appears that the more critical factor in the time of menarche is the percentage of total body fat, although critical height to weight ratios have been described also (83). Any factor affecting this critical percentage, the body fat ratio, can alter normal menarche. Due to multiple factors including variations in weight, accelerated activity level, and individual differences athletes are at great risk for delays in menarche or alteration in menstruation. Breast development also occurs when the estrogen production in the normal hypothalamic pituitary gonadal axis occurs. Poor nutrition and hormonal imbalance can alter normal development.

With the onset of puberty, the normal menstrual cycle occurs. Production of estrogen feeds back to the hypothalamic-pituitary axis to stimulate production of follicle stimulating hormone (FSH) and development of follicles within the ovary. The surge of a luteinizing hormone (LH) at midcycle results in ovulation, followed by an increase in progesterone production in the luteal phase of the cycle, and, subsequently, menses.

Delayed Menarche

Delayed age at menarche and increased incidence of oligomenorrhea and amenorrhea have been associated with training (84). Menarche in athletes appears to be delayed when compared to nonathlete sisters (85, 86). Premenarchal training does delay the onset of menses but not other pubertal changes (77).

Menstrual Abnormalities

Menstrual irregularities and nutritional abnormalities interrelate to increase the frequency and severity of injuries and illnesses. Differences in body composition between men and women may affect performance in environmental extremes (87). While the average women has a smaller surface area than her male counterpart, her ratio of body surface area (BSA) to weight is greater. In hot climates, women gain heat faster and have a smaller mass to store it in. In air temperature below skin temperature, women lose heat faster. In cold environments, increased subcutaneous fat enhances insulation in women, but the increased BSA/weight ratio in women allows greater heat loss, so that men and women with an equal percentage of body fat demonstrate no differences in metabolic rate, rectal temperature, or skin temperature.

Gynecologic concerns and menstrual dysfunction have been reviewed (51, 88). Decreased resting metabolic rates have been documented in amenorrheic runners (89). Unique gynecologic situations in the female dancer have been published (90). Women athletes with menstrual irregularity have an increased incidence of muscle injury (49). Premenopausal individuals with irregular menses are at increased risk for musculoskeletal injury (44).

Drinkwater (91) and Lutter (50) reviewed health concerns of women runners, including concerns about menstrual abnormalities and pregnancy. An association of athletic amenorrhea, major affective disorders, and eating disorders in runners has been suggested (92). The common occurrence of menstrual dysfunction in adolescents who are involved in intensive athletic activity or who limit their nutritional intake excessively has been established (93). Excessive exercise can alter body weight, decreasing the percentage of body fat, which in turn decreases estrogen production. In this situation, the hypothalamic pituitary ovarian axis is affected, and anovulation, abnormal bleeding, and amenorrhea occur. The association of menstrual dysfunction with low bone density has also been established (64, 91, 94). Lowered estrogen levels and decreased calcium binding in the bony matrix can cause osteoporosis (88). Oligomenorrheic runners have been noted to have decreased bone density compared with eumenorrheic runners (95).

Hypothalamic amenorrhea in dieters and athletic amenorrhea has been treated with estrogen replacement. Controversy exists over whether routine use of oral birth control pills should be implemented early in the treatment of athletic amenorrhea (32).

An excellent summary of indications, contraindications, benefits, and negative effects of oral contraceptives is presented by Kulpa (96). The athlete must understand the importance of taking her birth control pills regularly to prevent breakthrough bleeding and to report any side effects such as calf tenderness, chest pain, severe headaches, or visual symptoms. The basic problem of decrease in percentage body fat is not addressed.

Controversy exists about whether the use of oral birth control pills increases bone density. Use of birth control pills in the perimenopausal period may maximize genetic bone density (96). Runners who had never taken oral contraceptives were twice as likely to sustain stress fractures as runners taking birth control pills for more than one year (43). A definite decrease in the incidence of stress fractures in women athletes, particularly in gymnasts and cross country runners has occurred with the use of oral birth control pills at the University of Kentucky (Hager D, Caborn D, personal communication, 1992).

Athletic performance may be affected by the phases of the menstrual cycle. Exercise performance and muscle glycogen content are enhanced during the luteal phase (88, 96–98). Record breaking performances have occurred in all phases of the menstrual cycle.

Menstrual Abnormalities and Nutritional Disorders

The relationship between food intake, activity, leanness, and menstruation has been investigated. There are reviews of menstrual dysfunction of athletic women ranging from basic principles to evaluation and treatment literature (99–101). Other problems seen in athletic women are iron deficiency anemia and the association of affective disorders and eating disorders (71, 92). The causes of athletic amenorrhea continue to be debated and investigated. Low body fat and low weight have been shown to be a significant contributor to athletic amenorrhea (102–104). The association of the intensity of the athletic activity with changes in the menstrual cycle have also been explored (84, 105, 106). Stress and nutrition are critical factors in the development of menstrual abnormalities (107). Interaction between diet, particularly dietary fiber intake, decreased bone density, and menstrual dysfunction has been postulated (44). Reviews of athletic amenorrhea discuss its causes, complications, and management (108). Hormonal therapy and greater calcium intake have been suggested to treat the condition (108).

Interrelationships of diet and athletic activity, menstrual status and bone density in collegiate women have been reviewed (15, 75, 91, 109). Abnormality in one of these areas can result in increased illness and injury rates, with stress fractures as example.

Exercise and Pregnancy

Special consideration of exercise during pregnancy has been outlined in various articles (32, 110–117). When women who exercise routinely become pregnant, continuation of the same baseline program appears to be safe and should be encouraged. Women who have not exercised before pregnancy can cautiously begin an exercise program with the physician's permission. Guidelines for exercise in the pregnant and postpartum state have been set. Regular exercise is defined as a minimum of 3 periods of exercise per week. Strenuous exercises should be limited to 15 minutes. Exercise should not be done in a hot or humid environment or when mother is febrile. Maternal temperature should not exceed 38° centigrade. Conditioning during pregnancy is encouraged but it should be carried out in accordance with prior exercise patterns. Avoidance of jumping and loading activities lessens the risk of injury associated with presence of the hormone relaxin which stretches the ligaments. No supine exercises should be performed until after 4 months gestation. The maternal heart rate should not exceed 140 beats per minute. Appropriate warm-up and cool-down periods as well as the use of liquids is suggested. In the postpartum period of 4 to 6 weeks, women have been cautioned against exercise, although more research should be done in this area. In summary, for mental and physical health, during pregnancy, exercise according to above guidelines is suggested.

Breast Development

Hindle concisely reviewed the subject of the breast and its protective devices (118). The breast is composed of essential fat and sex-specific fat. There is no true change in breast size with exercise programs or with pectoralis-specific strengthening.

The breast is an endocrine end organ composed of fat, suspensory ligaments and ducts. The nipple is the end organ that receives the lactiferous, or mammary, ducts, and it is the most prominent part of the breast. Changes in weight and genetics influence breast size and shape. The development of this mammary gland occurs by hormonal influence, including estradiol growth hormone, hydrocortisone, insulin, oxytocin, progesterone, prolactin, and thyroxine. The glandular tissue responds to the menstrual cycle by changes in size and mitotic activity. Except for the period of pregnancy, the terminal duct units remain in a resting state.

Protective Devices

Sports Bras. Sports bras have design features of firm support of the breast, limitation of breast motion, and material which will not abrade the skin. The repetitive motion of exercise requires soft material to protect the nipple from abrasion or irritation. Small-breasted women attain comfort with a compression bra while large-breasted women require an encapsulation bra. Sports-type bras are recommended for women with larger breasts in order to limit motion to 2 cm in the vertical plane. The features important in a sports bra are the following: circumferential support, crisscross or Y construction, unstretchable straps, breathable material, no seams at the nipple area, no hooks or fasteners, and individualized fit. A sports bra should be comfortable during exercise and at rest.

Breast Problems

Breast Trauma. Breast discomfort related to sports activity is common. Use of sports bras and appropriate padding is beneficial. Nipple irritation caused by friction is more common in females and abrasions can result. Treatment is accomplished with local padding and lubricants. Breast trauma from contact is uncommon. When direct significant contact occurs, hematoma formation and prolonged pain can result. The recommended treatment is analgesics, support, and the avoidance of repetitive contact.

Fibrocystic Disease. The disorder is characterized by fibrous and cystic changes within the breast parenchyma. Since approximately 70% of women in the U.S. have this disorder, it is actually more unusual not to be affected by fibrocystic change. The precise cause of fibrocystic change remains unknown. Xanthines contained in caffeine and chocolate may accentuate the breast tenderness experienced by the individuals with fibrocystic change. Many women athletes are troubled with this disorder and experience cyclic breast discomfort. This can be relieved with the use of supportive bras and the restriction of caffeine in the diet.

Galactorrhea. Discharge from the nipples (galactorrhea) may be seen in normals. It also may be associated with irritation of the breast nipple or with the presence of a pituitary microadenoma. A pituitary microadenoma is a noninvasive lesion in the pituitary gland causing increase in the production of prolactin. Elevated prolactin levels inhibit normal menses and cause galactorrhea. Women athletes who present with a combination of amenorrhea and galactorrhea should be evaluated for a pituitary microadenoma.

Conclusion

Appreciation of the unique situations that exist for female athletes will improve their care and treatment. Medical personnel who have these added insights in their armamentarium can make diagnoses more efficiently and institute treatment earlier. The epidemic of knee injuries in females is of concern and requires further research. The high incidence of hormonal and nutritional imbalances increases the risk of stress fractures. These imbalances are common in the female athlete. Nutritional, gynecologic, and psychologic balance is vital to a healthy athlete. The eating disorders of anorexia nervosa and bulimia exist in epidemic proportions and treatment programs for these serious disorders must be instituted promptly. Certainly, encouragement of female participation in sports is beneficial to all, especially the athlete. The healthy female athlete can best be served by health professionals who appreciate these special and unique concerns.

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REFERENCES

1. Agostini R. The athletic woman. In: Mellion MB, ed. Office management of sports injuries and athletic problems. Philadelphia: Hanley and Belfus 1988;76–88.
2. Hunter LY, Andrews JR, Clancy WG, Funk JR Jr. Common orthopaedic problems of female athletes. A.A.O.S: Instructional Course Lectures. 1982;31:126–151.
3. Roy S, Irvin R. The female athlete. In: Sports medicine: preven-

tion, evaluation, management, and rehabilitation. Englewood Cliffs, NJ: Prentice-Hall Inc. 1983:457–467.
4. Hale RW, ed. Caring for the exercising woman. New York: Elsevier, 1991.
5. Clarke KS, Buckley WE. Women's injuries in collegiate sports. Am J Sports Med 1980;8:187–191.
6. Garrick JG, Requa RK. Girls' sports injuries in high school athletics. JAMA 1978;239:2245–2248.
7. DeHaven KE, Linter DM. Athletic injuries: comparison by age, sport, and gender. Am J Sports Med 1986;14:218–224.
8. Whiteside PA. Men's and women's injuries in comparable sports. Phys Sportsmed 1980;8:130–136.
9. National Collegiate Athletic Association: NCAA injury surveillance system. Overland Park, Kansas: NCAA, 1991–1992.
10. National Collegiate Athletic Association: NCAA injury surveillance system. Overland Park, Kansas: NCAA, 1992–1993.
11. Ciullo, Jerome V. Lower extremity injuries. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993:267–305.
12. Wadley GH, Albright JP. Women's intercollegiate gymnastics: Injury patterns and "permanent" medical disability. Am J Sports Med 1993;21(2):314–320.
13. Lutter JM. A 20-year perspective: What has changed? In: Pearl AJ ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993:1–10.
14. Hale RW. Historical perspective. In: Hale RW, ed. Caring for the exercising woman. New York, Elsevier 1991:1–3.
15. Ritter MA, Goie TJ, Albohn M. Sport-related injuries. Women's College Health 1980;28:267–268.
16. Gillete J. When and where women are injured in sports. Phys Sportsmed 1975;2:61–63.
17. Howell DW. Musculoskeletal profile and incidence of musculoskeletal injuries in lightweight women rowers. AM J Sports Med 1984;12:278–282.
18. Micheli LJ, Gillespie WJ, Walaszek A. Physiologic profiles of female professional ballerinas. Clin Sports Med 1984; Jan 3(1):199–209.
19. Marino M. Profiling swimmers. Clin Sports Med 1984:Jan 3(1):211–219.
20. Protzman RR. Physiologic performance of women compared to men. Am J Sports Med 1979;7:191–194.
21. Sady SP, Freedson PS. Body composition and structural comparisons of female and male athletes. Clin Sports Med 1984:3:755, 666.
22. Wilmore JH. The application of science to sport: Physiological profiles of male and female athlete. Canadian J Applied Sport Sciences. 1979;4(2):103–115.
23. Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993.
24. Protzman RR, Bodnari LM. Women athletes. Am J Sports Med 1980;8:53–55.
25. Protzman R, Griffis C. Stress fractures in men and women undergoing military training. JBJS 1977;59A:825.
26. Good JE, Klein KM. Women in the military academies: US Navy (part 1 of 3). Phys Sportsmed 1989;17:99–106.
27. Cox JS, Lenz HW. Women midshipmen in sports. Am J Sports Med 1984 May–June;12(3):241–243.
28. Berg K. Aerobic function in female athletes. Clin Sports Med 1984;3:779–789.
29. Scordo KA. Effects of aerobic exercise training on symptomatic women with mitral valve prolapse. Am J Cardiol 1991; Apr 15;67(9):863–868.
30. Baechle TR. Women in resistance training. Clin Sports Med 1984;3:791–880.
31. Ireland ML, Wall C. Epidemiology and comparison of knee injuries in elite male and female United States basketball athletes. [Abstract] Med Sci Sports Exer 1990;22(2):582.
32. Ireland ML. Problems facing the athletic female. In: Pearl AJ ed. The athletic female. Champaign, IL: Human Kinetics Pubs 1993:11–18.
33. Zelisko JA, Noble HB, Porter M. A comparison of men's and women's professional basketball injuries. Am J Sports Med 1982;10:297–299.
34. Insall J. Disorders of the patella. In: Insall J, ed. Surgery of the knee. New York: Churchill Livingstone 1984:191–260.
35. Insall J, Falvo KA, Wise PW. Chondromalacia patella. JBJS 1976;58:1–8.
36. Aglietti P, et al. A new pattellar prosthesis. Clin Orthop 1975;179:175–187.
37. Colosimo AJ, Ireland ML: Isokinetic peak torque and knee joint laxity comparison in female basketball and volleyball college athletes. [Abstract] Med Sci Sports Exer 1991;23(suppl 4): S135.
38. Souryal TO, Moore HA, Evans JP: Bilaterality in anterior cruciate ligament injuries. Am J of Sports Med 1988;16(5):449–454.
39. Micheli LJ, Sohn RS, Solomon R: Stress fractures of the second metatarsal involving Lisfranc's joint in ballet dancers. JBJS 1985:67A:1372–1375.
40. Protera C. Women in sports: the price of participation. Phys Sportsmed 1986;14:149–153.
41. Richardson A, Jobe F, Collins SH. The shoulder in competitive swimming. Am J Sports Med 1980;8(3):159–163.
42. Snook G. Injuries in women's gymnastics: a five year study. Am J Sports Med 1979;7(4):242–244.
43. Barrow GW, Saha S. Menstrual irregularity and stress fractures in collegiate female runners. Am J Sports Med 1988;16(3):209–216.
44. Lloyd T, Buchanan JR, Bitzer S, Waldman CJ, Myers C, Ford BG. Interrelationships of diet, athletic activity, menstrual status, and bone density in collegiate women. Am J Clin Nutr 1987 Oct;46(4):681–684.
45. Sullivan D, Warren RF, Pavlov H, et al. Stress fractures in 51 runners. Clin Orthop 1984 Jul;187:188–192.
46. Hershman EB, Mailly T. Stress fractures. Clin in Sports Med 1990 Jan;9(1):183–214.
47. Matheson GO, Clement DB, McKenzie DC, et al. Stress fractures in athletes: a study of 320 cases. Am J Sports Med 1987 Jan–Feb;15(1):43–58.
48. Lloyd T. Diet and menstrual status as determinants of injury risk for the athletic female. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993: 61–80.
49. Frusztajer N, Dhuper S, Warren M, et al. Nutrition and the incidence of stress fractures in ballet dancers. Am J Clin Nutr 1990;51:779–783.
50. Lutter JM. Health concerns of women runners. Clin in Sports Med 1985;4:671–683.
51. Shangold MM. Gynecologic concerns in the woman athlete. Clin in Sports Med 1984;3(4):869–878.
52. Holden DL, Jackson DW. Stress fracture of the ribs in female rowers. Am J Sports Med 1985 Sep–Oct;13(5):342–348.
53. Roy S, Caine D, Singer KM. Stress changes of the distal epiphysis in young gymnasts. A report of twenty-one cases and a review of the literature. Am J Sports Med 1985 Sep–Oct;13(5):301–308.
54. Blank S. Transverse tibial stress fractures: a special problem. Am J Sports Med 1987 Nov–Dec;15(6):597–602.
55. Ireland ML, Micheli LJ. Bilateral stress fractures of the lumbar pedicles in a ballet dancer: a case report. J Bone Joint Surg 1987;69-A(1):140–142.
56. Stark JA, Toulouse A. The young female athlete: psychological considerations. Clin Sports Med 1984;3:909–921.
57. Corbin CB. Self-confidence of females in sports and physical activity. Clin Sports Med 1984:3:895–908.
58. Morgan BLO. Nutritional needs of the female adolescent. Healthcare of the Female Adolescent. New York: Haworth Press, 1984:15–28.
59. Grandjean RD. Nutritional concerns for the woman athlete. Clin Sports Med 1984;3(4)923–938.
60. Nowak RK, Knudsen KS, Schulz LO: body composition and nutrient intakes of college men and women basketball players. J Am Diet Assoc. 1988;88(5):575–578.
61. Kleiner SM, Bazzarre TL, Litchford MD. Metabolic profiles, diet, and health practices of championship male and female bodybuilders. J Am Diet Assoc 1990;(7):962–967.
62. Keith RE, Okeeffe KA, Alt LA, et al. Dietary status of trained female cyclists. J Am Diet Assoc 1989;(11):1620–1623.
63. Clark N. Nutritional problems and training intensity, activity level, and athletic performance. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993;165–168.
64. Myburgh KH, Hutchins J, Fataar AB, et al. Low bone density is

an etiologic factor for stress fractures in atheletes. Ann Intern Med 1990 Nov 15;113(10):754–759.
65. Clark N. Sports Nutrition Handbook. Champaign, IL: Leisure Press, 1990:135–148.
66. Berning Jr, Steen SN. Sports Nutrition for the 90's. Gaithersburg, MD: Aspen, 1991.
67. Faber M, Spinnler-Benade AJ, Daubitzer A. Dietary intake, anthropometric measurements and plasma lipid levels in throwing field athletes. Int J Sports Med 1990;11(2):140–145.
68. Smith NJ. Weight control in the athlete. Clin Sports Med 1984 Jul;3(3):693–704.
69. Bernadot D, ed. Sports Nutrition: A guide for the professional working with active people, 2nd ed. Chicago: Sports and Cardiovascular Nutrition Practice Group of the American Dietetic Association, 1993.
70. Hoffman CJ, Coleman E. An eating plan and update on recommended dietary practices for the endurance athlete. J Am Diet Assoc 1991;(3):325–330.
71. Risser WL, Lee EJ, Poindexter HB et al. Iron deficiency in females: its prevalence and impact on performance. Med Sci Sports Exerc 1988 Apr;20(2):116–121.
72. Rowland TW. Iron deficiency in young endurance athlete. In: Advances in Pediatric Sports Sciences. Champaign, IL: Human Kinetics Pubs, 1989:169–190.
73. Rowland TW. Iron deficiency in the athlete. Pediatr Clin North Am 1990;37(15):1153–1163.
74. Eisenman PA, Johnson SC, Benson JE. Coaches guide to nutrition and weight control. Champaign, IL: Leisure Press, 1990.
75. Clark N. Eating disorders among female athletes. In: Pearl AJ, ed. The athletic female; Champaign, IL: Human Kinetics Pubs, 1993:141–148.
76. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. 3rd ed. Washington, D.C.: American Psychiatric Assoc., 1987.
77. Hale RW. Exercise, sports, and menstrual dysfunction. Clin Obstet Gynecol 1983 Sep;26(3):728–735.
78. Dalsky GP. The role of exercise in the prevention of osteoporosis. Compr Ther 1989;15(9):30–37.
79. Jacobson PC, Beaver W, Grubb SA, et al. Bone density in amenorrheic women: college athletes and older athletic women. J Orthop Res 1984;2(4):328–332.
80. Jones KP, Ravnikar VA, Tulchinsky D, et al. Comparison of bone density in amenorrheic women due to athletics, weight loss, and premature menopause. Obstet Gynecol 1985 Jul;66(1): 5–8.
81. Linnell SL, Stager JM, Blue PW, et al. Bone mineral content and menstrual regularity in female runners. Med Sci Sports Exerc 1984 Aug;16(4):343–348.
82. Rikli RE, McManis BG. Effects of exercise on bone mineral content in postmenopausal women. Res Q Exerc Sport 1990 Sep;61(3):243–249.
83. Frisch RE, McArthur JW. Menstrual cycles: fatness as a determinant of minimum weight for height necessary for their maintenance or onset. Science 1974;185:949–951.
84. Frisch RE, Gotz-Welbergen AV, McArthur JW et al. Delayed menarche and amenorrhea of college athletes in relation to age of onset of training. JAMA 1981 Oct 2;246(14):1559–63.
85. Stager JM, Wigglesworth JK, Hatler LK. Interpreting the relationship between age of menarche and prepubertal training. Med Sci Sports Exerc 1990 Feb;22(1):54–58.
86. Halfon ST, Bronner S. Determinants of physical ability in 7th grade school children. Eur J Epidemiol 1989 Mar;5(1):90–96.
87. Haymes EM. Environmental factors as they affect women. In: Hale RW, ed. Caring for the exercising woman. New York: Elsevier, 1991:37–45.
88. Noakes TD, Vanlend M. Menstrual dysfunction in female athletes. S Afr Med J 1988;73:350–355.
89. Myerson M, Gutin B, Warren MP, et al. Resting metabolic rate and energy balance in amenorrheic and eumenorrheic runners. Med Sci Sports Exerc 1991;23(1):15–22.
90. Shade AR. Gynecologic and obstetric problems of the female dancer. Clin Sports Med 1983;2(3):515–523.
91. Drinkwater BL, Bruemner B, Chesnut CH 3d. Menstrual history as a determinant of current bone density in young athletes. JAMA 1990 Jan 26;263(4):545–548.
92. Gadpaille WJ, Sanborn CF, Wagner WW Jr. Athletic amenorrhea, major affective disorders, and eating disorders. Am J Psychiatry 1987 Jul;144(7):939–942.
93. Mansfield MJ, Emans SJ. Anorexia nervosa, athletics, and amenorrhea. Pediatr Clin North Am 1989 Jun;36(3):533–549.
94. Baker E, Demers L. Menstrual status in female athletes: correlation with reproductive hormones and bone density. Obstet-Gynecol 1988 Nov;72(5):683–687.
95. Cook SD, Harding AF, Thomas KA et al. Trabecular bone density and menstrual function in women runners. Am J Sports Med 1987 Sep–Oct;15(5):503–507.
96. Kulpa PJ. Oral Contraceptives and the athletic female. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993:103–112.
97. Rebar RW. Exercise and the menstrual cycle. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs; 1993:59–75.
98. Nicklas BJ, Hackney AC, Sharp RL. The menstrual cycle and exercise: performance, muscle glycogen, and substrate responses.
99. Shangold M, Rebar RW, Wentz AC, et al. Evaluation and management of menstrual dysfunction in athletes. JAMA 1990 Mar 23–30;263(12):1665–1669.
100. Shangold MM. Menstrual irregularity in athletes: basic principles, evaluation, and treatment. Can J Appl Sport Sci 1982 June;7(2):68–73.
101. Baker ER. Menstrual dysfunction and hormonal status in athletic woman: a review. Fertil Steril 1981 Dec;36(6):691–696.
102. Sanborn CF, Albracht BH, Wagner WW Jr. Athletic amenorrhea: lack of association with body fat. Med Sci Sports Exerc 1987 Jun;19(3):207–212.
103. Sinning WE, Little KD. Body composition and menstrual function in athletes. Sports Med 1987 Jan–Feb;4(1):34–35.
104. Carlbert KA, Buckman MT, Peake GT, et al. Body composition of oligo/amenorrheic athletes. Med Sci Sports Exerc 1983;15(3):215–217.
105. Malina RM, Spirduso WW, Tate C, et al. Age at menarche and selected menstrual characteristics in athletes at different competitive levels and in different sports. Med Sci Sprts Exer 1978 Fall;10(3):218–222.
106. Eston RG. The regular menstrual cycle and athletic performance. Sports Med 1984 Nov–Dec;1(6):431–445.
107. Schweiger U, Laessle R, Schweiger M, et al. Caloric intake, stress, and menstrual function in athletes. Fertil Steril 1988;49(3):447–450.
108. Highet R. Athletic amenorrhea. An update on aetiology, complications and management. Sports Med 1989 Feb;7(2):82–108.
109. Arendt EA. Osteoporosis in the athletic female: amenorrhea and amenorrheic osteoporosis. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993:41–59.
110. Jarski RW, Trippett DL. The risks and benefits of exercises during pregnancy. J Fam Pract 1990 Feb;30(2):185–189.
111. Sady SP, Carpenter MW. Aerobic exercise during pregnancy. Special considerations. Sports Med 1989 Jun;7(6):357–375.
112. Hall DC, Kaufmann DA. Effects of aerobic and strength conditioning on pregnancy outcomes. Am J Obstet Gynecol 1987 Nov;157(5):1199–1203.
113. Mullinax KM, Dale E. Some considerations of exercise during pregnancy. Clin Sports Med 1986 Jul;5(3):559–570.
114. ACOG Home Exercise Programs: Exercise during pregnancy and the postnatal period. Washington DC, American College of Obstetricians and Gynecologists, 1985.
115. White J. Exercising for two: what's safe for the active pregnant woman. Phys Sportsmed 1992;20(5):179–186.
116. Wolfe LA, Hall P, Webb KA, et al. Prescription of aerobic exercise during pregnancy Sports Med 1989;8(5):273–301.
117. Artal R. Exercise and fetal responses during pregnancy. In: Pearl AJ, ed. The athletic female. Champaign, IL: Human Kinetics Pubs, 1993:103–117.
118. Hindle WH. The breast and exercise. In: Hale RW. Caring for the exercising woman. New York: Elsevier, 1991:83–92.

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