2 Adolescent Athletes

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2.1 Background

Adolescence is the developmental period occurring between childhood and adulthood during the second decade of life. It is a transitional period marked by substantial changes in physical maturation, cognitive abilities, and social interactions. Pubertal development is the hallmark of early adolescence characterized by rapid physical growth and the maturation of the reproductive system. Physical activity is associated with many benefits during adolescence, including improved aerobic fitness, muscle strength, motor skills, speed, coordination, balance, body composition and bone mineral density. Moreover, sport participation can reduce symptoms of depression, anxiety, and stress, and increase quality of life and wellbeing. It contributes also to improve the regulation of emotions, to develop inter-personal skills and quality peer relationships, and to enhance academic engagement and achievement. Despite its numerous known benefits, sports participation declines with age through adolescence, particularly for girls. This may be attributed to a number of factors including musculoskeletal injuries, competing demands between academic and social commitments, limited access to affordable opportunities, alternative interests, conflicts with coaches or peers, issues around self-presentation arising alongside puberty onset, and conformity to traditional gender roles. This has implications for immediate and maintained physical activity across the lifespan. On the other hand, young athletes are being encouraged to train intensively during the critical phase of puberty resulting in increased risks of musculoskeletal injuries, diseases and drop-out from sport. The purpose of this chapter is to review a number of physiological and medical issues that surround health and performance of adolescent athletes.

2.2 Physiological Aspects to Consider

2.2.1 Growth and Maturation

Puberty is designated by the development of secondary sex characteristics, the marked acceleration in linear growth, bone mineral acquisition and changes in body composition. Secondary sexual characteristics appear at a mean age of 10.5 years in girls and 11.5–12 years in boys. Five stages of puberty from childhood to full maturity (P1 to P5) have been described by J. Tanner. Girls are rated for breast development and pubic hair growth, while boys are rated for genital develop-

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Table 2.1 Pubertal development in girls and boys (Tanner stages)

Pubic hair scale (in female and male)	Stage 1: No hair Stage 2: Downy hair Stage 3: Scant terminal hair Stage 4: Terminal hair that fills the entire triangle overlying the pubic region Stage 5: Terminal hair that extends beyond the inguinal crease onto the thigh
Female breast development scale	Stage 1: No glandular breast tissue palpable Stage 2: Breast bud palpable under areola (first pubertal sign) Stage 3: Breast tissue palpable outside areola; no areolar development Stage 4: Areola elevated above contour of the breast, forming "double scoop" appearance Stage 5: Areolar mound recedes back into single breast contour with areolar hyperpigmentation, papillae development and nipple protrusion
Male external genitalia scale	Stage 1: Testicular volume < 4 mL or long axis < 2.5 cm Stage 2: 4–8 mL (or 2.5–3.3 cm long), first pubertal sign Stage 3: 9–12 mL (or 3.4–4.0 cm long) Stage 4: 15–20 mL (or 4.1–4.5 cm long) Stage 5: >20 mL (or >4.5 cm long)

ment and pubic hair growth (Table 2.1). Stages are typically assessed clinically, although self-assessments are also used. Breast and genital staging, as well as height velocity, should be relied on more than pubic hair staging to assess pubertal development because of the independent maturation of adrenal axis. In girls, puberty begins with the development of breast buds under the areola, also known as *thelarche* (Tanner stage 2), under the control of estrogens which are secreted by the ovaries. As puberty progresses, the glandular tissue of the breast increases in size and changes in contour. In females, *thelarche* is followed in 1–1.5 years by the onset of sexual hair (pubic and axillary), known as *pubarche*, secondary to androgen secretion by the adrenal cortex. The onset of menses, (*menarche*), arrives on average at the age of 12.5 years, regardless of ethnicity, following *thelarche* on average by 2.5 years. In boys, the onset of puberty ranges from 9 to 14 years of age. The first secondary sexual characteristic visible is when testicular volume reaches greater than or equal to 4 mL, or a long axis ≥ 2.5 cm, and enters Tanner stage 2 (*gonadarche*). Testicular development can be evaluated with a Prader orchidometer, a set of models (ellipsoids) indicating specific testicular volumes. The growth and maturation of the penis usually correlate with pubic hair development under the control of androgen. Other major physical changes in boys include facial, body and axillary hair and lowering of the voice pitch. *Spermarche*, the counterpart of menarche in females, is the development of sperm in males and typically occurs during genital Tanner stage 4.

The year of greatest height gain occurs at an earlier stage of puberty in girls (breast stage 2–3) than boys (testes stage 3–4). *Peak height velocity* (PHV) occurs at approximately 11 years of age (Tanner stage 2–3) and 13 years of age (Tanner stage 3), respectively, for girls and boys, and mean peak height gains for boys and girls average 9.5 and 8.3 cm per year, respectively. Linear height growth at puberty contributes approximately to one-fifth of the final height. Age at PHV is estimated from height measurements of individual children taken annually or semiannually across adolescence. Growth hormone plays a key role in the abrupt acceleration of linear growth that occurs during adolescence. Growth spurts in lower body dimensions occur, on average, before PHV, while spurts in body weight, lean tissue mass, bone mineral content and upper body dimensions occur after PHV in both genders. Many factors are known to influence growth and maturation: familial correlation, family stature, status at birth and early growth, household environment and nutrition. Acknowledging the normal variability, exercise training per se does not affect age at menarche in female athletes, and is not a factor affecting growth in height in adolescents. Skeletal age (SA) is an indicator of maturation of the hand-wrist skeleton viewed on a standard radiograph and can be performed in case of growth delay (height z-score below −2 or diminished height gain). Three methods for estimating SA can be used: Greulich-Pyle; Tanner-Whitehouse, and Fels; most adult height prediction protocols are based on SA. In many cases of short stature, a familial component can be identified (short stature or late maturation in parents). Other causes of growth failure include undernutrition, glucocorticoid therapy, gastrointestinal diseases, metabolic diseases, genetic diseases, other chronic diseases, cancer, growth hormone deficiency, hypothyroidism, Cushing syndrome and sexual precocity.

In girls and boys, peak bone mineral accrual is noted approximately 1 year later PHV, which may explain the increased incidence of fractures during puberty. The augmentation of bone mineral content and density during puberty is mainly due to bone growth in length and width. It can be assessed by dual-energy X-ray absorptiometry (DXA). Genetic factors account for 60–80% of bone development, however, extrinsic factors like weight-bearing physical activity, nutrition, substance abuse, diseases and injuries may influence it. Bone mineral accrual is clinically important as a 10% increase of peak bone mass at the end of growth may decrease by 25–50% the risk of osteoporosis fracture later in life.

In both gender, but more so in boys, there is a substantial gain in lean body mass during puberty. From 5 to 17 years of age, the muscle mass of males increases from approximately 40 to 55% of the total body mass. Over the same age range, the muscle mass of females increases from approximately 40 to 45% of the total body mass. The advantage of having greater active muscle mass to recruit during exercise is potentially useful in providing an enhanced functional capacity and possibly metabolic rate in the exercise performance of adolescent males compared with females. The greatest change in body composition of the adolescent girls occurs in fat mass; from approximately 15% fat at 6 years of age to 25% at 17 years of age. In comparison, at 6 years of age, boys have approximately 10% of body fat which increases to around 15% by 17 years of age. Body composition changes during puberty are a complex and interactive result of genetic factors, sex hormones, growth hormone, leptin, energy intake and expenditure.

Selection or exclusion in many sports follows a maturity-related gradient largely during the interval of puberty and growth spurt. Early developing pubescent males are advantaged by having greater muscle mass than their later developing peers. This benefit may be most evident during physical exercises requiring strength, speed and power. Boys who are perceived as physically suited for a sport generally experience greater success; are identified at an earlier age; are given more important roles; receive more playing time, encouragement and resources; and more likely have access to elite coaches. In girls, the physical and functional characteristics associated with advanced maturation (greater stature, absolute strength) may afford an advantage in swimming and tennis. On the other hand, early pubescent females can be disadvantaged by having the additional fat gain, their functional capacity and motivation being reduced compared to later developing peers. A maturity-related gradient among female athletes is most apparent in artistic gymnastics, diving, figure skating and distance running, which favors later maturing. It is therefore recommended for prepubescent girls to develop perceived physical competence in a broad range of skills so that early or late puberty does not lead to cessation of all physical activity. The gain in fat mass which commonly occurs in female during puberty can be limited by regular physical activity, thus providing health benefits during the life course.

2.2.2 Strength Training and Conditioning

Selectivity and talent development models consider the adolescent years as a "window of opportunity" for selection and sport-specific training, and imply enhanced trainability. A "trigger hypothesis" has been proposed for increased sensitivity of the muscular and cardiovascular systems to training associated with pubertal hormonal changes during adolescence, whereas the *Long-Term Athlete Development model* specifically indicated the interval of PHV as the reference for programming training protocols. There is some evidence that speed and flexibility peak gains appear before PHV in boys, while tests of strength and power attain peak gains after PHV, and peak velocity in maximal aerobic capacity (VO_2 max) occurs at the time of PHV in both gender.

Compared to adults, children have lower relative maximal strength and attain lower relative power outputs, mainly due to lower maximal voluntary muscle activation. Youth strength training can have potential benefits including improvement of motor unit recruitment and muscle strength, body composition, flexibility, coordination, aerobic capacity, serum lipid levels, sport performance, sport-related injury prevention and rehabilitation, and enhanced long-term health. It has been shown that preseason conditioning programs and pre-practice neuromuscular training can reduce injury rates in young athletes. With proper structure, technique, intensity, supervision and planning, regular participation in a resistance training program can be performed safely in the pediatric population. However, resistance training should be one component of a well-balanced and varied exercise program.

Pre-pubertal children are metabolically comparable to well-trained adult endurance athletes and are thus less fatigable during high-intensity exercise than untrained adults. This may be explained by a higher percentage of slow-twitch type-I motor units in the accessible pool. A greater parasympathetic reactivation of the autonomic nervous system early in the recovery period after exercise has been also observed. Pre-pubertal children are therefore capable of working at greater fractions of their maximal capacity prior to or without exhaustion, concomitantly with lower carbohydrate and higher fat metabolism. This is in line with observed higher relative lactate and ventilatory thresholds, lower lactate production and faster recovery. The reduced anaerobic power of the young athlete compared with that of an adult athlete is therefore due to the intrinsic properties of the muscle. During puberty, the anaerobic capacity and anaerobic-to-aerobic power ratio increases with age leading some to the illusion of deteriorating aerobic fitness, whereas it is not. Endurance-based aerobic activities or structured training (continuous or interval) should be incorporated in general training to preserve aerobic fitness during pubertal years. Normal adolescents can improve aerobic capacity by 10–25% with training. The primary concerns related to endurance training are overtraining (elevation in basal cortisol, increased resting heart rate, reduced physical and mental performance, gastrointestinal disturbances, chronic muscle soreness, elevation in skeletal damage markers, depressed immune function) and early specialization. In youths, the peak oxygen consumption (peak VO_2, $mL \cdot kg^{-1} \cdot min^{-1}$) can be objectively measured prior and after training by a multistage treadmill/cycle ergometer test using validated pediatric protocols, or can be estimated using a 20-m multistage shuttle run field test. A decrease in youth's aerobic fitness is usually a reflection of an increased sedentary lifestyle, or a limitation of physical activity due to a disease or injury. Aerobic training should be particularly encouraged in pubescent girls that commonly decrease their aerobic capacity during puberty.

2.3 Medical Aspects to Consider

2.3.1 Pre-participation Physical Examination

The pre-participation physical evaluation (PPE) serves as a tool to encourage safe athletic participation. It aims to identify and averting causes of severe health conditions but also provides an excellent opportunity to provide information and guidance on issues ranging from nutrition, sleep, alcohol and drug use, injury prevention and physical condition. The convenient time for PPE is 4–6 weeks before preseason practice. This allows the athlete and the physician to make adjustment or to establish a treatment plan in case of injuries. Annual PPE is often considered the norm, or before starting a new school level. The multiple components of PPE are presented in Table 2.2. Laboratory and imaging studies should only be used as an extension of the history and physical examination when additional information is needed to evaluate a concern. Screening blood

Table 2.2 Pre-participation physical evaluation in adolescents

Components of the PPE	Comments
Sport's history	
Discipline and level	Regional/national/international
Days and duration of sports training	
Days and duration of conditioning	
Other physical activities	
Number of competitions per month/year	
Coaches	Professional/volunteer
Athletes and parents expectations	
Medical history	
Past medical/surgical history	Including prior injuries
Growth and maturation	Height and weight at birth, evolution of height, weight and pubertal development
Medications	Check WADA prohibited list
Allergies	Food, medications, pollens
Immunization	Tetanus, diphtheria, pertussis, poliomyelitis, *Haemophilus influenzae*, measles, mumps, rubella, pneumococcal, meningococcal, influenza, hepatitis A and B, varicella and human papillomavirus vaccines are recommended
Substance use	Tobacco, alcohol and drugs
Supplement and ergogenic aid	
Sleep	Sleep duration and quality, use of screens at night
Nutrition	Dairy products and other source of proteins (meat, poultry, fish, egg), fruits, vegetables and legumes, grains and nuts. Water, sugar sweetened beverages, sports/energy drinks
Family history	Parental height/weight; age at menarche/gonardache; cardiomyopathy, congenital heart disease, arrhythmia, atherosclerosis, sudden death, genetic conditions, endocrine diseases, eating disorders
Social history	Ethnicity, language, school level and performance, relationships with coaches/peers/parents/siblings
Review of systems	
Medical examination	
Height and body weight	Barefoot with light clothes
Body mass index, z-score/percentile	BMI World Health Organization references
Waist circumference, waist/height ratio and skinfolds when indicated	
Skin	Infections, eczema, dryness
Eyes, oral cavity, ears, nose	Frequent external ear and nose infections in water sports
Cardiovascular system	Resting blood pressure, heart rate, radial/femoral pulses, rhythm and murmurs
Pulmonary system	Respiratory rate, signs of distress, wheezing, stridor
Digestive system	Abdominal masses, tenderness, organomegaly
Endocrine system	Tanner stage, single or undescended testicle, testicular mass in males, hernia
Musculoskeletal system	Contour, limbs alignment, range of motion, stability and synergy of neck, back, shoulder/arm, elbow/forearm, wrist/hand, hip/thigh, knee, leg/ankle, foot
Neurological system	Visual acuity; comprehensive examination if prior history of head trauma

BMI body mass index, *WADA* World Anti-Doping Agency

and urine tests are not recommended for asymptomatic athletes. Referral to a specialist should be considered whenever a serious health concern arises.

2.3.2 Musculoskeletal Injuries

Injuries are common in adolescents participating in sports, particularly for those participating in a single sport on a nearly continuous yearly schedule, and are the main cause of sports cessation. Many injuries require medical treatment that can include surgical repair and lengthy rehabilitation, and can result in time lost from school and other activities, social isolation, loss of motivation, and delays in conditioning and technical development. Injuries may also require parents to be absent from work whilst attending appointments. In the longer term, musculoskeletal injuries have been associated with significantly increased risks of osteoarthritis and other chronic conditions, and concussion and its long-term sequelae are currently of primary concern. Injuries therefore represent an important burden for families and the health care system. The characteristics of the growing musculoskeletal system have been described in Chap. 1.

Overuse injuries develop when repeated mechanical loading exceeds the remodeling capability of the structure under stress. They are the result of a complex interaction of multiple intrinsic and extrinsic factors, including growth-related factors that are unique to the pediatric population. Their prevalence ranges from 37 to 68% across various youth sports and half of the overuse injuries diagnosed in adolescents could be preventable. Intrinsic factors are individual biological characteristics and psychosocial traits (e.g. growth and maturation, anatomical factors, susceptibility of growth cartilage and bones to repetitive stress, muscle-tendon imbalance, previous conditioning, history of prior injury, menstrual dysfunction, psychological and developmental factors), whereas extrinsic factors are external forces related to the sport type, the biomechanics of the activity and the training environment (e.g. training workload, competition schedule, resting periods, sport technique, training environment and equipment, adult and peer influences). Many overuse injuries result from a complex interaction of multiple risk factors in specific settings, combined with an inciting event. Some risk factors are modifiable (e.g., muscle strength and neuromuscular function, training workload); whereas others are not (e.g. age, gender, anatomical factors). The injury risk seems to be greatest during the adolescent growth spurt and previous injury is the strongest predictor of future injuries, due to inadequate rehabilitation and/or a failure to identify and modify the factors that contributed to the first injury. The burnout is also a concern in competitive sport; young athletes with overuse injuries and/or presenting signs of burnout should benefit of a careful medical evaluation and treatment.

Musculoskeletal injuries in adolescents commonly affect physis (growth plate), apophysis or articular cartilages. Approximately 15% of all fractures in children involve the physis. Acute physeal injuries are generally described using the Salter and Harris system (type I–V). *Chronic physeal injuries* can be seen in the distal radius (e.g. in gymnasts), the proximal humerus or the medial epicondyle (e.g. in racquet or throwing sports) and the proximal tibia (e.g. in runners) in a variety of sports, as a result of diminished metaphyseal perfusion due to repetitive loading and damage to the growing cells. The natural mineralization of chondrocytes is inhibited and cells continue to divide in the zone of proliferation. A widening of the physis can be observed radiographically or with magnetic resonance imaging (MRI). In severe cases, a partial or complete growth arrest resulting in altered long-bone growth can be observed. *Apophyseal injuries* occur at immature tendon-bone attachment sites. The patellar tendon-tibial tuberosity apophysis (Osgood–Schlatter disease), the inferior patellar pole apophysis (Sinding–Larsen–Johansson), the Achilles tendon-calcaneal apophysis (Sever's disease), the ischial tuberosity apophysis, the antero-superior and antero-inferior iliac spines apophysis are common during the growth spurt, due to biomechanical factors related to long-bone growth and limb movement. The weakness of the growth cartilage relative to the tendon is a contributing factor in these injuries, as well as decreased flexibility that increase traction at the apophyseal insertion of the tendon. This may occur as a result of more rapid growth in the long bones than the muscle-tendon attachments. Sometimes, the whole physis can be avulsed (e.g. the tibial or ischial tuberosity). Osteochondritis dissecans is a focal *articular cartilage lesion* that typically occurs at the ankle, knee, or elbow. Its etiology remains unclear, but it may be due to a lack of adequate blood supply to the cartilage. In some cases, repetitive loading may aggravate the existing abnormality of the articular cartilage.

The first step of the treatment of overuse injuries is to protect the injured site by reducing tissue loading and mechanical stress. The training should be adapted but activities that do not stress the injured site generally can be continued. For example, weight-bearing activities (e.g. running, jumping) should be avoided for a patellar tendon-tibial tuberosity apophysis or an Achilles tendon-calcaneal apophysis, but cycling or swimming or running in a pool with the use of a flotation can be recommended. For chronic physeal injuries, a sufficient period of rest is important, usually at least 6 weeks. In some cases, the healing process can take several months and radiographs can help guide the treatment. Bracing generally is not needed for physeal injuries unless pain is occurring during routine daily activities. Reducing or temporarily eliminating the mechanical stress at the injured site is usually sufficient to relieve the pain, but ice or other methods of cold application can be helpful. Acetaminophen may be used for pain relief if symptoms do not respond to rest and ice. There is no evidence that nonsteroidal anti-inflammatory drugs (NSAID) have any benefit in overuse injuries beyond their analgesic properties. Once pain is relieved, a comprehensive rehabilitation program, including proprioceptive retraining, can be initiated to restore tissue strength and flexibility. The next steps are general conditioning and then sport-specific activities. When the adolescent is able to perform sport-specific skills without pain, a full level of training can be resumed.

2.3.3 Pubertal Abnormalities and Menstrual Dysfunction

Intensive physical training and participation in competitive sports during childhood and adolescence may impact athlete's pubertal development. On the other hand, pubertal timing, early or late, may influence an athlete selection for a particular sport. Precocious puberty is defined as the onset of Tanner 2 secondary sexual characteristics before the age of 8 years in girls or the age of 9 years in boys, if continued progression of pubertal development occurs in close follow-up. Delayed puberty should be considered if girls have not reached Tanner 2 stage (breast development) by age 13 years old, or if boys have not reached Tanner 2 stage (genital development) by the age of 14 years. Some boys can temporarily develop glandular breast tissue (pubertal gynecomastia) between genital tanner Stage 3 and 4, which may be psychologically disturbing but not physically harmful.

Genetic factors, training load, nutritional status and psychological stress are the main determinants of pubertal timing in young athletes and a wide variation can be observed among adolescents. Pubertal delay may be caused by idiopathic conditions, nutritional deficiencies, hypothalamic pituitary gonadal axis variations, or neoplastic and genetic disorders. Those that practice aesthetic sports, especially gymnasts, are predisposed to a delay in pubertal development, but it has been shown that chronic negative energy balance associated with disordered eating or eating disorders, not training per se, plays a crucial role in the pathogenesis of functional hypothalamic hypogonadism in female athletes. Metabolic and psychologic stresses activate the hypothalamic-pituitary-adrenal axis and suppress the hypothalamic-pituitary-ovarian axis. Girls who do not begin breast development by the age of 13 or have a delayed menarche need a comprehensive evaluation and a targeted treatment. *Primary amenorrhea* is defined as failure to start menses within 3 years of Tanner stage 2 or by the age of 14 years with the absence of growth or the development of secondary characteristics, or as absence of menses by the age of 16 years with normal development of sexual characteristics. *Secondary amenorrhea* is defined as the cessation of menstruation for at least 6 months or for at least 3 cycle intervals.

Primary amenorrhea is a symptom with an extensive list of underlying causes, the majority of which are rare: hypothalamic and pituitary diseases (functional, isolated GnRH deficiency, constitutional delay of puberty, hyperprolactinemia), gonadal dysgenesis/primary ovarian insufficiency, polycystic ovary syndrome, outflow tract disorders, receptor abnormalities and enzyme deficiencies. The incidence of delayed menarche, however, needs to be assessed in relation to the age of menarche in the mothers of the young athletes rather than in relation to a less active control group. Laboratory and imaging studies may include: urine pregnancy test; serum prolactin, thyroid stimulating hormone (TSH), free thyroxine (T4), gonadotrophins (follicle stimulating hormone (FSH), luteinizing hormone (LH)) levels; and an abdominal ultrasound scan. The patient should be referred to an obstetrician-gynecologist for a comprehensive medical evaluation.

Female adolescent athletes can also present a "female athlete triad," which refers to the combination of low energy availability with or without disordered eating, menstrual dysfunction, and low bone mineral density. Low energy intake is a common cause of menstrual dysfunction in this population, up to 80% of athletes in aesthetic sports, athletics or weight-related sports being affected. Clinically, these conditions can manifest as disordered eating behaviors, menstrual irregularity or amenorrhea, and stress fractures (femoral neck, tarsal navicular, metatarsal, anterior tibial cortex). Consequences of these clinical conditions may be reversible so prevention, early diagnosis and intervention are critical. The goal of the treatment is restoration of regular menses as clinical marker of reestablishment of energy balance, and an increase of bone mineral density assessed by DXA. Adjusting energy expenditure and energy availability is the main intervention. A team approach involving the youth female athlete, obstetrician-gynecologist, dietician or nutritionist, coaches, parents and psychologist is recommended. Primary and secondary amenorrhea in youth female athletes can serve as a warning sign, as adolescence is an important time for bone accrual, growth, and development. Thus, screening systematically for low energy intake, weight loss or insufficient weight gain for age, establishing causes and consequences of menstrual disorders, and managing the condition with an interdisciplinary team is most effective. Screening for the female athlete syndrome should be an integral part of the PPE. The *Female Athlete Triad Coalition's Recommended Screening Questions* can be used. In addition, parents and coaches should be educated and informed.

2.4 Pitfalls in This Population

- Wide variation among individuals in the timing of the pubertal growth spurt; the selection or exclusion in many sports follows a maturity-related gradient.
- Insufficient knowledge about the growth and maturation, benefits and risks of competitive sports in adolescent athletes among adolescents, parents, coaches, and health care professionals.
- Increased risk of disordered eating, amenorrhea and osteoporosis in adolescent female athletes due to norms in aesthetic or weight-related sports; coaches and peers can reinforce a negative body image and disordered eating.

2.5 Fact Box

- Regular physical activity promotes physical and psychological health in adolescents.
- The pubertal period is marked by substantial physical, psychological and social changes, and is considered as a critical window in competitive sports because it is associated with an increased risk of musculoskeletal injuries.
- The pre-participation evaluation may identify prior injury and underlying causes, and is an opportunity to provide information and guidance on lifestyle (e.g. nutrition, sleep) and health issues.
- A history of prior injury is a risk factor for overuse injuries and should be systematically recorded during examinations.
- Youth strength training can have potential benefits including sport performance, injury prevention, and rehabilitation.
- Adolescent female athletes should be screened for eating disorders and menstrual dysfunction, as potential predisposing factors to bone fragility and susceptibility to stress fracture.
- Education of adolescents, parents, and coaches regarding growth, maturation, benefits, and risks of competitive sports, and preventive measures is recommended.
- Communication between athletes, parents, coaches, and health care professionals is a key to prevent and manage injuries and diseases.

– Weekly and yearly participation time, and sport-specific repetitive movements should be limited, and resting periods should be preserved.
– An individual training and competition plan based on the sport and the athlete's age, growth gain, readiness, prior injury history and current health status should be established.

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