Review Article

Participation in sports in relation to adolescent growth and development

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Abstract: Puberty is defined by physical growth, development of secondary sexual characteristics, and maturation of psychosocial skills. The initiation and rate of progression of pubertal events varies among adolescents, but pubertal changes occur in a predictable stepwise manner. Factors including individual differences in physical and psychosocial development, stage of development based on age (early, middle, and late), and the rate of pubertal development, may all contribute to the way in which adolescents experience sports activities. During adolescence, gender differences also become more apparent and may significantly impact sports participation. As practitioners evaluate overall development and adolescent readiness for sports participation, they should consider the different areas of development including: somatic, neurologic, cognitive, psychosocial-function in an integrated and interdependent approach.

Keywords: Adolescence; development; sports participation

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Somatic growth & maturation

Since chronologic age does not necessarily correlate with physiologic or somatic pubertal changes, it is clinically important to assess an individual's Tanner stage or sexual maturity rating (SMR) (1). Bone age is the ideal method to assess skeletal maturity. Several reviews and studies have examined aspects of somatic, sexual, and skeletal growth and maturation during adolescence that are particularly relevant to sport participation and performance (1-8). Key elements of these studies, as well as the developmental continuity and interrelatedness are discussed as follows.

Weight

The average weight gain for adolescent males ranges from 6–12.5 kilograms (kg) per year with a peak weight gain of 9 kg per year. Likewise, the average weight gain for adolescent females ranges from 5.5–10.5 kg per year with a peak weight gain of kg per year (9,10). In males, the peak growth spurts of height, weight, and muscle occur at the same time in adolescent males, but in females, the growth spurts occur in sequence, in that order respectively (2,11).

Height

During adolescence, the maximal rate of linear growth is known as peak height velocity (PHV). Male adolescents generally reach PHV by 14 years of age during SMR 4, with an average gain of 9 cm per year with a range of 7–12 cm per year (1,2,10). Typically, adolescent females reach PHV somewhat earlier, by 12 years of age during SMR 3, usually correlating with the time period that is 6 to 12 months before onset of menstruation (menarche). Female adolescents experience an average growth in height of 8 centimeters (cm) per year, with a range of 6–10.5 cm per year (1,2,10). In general, the progression of linear growth starts in the lower extremities, followed by growth of the torso, and upper extremities.

Body composition

Body composition changes during adolescence vary by gender. Body composition is described in terms of fat mass (FM), fat-free mass (FFM), and body fat distribution (8,12-15). During early to middle adolescent years, males and females tend to have increases in both FM and FFM (6). The increase in FM and FFM continues during PHV, however fat accumulation in the extremities may transiently decrease. By SMR 4 and 5, females continue to gain FM with proportionately more fat concentrated on the lower body (16). In general, body mass index (BMI), which is calculated as weight in kg divided by stature in meters squared, has been shown to have a better correlation with FM than with weight (17). Muscle mass and bone mass also contribute to the numerator in BMI calculation, which can lead to a falsely high BMI value in an individual with low FM and high muscle mass (14).

Flexibility

Generally, female adolescents have greater musculoskeletal and physical flexibility compared with males. Overall flexibility tends to decrease leading up to mid-adolescence in males. However, flexibility tends to increase slightly during early adolescence in females and typically plateaus by age 14–15 years (8,11,15,18). During early to mid-adolescence, skeletal growth typically occurs before musculotendinous growth and especially in males; this pattern of growth may partly contribute to a relative decrease in musculotendinous flexibility (4,6,15). Physical internal factors that influence an individual's flexibility include muscle volume, bone structure, and the muscles, tendons, joint capsules, and ligaments that contribute to tissue elasticity. External factors that influence an individual's flexibility include environmental factors such as temperature or an athlete's warm-up time/physical exercise.

Muscle growth and strength

Muscle mass growth occurs during adolescence in both males and females, accompanying a linear increase in muscle strength. However, muscle mass growth may be relatively more pronounced among males due to the greater androgenic effects. Female adolescents reach a plateau of muscle strength increases by about age 15 years (2,4,15,19), while males demonstrate an acceleration of muscle strength around age 13 years. The peak increase in muscle strength follows a peak in muscle mass by about 12 months (2,8,15). Researchers have found that an adolescent's response to strength training optimal during SMR 4 and 5 in both male and female athletes (2,4,6,19,20). Some research has additionally shown that high intensity exercise in primary school children enhances musculoskeletal and metabolic outcomes in pre- and early-pubertal girls (21).

Bone mass

Appropriate nutrition and physical activity, including weight-bearing and loading, are essential contributors to optimal bone growth. Lifetime bone mineral density acquisition occurs primarily during the second decade of life (13,22,23). Physical activity improves bone health in children and adolescents, particularly at a weight-bearing site. Weight bearing activity improves cortical bone structure due to reduced endocortical expansion (24-30). In addition to exercise and nutrition (including calcium intake), factors such as genetics and hormonal status determine peak bone mass (16). Athletes who employ drastic weight-control measures may lack proper nutrition, predisposing them to impaired bone mass accumulation (8,13). Similarly, lower bone mineral density may be seen in young amenorrheic athletes and may increase fracture risk (31).

Menstrual considerations

As previously mentioned, exercise-related menstrual dysfunction may negatively affect growth velocity and peak bone mass acquisition. Higher ghrelin and lower leptin secretion (related to lower FM) is associated with lower luteinizing hormone (LH) secretion in amenorrheic athletes compared to eumenorrheic athletes (32). Some studies have suggested that young female athletes have a higher prevalence of menstrual disorders (33,34) and that premenstrual syndrome (PMS) increases in prevalence with duration and intensification of competitive exercises in girls and young women (35). However, other studies have shown that physical activity can improve dysmenorrhea and decrease the need for analgesics for improving dysmenorrhea in women 18–28 years old (36).

Implications of early and late maturation

Early pubertal development is characterized by advanced bone age compared with chronologic age. Conversely, late pubertal development is defined by delayed bone age compared with chronologic age (1,2,10). PHV attainment prior to age 11 years in females and 13 years of age in males may be seen in early-developing adolescents. PHV may not be reached before 13 years of age in females and 15 years in males in late-developing adolescents (1,2,37,38). Early maturing adolescent males tend to be taller, have greater muscle mass, FM, and muscle strength compared with average or late-maturing males. Later maturing adolescent males typically have smaller stature with weaker muscle strength and coordination. The later maturing adolescent male may struggle to meet performance expectations depending on the sport, leading to potential anxiety and frustration.

Early maturing adolescent females tend to initially be taller, have greater FM and FFM, and greater weight for height. These physical features may give a modest (if any) advantage in sports and actually may lead to difficulty with particular motor tasks. Depending on individual physical features, early maturing adolescent females may not be considered ideal for certain sports (e.g., gymnastics, dancing, diving, and figure skating). Later maturing adolescent females tend to be taller, have lower weight for height, and less FM (18).

Early adolescence (10–13 years)

Physical growth and development

Early adolescence is characterized by rapid changes in physical growth and motor skills, as well as the emergence of special skills and talents. In general, females experience puberty earlier than males and therefore may become temporarily taller and heavier than their male peers. Physical performance differences are more significantly influenced by age at onset of puberty and environmental conditions than by an individual's chronologic age (4,8,37,39). Overall development, physical differences, rate of growth progression, and physical skills can vary widely among adolescents, and may contribute to body image concerns in some. Increases in muscle mass, strength, and cardiopulmonary endurance that occur during puberty are greater than at any other age (2,6,15,18,40). Specifically, adolescent males demonstrate sharp increases in their ability to perform tasks that require muscle strength, while adolescent female athletes tend to show a gradual improvement in muscle strength skills (6,11,18,37).

Cognitive development

According to Piaget, early adolescents are beginning the formal operational stage of cognitive development, with improved inductive and deductive reasoning abilities (41-44). In this stage, early adolescents develop prepositional logic and move towards a more developed a sense of morality and altruism. For most individuals in this age range, cognitive functioning still occurs at a concrete level and future time perspective has not been fully developed (1,42,43,45). However, some early adolescents begin to develop abstract thinking, analytic abilities, problem-solving skills, and transitional skills (41,43,44,46,47).

In this stage, individuals develop the cognitive ability to understand and remember complex strategies, which can be applied in sports such as football or soccer. The cognitive aspects of language development, such as the ability to understand semantics and the ability to use language to convey variety and quality of information, develop in this stage. Adolescents within this age range are typically able to understand the concepts and basic theories behind how a sport is played (48). In order to understand more complex "plays", an early adolescent can write down symbols, signs, and coded words, as well as use such language to communicate with teammates the special language related to specific sport activities.

As a result of this developing process, problems may arise (49). One such problem is that early adolescents often have difficulty extrapolating general rules of the game from one situation to another. Early teens may also fail to connect the importance of regular practice or training to the logical outcome of future athletic success, and may instead believe athletic failure or success is due to one's own uniqueness. Since early adolescents are preoccupied with bodily concerns they may have a reaction to minor injuries that is out of proportion to actual level of severity. Other problems include the fact that some teens may argue or disagree with adults as cognitive reasoning abilities become more sophisticated. This can lead to arguments with referees, trainers, coaches, or peers, and the consequences of penalties or ejection from games. Early adolescents also seek approval from peers, and may go to great lengths to gain acceptance, including the impulsive engagement in high risk-taking behaviors.

Psychosocial development

During the early phase of adolescence, a convergence of body image and motor skills occurs (48). Sports participation provides an early opportunity for a sense of independence and freedom (40,50). Much of an early adolescents' time is occupied by comparing the self to peers and worrying over perceived physical differences (1,5,51). Before taking action, these adolescents can listen to opinions of peers and adults and independently weigh consequences of their decisions. While peer acceptance is important to young teens, family approval and support are substantial guiding forces (43,44). The ability to enjoy and take pride in increasingly complex accomplishments in sports can contribute to improved self-image. Some studies suggest adolescents that develop a positive self-image tend to experience consistent successes, while those who encounter recurring failures tend to develop a less healthy self-image (3,5,18,46,52).

Implications for sports participation

Entry level competitive sports, such as football, basketball, baseball, and tennis, are appropriate for most early adolescents (48). Exposure to and participation in a variety of different activities is usually preferable, but depending on innate ability and talent, individuals may begin to specialize in their favorite sport. When starting, it is important to consider that young adolescents require demonstrations of activities in addition to verbal instructions.

It is also important to recognize that the behavior of adults and peers in a sports activity environment directly influences the behavior of a young adolescent. Bullying and even teasing may have negative psychosocial and mental health effects on children and teens and should be discouraged in sports settings. Since young adolescents have limited life experiences, they may be highly sensitive to criticism and negative comments from others, potentially leading to false beliefs that their coach, trainer, or teammates "hate them". At the other end of the spectrum, adults may try to convey positive messages that may inadvertently cause problems when a precocious athlete is no longer superior to their peers.

Middle adolescence (14–16 years)

Physical growth and development

During middle adolescence, individuals continue to hone their gross motor skills as they experience continued increases in muscle mass, strength, and cardiopulmonary endurance (48). A study of competitive athletes between the ages of 14 to 24 years demonstrated that dynamic strength of the quadriceps muscle was positively associated with body weight, years of jogging, years of soccer, and weekly hours of basketball (53). Time spent in sports specific activities during this stage of adolescents positively contributes to strength and skill. Agility skills, motor coordination, power, and speed continue to improve and develop during middle adolescence (11,15). Females generally perform better than males in balance tasks, but generally do not show improvement in motor performance after age 14 years, while males continue to improve throughout adolescence (4,11,15,18). In male adolescents maximal speed peak occurs before PHV and both strength and power peaks follow PHV (4,11,14,15,18).

A transient period of motor incoordination may occur during the adolescent growth spurt (between 12–14 years of age) and occurs predominately in boys (4,8,11,18). The period of incoordination typically lasts 6 months and is thought to be secondary to a temporary disturbance of performance tasks that require balance. Some experts doubt the clinical significance of this period of incoordination and some doubt the existence of this phenomenon. No unique characteristics (sociocultural, anthropometric, or physical activity) have been identified in adolescents experiencing transient incoordination and in the absence of any underlying neuromuscular disorder; reassurance is the treatment of choice.

Cognitive development

During middle adolescence, individuals experience improved abstract thinking and the ability to understand behavioral consequences (1,6,41,43). Adolescents in this stage may use creativity, implementation helpful strategies and techniques along with physical execution, as they experience improved understanding of a particular sport (54). An athlete may observe their own behavior and analyze what was done correctly and what could be improved upon; evaluating strengths and weaknesses. The athlete can also compare and contrast behaviors with their personal best or other training data, determine what needs to change, develop action plans, formulate and implement new approaches, and begin the process again (54,55). While the adolescent in this stage can perform these functions independently, feedback from coaches or trainers remains valuable.

Psychosocial development

Levels of independence increase during middle adolescence

(43,44). Adolescents are capable of improved critical thinking skills and are able to have multiple interpersonal relationships (1,51). Adolescents in this phase rely more on peers (as opposed to parents) as a frame of reference and use peer feedback to set goals and rules of conduct. The coach may become a significant role model for a middle adolescent as they identify with non-parental adults (8). Conflicts with parents or other authority figures may arise during middle adolescence, as emotions can feel very intense and risk-taking behaviors may occur, including increased risk taking in sports. In this stage, sports participation may be used to impress others or achieve social status (8,52). It is important to recognize that media portrayals of professional athletes exert greater influence at this stage of development, leading to potentially unrealistic expectations of personal and monetary success from participation in sports (7,8,18,46,52).

Implications for sports participation

During middle adolescence, individuals may find it difficult to adjust to the somatic growth spurt in the context of their sports or physical activity specific performance. For example, adolescents participating in wrestling may have difficulty maintaining a personally desired lower weight in spite of intentional weight control measures. A teen may refuse to move to a higher weight class for fear of losing in a category in which they would be at the lower end of weight limits. Female athletes also may react to normal pubertal weight gain by engaging high calorie-burning sport activities to lose weight. In particular, female adolescents participating in dance may engage in excessive weight-control measures to maintain an extremely thin physique.

Adolescents at this stage of development are able to recognize and understand the demands of a particular sport and can decide if they are willing to engage in the necessary behaviors to meet those requirements. However, adolescents may encounter pressure to increase muscle bulk, weight, strength, and/or endurance to improve performance, depending on the specific sport in which they are participating. Increasingly competitive sports participation leads to additional pressure on athletes to meet a specific body type or performance standard. For example, adolescents who play football may be encouraged to gain weight, lift weights, run, engage in multiple activities, and increase their flexibility and agility in order to be considered competitive by coaches and trainers. Adolescents in this stage are still sensitive to peer pressure and the need to please significant adult figures. This may lead to athletes engaging in unhealthy practices to achieve weight gain or bulk, such as using anabolic steroids or other drugs (6,50,52). Adolescents may understand the consequences of unhealthy methods, such as using steroids, but the desire for peer and athletic recognition may outweigh their knowledge of the negative consequences.

Overall, competitive sports can be a rewarding experience, however the personal limitations of each athlete should be recognized and alternate avenues for peer approval and acceptance should be available for adolescents.

Late adolescence (16–20 years)

Physical growth and development

Full physical maturity is reached by most adolescents at this stage of development. During this phase gross motor skills continue to grow and skills continue to specialize. Strength, speed, and size are gained for male adolescents during this phase, but at a slower rate compared with earlier development. Unfortunately, female athletes may continue to accumulate FM that has the potential to negatively affect performance. Additionally, aerobic capacity and muscular strength can continue to increase into adulthood, albeit at a slower rate than early puberty.

Cognitive development

Athletes in late adolescence may establish more realistic goals about their sports abilities and participation. As decision making becomes more future oriented, competing priorities including academics, dating, and future career or educational goals may supersede the importance of sports participation for an individual. During this period in life, an athlete's personal values may be more defined, and their intellectual capacity, functional capacity, and abstract thought processes are well developed (1,41-44). For participation in sports, adolescents now possess the cognitive ability to understand and remember complex strategies and have fully developed perceptual motor abilities. Late stage adolescents are fully capable of competitive sports and specialization, but most individuals prefer to engage in recreational sports.

Psychosocial development

Adolescents at this stage are more adept at emotionally dealing with successes and failures, as well as potential pressures from parents, coaches, societal expectations, and sports demands. Adolescents with secure mental and physical health will demonstrate well-adjusted body image. In this phase, adolescent athletes understand and accept a realistic view of the role of sports in their lives (5,7,8).

Implications for sports participation

The demands of most sports can be met by individuals in late adolescence as they possess well developed physical, cognitive, social, emotional, visual-motor, and perceptual motor capabilities. The ability to engage in professional or high level Olympic sports, however, depends on the individual athlete and their ability to attain elite skills and remain psychologically motivated. Athletes who are physically and mentally able to qualify for competitive sports are faced with the decision of whether or not to make this a priority in their lives. Participation in sports activities for recreation, exercise, and fitness, can be enjoyed by all adolescents at this stage.

Growth, development, and training

PHV timing, rate, and magnitude are not impacted by regular physical training or sports participation, as demonstrated by several research studies (4,8,11,14,15,18,19,56). However, regular weight training may positively change the FM/FFM ratio and contribute to increase FFM. Aerobic capacity can be improved by endurance training and muscular strength may be improved by resistance training in children and adolescents (15,18-20,57). However, gains in strength in pre-pubertal children may not be the result of muscle hypertrophy, rather more of a reflection of neuromuscular adaptation.

Parents may question if special talent for sports can be identified early in childhood or adolescence, but due to the numerous and complex factors that contribute to athletic success, it is very difficult to accurately predict such talent. Researchers have studied various characteristics of children and adolescents to attempt to identify athletic talent. Some of the variables affecting athletic ability include the continuous growth and development process that vary among individuals, different sport-specific demands, and cultural factors (8,18,48,58,59).

Early sports specialization and intense training before an athlete is developmentally ready has not been shown to enhance sports performance or guarantee future athletic success, in some reports (18,56,60). Early intense athletic participation may contribute to stress-related physical complications such as overuse injuries, stress fractures, menstrual disorders, or growth plate injuries. Some athletes may also experience emotional issues from intense early participation, such as depression or anxiety, conversion reactions, or disordered eating behaviors (18,56,60).

Neuromuscular adaptive responses are improved by regular physical training, contributing to improved sport-specific skills and performance (8,15,18,19,53,56). Physiologic, psychologic, and environmental variables that influence athletic performance may include: somatotype, age, nutritional status, motor skills, perceived physical abilities, training level, genetics, and injury risk based on prior injury. Throughout childhood and early adolescence, motor skill efficiency progressively increases (4,11,39,61). From a physiologic standpoint, performance ability may be limited by lower anaerobic and aerobic capacity in a young athlete. However throughout childhood and adolescence, the relationship aerobic capacity, endurance, and performance is not robust. Athletic performance is also influenced by psychologic factors such as internal motivation, aggression, personality, and self-confidence. Negative impacts on athletic performance may come from factors such as, but not limited to inadequate nutrition, prior injury, excessive training, decreased fitness, decreased endurance, and joint laxity.

Neurodevelopment and injuries

An adolescent's growth and development has implications regarding specific risks of sports-related injuries. Growth and development also may impact short- and long-term complications of sports-related injuries. Numerous reports have suggested precautions and preventive measures to avoid such injuries (4,6,8,11,14,15,18). Neurodevelopmental immaturity can predispose young children to injury. Children and young teens may lack both the motor skills and cognitive abilities to fully understand risks and demands of a particular sport. Children may be unintentionally pushed beyond developmental limits when parents or coaches sometimes fail to appreciate an athlete's readiness, which may result in injury.

Adverse effects of intensive training have previously been noted and such consequences may include overuse injuries, adverse effects on growth, delayed menarche or amenorrhea, and disordered eating. Certain specific activities may be more stressful than others for developing children. For example, the American Academy of Pediatrics

(AAP) recommends that for children participating in triathlons, the specific triathlon event should be specifically designed with consideration of an athlete's developmental stage (62). In addition, young athletes may suffer significant long-term cognitive, memory, and fine motor impairment secondary to sports related, mild, traumatic brain injuries (12,63).

The adolescent years are associated with special risks for injuries related to growth and development (64). Given the rapid growth in height and weight that occurs during adolescence, specific risk of injuries should be considered. For example, increased risk of injury in football and other contact collision sports may occur from increased force and momentum during collisions, due to the rapid growth during adolescence (63,65,66). Later stage adolescents may also have increased risk of injury due to their enhanced motor skills, which may allow for athletes to participate in higher level, more intensely competitive sports (58). During childhood and adolescence, the growth cartilage at the epiphyseal plate, joint surface, and apophyses tends to be "the weaker link" in the musculoskeletal system, and is especially susceptible to injuries (65-68).

Special considerations: neurodevelopmental disabilities and sports participation

Neurodevelopmental disabilities occur on a wide spectrum, ranging from mild, with minimal effect on a child's daily life, to severe, with the child being fully dependent on others and on assistive technology (9,59,69). This group of individuals includes children with cerebral palsy, intellectual disability, communication disorders (language disorders and autism), learning disorders, attention and cognitive disorders, visual and hearing impairment, and various neuromuscular disorders (2,9,69,70). Participation in sports should be available to the vast majority of children and adolescents with neurodevelopmental disabilities. However, sports should be modified or adapted as appropriate with disability-specific provisions.

Conclusions

The growth and development process in children and adolescents is a complex process and impacts athletics and sports participation. The rate of developmental progress varies by individual; however the sequence of events occur the same during normal development. As one looks at the overall development of a child or adolescent, consideration of the interrelated areas of development (somatic, neurologic, cognitive, and psychosocial) and level of maturation of each area should guide the level of an athlete's sports participation.

Early sports training for younger athletes do not appear to enhance athletic achievement or abilities and it is not possible to predict future athletic excellence. In general, most children are physically and cognitively equipped to participate and compete in sports by age 12 years and are able comprehend the complex tasks required in specific sports.

Sports participation is generally a positive experience for children and adolescents and should be encouraged. All adolescents can participate in some level of physical activity. Individuals with physical, cognitive, behavioral, or neurodevelopmental disabilities may require adaptation or assistance with specific sports activities. Level of involvement in specific sports is determined by many factors, including physical growth and development, cognitive development, psychosocial development, as well as environmental factors such as financial ability, social resources and expectations, and motivation or interest of the athlete. Overall, participation should be individualized and appropriate to the developmental stage and personal interests and abilities of the adolescent.

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Footnote

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