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GROWTH AND MATURATION: BASIC PRINCIPLES AND EFFECTS OF TRAINING

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I. PRINCIPLES OF GROWTH, MATURATION, AND DEVELOPMENT

1.1. INTRODUCTION

The interval between birth and adulthood is commonly divided into age periods. The first year after birth (birth to the first birthday) is labeled infancy, which is followed by childhood. Childhood is usually subdivided into two phases, early and middle. The former approximates the "preschool" years, about 1 through 5 years of age. The latter approximates the "elementary school" years, about 5-6 through 10-11 years. The upper limit of middle childhood is arbitrary because it is followed by adolescence, which is variable in when it starts. Some fourth grade girls, for example, who are about 9-10 years of age, have already entered the early stages of adolescence. The termination of adolescence is also quite variable so that it is also difficult to specify when adulthood begins. Biologically, some girls are sexually mature by 12 years of age and some boys are sexually mature by 14 years of age; i.e., they are biologically adult. Yet, they are adolescents in the eyes of society. Adulthood is a socially defined concept, usually in the context of completing high school, and in some instances, completing college.

This chapter has several objectives:

- What are the basic principles of growth, maturation, and development?
- How do they interact during childhood and adolescence?
- What is the pattern of age changes and sex differences in growth, maturation, and development from childhood through adolescence?
- What is the pattern of change in the performance motor, strength and aerobic tasks from childhood through adolescence?

1.2. GROWTH, MATURATION, AND DEVELOPMENT

Children and adolescents experience three interacting processes: they grow, mature and develop (Table 1). These terms are often treated as having the same meaning. They are, however, three distinct tasks in the daily lives of children and adolescents for approximately the first two decades of life.

Growth

Growth refers to the increase in the size of the body as a whole and of its parts. Thus, as children grow, they become taller and heavier, they increase in lean and fat tissues, their organs increase in size, and so on. Heart volume and mass, for example, follow a growth pattern like that for body weight, while the lungs and lung functions grow proportionally to height. Different parts of the body grow at different rates and different times. This results in changes in body proportions - relationship of one part of the body to another. The legs, for example, grow faster than the trunk during childhood; hence, the child becomes relatively longer-legged for his or her height.

Table 1. Universal tasks of childhood and adolescence.

GROWTH:	MATURATION:	DEVELOPMENT:
Size	Skeletal	Cognitive
Proportions	Sexual	Emotional
Physique	Somatic	Social
Composition	Neuroendocrine	Motor
Systemic	Neuromuscular	Moral

SELF-ESTEEM
BODY IMAGE
PERCEIVED COMPETENCE

Adapted from Malina *et al.* (in press)

Maturation

Maturation refers to progress towards maturity or the biologically mature state. It is an operational concept because the mature state varies with body system. All tissues, organs, and systems of the body mature. Maturation is process which should be viewed in two contexts - timing and tempo. Timing refers to when specific maturational events occur, e.g., age at the beginning of breast development in girls, the age at the appearance of pubic hair in boys and girls, or the age at maximum growth during the adolescent growth spurt. Tempo refers to the rate at which maturation progresses, e.g., how quickly or slowly the youngster passes through the adolescent growth spurt. Timing and tempo vary considerably among individuals.

Development

Development refers to the acquisition of behavioral competence - the learning of appropriate behaviors expected by society. As children experience life at home, school, church, sports, recreation, and other community activities, they develop cognitively, socially, emotionally, morally, and so on. They are learning to behave in a culturally appropriate manner.

The three processes, growth, maturation and development, occur at the same time and interact. They interact to influence the child's self-concept, self-esteem, body image, and perceived competence. Teachers and coaches (note, coaching is teaching) should be aware of these interactions. A mismatch between the demands of a sport and those of normal growth and maturation may be a source of stress among young athletes. How a youngster is coping with his/her sexual maturation or adolescent growth spurt, for example, may influence his/her behaviors, including sport-related behaviors and performance.

1.3. GROWTH IN BODY SIZE AND COMPOSITION

Height and weight are the two body dimensions most commonly used to monitor the growth of children and adolescents. With age, children are expected to become taller and heavier. Size attained at a given age (status) and rate of growth (progress) are usually monitored relative to growth charts. These charts are a reference for comparison for monitoring the growth status (size attained) of individuals or samples of children and adolescents. Revised charts height, weight and the body mass index (BMI, see below) for American children from birth to 20 years of age were recently made available (Kuczmarski *et al.*, 2000). These are based on a nationally representative samples of American children and adolescents, and replace the earlier charts which were used internationally (Hamill *et al.*, 1979). The charts include several curves which indicate the distribution of heights and weights (percentiles) at a given age. For example, a child at the 25th percentile for height is taller than 25%, and is shorter than 75% of the children of the same age and sex.

Height and weight increase gradually during childhood. By about 9-10 years in girls and 11-12 years in boys, the rate of growth in height begins to increase. This marks the beginning of the adolescent growth spurt, a period of rapid growth that is highly variable among individuals. The rate of growth increases until it reaches a peak, which is called peak height velocity (PHV) or maximum growth in height during the adolescent spurt. Then it gradually decreases and growth in height eventually stops. Girls, on average, start their growth spurts, reach PHV, and stop growing about two years earlier than boys. Nevertheless, when the growth spurt starts, when PHV is reached, and

when growth stops are very variable among individuals. Most other body dimensions follow a growth pattern similar to that for height and weight.

The growth spurt in body weight begins slightly later than that of height. Body weight is a composite measure of many body tissues, but it is often viewed in terms of its lean (fat-free) and fat components. Thus, body weight = fat-free mass (FFM) + fat mass (FM). Major components of FFM are skeletal muscle and bone mineral. FFM has a growth pattern like that for body weight and experiences a clear adolescent spurt. FM increases more gradually during childhood and adolescence. General guidelines for expected changes in height, weight, and body composition are summarized in Table 2.

Height and weight are frequently used in the form of the body mass index (BMI) – weight divided by height squared (kg/m^2). After an increase in infancy, the BMI declines through early childhood. It reaches its lowest point at about 5-6 years of age, and then increases with age through childhood and adolescence, and into adulthood. Sex differences in the BMI are small during childhood, arise during adolescence, and persist into adulthood. The rise in the BMI after the low point at about 5-6 years of age has been labeled the "adiposity rebound". It is suggested that children who have an early "rebound" have an increased probability of being overweight in late adolescence and young adulthood. This hypothesis, however, needs further confirmation.

An elevated BMI is generally accepted as an indicator of adiposity or fatness in public health and nutritional surveys. An international reference for the definition of overweight and obesity during childhood and adolescence has been recently developed (Cole *et al.*, 2000). These internatinally recommended age- and sex-specific cut-off points of the BMI for overweight and obesity between 2 and 18 years of age are based on pooled data from six nationally representative cross-sectional growth surveys – Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. In establishing the cut-off points, a BMI of 25.0 kg/m^2 at 18 years of age was considered overweight and a BMI of 30.0 kg/m^2 at 18 years of age was considered obese. Curves were then mathematically fit to the pooled BMI data from 2 years of age on so that they passed through a BMI of 25 kg/m^2 and 30 kg/m^2 at 18 years of age (retro-fitting). The values at each half year from 2 to 18 years of age are the respective cut-off points for overweight and obesity.

The interpretation of the BMI in childhood, adolescence and young adulthood as an indicator of fatness needs care. An elevated BMI is not necessarily indicative of fatness during childhood and adolescence. The BMI is reasonably well correlated with total body fat and percentage fat in heterogeneous samples, but has limitations. Associations between BMI and

fatness indicate a wide range of variability so that children with the same BMI can differ considerably in percentage fat and total fat mass, which emphasizes the need for care and sensitivity in the use and interpretation of the BMI as an indicator of fatness in individual children and adolescents.

Table 2. Guidelines for expected changes in height, weight, and body composition.

Pre-Adolescence or Pre-Puberty (about 6-10 years of age)

Children are expected to grow, i.e., increase in weight and height. Although there is much variation among individuals, children gain, on average, about 5-8 cm (2 to 3 inches) per year and about 2-3 kg (5 to 7 pounds) per year between 6 and 10 years of age. As adolescence and puberty begin, growth rates increase, first in height and then in weight.

Adolescence and Puberty

Adolescence is characterized by the growth spurt and sexual maturation. It is a time of considerable variation in when events occur and the rate at which children pass through them.

The following highlights general trends that characterize the growth spurt:

GIRLS - begins around 9-10 years
- reaches maximum around 12 years
- rate slows after 12 years, but growth continues to about 16-18 years

BOYS - begins around 11-12 years
- reaches maximum around 14 years
- rate slows after 14 years, but growth continues to about 18-20 years

Growth in height continues into the early 20s in some girls and boys

There is considerable variation among individuals in
TIMING - when the adolescent spurt occurs
TEMPO - rate of progress through the spurt

Body weight, FFM, and muscle mass also show adolescent spurts; they occur, on average, several months after the maximum rate of growth in height.

During the interval of maximum growth in height (about 11-13 years in girls and 13-15 years in boys), girls gain about 7 kg (15 pounds) in FFM while boys gain double this value, 14 kg (31 pounds); girls gain a bit more FM than boys during the interval of the growth spurt, 3 kg (6 pounds) versus 1.5 kg (3 pounds).

In a sense, during the growth spurt, "First you stretch them and then you fill them out!"

Adapted from Malina *et al.* (in press).

1.4. BIOLOGICAL MATURATION

The maturity status and progress of children and adolescents are ordinarily viewed two ways: skeletally and sexually. The timing of PHV is also an excellent maturity indicator, but longitudinal data are required to derive it.

Maturation of the skeleton focuses on the bones of the hand and wrist, which generally reflect the remainder of the skeleton. An x-ray of the hand and wrist is needed to assess skeletal maturation. As such, the method has limited utility outside of a clinical setting. It is, however, a valuable method that is useful throughout childhood and adolescence, and is also used along with height at a given age to predict adult height.

Sexual maturation is based on the development of the breasts and pubic hair in girls and the testes and pubic hair in boys. Assessment of sexual maturation is ordinarily done at clinical examination by a physician. Age at menarche, the first menstrual period, is the most commonly used indicator of sexual maturity in girls.

The two most obvious features of biological maturation during adolescence are puberty or sexual maturation, and the growth spurt (see above). The first physically apparent sign of sexual maturation in girls is usually the initial development of the breasts, followed by the appearance of pubic hair. The first overt sign of sexual maturation in boys, on average, is the initial enlargment of the testes, followed by the appearance of pubic hair. Each of these secondary sex characteristics goes through a series of changes as the individual passes through puberty to maturity. They are usually assessed by a physician at a clinical examination. Their assessment requires invasion of the youngster's privacy at a time of life when he/she is learning to cope with the physiological changes that are occurring during puberty. Monitoring of these characteristics requires utmost care and sensitivity to the youngster involved. Guidelines for normal variation in sexual maturation are outlined in Table 3.

Age at menarche is limited to girls since male puberty has no corresponding physiological event. Menarcheal status (i.e., has menarche occurred or not occurred) and age at menarche in individual girls can be obtained with a careful and sensitive interview. The average age at menarche in American girls is 12.8 years, although normal variation ranges from 9 through 17 years of age.

It is important that teachers and coaches are aware of such variation among individuals as well as the significance of sexual maturation for growth and behavioral development. Sexual maturation in boys is accompanied with marked gains in muscle mass and strength, and broadening of the shoulders relative to the hips. In girls, it is accompanied by smaller gains in muscle mass and strength, by a widening of the hips relative to the shoulders, and by gains in fatness. The net result is sex differences in strength, body build, and body composition in late adolescence and young adulthood. Sexual maturation also influences behavioral development, for example, increased self-consciousness,

concern with weight gain in girls, relationships with the opposite sex, and so on.

Table 3. Guidelines for normal variation in sexual maturation.

GIRLS

- The first physically apparent sign of sexual maturation in girls is the initial enlargement of the breasts. It occurs, on average, at about 10 years of age, but may occur before 9 years in about 10% of girls and not until after 12 years in another 10%.
- Mature breast development occurs, on average, between 14 and 15 years of age. However, maturity may occur as early as 12 years in some girls and not until 16 or 17 years in others.
- Progress from initial to mature breast development is highly variable among girls. Some girls may pass through the process in 2 years, while others may take 5 or more years.
- Menarche, the first menstrual period, is a rather late maturational event of puberty. It ordinarily occurs after maximum growth in height (peak height velocity). The average age at menarche for American girls is 12.8 years.

BOYS

- Initial enlargement of the genitals (testes and penis) marks the first physically apparent sign of sexual maturation in boys. It occurs, on average, about 11 years of age, but may occur around 9 years in about 10% of the boys and not until after 13 years in another 10% of the boys.
- Mature genital development occurs, on average, at about 15 years of age. However, maturity may occur as early as 13 years and after 18 years.
- Progress from initial to mature genital development is highly variable among boys. Some boys may pass through the process in 2 years, while others may take about 5 or more years.

Adapted from Malina *et al.* (in press).

1.5. BEHAVIORAL DEVELOPMENT

Development of behavioral competence proceeds simultaneously in several domains - cognitive, social, emotional, moral, and motor. Motor development, i.e., the acquisition of motor competence, and motor performance are considered in a separate section.

Middle Childhood

The period between the preschool years and adolescence is often called middle childhood. It approximately spans entrance into school (first grade) to the onset of puberty (which, as indicated above, is variable in timing).

Competence gradually develops in many behavioral domains during middle childhood. However, two features are especially significant. First, the child gradually refines his/her self-concept: Who am I?, How do I feel about myself?, Where do I fit in?, and so on. Second, the child learns many skills, including cognitive skills - reading, writing, number manipulation and others, and interpersonal behaviors and relationships that underlie social, emotional

and moral competence - sharing, cooperation, honesty, sensitivity to others, and so on. In the development of behavioral competence, the child often evaluates himself or herself. They very often ask questions about their identity and how others perceive them. Two primary sources of feedback in this self-evaluative process are adults, specifically parents, teachers and coaches, and peers (playmates and teammates). It is essential that adults who work with children be aware of their developing sense of self and the ongoing process of self-evaluation. Guidelines for the development of cognitive and social competence during middle childhood are summarized in Table 4.

Table 4. Guidelines for the development of cognitive and social competence during middle childhood.

5-8 years

Cognitive Competence

- Cognitive skills become elaborated as children show longer attention spans and increased problem solving ability.
- Children are able to handle multiple pieces of information; however, they have difficulty handling abstract or hypothetical questions.
- A major factor limiting the cognitive competence of young children is their lack of knowledge and experience using their developing skills.

Social Competence

- Children are expanding their understanding of self, i.e., self-concept formation.
- Children are interested in others, and often use other children as a reference of comparison in making self-evaluations and in defining themselves in terms of groups to which they belong.
- The peer group emerges as an important influence on children's behaviors. They are generally same-sex groups. Children have a strong sense of security in the group and in organized group activities.
- Given this sense of the group, children can learn a good deal from each other, which emphasizes the potential importance of cooperative learning environments.

9-12 years - transition from childhood to adolescence

Cognitive Competence

- Cognitive skills become more elaborated as children show longer attention spans and increased problem solving ability, and are able to handle multiple pieces of information.
- Logical thinking skills and hypothetico-deductive reasoning, and the ability to think about abstract concepts emerge during early adolescence.

Social Competence

- The strength of the peer group increases. The group is focal and is a means of establishing independence from adults.
- Individual differences in the onset of the growth spurt and puberty influence relationships with others and definition of the social self.
- A major social developmental task that emerges at this time is the formation of personal identity, i.e., accepting the self as worthy and different from others.
- There is a gradual shift from identifying with same sex peers to learning roles in heterosexual situations.

Adapted from Sproufe *et al.* (1992).

It is during middle childhood that the peer group emerges as a source of support, criticism, and comparison in handling the many challenges associated with an emerging sense of behavioral competence. Peer group activities occur in many settings and children have multiple peer groups, both formal as in school, church and organized sport, and informal as in neighborhoods and playgrounds. The significance and strength of peer groups increase with age during middle childhood.

The organized sport setting is a major source of peer group experiences for many children. In highly individual sports such as gymnastics, swimming, diving, figure skating and wrestling, coaches need to be especially sensitive to the child's need for group affiliation and the need to develop a sense of the group.

Table 5. Guidelines for the development of cognitive and social competence during adolescence.

Cognitive Competence
• Progress in logical thinking, hypothetico-deductive reasoning, and handling of abstract concepts continues.
• Enhanced abstract thinking is the basis for the ability for introspection. It is also the basis for emerging relationships between cognition and emotions.
• These cognitive skills expand the adolescent's ability to reason about moral and ethical issues.
Social Competence
• The formation of personal identity becomes crystallized, which contributes to establishing independence, i.e., the self as an independent person.
• The older adolescent's sense of self becomes more integrated, which contributes to better understanding of the uniqueness of each individual and to the ability to reconcile personal inconsistencies.
• Social relationships become more important. These contribute to self-evaluation and identify formation. Relationships with the opposite sex are especially important.
• There is increased acceptance of an adult role in different groups.

Adapted from Sproufe *et al.* (1992).

Adolescence

Adolescence, the transition from childhood to adulthood, is a period of major changes physically and behaviorally. The developmental tasks of adolescence are many, but three stand out. First, it is a period of physiological learning as the youngster copes with the physical and physiological changes associated with the growth spurt and sexual maturation. The youngster must learn to understand and accept the changes, to accept his/her body, and to adapt to masculine and feminine roles. A major concern of adolescents is their physical appearance. Second, it is a period of new relationships with age peers. During middle childhood, peer groups were largely same sex. During adolescence, youngsters develop relationships with age peers of both sexes, so that they have a major concern for social acceptance. And, third, it is a

period of striving for independence. The youngsters strive for emotional independence from parents and other adults as they prepare for adult roles. Hence, it is a time of emotional peaks and valleys, of self-doubt, of changes in self-esteem, and of changing interests. Many youngsters experience a decline in self-esteem as they go through the developmental tasks of adolescence. It is no surprise that many youngsters drop out of sport between 12 and 14 years of age. The demands of normal adolescence may play a role in this decision. Guidelines for the development of cognitive and social competence during adolescence are outlined in Table 5.

Adolescence appears to be a drawn out process in some cultures, for example, the United States. It appears to be a time of confusion and insecurity for many youth as they strive for independence and adulthood.

1.6. PERFORMANCE

The development of proficiency in a variety of movement skills is a major developmental task of childhood and adolescence. Skillful performance, of course, is an important component of sports. During the preschool years and extending into middle childhood, children develop basic competence in fundamental movement patterns such as running, jumping, skipping, and so on. These movements are the foundation for other skills and sport-specific skills, and for physical activity in general.

Children commonly enter school or organized youth sports programs at 5 or 6 years of age, when many are still developing the basic movement patterns. One of the objectives of physical education and youth sports programs is to teach skills. Teachers and coaches of children entering school or a sport should have an understanding of the development of movement patterns and knowledge of how to provide an environment in which these patterns can be nurtured and improved. A primary responsibility of teachers and coaches is to guide the skill development process from basic patterns to skillful performance.

As basic movement patterns are refined through appropriate instruction and practice, performance quality improves and the basic patterns are integrated into more complex movement sequences and skills required for specific games and sports. The transition from basic movement patterns to more complex sports skills depends upon individual differences in neuromuscular maturation, earlier experiences and opportunity for movement, and the quality of instruction and practice. A proficiency barrier may exist for some children who do not have such opportunities for instruction and practice. A key person in this process is the teacher or coach, who should be able to meet the developmental needs of young children or

sport participants though appropriate instructional sequences and guided practice opportunities. It is important for teachers and coaches to know how to observe the movements of a child. All too often, individuals tend to focus on the end product of a movement, e.g., whether the ball was struck or how far a ball was kicked. A teacher or coach should be able to analyze a movement to determine what are the important elements to observe. As a corrollary, the teacher or coach should have a sound knowledge of activities and experiences that will help the young athlete to progress in the development of a basic skill or a more specialized skill sequence. This way they will be able to know the process of what the child is doing rather than the result of what the child is doing. Knowing the process of performance is important to being able to provide corrective, positive instructional feedback to help improve performance.

The development of proficiency in basic movement patterns is accompanied by improved levels of performance which can usually be quantified. These are outcomes of the performance of tasks, e.g., the distance or height jumped (power), the distance and accuracy a ball is thrown (power and coordination), the time elapsed in completing a 30-yard dash (speed). Performances on such standardized tasks improve with age during childhood, and boys perform, on average, better than girls. There is considerable overlap between the sexes during early and middle childhood. With the onset of adolescence, the performances of boys show an acceleration whereas those of girls improve to about 13-15 years of age and then improve only slightly.

Tests of performance include anaerobic and aerobic components. Anaerobic power is the maximal ability to perform short-term (usually less than 30 seconds), high intensity bouts of exercise as in the vertical jump or a sprint. As such, anaerobic power follows a pattern of growth like that for sprints and jumps. Aerobic power is the maximal ability to uptake, deliver, and utilize oxygen to produce energy under aerobic conditions. It is an important determinant of endurance events. Absolute maximal aerobic power (expressed as liters of oxygen per minute) increases in boys and girls with age, and shows a clear adolescent spurt as do other performance tasks. When maximal aerobic power is adjusted for body weight, it shows little change with age in boys but declines with age in girls.

Performance during adolescence is influenced in part by individual differences in the timing of the adolescent growth spurt. Performances in a variety of tasks show well-defined adolescent spurts. Measures of strength tend show peak gains after the time of maximum growth in height (peak height velocity) in boys and girls. However, the magnitude of the growth spurt in strength is only about one-half of the maximum gain in boys. The same

trend is apparent for power (vertical jump) in boys, but corresponding data are not available for girls. The trends for measures of strength and power are similar in timing to those for body mass and muscle mass, both of which experience their maximum growth after peak height velocity. Maximal aerobic power shows an adolescent spurt that occurs very close in time to that for height in boys and girls. When motor performances of girls are related to the time before and after menarche, there are no consistent trends. Menarche is a late maturational event during puberty, and major gains in growth and performance have already occurred.

The overall pattern of age- and sex-associated changes in a variety of performance tasks during childhood and adolescence is summarized in Table 6. The trends are based on group averages. Some girls, especially those active in sport, improve their performances through adolescence.

Table 6. Guidelines for the development of motor competence during childhood and adolescence.

5-8 years

- By these ages, the majority of children have developed the basic movement patterns. Note, however, that some children have not yet mastered the basic movement patterns at theses ages and would benefit from systematic instruction and practice under the supervision of qualified teachers/coaches.
- Performance in a variety of strength, speed, and power tasks improves more or less proportionally to gains in body size. Balance and coordination tasks also improve.

9-12 years - transition into adolescence

- Performances in motor (many are anaerobic), strength and endurance (aerobic) tasks, on average, improve with age.
- Individual differences in the timing and tempo of the growth spurt and sexual maturation exaggerate differences among children in performance. This is especially apparent among children of the same age who differ in maturity status.

13+ years -adolescence

- Performance in motor, strength, and aerobic tasks continues to improve, on average, in boys.
- On average, the performances of girls tend to reach a plateau at these ages or improve only slightly. In young female athletes who are systematically training for a sport, performances improve into late adolescence.

Adapted from Malina *et al.* (in press).

1.7. OVERVIEW AND IMPLICATIONS FOR TEACHING AND COACHING

For the sake of convenience, the preceding discussion arbitrarily partitioned childhood and adolescence into three periods that approximate childhood (5-8 years), the transition into puberty (9-13 years) and later adolescence (14-18 years). The first period represents the ages when the majority of children enter organized sports programs. The second period highlights the transition from childhood into adolescence which has major

physical, physiological, and behavioral changes. It is also a period during which many youth drop out of sport programs, either by choice or by the more selective nature of many programs. The third period approximates the high school years, when sport programs are more selective and demanding.

It is important to note that the age ranges are arbitrary, especially between the second and third periods. These ages span the transition from childhood into adolescence, and the timing and tempo of the transition is variable within and among individuals. Thus, many of the cognitive and social developmental issues in the high school years are reworked in the context of those in the transitional period.

Variation within and between individuals in growth, maturation, and development is considerable. The marked changes in body composition are of specific concern, especially to adolescent girls and to many coaches. Motor performance may be influenced by an especially rapid growth spurt in both sexes. Relationships between peers may influence social behaviors and in turn relationships with coaches.

A teacher or coach should be able to apply these general concepts of growth, maturation and development to fit the needs of the young athletes in his/her program. Several suggestions for coaches in dealing with the physical, behavioral, and motor changes associated with the transition into and during the adolescent growth spurt and sexual maturation follow:

- Be aware of individual differences. As youth enter adolescence and during adolescence, they needs reassurance that they are "normal", i.e., not different from their peers. This need most often occurs in youngsters who are extremely early or extremely late in maturation. Above all, coaches should not make fun of them; peers often do, especially in locker rooms. The young adolescent is very sensitive to the growth and maturational changes that are occurring, and must learn to adjust to them. Adolescence is a period of physiological learning. The adolescent needs the support of understanding adults to transcend these changes with a positive view of self.

- Adolescents are very sensitive about their body weight and shape. Given changes that occur in body composition during later childhood and adolescence, teachers and coaches should avoid comments about body weight, especially in girls who in many cultures are being taught that "thin is in." Adolescent girls are very sensitive to weight changes associated with growth and maturation, and do not need to be reminded of them.

- Coaches should be careful in using body size as cut-points in sports. This especially affects late maturing youngsters who need to be given the

opportunity to participate and to keep working at improving skills, and who need to be reassured that they will eventually grow and mature.

- Coaches should pay attention to the child's eating behaviors and diet. A well-balanced diet is essential to support the needs of growth and maturation, in addition to those specific to physical activity and regular training for sport. Megavitamins are not a replacement for a well-balanced meal. Be aware of the use of antihistamines to suppress diet and of other ergogenic aids.
- Teachers and coaches should be aware of expected developmental changes and should also be aware of how developmental changes may influence performance. Some examples:
    - Since growth in height occurs before growth in body mass and strength, there may be temporary periods during which a boy or girl may appear to "outgrow his/her strength". The youngster needs reassurance that his/her strength will eventually catch-up.
    - There may be intervals during which a skill may temporarily decline compared to performances prior to the growth spurt, or there may be intervals during which skills may not improve as quickly. These may be associated with rapid changes in body proportions during the adolescent growth spurt, or changes in body composition associated with sexual maturation. The legs, for example, experience their grow spurt before the trunk does, which temporarily alters the position of the center of gravity.
    - Changes in body composition and development of the hips, particularly in girls, also may influence performance. The adolescent girl needs to be nurtured through these changes in a positive manner with appropriate instruction and practice in movement and sport-specific skills.

II. EFFECTS OF TRAINING ON GROWTH AND MATURATION

2.1. INTRODUCTION

- What are the trends in growth and maturation that characterize young athletes in several sports?
- What is the role of training for sport as factor that may influence growth and maturation?

It is often assumed that regular physical activity, including training for sport, is important to support normal growth and maturation. Just how much

activity is needed is not known. Some have suggested that sport training has a positive influence on these processes, while others have suggested a potentially negative influence. Given questions raised by parents and at times the medical community, it is important that coaches be aware of the currently available information on the influence of regular training for sport on indicators of growth and maturation.

Young athletes in many sports have size, physique and functional characteristics that are similar to adult athletes in the respective sports. This would seem to emphasize an important position for growth and maturation in the processes through which children are selected or excluded from some sports.

This chapter first summarizes the body size, maturity status and functional capacities of young athletes in a variety of sports, and then discusses the potential role of training for sport as a factor influencing growth, maturation and function.

2.2. GROWTH AND MATURITY STATUS OF YOUNG ATHLETES

In order to evaluate the potential influence of training for sport on the growth and maturation, it is important to be familiar with the growth and maturity characteristics of young athletes. Some sports selectively choose or exclude youth on the basis of body size during childhood. The role of body size becomes more important in other sports later in childhood and during the transition into adolescence. At this time, size is closely related to the youngster's maturity. This section summarizes information on the heights, weights, and maturity of young athletes in a several of sports.

Size Attained

Average heights of athletes in different sports are expressed relative to percentiles of the growth charts for American boys and girls (Chapter 1) in Tables 2.1 and 2.2 for boys and girls, respectively. For example, male athletes in many sports have heights that fluctuate just above and below the median; this is indicated in the table as ±P50. If average heights are consistently above the median, this is indicated as >P50, and if average heights of athletes in a sport are consistently below the median, this is indicated as <P50.

Athletes of both sexes in most sports have, on average, heights that equal or exceed reference medians. Gymnastics is the only sport that consistently presents a profile of short height in both sexes. Most average heights of gymnasts are near P10. Figure skaters of both sexes also present shorter heights, on average, though data are less extensive than for gymnasts. Note that the trends are based on group means. However, given the wide range of normal variation among individuals and variation associated with

individuals differences in biological maturation, there undoubtedly are exceptions to the trends suggested in the tables.

Table 2.1. Heights and weights of young male athletes relative to percentiles (P) of United States reference data.

Sport	Height	Weight
Basketball	P 50 - >P90	P 50 - >P90
Soccer	P 50±	P 50±
Ice Hockey	P 50±	P 50
Distance Runs	P 50±	≤P 50
Sprints	≥P 50	≥P 50
Swimming	P 50 - P 90	> P 50 - P 75
Diving	<P 50	≤P 50
Gymnastics	≤P 10 - P 25	≤P 10 - P 25
Tennis	P 50±	≥P 50
Figure Skating	P 10 - P 25	P 10 - P 25
Ballet	<P 50	P 10 - P 5

Adapted from Malina (1994. 1998) which contains the references for individual studies.

Table 2.2. Heights and weights of young female athletes relative to percentiles (P) of United States reference data.

Sport	Height	Weight
Basketball	P 75 - >P90	P 50 - P 75
Volleyball	P 75	P 50 - P 75
Soccer	P 50	P 50
Distance Runs	≥P 50	<P 50
Sprints	≥P 50	≤P 50
Swimming	P 50 - P 90	P 50 - P 75
Diving	≤P 50	P 50
Gymnastics	≤P 10 - <P 50	P 10 - <P 50
Tennis	>P 50	P 50±
Figure Skating	P 10 - <P 50	P 10 - <P 50
Ballet	≤P 50	P 10 - <P 50

Adapted from Malina (1994, 1998) which contains the references for individual studies.

Body weights present a similar pattern. Young athletes in most sports tend to have body weights that, on average, equal or exceed the reference medians. Gymnasts, figure skaters and ballet dancers of both sexes consistently show lighter body weight. Gymnasts and figure skaters have appropriate weight-for-height, while ballet dancers have low weight-for-height. A similar trend in indicated in female distance runners.

Body Composition of Young Athletes

Child and adolescent athletes have less relative fatness (% body fat) than non-athletes of the same age and sex. Male athletes and non-athletes both show a decline in % body fat during adolescence, but athletes have less relative fatness at most ages. Female athletes also have a lower % body fat less

than non-athletes, especially during adolescence, and it appears that difference between female athletes and non-athletes is greater than the corresponding difference in males. Relative fatness, on the average, does not increase much with age during adolescence in female athletes, while it does in non-athletes. Although athletes tend to have less fat than non-athletes, there is variation among athletes and among different sports.

Maturity Status of Male Athletes

With few exceptions, male athletes in a variety of sports tend to be average (on time) or advanced (early) in biological maturation. Other than gymnasts, who show later skeletal maturation, there is a lack of late maturing boys who are successful in sport during early and mid- adolescence (about 12-15 years). However, late maturing boys are often successful in some sports in later adolescence (16-18 years), e.g., track and basketball, which emphasizes the catch-up in maturation and reduced significance of maturity-based differences in body size and performance of boys in late adolescence.

Maturity Status of Female Athletes

Most discussions of biological maturation of female athletes focus on the age at menarche, which is a late event during the adolescent growth spurt and puberty. Average ages at menarche in North American and European girls vary between 12.5 and 13.5 years, but the age range within which menarche may normally occur is 9 through 17 years.

Later average ages at menarche are often reported in athletes in many, but not all, sports. There is confusion about later ages at menarche in athletes, which is related, in part, to the fact that most of the information is based on recalled ages reported by college age and older athletes. The athletes are asked at interview or by questionnaire to recall when menarche occurred. Such data include potential error associated with accuracy of memory or recall.

When the distribution of recalled ages at menarche in large samples of athletes and non-athletes of the same chronological age and from similar social backgrounds are considered, there is considerable overlap between the samples. The distribution for athletes is simply shifted to the right, or later ages, by about one year or so. However, there are both early and late maturing athletes and non-athletes; it is just that there are more later maturing athletes than non-athletes.

Information on the age at menarche in adolescent athletes, i.e., teen-age athletes, is very limited. Presently available data are illustrated in Table 3. If an average of 13.0 years is accepted for North American and European girls, about 95% of girls will attain menarche between 11.0 and 15.0 years. Most

samples of adolescent athletes have average ages at menarche within the range of normal variation. Only several samples of gymnasts and ballet dancers have average ages at menarche older than 15.0 years. Both of these activities have extremely selective criteria which tend to favor the late maturing girls.

Sample sizes in studies of adolescent athletes are generally small, and studies in which the athletes are followed from prepuberty through puberty are often limited to small, select samples. A potentially confounding issue in such studies is selective drop-out. For example, do earlier maturing girls selectively drop-out of gymnastics or figure skating? Or, do sports like gymnastics, figure skating and ballet select for late maturing girls, or do these sports systematically eliminate early maturing girls?

Table 3. Prospective and status quo ages at menarche (years) in samples of adolescent athletes (*1)

Athletes - Prospective		Athletes - Status quo	
Gymnasts, Polish	15.1±0.9	Gymnasts, world (*3)	15.6±2.1
Gymnasts, Swiss	14.5±1.2	Gymnasts, Hungarian	15.0±0.6
Gymnasts, Swedish	14.5±1.4	Figure skaters	14.2±0.5
Gymnasts, British (*2)	14.3±1.4	Swimmers, age group, U.S.	13.1±1.1
Swimmers, British	13.3±1.1	Swimmers, age group, U.S.	12.7±1.1
Tennis players, British	13.2±1.4	Divers, Junior Olympic, U.S.	13.6±1.1
Track, Polish	12.3±1.1	Ballet dancers, Yugoslavia	13.6
Rowers, Polish	12.7±0.9	Ballet dancers, Yugoslavia	14.1
Elite ballet dancers, U.S	15.4±1.9	Track, Hungarian	12.6
		Soccer players, age group, U.S	12.9±1.1
		Team sports, Hungarian	12.7

Adapted from Malina (1998a) which includes the references for specific studies, with the exception of figure skaters (Vadocz and Malina, under review). (*1) Prospective data report means, while status quo data report medians based on probit analysis. (*2) Among the British athletes, 13% had not yet attained menarche so that the estimated mean ages will be somewhat later. Small numbers of Swiss and Swedish gymnasts and ballet dancers also had not reached menarche at the time of the studies. (*3) This sample is from the 1987 world championships in Rotterdam. It did not include girls under 13 years of age so that the estimate may be biased towards an older age.

Performance Characteristics of Young Athletes

How do young athletes compare to non-athletes in motor performance? A priori, it might be assumed that athletes will perform better given the premium placed on skill and practice, and sport-related motor skills. However, data comparing the performances of athletes and non-athletes on standard tasks are quite limited.

Comparisons of athletes in several sports (divers, skiers, distance runners) and non-athletes can be made for two tasks commonly used in

assessment batteries - vertical jump and sit and reach. Divers consistently exceed the values for non-athletes at all ages, while alpine skiers approximate the values for non-athletes. Distance runners are near the non-athletes until about 13 years of age and then lag behind. The trends for athletes in these three sports probably reflect the specific training demands of the respective sports. Diving places a premium on vertical jumping ability, while the other sports do not. Alpine skiing places more emphasis on side to side jumping, while distance running often focuses on endurance training to the neglect of explosive power. In contrast to the vertical jump, the young athletes have greater flexibility of the hamstrings/lower back. This trend probably reflects the emphasis on stretching as a preliminary to more specific training activities in a sport.

The limited data emphasize the need for further comparative research with young athletes. They also emphasize the specificity of training. Training programs emphasize the specific skills or demands of a sport. Other basic skills are perhaps taken for granted, or perhaps neglected. Early specialization and exclusive training in a specific sport may be an additional contributing factor.

Sex differences in motor performance for the general population of children and adolescents have been summarized in Chapter 1. A question of interest is the following: What is the magnitude of sex differences in the performances of elite young athletes within the same sport? Such data are not extensive, but suggest several interesting contrasts. Comparative data for elite female and male athletes in three sports - diving, downhill skiing and distance running, suggest the following. Sex differences in the performances of elite young athletes in the same sport are relatively minor until the male adolescent spurt. The male growth spurt in muscle mass, specifically upper body musculature, and in strength and power contributes to the sex difference in strength and power items at this time. In contrast, female athletes are more flexible than male athletes at all ages, and have a less intense adolescent spurt in strength and power.

Young athletes of both sexes differ from non-athletes in several physiological characteristics. Absolute and relative maximal aerobic power are greater in young athletes who train regularly in endurance sports such as swimming, running and cycling. The same is also true for soccer, which also has a major aerobic component. This is in keeping with the aerobic demands of these sports and the effects of regular aerobic training in contrast to limited aerobic training in such sports as baseball and American football. Since maximal aerobic power is related to body size, the differences in relative maximal aerobic power (per kg body weight) between athletes and non-athletes is more significant given variation in body size and maturity status

among young athletes in many sports. The differences between athletes and non-athletes in relative maximal aerobic power tend to be small during childhood, but become progressively greater during adolescence, especially in males. This is related in part to the effects of regular training for several years and perhaps to a greater trainability of the oxygen delivery and utilization systems during male adolescence.

Comparisons of the aerobic power of young male and female athletes in the same sports indicate a relatively similar pattern of sex differences. Among young distance runners, sex differences in absolute maximal aerobic power (VO_2 peak) are small in late childhood and the transition into early adolescence (about 4-8%), but increase during adolescence so that the sex difference is about more than 20% between 15-17 years. When maximal aerobic power of the young runners is expressed per unit body weight, a similar pattern is apparent.

2.3. DOES REGULAR TRAINING FOR SPORT INFLUENCE GROWTH AND MATURATION?

Training refers to systematic, specialized practice for a specific sport or sport discipline for most of the year or to specific short-term experimental programs. Physical activity is not the same as regular training. Training programs are ordinarily specific (e.g., endurance running, strength training, sport skill training, etc.), and vary in intensity and duration. The quantification and specification of training programs by sport needs further attention.

2.3.1. Training and Growth in Height and Weight

Sport participation and training for sport have no apparent effect on growth in height (how tall a child is at a given age) and the rate of growth in height (how much a child grows in a year) in healthy, adequately nourished children and adolescents. The heights of young athletes probably reflect the size demands of specific sports. The smaller size of athletes in gymnastics and figure skating is evident long before any systematic training has started. Athletes in these two sports also have parents who are shorter than average, suggesting a familial contribution to their smaller size. Both sports also tend to selectively favor shorter participants.

Short term studies of athletes in several sports in which the same youngsters are followed on a regular basis over time, indicate rates of growth in height that closely approximate rates observed in the nonathlete children and adolescents. The growth rates are well within the range of normally expected variation among youth.

In contrast to height, body weight can be influenced by regular training for sport, resulting in changes in body composition. Training is associated with

a decrease in fatness in both sexes and occasionally with an increase in fat-free mass, especially in boys. Changes in fatness depend on continued, regular activity or training (or caloric restriction, which often occurs in sports like gymnastics, ballet, figure skating and diving in girls and wrestling in boys) for their maintenance. When training is significantly reduced, fatness tends to accumulate. It is difficult to separate specific effects of training on fat-free mass from expected changes that occur with normal growth and sexual maturation during adolescence. This is especially so in boys because with the growth spurt and sexual maturation, boys almost double their estimated fat-free mass.

2.3.2. Training and Specific Tissues

Bone (skeletal), muscle and fat (adipose) tissues are three primary components of body composition. The skeleton is the framework of the body and the main reservoir of minerals. Skeletal muscle is the major work-producing and oxygen-consuming tissue, while adipose tissue represents energy in stored form.

a) Bone

Regular physical activity and training during childhood and adolescence are associated with increased bone mineral content and mass. The beneficial effects are more apparent in weight bearing (e.g., running, soccer, gymnastics) than non-weight bearing (e.g., swimming) activities. Of particular importance to physical activity and the integrity of skeletal tissue is the observation that bone mineral levels established during childhood and adolescence may be an important determinant of bone mineral status in adulthood.

In contrast to the positive influence of physical activity and training on bone mineralization, excessive training associated with changes in the menstrual cycle in some, but not all, post-menarcheal adolescent athletes may be potentially associated with loss of bone mineral if the alterations in menstrual function persist for some time. This is labeled as the "female athlete triad" - altered menstrual function, disordered eating and loss of bone mineral. Most of the data dealing with this issue are derived from adult athletes who have been intensively training in their given sport, usually distance running, for a long time. It should also be noted that variation in menstrual cycles after the onset of the first menstruation (menarche) in adolescent girls is the rule rather than the exception. It ordinarily takes about two to three years for menstrual cycles to become "regular". Coaches should not, therefore, be overly concerned about early "irregularity" in adolescent athletes. The adolescent girl needs assurance and understanding as she adjusts to the physiological changes of pubertal maturation.

b) Muscle

Information on skeletal muscle tissue is derived largely from short-term, specific training studies of small samples. Increase in muscle size (hypertrophy) is associated with heavy-resistance exercise programs, such as weight or strength training in adolescent boys, and may not occur or may occur to a much lesser extent in preadolescent boys and girls, and in other forms of training. There is no strong evidence to suggest that fiber type distribution in children and adolescents can be changed as a result of training.

Limited data for adolescent boys suggest that regular endurance training has the potential to modify the activities of oxidative enzymes (those involved in prolonged activities as in distance running). In contrast, regular sprint training has the potential to modify the activities of glycolytic enzymes (those involved in bursts of activity as in sprinting). The changes are specific to the nature of the training program, i.e., endurance or sprint. However, after cessation of training, enzyme levels return to pretraining levels, which indicates an important feature of training studies. Changes in response to short-term programs are generally not permanent and depend upon regular activity for their maintenance. An important question that needs further study is: How much activity is needed to maintain the beneficial changes associated with training?

c) Fat

In studies of children and youth, subcutaneous fat is most often measured in the form of skinfold thicknesses. Regularly active young athletes generally have thinner skinfold thicknesses compared to reference samples. It should be noted that individual skinfolds change differentially during growth, e.g., skinfolds on the extremities and not those on the trunk generally decline during adolescence in boys. Data for % body fat indicate similar trends - lower fatness in young athletes of both sexes than in non-athletes. As with skeletal muscle enzymes, regular training is necessary to maintain these beneficial effects on relative fatness. When training stops, relative fatness increases. Just how much physical activity or training is essential to modify skinfold thicknesses or maintain lower levels of fatness in growing children and adolescents is not known.

2.3.3. Training and Biological Maturation

Does regular training for and participation in sport influence the timing and tempo of biological maturation? As noted earlier, there is a wide range of normal variation among youth in the timing and tempo of biological maturation. It is a highly individual characteristic that often shows a tendency

to run in families, i.e., mothers and their daughters may both be early or late maturers.

a) Skeletal maturation

Regular activity does not influence the rate of maturation of the skeleton. Short term longitudinal studies of boys and girls in several sports indicate similar gains in skeletal maturation in both athletes and non-athletes.

b) Somatic maturation

Regular training for sport does not influence the timing of maximum growth in height (age at peak height velocity) and growth rate in height (cm/yr or in/yr) during the adolescent spurt in boys and girls. It has been suggested that intensive training may delay the timing of the growth spurt and stunt the growth spurt in female gymnasts. These data are not sufficiently longitudinal to warrant such a conclusion. Many confounding factors are not considered, especially the rigorous selection criteria for gymnastics, marginal diets, and so on. Female gymnasts as a group show the growth and maturity characteristics of short normal, slow maturing children with short parents!

c) Sexual maturation

Longitudinal data on the sexual maturation of either girls or boys who are regularly active in and/or training for sport are not extensive. The limited longitudinal data indicate no effect of activity or training on the timing and progress of breast and pubic hair development in girls, genital and pubic hair development in boys.

Most discussions of the potential influence of training on sexual maturation focus on the later average ages at menarche which are often observed in females athletes in many, but not in all sports. Training for sport is indicated as the factor which is responsible for the later average ages at menarche, with the inference that training "delays" the onset of this maturational event. Unfortunately, studies of athletes ordinarily do not consider other factors which are known to influence menarche. For example, there is a familial tendency for later maturation in athletes. Mothers of ballet dancers, gymnasts, and athletes in several other sports attain menarche later than mothers of nonathletes, and sisters of elite swimmers and university athletes attain menarche later than average. The conclusions of two comprehensive discussions of exercise and reproductive health of adolescent girls and women are important to the present discussion:

> "although menarche occurs later in athletes than in nonathletes, it has yet to be shown that exercise delays menarche in anyone" (Loucks *et al.*, 1992, p. S288),

and,

> "the general consensus is that while menarche occurs later in athletes than in nonathletes, the relationship is not causal and is confounded by other factors" (Clapp and Little, 1995, pp. 2-3).

2.4. OVERVIEW

- Athletes of both sexes in most sports have, on average, heights and weights that equal or exceed reference values for the general population of children and adolescents.
- Gymnasts and figure skaters of both sexes present shorter heights, on average, but have appropriate weight-for-height. Female distance runners tend to show have low weight-for-height.
- Intensive training for sport has no negative effect on growth and maturation. In adequately nourished children and adolescents, growth in height and biological maturation are under genetic control.
- Regular training for sport has the potential to favorably influence body composition by increasing bone mineral and skeletal muscle, and decreasing fatness.
- In the few young athletes who present problems related to growth and maturation, factors other than physical training must be more closely scrutinized. In many cases of short stature, the shortness is largely familial, i.e., short children tend to have short parents. Shortness may also be related to late maturation, which may also be familial. In some sports, the growth of the young athletes may be compromised by marginal or poor nutritional status, and occasionally by eating disorders.

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