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Youth Sports

Participation, Trainability and Readiness

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Part 2:

TRAINABILITY AND READINESS

CHAPTER 8: EFFECTS OF TRAINING FOR SPORT ON GROWTH AND MATURATION

Robert Malina

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.

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.

a) Size Attained

Average heights of athletes in different sports are expressed relative to percentiles of the growth charts for American boys and girls in Tables 1 and 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 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. 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.

b) 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.

c) 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.

d) 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

(1) Adapted from Malina (1998a, see Malina et al., 2004) which includes the references for specific studies. 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.

e) 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 an earlier chapter of this volume. 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.

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.

a) 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.

b) 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.

b.1.) 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.2.) 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?

b.3.) 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.

d) Training and Biological Maturation

Does regular training 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.

d.1.) 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.

d.2.) 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!

d.3.) 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).

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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