SPECIFIC CONSIDERATIONS FOR THE CHILD AND ADOLESCENT ATHLETE

Sports medicine physicians must be familiar with the normal patterns of growth and development of the child and adolescent, in order to detect any abnormal patterns, and make appropriate judgments. This will allow the physician to detect any deviations during the pre-participation examination, guide children into appropriate activities, aid them in setting realistic goals concerning sports participation, and provide guidance to the community and coaches in the design of safe and effective training and sports programmes.

A. Developmental Levels (see Table 4-1)

1. Early Childhood (ages 3–5 years)
    a. Vision: not fully mature (difficulty in tracking moving objects and judging velocity)
    b. Balance: paradoxical decrease at 4–5 years due to overload in integrating visual and proprioceptive input.
    c. Motor Skills: Age 4—run, kick, hop, throw (20%), catch (30%)
    d. Learning Ability: short attention span; easily distracted; need instruction via auditory and visual input.
    e. Activity Recommendations: PLAY in a closed system (few variables, constant conditions); walk, run, swim, tumble. Organised sports and competition may INTERFERE with learning.

2. Childhood (ages 6–9)
    a. Vision: tracks speed and direction of moving objects with difficulty.
    b. Balance: automatic by age 7.
    c. Motor Skills: age 6—basic overhead throw developed; age 8—running skills matured.
    d. Learning Ability: short attention span; easily distracted; lacks rapid decision making; needs verbal and visual instruction; cooperation improved.
    e. Activity Recommendations: Skills acquisition in a closed system (run, swim, gymnastics); recreational play; low level organised sports.

3. Late Childhood (ages 10–12)
    a. Vision: adult pattern.
    b. Balance: improved; declines at puberty during peak height velocity (Tanner stage 3).
    c. Motor Skills: complex skills develop, but postural control may deteriorate (uncoordinated body segment growth patterns).

Table 4-1. Developmental characteristics of and sports participation guidelines for various age groups.

	Infancy (0–2 years)	**Early Childhood (3–5 years)**	**Childhood (6–9 years)**	**Late Childhood (10–12 years)**
Motor Skills	Skills primarily reflex; posture depends on visual input	Fundamental skills limited; balance skills limited	Fundamental skills improved; transitional skills begin; balance control becomes automatic	Transitional skills improved; balance control declines at puberty
Learning Skills	Response to training minimal; benefits of training not long-term	Attention span short; attention overexclusive; response to training limited	Attention span limited; attention overinclusive; cooperation improved	Attention selective; memory strategies used
Vision	Farsighted	Farsighted; eye movements imprecise; tracking of speed and direction of moving objects difficult	Tracking of speed and direction of moving objects improved, but still difficult	Patterns same as for adults
Guidelines for Sports Participation	Recognise that swimming programmes and exercise programmes of no advantage; encourage free play; provide safe, unstructured play environment	Avoid competition; provide limited instruction verbally and by demonstration; emphasise fun play	Keep competition minimal; keep rules of sport flexible; emphasise fundamental skills; keep instruction time short	Minimise competition; emphasise fundamental and transition skills; decrease intensity of sports involvement at puberty
Recommended Activities	Free play	Walking, running, swimming, tumbling, throwing, catching	Swimming, running, gymnastics, entry-level soccer and baseball; complex-skill sports such as football, hockey, basketball, and wrestling are difficult	Entry-level football, basketball, wrestling, and other contact/collision sports

d. Learning Ability: integrate information from multiple sources; respond to verbal instruction.
e. Sport Recommendations: continue fundamental and transitional skills; successful in skill and team sports, low level competitive sports.

B. Adolescent Growth and Maturation

1. Endocrinology

Prior to puberty, the hypothalamic-pituitary-gonadal feedback system is operative in a negative mode, and hormone levels remain low. With the onset of puberty, feedback sensitivity is diminished. This allows increased synthesis and secretion of hypothalamic gonadotrophin-releasing hormone (GnRH), which stimulates the anterior pituitary to produce gonadotrophins (LH and FSH) with subsequent rises in the gonadal sex steroids estrogen and testosterone.

2. Stages of Growth and Development

Growth and development at puberty occur in an orderly fashion, as described by Tanner. In general, the onset of pubertal maturation occurs earlier in girls than in boys. On average, the height spurt in girls occurs about two years earlier than in boys, with a peak height velocity at age 12 for girls, and age 14 for boys. This may vary, depending upon the nutritional status and geographic location of the subjects. (See Figures 4-1 and 4-2, and Table 4-2.)

Tanner's Sexual Maturation Ratings (Table 4-3) have been recommended as a means of determining a child's readiness to participate in certain sports, especially those involving complex skills, teamwork, and body contact.

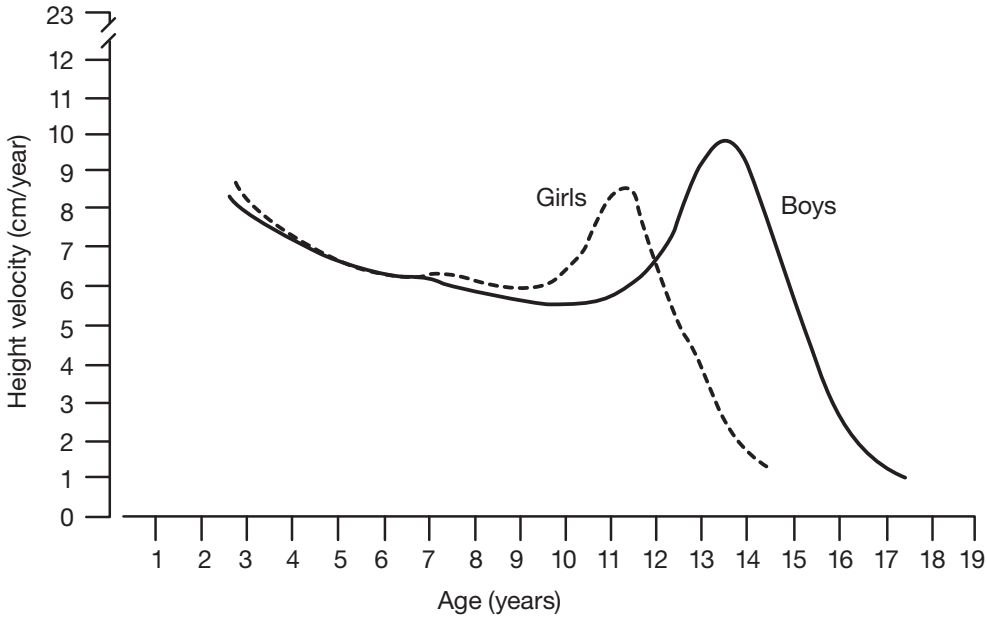


Figure 4-1. Fiftieth percentile height velocity curve for American boys and girls (Slap 1986).

Table 4-2. Typical timing of normal pubertal events in girls and boys (SMR=Sexual Maturity Rating—Tanner).

Event	Girls	Boys
onset of puberty	10 years (8–14 years)	12 years (9–15 years)
first sign	breast bud	testicular enlargement
PHV	12 years SMR = 2–3	14 years SMR = 3 –4
peak weight gain		6 months after PHV
end of growth and maturation	16.5 years	15–18 months later than girls

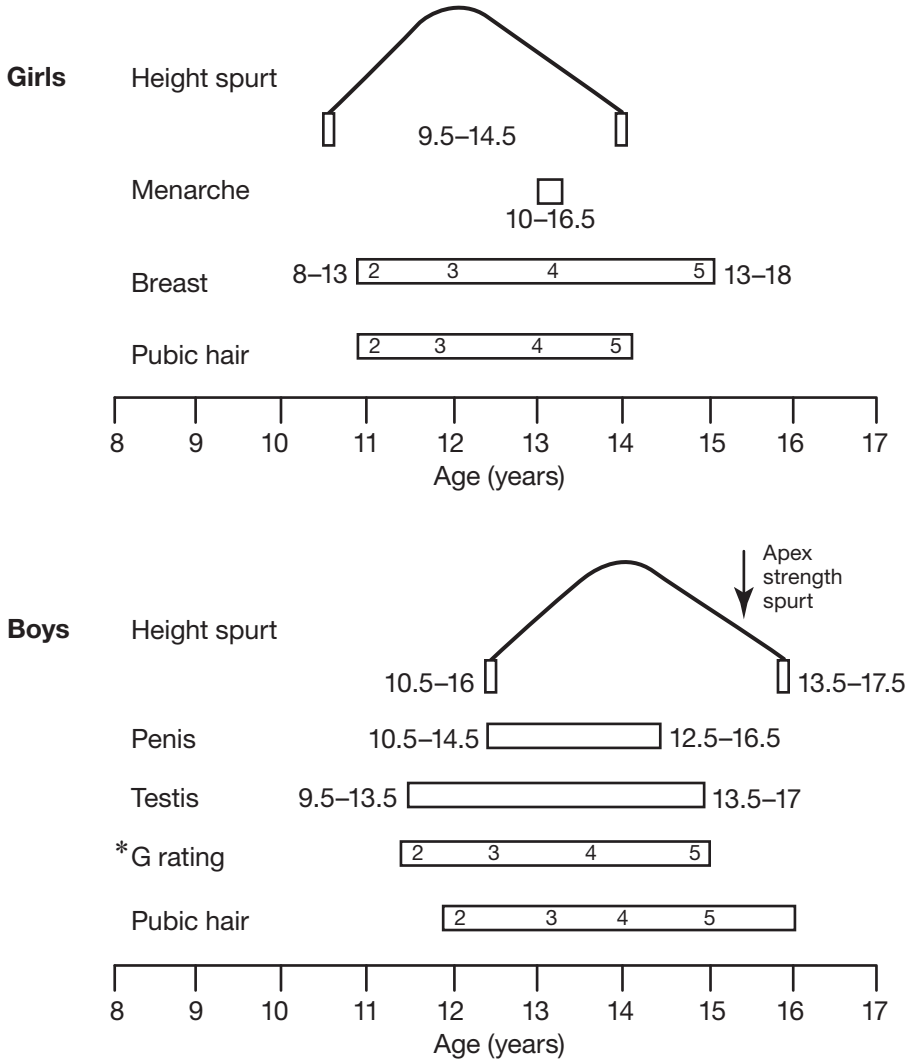
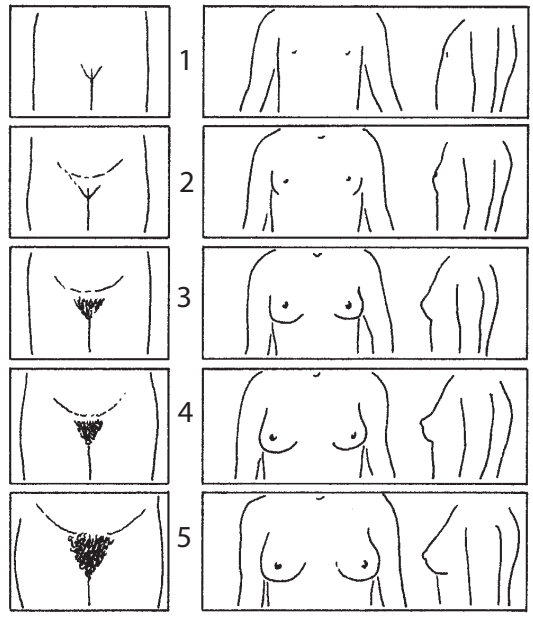


Figure 4-2. Sequence of pubertal events (Slap 1986). (*Genitalia)

Table 4-3. Tanner's stages of sexual maturation in girls (a) and boys (b).

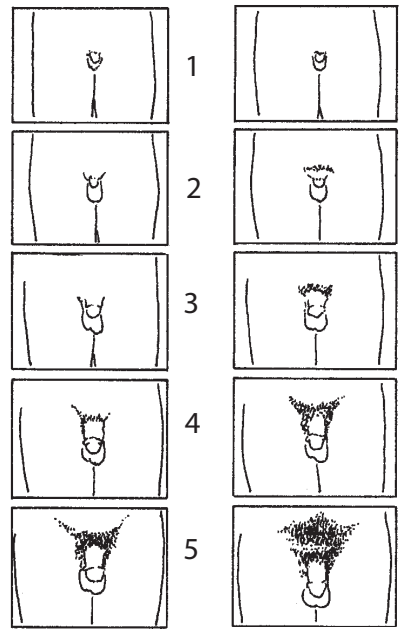
a. Sexual Maturing Ratings (SMR) in girls (Tanner ratings)

Stage	Pubic Hair	Breasts
1	Preadolescent	Preadolescent
2	Sparse, slightly pigmented, straight, at medial border of labia	Breast and papilla elevated as small mound, areolar diameter increased
3	Darker, beginning to curl, increased amount	Breast and areola enlarged, without contour separation
4	Coarse, curly, abundant, but amount less than in adult	Areola and papilla form secondary mound
5	Adult feminine triangle, spread to medial surface of thighs	Mature, nipple projects, areola part of general breast contour



b. Sexual Maturing Ratings (SMR) in boys (Tanner ratings)

Stage	Pubic Hair	Penis	Testes
1	None	Preadolescent	Preadolescent
2	Scanty, long, slightly pigmented	Slight enlargement	Enlarged, scrotum pink, texture changed
3	Darker, begins to curl, small amount	Longer	Larger
4	Resembles adult type but less in quantity; coarse, curly	Larger, glans and breadth increased	Larger, scrotum darker
5	Adult distribution, spread to medial thighs	Adult	Adult



3. Clinical Conditions and Maturation Levels

A number of clinical conditions are associated with certain stages of maturation (Table 4-4).

Table 4-4. Clinical factors and Sexual Maturity Ratings (Tanner stages).

Clinical Factor	**Sexual Maturity Rating (SMR)**
Hematocrit rise (male)	2–5
Male gynecomastia	2 or 3
Slipped capital femoral epiphysis	2 or 3
Worsening idiopathic scoliosis	2–4
Osgood-Schlatter's disease	3

Body composition changes markedly at puberty, as a result of rises in sex steroids secretion. Males exhibit a typical growth in muscle mass, while females show a deposition of fat in the estrogen-sensitive areas of the hips, thighs, and breasts (Figure 4-3).

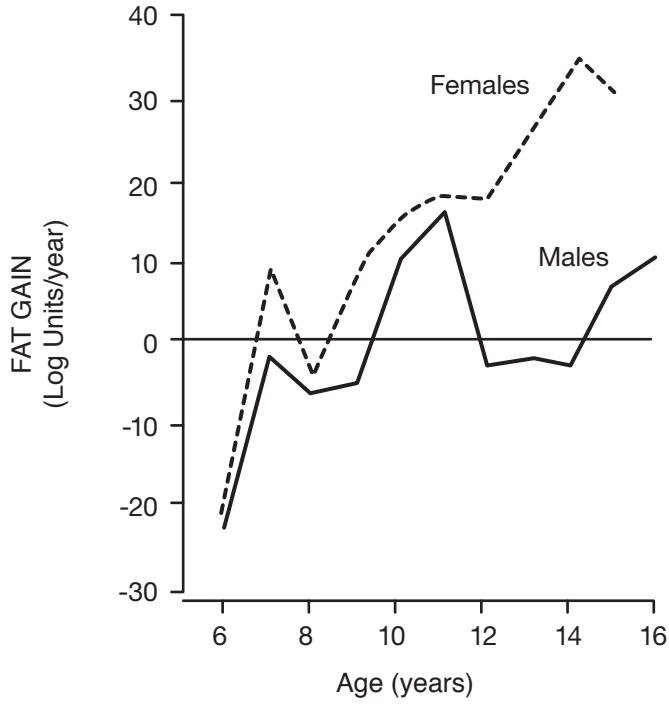


Figure 4-3. Mean increment in fat in boys and girls based on skinfold measurements at four sites (Tanner 1955).

C. Abnormal Patterns of Development

1. Precocious Puberty

Precocious puberty is defined as showing signs of the onset of puberty prior to age 8 in girls, and age 9 in boys.

2. Delayed Puberty

Delayed puberty is defined as:

a. Female—lack of evidence of breast development by age 13.
b. Male—no signs of testicular enlargement by age 14 1/2.
c. Either sex—children who fail to progress normally through puberty.

3. Primary Amenorrhea

Primary amenorrhea is defined as the absence of menarche in a female of reproductive age. Signs include:

a. Delay of menarche beyond age 16.
b. Absence of menarche more than four years after thelarche (onset of breast development).

(See also Chapter 13, Part 1, *Endocrine/Menstrual Factors.*)

D. Musculoskeletal Growth and Development

1. Regulation of Musculoskeletal Growth

Bone responds to a wide variety of growth stimulators, including growth hormone, testosterone, sulfation factor, thyroxine, parathyroid hormone, and insulin-like growth factor. Muscle lengthens in response to stretch; growth occurs in the region of the musculo-tendinous junction. The maximum potential for growth is determined genetically. However, this potential can be attained only if there is adequate nutrition, physical activity, and good general health.

2. Bone Growth: Definitions (see Figure 4-4)

a. Epiphysis—the end of the long bone that is bordered by the growth plate (physis) and by articular cartilage.
b. Metaphysis—the flared portion of the bone that is between the epiphysis and the diaphysis.
c. Diaphysis—the shaft of the long bone.
d. Apophysis—the site of attachment of musculo-skeletal structures to the long bone; it is extra-articular.

3. Growth of Long Bones

a. Longitudinal Growth

Longitudinal growth occurs at the epiphyseal growth plate (physis) and at the articular cartilage. Chondrocytes divide, align longitudinally to form columns, and begin to enlarge and calcify. In this fashion, the epiphysis moves further away from the center of the bone.

b. Latitudinal Growth

The periosteum contributes to new bone formation from fibroblasts, to enlarge the circumference of the long bones. The ring of Ranvier enlarges the diameter of the physis.

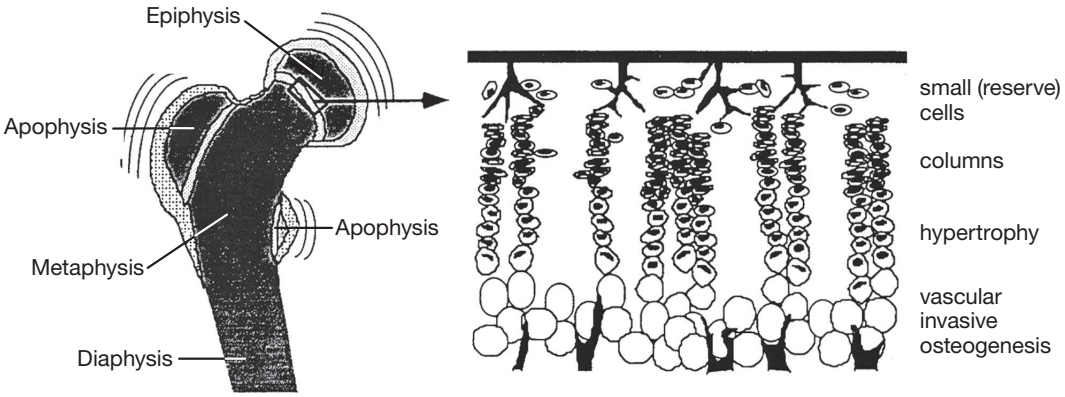


Figure 4-4. Bone growth.

c. Apophyseal Growth
   i. Physeal growth occurs as in a (see Figure 4-4), at the junction of the metaphysis and the apophysis.
   ii. Periosteal and fibro-cartilaginous formation of new bone occurs at the site of tendinous insertions.

d. Growth Rate

Growth is very rapid during the first two years of life, then slows to a relatively constant rate, except for brief, intermittent spurts. During pre-adolescence there is another major growth spurt (peak height velocity). Then the growth rate begins to plateau as maturity approaches.

E. Injuries to the Immature Skeleton—Musculo-skeletal Injuries Unique to Children and Adolescents

1. Unique characteristics of the immature musculo-skeletal system:
   a. Open growth plates afford both longitudinal and appositional growth.
   b. There is a relative disproportion between long bone length and adjacent musculature, as muscles lengthen in response to stretch.
   c. The periosteum is thicker. This stabilises the bone, both intact and fractured. The thicker periosteum requires more force to disrupt than in adults. Following a fracture, the vascular periosteum aids in rapid healing; however, it may act as a deforming force as it contracts over time.
   d. The long bones are more porous, so buckling (torus) fractures are more common.

e. Long bones are more "flexible," and may undergo plastic deformation as part of a fracture.
f. Thicker, growing articular cartilage leads to chondral or osteo-chondral fragmentation from over-use, especially at the distal femoral condyle, radial head, and humeral head.
g. There is greater vascularity of the knee menisci. This allows for healing more often than in the adult.
h. Different injury patterns occur at different ages, dependent upon the strength of the adjacent structures at the particular skeletal age.

2. Special Considerations in Injury Assessment

In addition to the usual diagnostic considerations, additional factors must be kept in mind when assessing injuries to the child and adolescent.

a. Acute Injuries

In evaluating all musculo-skeletal injuries, consider:

i. Physeal injuries
ii. Congenital anomalies
iii. Neoplasms
iv. Infections

in addition to the more common sprains and strains. During on-field examinations, DO NOT STRESS an injured joint, as it may cause further physeal damage. DO an X-ray first!

b. Over-use Injuries

Over-use injuries may affect all joints, and especially the physes. Consider:

i. Inflammatory processes—apophysitis; osteochondritis dissecans
ii. Metabolic diseases
iii. Neoplasms
iv. Infections

F. Physiological Characteristics of Children

1. Aerobic Capacity

Aerobic capacity (VO_2 maximum) increases with age. However, in terms of body mass, when aerobic capacity is expressed in terms of ml/kg, maximal aerobic power does not increase, and may even decrease in the second decade, with the increase in the child's fat mass.

2. Anaerobic Capacity

Anaerobic performance in children is much lower than in adolescents and adults. This is likely due to the development of anaerobic enzyme systems, and also to poorer neuro-muscular control.

3. Energy Cost of Running

The metabolic costs of locomotion are higher in children, hence they have a lower metabolic energy reserve (the difference between maximal and sub-maximal energy cost). This is probably due to: 1) shorter stride length and faster leg turnover during running; and, 2) greater co-contraction of antagonist muscles during activity. Flexibility and relaxation training may help to reduce the energy costs of running, and improve economy.

G. Effects of Training on the Child and Pre-adolescent

1. Measurement Problems

A variety of physiological changes in children and pre-adolescents might be expected to accrue as a result of a training programme. However, it is difficult to assess the degree of trainability of various systems, due to a variety of confounding factors.

a. The role of normal growth and development is difficult to differentiate from the effects of training. For example, relative changes in maximum oxygen uptake (ml/Kg) may be masked by changes in maximal heart rate, and increases in body fat mass.
b. Children may lack the discipline required for training that is intensive enough to induce measurable physiologic changes.
c. Intense training may not be employed for fear of causing injuries.
d. Suitable control groups are difficult to select, as they should not be chosen solely on the basis of age and sex.
e. Ethical and methodological problems limit the extent of studies, e.g. muscle biopsies, invasive procedures, etc.

2. Probable Physiologic Changes

Despite these limitations, a number of studies have suggested that the major physiological systems that respond to training in adults also respond in a similar fashion in children, though not always to the same degree.

a. Aerobic capacity

Aerobic capacity may improve nearly as much as in adults. This capacity may be limited by the lower hemoglobin seen in children, with consequent lower oxygen-carrying capacity.

b. Anaerobic capacity

Anaerobic systems may not be sufficiently mature to adapt well to training, and hence may limit the ability to respond well to anaerobic activities such as the 200m and 400m dashes.

c. Strength

Strength may improve relative to body size compared to older children, though absolute gains may be small. Little muscle hypertrophy occurs, due to low hormonal (testosterone) levels. Strength gains are due to improvement

in a number of neurological factors, including increased neural recruitment, improved synchronisation of motor unit fibres, and better motor skills coordination. (See Table 4-5 for strength training guidelines.)

Table 4-5. Guidelines: strength training for children and adolescents.

1. Pre-participation evaluation by a physician knowledgeable in sportsmedicine
2. Good quality equipment suitable to the size and age of the athletes
3. Strength training should be part of an overall conditioning and fitness programme
4. Supervision by a well-trained adult (National Strength and Conditioning Association)
5. Appropriate warm up and cool down period before and after strength training
6. Selection of sports-specific exercises appropriate to the level of physical and emotional maturity of the participant
7. Attention to proper technique: avoid Valsalva maneuver, hyperventilation, back hyperextension
8. Emphasis on dynamic concentric contractions as opposed to eccentric overload exercises
9. Emphasis on sets of high repetitions at low resistance
10. Each exercise should be taken through the full range of motion for maximum muscle development and to maintain flexibility
11. Competition (weight lifting, power lifting, body building) should be prohibited
12. Maximal lifts should not be performed until skeletal maturity (Tanner stage 5; see Table 4-3)
13. Programme design should be based on the principle of progressive resistance

Sample Programme Prescription

- 1-3 sets of 6–10 exercises per session
- Frequency of 2–3 sessions per week with rest day in between
- Duration of 20–60 minutes per session
- Progressive resistance:
    - Start at no resistance/weights until proper form is achieved
    - Then initiate resistance at the 6 repetition level, advance to 15 reps
    - Weight then added in 1–3 lb (500–1500 g) increments until child can do just 6 reps
    - Advance again to 15 reps before increasing weights

d. Heat Adaptation

Children adapt less well to exercise in the heat, especially at temperatures above skin temperature. Several factors are responsible for this discrepancy:

i. At any exercise level, children produce more metabolic heat per kg of body weight (i.e., are less efficient).
ii. Their larger surface area/body weight ratio permits greater heat absorption from the environment when air temperature exceeds skin temperature (approximately 32º–33º C). The smaller the child, the greater the potential for heat absorption.
iii. Children produce less sweat. This is likely due to limitations in anaerobic energy production by sweat glands. Thus, the ability for evaporative cooling is lower. This is critical, as evaporation of sweat is the most important means of heat dissipation during exercise, especially under hot conditions.
iv. Children require longer to acclimatise to a hot climate. Several days are needed for adjustment of the enzymatic and hormonal changes that affect the sweating mechanisms. Fourteen days may be required for full acclimatisation.
v. Hypohydration (lower body water content) has more profound effects on children. During exercise, core temperature rises faster, affecting motor performance and cognitive skills. Children must be trained to drink frequently (every 15–20 minutes) even when not thirsty. A drink with electrolytes (especially sodium) and carbohydrate enhances palatability and fluid consumption.

H. Guidelines for Youth Training Programmes

Effective, safe training programmes for young athletes must take into account the age, sex, and maturation levels of each child. The duration, intensity, and frequency of training sessions will vary considerably, depending upon the above factors. Children should be encouraged to participate in a wide variety of activities and sports, and not be channeled into "specialisation" in one sport or event before reaching the mid- or late-teen years.

It is difficult to provide definite "dosages" of training for children who participate in the varied event disciplines of athletics. However, some general guidelines have been developed, based upon practical experience as well as a knowledge of the developmental levels of children (see Table 4-1).

All training sessions should be preceded by a suitable 20–30 minute warm-up period with emphasis on gradually increasing activity and stretching of all muscle groups, and followed by a gradual cooling down and further stretching.

1. Endurance Training (long distance running)

The recommended maximum competition distances for children of various ages are shown in Table 4-6. The weekly training distance should not be more than twice

Table 4-6. Recommended maximum running distance at different ages.

Age (Years)	Distance
Under 9	3 km
9–11	5 km
12–14	10 km
15–16	Half marathon (21.1 km)
17	30 km
18	Marathon (42.2 km)

the recommended maximum competition distance. Runs or races up to 10 km in length can be undertaken on a weekly basis for children aged 12–14; runs or races over 10 km in length require longer recovery periods. Training frequency for those up to 14 years old should not exceed 3 times per week. Those aged 15–18 can train up to 5 times per week.

2. Sprints

Training frequency for those up to 14 years old should not exceed 3 times per week. Those aged 15–18 can train up to 5 times per week. The duration of each session should not exceed 1.5 hours, including a warm-up and stretching component.

3. Throwing Events (shot put, discus, javelin, hammer)

Injuries can be avoided in throwing events if the correct technique is developed for each throwing discipline. Training frequency and duration should follow the following guidelines:

a. No more than 3 training sessions per week.
b. Each session should not exceed 1.5 hours (including warm-up).
c. The total number of throws permitted for each session should not exceed 20 for athletes up to 14 years old and 40 for those between 15 and 18 years old.

4. Jumping Events (long jump, triple jump, high jump, pole vault)

Training frequency and duration should follow the following guidelines—

a. Each session should be no longer than 1.5 hours (including warm-up).
b. Athletes up to 14 years old should not perform more than 3 sessions per week with a maximum of 10 jumps per session.
c. Athletes from 15 to 18 years old should not perform more than 5 sessions per week with a maximum of 20 jumps per session.

I. Roles of the Parents and Coach

The collaborative involvement and support of the parents and coach is essential if children are to achieve an enjoyable and successful experience in sports. Unreasonable demands and expectations from adults are a common cause for a child's dropping out of sport.

The child's reaction to this pressure may manifest itself in a wide variety of psychosomatic symptoms that may come to the attention of the sports physician. These may include headaches, gastro-intestinal disturbances, muscle aches out of proportion to the training load, and even proneness to injury in order to avoid participation. Guidelines for avoiding such situations are seen in Table 4-7.

Table 4-7. Guidelines for parents.

- Encourage children to participate if they are interested.
- Focus on the child's effort/performance, not the outcome of the events.
- Honest effort is as important as victory.
- Encourage children to participate according to the rules.
- Never ridicule.
- Children learn best from example. Applaud good plays by all teams.
- Do not question officials' judgement in public.
- Support efforts to remove verbal and physical abuse.
- Recognise the value and importance of volunteer coaches.

J. Special Considerations in Injury Rehabilitation

1. Goals of the Rehabilitation Programme
    a. Prevent recurrence of the injury or related injuries.
    b. Restore muscle strength to full power, strength, and endurance.
    c. Regain flexibility and coordination.
    d. Restore full performance capability.

2. Principles of Rehabilitation
    a. Special Problems
        i. Short attention span.
        ii. Unable to comprehend need for rehabilitation programme
        iii. Teenagers feel invulnerable to injury.
        iv. Feel set apart from peers.
    b. Application of Principles
        i. Set a defined time limit for meeting goals—no more than two months.

ii. Make the patient an active participant in the programme by using active exercises. Control pain and swelling so the rehabilitation programme can begin as soon as possible.
iii. Use short periods of activity.
iv. Utilise a small number of exercises, done correctly.
v. Make progress apparent by using many intermediate goals. Reward the patient for attaining each goal.
vi. Integrate the programme into the patient's regular schedule, i.e., while watching TV, talking on phone, etc.

c. Special Rehabilitation Considerations for Children
i. Flexibility and strengthening must be stressed. Muscles may be relatively short compared to bones, especially during periods of rapid growth. Non-ballistic stretching must be taught.
ii. Exercise programmes must be supervised carefully.
iii. Machines must be adjusted to the child's frame.
iv. Use caution with ultra-sound near growth plates.

d. Athletic Activity During Rehabilitation
i. Must be pain-free the morning after activity.
ii. Avoid activities that interfere with doing the rehabilitation exercises.
iii. No participation if the weakened area is likely to cause further injury.
iv. Do not use modalities (e.g. ice) or analgesics that could mask pain before an "at risk" activity.

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