The Adolescent Athlete
The Adolescent Athlete
A Practical Approach

Edited by

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Preface

Good health should be a goal of all children and adolescents, as well as the parents and guardians who care for them. Regular physical activity is part of achieving this goal. Sports can provide manifold benefits, including fitness, motor skill development, teamwork, and of course, *fun*. As with any pursuit that provides such benefits, however, there are risks involved, particularly for growing athletes. Physicians and other health professionals caring for active children should be able to provide appropriate care and advice for sport and fitness-related medical issues.

This book is written as a practical guide for those of us who provide care for young athletes. The focus is on musculoskeletal injuries that occur in this unique population, as well as conditions that may present as a musculoskeletal injury, but may have more serious consequences. The first section of the book focuses on rehabilitation and diagnostic imaging of musculoskeletal conditions in adolescents. The second section—organized according to anatomical region—addresses specific injuries that adolescents may sustain as a result of sport/activity participation. Each of these body part–specific chapters begins with a review of the relevant anatomy, followed by details of clinical evaluation. Specific injuries, such as acute and chronic injuries, are described in detail, including the management/treatment of each condition. Prevention of injuries and return to play guidelines are given full shrift. Each chapter concludes with “clinical pearls” that provide an insight into the way each of our expert authors practice their craft. Given the distinguished group of authors who graciously agreed to contribute to this resource, just these pearls themselves are worth the “price of admission”!

This prompts us to thank all those who generously donated their time and expertise to this project, particularly the chapter authors and our editors at Springer. Without their contributions, this project would not have come to fruition.

*Lyle J. Micheli, MD*

*Laura Purcell, MSc, MD, FRCPC, FAAP, Dip Sport Med*
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Introduction

Sports participation by children and adolescents has exploded in recent years. In the United States, more than 35 million children participate in organized sport, with millions of others participating at a recreational level (1). Children are becoming involved at younger and younger ages, and are often participating in sports year-round. They are also participating at more and more competitive levels, necessitating training with increased intensity.

Injuries related to sports participation occur frequently (2), accounting for more than one third of all injuries (3). The majority of injuries occur in young athletes, with an estimated 2.6 million emergency visits per year related to sport injury for those aged 5–24 years (4). Childhood injuries are a frequent reason for visits to primary care offices as well, accounting for 1 of every 10 visits, with $>25\%$ of adolescent visits attributable to sports (5). Musculoskeletal injuries are the third most common reason for adolescents to seek medical attention, with knee pain being the most frequent complaint (6).

With the increasing participation of today’s youth in sports, it is imperative that health care providers taking care of these children and adolescents are prepared to address their unique needs. Young athletes have specific needs that set them apart from adult athletes. Understanding the developmental changes that occur during childhood and adolescence, which result in different injury patterns and psychological issues, is essential to provide exceptional care for young athletes. Knowledge of the physical and emotional development, as well as the level of skill and motivation, of adolescents will help prevent injuries and promote healthy participation and enjoyment of sport.

Benefits of Sports

The benefits of sports include psychosocial, physical, and health-related benefits. Sports provide an enjoyable opportunity for children and adolescents to be active. Being active helps youths to achieve a healthy weight
and increase physical fitness. Sports may provide youth the opportunity to develop independence, identify with a peer group, and increase social interaction. Youths can achieve success by improving and mastering new skills and participating in a common goal. This success can improve their sense of self-esteem and can help build confidence (7).

Older children who participate in sports are less likely to adopt risky behaviors, such as smoking, doing drugs, and breaking the law. Sports participation is associated with elevated social status among peer groups, and it may provide opportunities for traveling with a team, as well as the possibility of athletic scholarships (7).

Positive sport experiences may go a long way to maintaining exercise and sport during the adult years. By adopting a healthy active lifestyle, adolescents may reduce the risk of chronic health problems in adulthood, such as cardiovascular disease, obesity, and Type II diabetes (7).

Adults play an important role in providing positive sports experiences for children. They teach children motor skills, the rules of the sport, and sportsmanship. Adults can act as role models for youth, and are instrumental in organizing sporting opportunities for children. However, organized sports should be developmentally appropriate for children so that they have fun being physically active (8–11). Children should be encouraged to participate in a variety of activities and avoid early specialization (12).

Sport Readiness

“Sport readiness” implies a certain level of physical, cognitive, and emotional development that allows the acquisition of the necessary skills to meet the demands of sports (8–11). Although there are many benefits to sport, sporting activities must be developmentally appropriate to ensure that children enjoy the activity. Placing children in sports that are beyond their developmental ability can cause frustration and loss of enjoyment, and ultimately lead to the decision not to participate (8–11).

One aspect of sport readiness is motor development. Learning and mastering fundamental motor skills such as throwing, running, and jumping, is an innate process, independent of gender or physical maturity. Each fundamental skill is composed of a sequence of developmental stages that all children progress through, but at variable rates. Most children have acquired some fundamental skills by preschool age. However, it is not until children reach 6yr of age that sufficient combinations of fundamental skills are attained to allow them to begin organized sports (8–11).

Choosing appropriate sport activities can be guided by knowledge of the developmental capabilities of children of various ages (Table 1.1). Sports activities can be modified to match children’s developmental levels by simple modifications, such as shorter games, smaller equipment, and frequent changing of positions (8–11).
## Table I.1. Developmental skills and sport recommendations during childhood and adolescence.

<table>
<thead>
<tr>
<th></th>
<th>Middle childhood 6–9yr</th>
<th>Late childhood 10–12yr</th>
<th>Early adolescence 13–15yr</th>
<th>Late adolescence 16–18yr</th>
</tr>
</thead>
</table>
| **Motor skills** | • Mature fundamental sport skills  
• Posture, balance improving  
• Beginning transitional skills (e.g., throwing for accuracy) | • Improving transitional skills  
• Mastering complex motor skills (e.g., layup in basketball) | • Tremendous growth  
• Loss of flexibility  
• Differences with timing of puberty | • Continued growth into adulthood  
• Mature sport skills |
| **Learning**     | • Short attention span  
• Limited memory and rapid decision-making | • Attention span improving but remains selective  
• Improving memory  
• Emphasize skill development  
• Increasing emphasis on tactics and strategy | • Improved attention span  
• Good memory skills, able to memorize plays and strategize  
• Promote individual strengths | • Good attention span, memory skills |
| **Skill emphasis** | • Emphasize fundamental skills  
• Encourage beginning transitional skills | • Emphasize skill development  
• Increasing emphasis on tactics and strategy | • Promote individual strengths  
• Promote individual strengths | • Promote individual strengths |
| **Suggested activities** | Entry level soccer and baseball; swimming; running; gymnastics; skating; dance; racquet sports | Entry-level football, basketball, ice hockey | Early-maturing boys: track and field, basketball, ice hockey  
Late-maturing girls: gymnastics, skating | All sports depending on interest |

*Source: Purcell, 2005. Adapted with permission from Paediatrics and Child Health.*
By middle childhood, most children achieve mature patterns of fundamental motor skills and are beginning to learn transitional skills (Table I.1). Transitional skills are fundamental abilities performed in combination or with variation, for example, throwing for distance or accuracy. Improvement of transitional skills progresses through late childhood, and by the time they reach adolescence, most youths are able to master complex motor skills, such as a lay-up in basketball. Motor skills continue to improve throughout adolescence (8–11).

Cognitive development is another aspect of determining sport readiness. Young children have short attention spans, limited memory, and an inability to make rapid decisions. Sports activities for young children should therefore concentrate on mastering fundamental skills and the development of transitional skills. Instruction should be short, rules should be flexible, and the emphasis should be on fun, not competition. As children grow older, their memory improves and their attention spans increase, but may remain selective. Older children are capable of learning strategy and tactics, and can begin to master more complex play combinations (8–11).

Children are unique from adults in that they are growing, which predisposes them to unique injuries. Growth during adolescence is particularly marked. There are dramatic increases in muscle mass, muscle strength, and cardiopulmonary endurance during this period. Adolescents continue to increase both fat mass and fat-free mass, although during puberty, girls tend to accumulate fat mass at a greater rate. Muscle strength increases in both sexes, but is greater in boys. Loss of flexibility and a temporary decrease in coordination and balance is common during adolescence (13).

Growth, Maturation, and Development

As children progress through adolescence to adulthood, they are subject to three interacting processes: growth, maturation, and development (14,15). As they grow, children increase in height and weight, in lean and fat tissues, and in the size of their organs. Maturation is the state of maturity, in which growth has been completed. Development is the process of learning appropriate behaviors in society. Children develop behaviorally in the acquisition of motor skills, as well as cognitively, emotionally, socially, and morally. It is important to be aware of these interactions in children and adolescents, and how they may potentially affect a youth’s ability to participate in sports (14,15).

Sexual Maturity

Adolescence is marked by sexual growth and maturity, i.e., the process of puberty. Secondary sexual characteristics, including pubic hair in both sexes, breast development and menarche in girls, and penis and testes
development in boys, forms the basis of assessment of sexual maturity (14). Tanner developed a sexual maturation scale based on the development of secondary sexual characteristics (Table I.2) (16).

Puberty can affect sports performance (14,15). The onset of puberty can be quite variable and can result in differences in physical attributes important to sport. Boys who mature early are taller, stronger, and have greater muscle mass than those who enter puberty later, and are therefore usually better suited to sports requiring physical strength, such as American football. Girls who mature late have narrower shoulders and hips, and are well-suited to esthetic sports, such as figure skating and dance (8–15).

<table>
<thead>
<tr>
<th>Table I.2. Tanner staging.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Girls</strong></td>
</tr>
<tr>
<td><strong>Tanner stage</strong></td>
</tr>
<tr>
<td>Stage 1</td>
</tr>
<tr>
<td>Stage 2</td>
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<tr>
<td>Stage 3</td>
</tr>
<tr>
<td>Stage 4</td>
</tr>
<tr>
<td>Stage 5</td>
</tr>
</tbody>
</table>

| **B. Boys** |
|------------------|------------------|------------------|
| **Tanner stage** | **Stage of development** | **Pubic hair** | **Penis/testes** |
| Stage 1 | Preadolescence | No pubic hair | Identical to early childhood |
| Stage 2 | Early adolescence (10.5–14 yrs) | Sparse, long, and straight, slightly pigmented at base of penis | Enlargement of testes and scrotum; reddish color and enlargement of penis |
| Stage 3 | Middle adolescence (12.5–15 yrs) | Increase curl and pigmentation, spreading laterally | Continued growth, penis increases in length |
| Stage 4 | Middle adolescence | Coarse in texture, more adult in distribution | Continued growth of testes and scrotum skin darkens, penis grows in width, glans penis develops |
| Stage 5 | Late adolescence (14–16 yrs) | Mature distribution with spreading to medial thigh | Mature adult size and shape of testes, scrotum, and penis |

Skeletal Maturity

Children's bones are different from those in adults in that they are still growing. The reaction of growing bones to trauma is therefore different. Growing bones are not as dense, are more porous, and possess a striated cortex with loosely attached periosteum. Bones in children have a growth plate complex, which includes the epiphysis, physis, and diaphysis. The developing physis or growth plate is especially vulnerable to injury, and if growth plate injuries are not managed properly, can lead to permanent disability (17).

The physis is located between the epiphysis and metaphysis (Figure I.1). It is a cartilaginous plate where endochondral growth occurs, resulting in bone lengthening. It is the weakest link in the bone–ligament complex, which results in different injury patterns in children. Injuries in adults are more likely to be ligament ruptures, whereas in children, because the ligament is stronger than the physis, a child is more likely to sustain a growth plate injury, particularly in the knee and ankle (17).

As skeletal maturity approaches, the physis narrows and is replaced by bone until it closes. This results in unique injuries at this age, particularly in ankle injuries. Fractures in young children usually occur parallel to the physis, whereas in adolescents, fractures occur through the physis and into the articular surface (Figure I.1) (17, 18).

Another unique feature of children's bones is the presence of apophyses. An apophysis is a prominence of bone that is also a center of growth of the bone. It acts as an attachment for muscle groups. Apophyses are found around the pelvis, the patella, the tibial tubercle, the calcaneus, and the base of the fifth metatarsal, and are sites of avulsion injuries in growing athletes. During growth spurts, muscles and tendons get stretched out and can result in increased tension at the sites of attachment, causing inflammation and pain (apophysitis). Some examples of apophysities include

Osgood–Schlatter and Sever’s diseases. With sufficient force, the muscles attached to apophyses can pull off a piece of bone, resulting in an avulsion fracture. These injuries are commonly seen in adolescents who are going through growth spurts (18).

**Risk of Injury**

Injuries are an inevitable part of participating in sports. Certain injuries are associated with particular sports, such as patellar tendonitis and ankle injuries in basketball (19). Certain sports are associated with more injuries. Girls’ cross-country, football, wrestling, and girls’ soccer have been associated with the greatest number of injuries, based on injury rate/1,000 athletic exposures (19). Ankle and knee injuries are among the most common injuries as a result of sports (6,19).

Various methods of preventing injuries can be employed. Preparticipation physicals can help identify medical problems, previous injuries, or risk factors for further injury in young athletes. By assessing an athlete’s general health, level of fitness, flexibility, strength and joint stability, treatment or preconditioning recommendations can be made to reduce injury risk before sports participation. Appropriate sport-specific conditioning programs can prepare athletes for the demands of their particular sport (20).

Ensuring a proper diet and conditioning in all adolescent athletes is key to maintaining general health. Rest is also important for growing athletes to recuperate from sport, particularly during times of growth when injury risk is higher. Avoidance of overtraining will help ensure athletes are not developing overuse injuries or burning out. Participating in a variety of activities will help ensure children develop a variety of skills and help prevent overuse injuries (12). Making sure that injuries are properly rehabilitated will help prevent further injury (20).

Parents, coaches, and trainers can reduce the incidence of injuries by ensuring the proper use of protective equipment, ensuring safe play conditions, enforcing rules, and providing appropriate supervision. Ensuring the proper selection of sporting events can also minimize injuries. Sports should be matched to the child’s interest and abilities (8–11,20).

**Conclusion**

Sports are a great way for youth to be physically active. There are many benefits to sports participation, including physical health, skill development, and social interaction. Children and adolescents can get the most out of sports when the activities are geared towards their interests and developmental level.

The risk of injury is inherent to sports participation. Children and adolescents are subject to unique injuries because they are still growing.
Injuries can be prevented by ensuring children are in good physical condition, by the use of proper equipment and by ensuring that playing conditions are safe. Participating in a variety of activities will also help minimize injuries.

References

Section I
Rehabilitation and Diagnosis
The number of adolescent athletes competing in organized sports has significantly increased over the past several years, thus causing a rise in sport-related injuries. Adolescents are specializing in sports at an earlier age and, in some cases, performing excessive and repetitive training that often leads to overuse injuries. Sport is the number one cause of injuries in 5–17-yr-old children (1). Many sports-related injuries do not receive proper rehabilitation. Adolescents may return to sports training and/or competition too quickly after an injury. This often causes a recurrence of the injury and/or the development of a new injury. Therefore, a comprehensive rehabilitation program to successfully manage an injury is extremely important to ensure the safe return to sport and/or competition. Appropriate rehabilitation and education of athletes, parents, and coaches are essential components in assisting the young athlete’s recovery. In addition, the rehabilitation program should include the athlete’s personal goals.

The evidence for rehabilitation practice in the field of adolescent sports medicine is often lacking proper research studies, particularly clinical trials. Many of the recommended rehabilitation programs are based on clinical experience, mainly with an adult population.

Before establishing a rehabilitation program, consideration must be given to the adolescent athlete’s stage of maturation, which is more important than chronological age. Adolescence is a difficult period to define because of the wide variation in time of onset and termination. Age ranges of 8–19 yr in girls and 10–22 yr in boys are often listed as limits for the adolescent period. During this period, bodily systems become adult both structurally and functionally. Structurally, the rate of growth in stature marks the onset of the adolescent growth spurt. The rate of the statural growth reaches a peak, decelerates, and finally terminates with the attainment of adult stature (2).

Functionally, adolescence is defined by sexual maturation. Tanner and associates developed a sexual maturation scale that correlates with peak height velocity (see Table I.1 in the Introduction) (2). Tanner stage 1 is determined by growth hormone production, whereas stages 2–5 are related to sex hormones (3). Therefore, children are described as prepubertal
Principles of Rehabilitation

The major principle of rehabilitation is to safely maximize the athlete's abilities, despite an existing and/or a developing impairment. The goals of a rehabilitation program are to control inflammation and pain, promote healing, restore function, safely return to sports training and/or competition, and prevent future injury. In addition, maintaining the athlete's level of physical fitness while recovering from an injury is an essential component of the rehabilitation program.

The rehabilitation program includes assessments of posture, joint range of motion, muscle strength, endurance, balance, coordination, and function (4-8). Posture deviations and muscle weakness and/or tightness often lead to serious imbalances that can cause malalignment, an increase in pain, a decrease in function, and a predisposition to future injury.

Rehabilitation Program

A comprehensive rehabilitation program includes a detailed patient history, a review, an examination of all systems, and the establishment of a plan of care.

Patient History

Information is gathered from both the patient and parent (Table 1.1).

<table>
<thead>
<tr>
<th>Table 1.1. Patient history.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient history</td>
</tr>
<tr>
<td>• Demographics and developmental history</td>
</tr>
<tr>
<td>• Current medical diagnoses</td>
</tr>
<tr>
<td>• Previous diagnoses</td>
</tr>
<tr>
<td>• Past injuries with dates</td>
</tr>
<tr>
<td>• Surgical history with dates and complications (if any)</td>
</tr>
<tr>
<td>• Medications</td>
</tr>
<tr>
<td>• Chronological age; bone age</td>
</tr>
<tr>
<td>• Review of clinical tests (MRI, bone scan, radiograph)</td>
</tr>
<tr>
<td>• Past and present activity level</td>
</tr>
<tr>
<td>• Recreational versus competitive activity</td>
</tr>
<tr>
<td>• Pain assessment at rest, night, with activity (age appropriate pain scale) patient’s current concerns and goals</td>
</tr>
</tbody>
</table>

**Systems Review**

Gathering baseline information before treatment intervention is necessary to establish goals, monitor the effects of both therapeutic and conditioning exercises, and identify risk factors that may contribute to future injury. Systems to review include:

1. **Cardiovascular/Pulmonary**: Knowledge of normal respiratory rates, heart rates, and blood pressure for adolescents is necessary to monitor their response to treatment (Tables 1.2 and 1.3) (9,10).

2. **Integumentary**: Assessment of the integumentary system includes skin integrity, color, trophic changes, and scar formation. Blistering, skin temperature, scar tissue pliability, texture, and sensation should be observed. Activities or movements that aggravate the incisional site should be documented in adolescents who have had surgery. Scar types include contracture, hypertrophic, and keloid. A contracture scar is a tightening of surrounding tissues. These scars tend to cause impaired movement. Hypertrophic scar tissue can be caused by the overproduction of connective tissue. They are raised above the skin, thick, red, and itchy. Keloid formations are highly thickened areas of scar tissue. They are larger and more raised than the hypertrophic scars. This type of scarring is often genetic (11).

3. **Musculoskeletal**: Tightness in the muscle–tendon units seems to occur in the absence of injury as the athlete enters puberty. Adolescent athletes,

---

**Table 1.2. Resting adolescent heart rate by sex and age.**

<table>
<thead>
<tr>
<th>Age</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>White males</td>
<td>76</td>
<td>76</td>
<td>74</td>
<td>73</td>
<td>70</td>
<td>73</td>
</tr>
<tr>
<td>White females</td>
<td>86</td>
<td>83</td>
<td>84</td>
<td>83</td>
<td>84</td>
<td>81</td>
</tr>
<tr>
<td>Afro-american males</td>
<td>75</td>
<td>71</td>
<td>73</td>
<td>71</td>
<td>69</td>
<td>66</td>
</tr>
<tr>
<td>Afro-american females</td>
<td>81</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>78</td>
<td>77</td>
</tr>
</tbody>
</table>

*Source: Rabbia et al., 2002.*

**Table 1.3. Blood pressure for girls and boys by age and height percentile of 50%.*

<table>
<thead>
<tr>
<th>Age</th>
<th>Girls systolic/diastolic</th>
<th>Boys systolic/diastolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>103/61</td>
<td>104/61</td>
</tr>
<tr>
<td>12</td>
<td>105/62</td>
<td>106/62</td>
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<tr>
<td>13</td>
<td>107/63</td>
<td>108/62</td>
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<tr>
<td>14</td>
<td>109/64</td>
<td>111/63</td>
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<tr>
<td>15</td>
<td>110/65</td>
<td>113/64</td>
</tr>
<tr>
<td>16</td>
<td>111/66</td>
<td>116/65</td>
</tr>
<tr>
<td>17</td>
<td>111/66</td>
<td>118/67</td>
</tr>
</tbody>
</table>

*Source: Staley and Richard, 2001.*
particularly males, demonstrate a generalized loss of flexibility, especially in larger muscle groups, such as the hip flexors, hamstring, quadriceps, and triceps surae. Linear growth in the long bones and spine exceeds the rate of growth of the muscle–tendon unit. Therefore, during the adolescent growth spurt, a loss of both strength and flexibility can often occur (Figure 1.1) (12). The loss of strength and flexibility not only impacts the athlete’s athletic ability, but also often leads to serious injuries. Therefore, detailed posture, joint range, muscle strength, and functional assessments should be performed at regular intervals to determine the athlete’s fitness for sports activities. Specific tests and measurements will enable the professional to establish a baseline for appropriate treatment interventions for an existing injury and to prevent future injuries.

4. Posture: A detailed posture assessment helps the examiner identify deviations and/or malalignment (Table 1.4). Both can have a serious, nega-
## Table 1.4. Posture assessment.

<table>
<thead>
<tr>
<th>Posture Evaluation Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: __________________ Medical Record</td>
</tr>
<tr>
<td>NO. _______ D.O.B. _______ Sex ______</td>
</tr>
<tr>
<td>Diagnosis ______________ Surgical Procedure/Date ______________</td>
</tr>
<tr>
<td>Precautions __________________</td>
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</table>

### Posterior view

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
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</thead>
<tbody>
<tr>
<td>Head</td>
<td>Centered</td>
<td>Tilt</td>
</tr>
<tr>
<td>Shoulders</td>
<td>Level</td>
<td>Elevated</td>
</tr>
<tr>
<td>Scapulae</td>
<td>Level</td>
<td>Elevated</td>
</tr>
<tr>
<td>Spine</td>
<td>Aligned</td>
<td>Shifted</td>
</tr>
<tr>
<td>Waist folds</td>
<td>Symmetrical</td>
<td>Increased</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Level</td>
<td>Elevated</td>
</tr>
<tr>
<td>Knees</td>
<td>Aligned</td>
<td>Varus</td>
</tr>
<tr>
<td>Heels</td>
<td>Aligned</td>
<td>Valgus</td>
</tr>
</tbody>
</table>

### Anterior view

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Centered</td>
<td>Tilt</td>
</tr>
<tr>
<td>Neck folds</td>
<td>Symmetrical</td>
<td>Increased</td>
</tr>
<tr>
<td>Breasts</td>
<td>Symmetrical</td>
<td>Prominent</td>
</tr>
<tr>
<td>Arm length</td>
<td>Equal</td>
<td>Longer</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Level</td>
<td>Elevated</td>
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<tr>
<td>Knees</td>
<td>Aligned</td>
<td>Varus</td>
</tr>
<tr>
<td>Heels</td>
<td>Aligned</td>
<td>Valgus</td>
</tr>
</tbody>
</table>

### Lateral view

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Head</td>
<td>Aligned</td>
<td>Forward</td>
</tr>
<tr>
<td>Cervical (anterior) curve</td>
<td>Normal</td>
<td>Increased</td>
</tr>
<tr>
<td>Shoulders</td>
<td>Level</td>
<td>Forward</td>
</tr>
<tr>
<td>Scapulae</td>
<td>Aligned</td>
<td>Protracted</td>
</tr>
<tr>
<td>Thoracic (posterior) curve</td>
<td>Normal</td>
<td>Increased</td>
</tr>
<tr>
<td>Lumbar (anterior) curve</td>
<td>Normal</td>
<td>Increased</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Aligned</td>
<td>Anterior Tilt</td>
</tr>
</tbody>
</table>

### Adams forward bend test

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic</td>
<td>Negative</td>
<td>Rib hump</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Negative</td>
<td>Increased m. bulk</td>
</tr>
<tr>
<td>Knees</td>
<td>Aligned</td>
<td>Hyperextension</td>
</tr>
<tr>
<td>Ankles</td>
<td>Aligned</td>
<td>Increased DF</td>
</tr>
</tbody>
</table>

A negative impact on body mechanics and sport-specific techniques. In addition, identifying postural deviations leads the examiner to further investigate specific joint and/or muscle impairments.

5. Joint range of motion: Standardized testing includes measuring each joint, especially those that impact the athlete’s performance. A few examples of tests that measure tightness in muscle groups that are generally affected during the adolescent growth spurt are as follows:

a. Thomas test: The Thomas test measures tightness in the iliopsoas muscle (Figure 1.2). Restricted flexibility in this muscle can cause increased
lumbar hyperlordosis, decreased hip extension, and an increase in knee hyperextension. The test is performed passively. The patient is positioned supine with both hips and knees flexed to the chest, with the lower back flat on the table. The patient holds one leg flexed to the chest. The examiner cradles the other leg and has one hand around the pelvis. The examiner's thumb is positioned on the anterior superior iliac spine (ASIS) to determine when the pelvis begins to move anteriorly. The examiner passively lowers the leg. When the ASIS begins to move anteriorly, the test is stopped and the angle of hip flexion is measured (13).

b. Straight leg raise: The straight leg raise measures hamstring tightness (Figure 1.3). Restricted flexibility in the hamstrings will negatively affect

![Figure 1.3](image.png)

**Figure 1.3.** Straight leg raise test. *(A) Negative* straight leg raise test. The pelvis remains in a neutral position as the straight leg is passively flexed to 90 degrees, indicating appropriate length of the hamstrings muscles. *(B) Positive* straight leg raise test. The pelvis begins to move anteriorly at 40 degrees of hip flexion, indicating tightness in the hamstrings muscles.
low back, pelvis, hip, and knee alignment. The straight leg raise test focuses on proximal hamstring tightness. The test is performed passively. The patient is positioned supine with hips and knees extended and the pelvis in a neutral position. The examiner cradles the leg with one arm and has the other hand around the pelvis. The examiner’s thumb is positioned on the ASIS. The examiner passively raises the leg, keeping the knee straight. As soon as the ASIS begins to move posteriorly, the test is stopped and the angle of hip flexion is measured (14,15).

c. Ober test: The Ober test measures tightness in the iliotibial band (ITB) (Figure 1.4). Restricted flexibility of the ITB often promotes lateral
tracking of the patella. This malalignment of the patella can disrupt knee joint mechanics. Tightness of the ITB not only contributes to knee pain but can also interfere with function. The test is performed passively. The patient is positioned sidelying, with the lumbar spine in flexion. The hips and knees are flexed to the chest. The patient’s neck and trunk are also flexed. The patient holds the bottom leg to the chest while the examiner cradles the top leg, keeping the knee flexed. The examiner flexes the hip and then widely abducts and extends the hip to allow the tensor fasciae latae muscle to move over the greater trochanter. The examiner attempts to passively lower the leg to the horizontal position (14).

d. Ely Test: The Ely test measures tightness in the rectus femoris muscle (Figure 1.5). Restricted flexibility in this muscle can also have a negative

![Figure 1.5. Ely test. (A) Negative Ely test. The anterior hip remains in contact with the table when the knee is flexed to 90 degrees, indicating appropriate length of the rectus femoris muscle. (B) Positive Ely test. The anterior hip loses contact with the table and the buttock begins to rise when the knee is flexed to 60 degrees, indicating tightness in the rectus femoris muscle.](image)
effect on patellar alignment. The test is performed passively. The patient
is positioned prone, with the hips and knees extended. The examiner
grasps the lower leg and slowly flexes the knee. The test is stopped when
the hip begins to flex and the buttock begins to rise. The angle of knee
flexion is measured (14).

6. Neuromuscular system: The neuromuscular system includes assess-
ment of strength, coordination, balance, proprioception, agility, and gait.
Coordination and agility are the ability to perform movements with appro-
priate speed, distance, direction, rhythm, and muscle tension. When assess-
ing adolescents, normal development of skill acquisition must be taken
into consideration so that testing is age appropriate. By age five, the child
can hop 10 hops, but a skillful hop that requires flight and distance con-
tinues to develop into early adolescence (15). Neuromuscular training
describes a progressive exercise regimen that restores synergy and syn-
chrony of the muscle-firing patterns that are necessary for dynamic stabil-
ity and fine motor control. This is accomplished by enhancing the dynamic
muscular stabilization of the joint and by increasing the athlete’s cognitive
awareness of both joint position and motion.

Establishment of A Plan of Care

A successful rehabilitation program depends not only on physiological
factors but also on the emotional and psychosocial attitudes of the adoles-
cent athlete (16). These factors have a significant influence on compliance,
performance, and the expectations of both the athlete and the health
professional.

Positive communication is the key to a successful rehabilitation program.
Communication between health professionals, team members managing
the athlete’s condition, and the parents is necessary to achieve a positive
outcome. The adolescent understands the consequences of compliance, but
often focuses on the here and now (17). Education and detailed explana-
tions with the rationale for each activity will help to promote the athlete’s
compliance.

The rehabilitation program is based on the diagnosis, the goals of treat-
ment, the athlete’s expectations, and the anticipated course of healing
(Table 1.5). Acute injuries require early medical attention, especially if the
injury affects mechanics and performance. An accurate diagnosis is neces-
sary so that the appropriate management can be planned. The goals of
rehabilitation are to control inflammation and pain, promote healing, and
restore function. Once the athlete has recovered sufficiently, return to
sports and/or competition can be considered. Maintaining the athlete’s
physical fitness during recovery, education on preventing future injuries,
and specialized training to increase performance are essential components
of the rehabilitation program.
### Table 1.5. Guidelines for a rehabilitation program based on the stages of healing.

<table>
<thead>
<tr>
<th>Time</th>
<th>Stages of Healing</th>
<th>Rehabilitation program</th>
<th>Therapeutic goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong></td>
<td>Acute Inflammation</td>
<td>Modified activities, Ice, Compression, Elevation (MICE); crutches, braces, supportive devices PRN</td>
<td>1. <strong>Control Inflammation and Pain</strong>&lt;br&gt;Acute care management&lt;br&gt;Protect affected area (protective weight bearing in lower extremity injuries)&lt;br&gt;Reduce swelling and inflammation&lt;br&gt;Minimize hypoxic damage to tissue</td>
</tr>
<tr>
<td>Days 1–3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days 4–7</td>
<td>Repair/Substrate/Inflammation</td>
<td>Isometric exercises&lt;br&gt;Gentle “pain free” active range of motion</td>
<td>Limit further tissue damage&lt;br&gt;Gradually increase “pain free” range of motion</td>
</tr>
<tr>
<td><strong>Phase 2</strong></td>
<td>Proliferation</td>
<td>Restore active full range of motion&lt;br&gt;Gentle progressive resistive exercises</td>
<td>2. <strong>Promote Healing</strong>&lt;br&gt;Decrease protected status if indicated (i.e. partial weight bearing status)&lt;br&gt;Reduce muscle atrophy&lt;br&gt;Improve: range of motion, flexibility, strength</td>
</tr>
<tr>
<td>Days 7–21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phase 3</strong></td>
<td>Healing and Maturation</td>
<td>Functional activities as tolerated&lt;br&gt;More complex movements&lt;br&gt;Progress loading (i.e. cycling, light weights)</td>
<td>3. <strong>Restore Function</strong>&lt;br&gt;Continue to restore range of motion and strength&lt;br&gt;Restore proper muscle activation and biomechanics&lt;br&gt;Improve: proprioception, endurance</td>
</tr>
<tr>
<td>Week 3 to 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phase 4</strong></td>
<td>Tissue Remodeling</td>
<td>Sport specific training&lt;br&gt;Simulate the demands of the sport/activity&lt;br&gt;Coordination and balance exercises&lt;br&gt;Eccentric loading exercises</td>
<td>4. <strong>Return to Activities and Sports</strong>&lt;br&gt;Restore anatomic form, physiologic function&lt;br&gt;Improve conditioning&lt;br&gt;Return to play/sport&lt;br&gt;Consider training modifications and return to play/sports</td>
</tr>
<tr>
<td>Week 6–6mo</td>
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<td></td>
<td>5. <strong>Prevent Future Injury</strong>&lt;br&gt;Protective equipment&lt;br&gt;Injury prevention exercises/ programs</td>
</tr>
</tbody>
</table>