

The Adolescent Athlete and the Team Physician: A Consensus Statement. 2025 Update

MARGOT PUTUKIAN¹, LANCE E. LECLERE², STANLEY A. HERRING³, HOLLY J. BENJAMIN⁴, CRAIG H. BENNETT⁵, LORI BOYAJIAN-O'NEILL⁶, SHELLEY STREET CALLENDER⁷, MOLLY DAY⁸, JONATHAN T. FINNOFF^{9,10}, ROBERT FRANKS^{11,12}, NEERU JAYANTHI¹³, SCOTT A. MAGNES¹⁴, JASON MATUSZAK¹⁵, RYAN ROACH¹⁶, and SIOBHAN M. STATUTA¹⁷

¹Consultant, Major League Soccer, Princeton, NJ; ²Vanderbilt University Medical Center, Nashville, TN; ³Department of Rehabilitation Medicine, University of Washington, Seattle, WA; ⁴Primary Care Sports Medicine, UChicago Medicine, Chicago, IL; ⁵Lifebridge Health, Sports Medicine Institute, Baltimore, MD; ⁶Kansas City University of Medicine and Biosciences, Kansas City, KS; ⁷Sports Medicine, Mercer University, Macon, GA; ⁸University of Wisconsin, Madison, WI; ⁹University of Colorado, Denver, CO; ¹⁰US Olympic and Paralympic Committee, Colorado Springs, CO; ¹¹Departments of Family and Community Medicine, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA; ¹²Rothman Orthopaedic Institute, Philadelphia PA; ¹³Emory University School of Medicine, Atlanta, GA; ¹⁴Department of Surgery, Uniformed Services University of the Health Sciences, Jacksonville, FL; ¹⁵University of Buffalo, Buffalo, NY; ¹⁶Orthopedics and Sports Medicine Institute, University of Florida, Gainesville, FL; and ¹⁷University of Virginia Health, Department of Family Medicine, Charlottesville, VA

ABSTRACT

PUTUKIAN, M., L. E. LECLERE, S. A. HERRING, H. J. BENJAMIN, C. BENNETT, L. BOYAJIAN-O'NEILL, S. S. CALLENDER, M. DAY, J. T. FINNOFF, R. FRANKS, N. JAYANTHI, S. A. MAGNES, J. MATUSZAK, R. ROACH, and S. M. STATUTA. The Adolescent Athlete and the Team Physician: A Consensus Statement. 2025 Update. *Med. Sci. Sports Exerc.*, Vol. 58, No. 2, pp. 371–402, 2026. Team physicians may be called upon to treat adolescent athletes, defined in this document as those in the range of 12–18 yr of age. Many are involved in school-based, intramural, or specialized sports participation and/or training, potentially resulting in injury and/or illness. Specialized treatments may be necessary due to growth and development of the adolescent. Additionally, psychological factors in this age group may play an important role in sports participation, emotional well-being, and injury rehabilitation. While many children younger than 12 yr of age are active in sports participation, their medical and musculoskeletal concerns are not included in the scope of this consensus statement. The healthcare team must stay educated and knowledgeable regarding potential challenges to individuals participating safely in sport. All healthcare professionals should provide quality care, free from discrimination and specific to the needs of every unique individual. Ensuring access to care, fostering welcoming sporting environments, and recognizing the distinct challenges faced by underrepresented populations will reduce healthcare disparities and improve safe participation across all sports. **Key Words:** ADOLESCENT ATHLETE, COMMON MUSCULOSKELETAL ISSUES, MEDICAL ISSUES, OVERTRAINING, RETURN TO SPORT, SPORT SPECIALIZATION, TEAM PHYSICIAN

DEFINITION

Team physicians may be called upon to treat adolescent athletes, defined in this document as those in the range of 12–18 yr of age. Many are involved in school-based, intramural, or specialized sports participation and/or training, potentially resulting in injury and/or illness.

Specialized treatments may be necessary due to growth and development of the adolescent. Additionally, psychological factors in this age group may play an important role in sports participation, emotional well-being, and injury rehabilitation. While many children younger than 12 yr of age are active in sports participation, their medical and musculoskeletal concerns are not included in the scope of this consensus statement.

The healthcare team must stay educated and knowledgeable regarding potential challenges to individuals participating safely in sport. All healthcare professionals should provide quality care, free from discrimination and specific to the needs of every unique individual. Ensuring access to care, fostering welcoming sporting environments, and recognizing the distinct challenges faced by underrepresented populations will reduce healthcare disparities and improve safe participation across all sports.

Address for Correspondence: Margot Putukian, M.D., F.A.C.S.M., F.A.M.S.S.M., 2 English Lane, Princeton, NJ 08540; E-mail: mputukian@gmail.com.

Submitted for publication September 2025

Accepted for publication September 2025

0195-9131/2026/582-371/402

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DOI: 10.1249/MSS.00000000000003863

GOAL

The goal of this document is to help the team physicians improve the care of the adolescent athlete by understanding the medical and musculoskeletal factors common in this age group. To accomplish this goal, the team physicians should have knowledge of and be involved with:

- Musculoskeletal injuries of the adolescent athlete, specifically those to the shoulder, knee, hip/groin, elbow, and spine.
- Medical conditions of the adolescent athlete, especially those pertaining to cardiac issues, infectious diseases, concussion, and nutrition and supplementation.
- Issues related to sports specialization and overtraining.

SUMMARY

This document provides an overview of selected medical issues that are important to team physicians who are responsible for the care and treatment of athletes. It is not intended as a standard of care and should not be interpreted as such. This document is only a guide and, as such, is of a general nature, consistent with the reasonable, objective practice of the healthcare profession. Adequate insurance should be in place to help protect the physician, the athlete, and the sponsoring organization.

This statement was developed by a collaboration of six major professional associations concerned about clinical sports medicine issues; they have committed to forming an ongoing project-based alliance to bring together sports medicine organizations to best serve active people and athletes. The organizations are: American Academy of Family Physicians, American Academy of Orthopaedic Surgeons, American College of Sports Medicine, American Medical Society for Sports Medicine, American Orthopaedic Society for Sports Medicine, and the American Osteopathic Academy of Sports Medicine.

MUSCULOSKELETAL ISSUES

The Adolescent Athlete's Shoulder

Traumatic injuries of the adolescent athlete's shoulder may include glenohumeral instability, acromioclavicular joint injuries, and clavicle fractures. Atraumatic conditions such as multidirectional instability frequently occur in repetitive overhead athletes, and overuse injuries such as physeal injuries may result in throwing athletes. Assessment should include a thorough throwing/overhead history, throwing mechanics, physeal status, and kinetic chain evaluation. Skeletal maturity/physeal status may influence injury patterns and treatment.

Traumatic shoulder instability.

- Stability of the shoulder joint is from static (bone, labrum, and ligaments) and dynamic (neuromuscular) control factors.

- Risk factors may include dominant shoulder, volume/overuse, time in sport, age at time of injury, past injury, and multidirectional instability (1).
- Subluxation or dislocation results from direct or indirect injury to the shoulder.
- Dynamic muscular control is often lost.
- Instability is typically associated with capsulolabral tearing; this may be magnified by bony injury to glenoid and/or humeral head.
- Instability is most commonly anterior; it may also be posterior or multidirectional.
- Associated with a high rate of recurrence that leads to increased likelihood of additional soft tissue injury and glenohumeral bone loss (2,3).

History.

- Mechanism of injury for anterior instability is commonly caused by direct trauma to the upper extremity with the shoulder in an abducted and externally rotated position.
- Mechanism of injury for posterior instability is typically caused by an axial load to the upper extremity with the shoulder forward flexed, adducted, and internally rotated (e.g., blocking in American football).
- Determine the number of prior subluxations/dislocations and if reduction was manual or spontaneous.
- Determine if numbness or weakness occurred.

Physical examination.

- Determine if currently dislocated or if spontaneous reduction has occurred.
- Neurovascular examination, with specific attention to the axillary and musculocutaneous nerves.
- Active and passive shoulder range of motion (ROM) and strength testing with emphasis on rotator cuff and deltoid.
- Shoulder stability testing (e.g., anterior apprehension/relocation).

Imaging.

- X-rays in at least two orthogonal planes (i.e., axillary or Velpeau views with anteroposterior [AP]) to confirm reduction and evaluate physes and other associated bony injuries (e.g., bony Bankart and/or Hill Sachs lesion).
- Magnetic resonance imaging (MRI) with or without intra-articular contrast (arthrogram) is the imaging modality of choice to better define the injury, but indications and timing are controversial.

Treatment.

- Early reduction on the field or sideline is desirable for pain relief, ease of reduction, and to protect neurovascular function.

- Duration of immobilization and positioning in internal or external rotation is controversial.
- Rehabilitation and braces that limit ROM may be helpful in allowing return to sport (RTS) for certain athletes, although recurrent instability may occur.
- Risk of recurrence is associated with baseline ligamentous laxity, age, contact sport, level of competition, and degree of bony involvement (2,4,5).
- Early operative intervention with first-time dislocation may be indicated (6).
- Bony involvement (glenoid fracture, bony Bankart lesion, and physeal injury) is generally an indication for operative treatment.
- Timing and method of repair are controversial (immediate or at end of season, arthroscopic vs open surgery) (7).
- RTS without surgical treatment has been shown to result in a higher likelihood of recurrent instability, loss of playing time, and inability to complete the season (8).
- RTS criteria are controversial, but general requirements include full ROM and strength, resolution of neurological signs and symptoms, and no apprehension (8).

Prevention.

- Prevention strategies have not been shown to decrease the risk of first-time traumatic dislocations.
- Rehabilitation and/or bracing has not been shown to prevent recurrent dislocations.

Clavicle fractures.

- Fractures are caused by direct contact to the clavicle or lateral shoulder. The most common location of clavicle fractures in adolescents is mid-shaft.
- Evaluate for injuries to the acromioclavicular and sternoclavicular (SC) joints. Pure ligamentous acromioclavicular injuries are rare in the adolescent athlete. Most SC injuries are associated with physeal fractures (9).
- Posterior SC dislocation requires emergent evaluation.

History.

- Determine mechanism of injury, location of pain, and if numbness or weakness is present.
- Pain/dislocation in the SC region requires emergent evaluation for airway and neurovascular compromise.

Physical examination.

- Inspect for clavicle deformity and skin tenting or compromise.
- Localized tenderness.
- Neurovascular examination.

Imaging.

- X-rays may include standard shoulder views or clavicle-specific views (AP and apical).
- Ultrasound (US) may be used to identify fractures and dislocations (10).
- MRI and/or computed tomography (CT) is typically not required unless concerned about the SC joint.

Treatment.

- Open injury requires emergent evaluation and treatment.
- Initial treatment is immobilization with a sling/brace for comfort.
- Duration of immobilization and positioning is controversial.
- Adolescent clavicle fractures are typically managed nonoperatively due to a high rate of healing, remodeling potential, and good long-term functional outcomes (11).
- Braces have not been shown to be effective in decreasing pain, improving function, or accelerating healing time.
- RTS criteria are controversial, but general requirements include radiographic healing, no tenderness at the fracture site, full ROM and strength, and resolution of neurological signs and symptoms.

Prevention.

- There are no known prevention strategies.

It is essential that the team physicians:

- Perform a history and physical examination of the shoulder.
- Understand initial treatment of traumatic shoulder dislocations/subluxations and clavicle fractures.
- Recognize emergent injury (e.g., dislocated joint, open injury, and neurovascular injury).
- Understand RTS with first-time and recurrent traumatic dislocations of the shoulder.
- Recognize the higher incidence of recurrence after traumatic shoulder subluxation/dislocation treated nonoperatively.

It is desirable that the team physicians:

- Be familiar with and perform a reduction of a shoulder dislocation on the sideline.
- Understand associated injuries of bony Bankart and Hill Sachs lesions, physeal injuries of the proximal humerus or distal clavicle, and associated nerve injuries that may affect the outcome of treatment.
- Work with the athletic care network to educate athletes, parents, coaches, and additional stakeholders on traumatic shoulder injuries, treatment strategies, and RTS criteria.

Atraumatic shoulder injuries.**Proximal humeral physeal injury (little league shoulder).**

- Overuse injury leading to epiphysiolysis of the proximal humeral physis secondary to repetitive micro-trauma from throwing/overhead activities.
- May be associated with poor muscle control, poor throwing mechanics, and muscle–tendon imbalance (12).

History.

- Typically presents without a history of specific injury or trauma.
- May be associated with a recent increase in throwing/overhead regimen or use of a weighted ball program.
- Presenting symptoms include diffuse shoulder pain, worsened with throwing.
- Throwing/overhead history to include volume (e.g., pitch/serve count) to determine exposure and potential of overuse.
- Performance issues such as velocity, control, stamina, and change in mechanics.

Physical examination.

- Diffuse tenderness throughout the proximal and lateral shoulder.
- Typically full ROM, but at times may be limited by pain.
- Typically full strength, but at times may be limited by pain.
- Assess for kinetic chain deficits and shoulder maladaptations to throwing/overhead shoulder (e.g., scapular dyskinesis, external rotation strength deficit, and glenohumeral internal rotation deficit [GIRD]).
- Provocative examination maneuvers for instability are typically negative.

Imaging.

- X-rays include a minimum of two views (e.g., AP with internal and external rotation views and axillary lateral).
- Comparison radiographs of the contralateral side are often beneficial.
- Diagnosis can often be made with plain radiographs. Widening of the proximal humeral physis is seen best at the lateral aspect of the humerus on AP external rotation views.
- MRI is usually not necessary for diagnosis. If obtained, it may show physeal widening and edema and identify associated pathology.

Treatment.

- Rest and cessation of throwing/overhead activities for a duration of 6–12 wk may be necessary, followed by gradual RTS based on stage of development.

- Physical therapy can improve ROM, strength, and proprioception and correct kinetic chain deficit and scapular dyskinesis during RTS.

Prevention.

- Proper throwing/overhead mechanics and maintenance of core, shoulder, and rotator cuff strength.
- Enforcement of pitch/serve counts and avoidance of year-round throwing.

Atraumatic multidirectional shoulder instability.

- Multidirectional shoulder instability is typically not associated with trauma and may be volitional and/or voluntary.
- Associated with a high rate of recurrence.
- Often occurs bilaterally and can be associated with generalized ligamentous laxity or connective tissue disorders.
- Dynamic muscular control is often poor, as are scapular kinematics.

History.

- Evaluate for diffuse shoulder pain, “dead arm” sensation, and numbness and weakness.
- Confirm directions of instability, recognizing posterior and inferior instability is usually present along with anterior instability.
- Evaluate for prior subluxations/dislocations and if reduction was performed. Typically, manual reductions are not required in multidirectional shoulder instability.

Physical examination.

- Active and passive shoulder ROM and strength testing with emphasis on rotator cuff and deltoid.
- Neurovascular examination.
- Shoulder stability testing (e.g., sulcus sign, anterior apprehension/relocation).
- Perform an assessment of scapular kinematics, core strength, and generalized ligamentous laxity with Beighton score.

Imaging.

- Imaging is often normal.
- X-rays in at least two planes (e.g., axillary or Velpeau views with AP) to evaluate physes and other associated bony injuries (e.g., bony Bankart and/or Hill Sachs lesion).
- MRI with intra-articular contrast (arthrogram) is the imaging modality of choice and often identifies a patulous capsule. Other findings may include labral tears, which may be absent or more subtle in this population compared with traumatic shoulder instability.

Treatment.

- Rehabilitation is the standard nonoperative treatment.
- Operative treatment is rarely recommended as initial treatment; a minimum of 6 month of nonoperative treatment should be completed before surgery (13).
- Optimal timing and method of surgical treatment are controversial (13).

Prevention.

- Prevention strategies have not been shown to decrease the risk of multidirectional instability.
- Strategies may include sport/activity modification.
- Rehabilitation and bracing are standard and may improve stability.

It is essential that the team physicians:

- Perform a history and physical examination of the shoulder.
- Understand atraumatic shoulder pain may be due to overuse injury or an underlying ligamentous laxity condition, rather than an acute injury event.

It is desirable that the team physicians:

- Understand the demands of throwing/overhead activity and multiple musculoskeletal and biomechanical factors can contribute to decline in performance or injury.
- Understand prevention strategies (e.g., pitch/serve counts and fatigue avoidance).
- Understand that rehabilitation, rest from overhead activity, maintaining ROM, scapular control, and strength are primary treatments.
- Understand kinetic chain deficits and shoulder maladaptations to throwing/overhead shoulder (e.g., scapular dyskinesis, external rotation strength deficit, and GIRD).
- Work with the athletic care network to educate athletes, parents, coaches, and additional stakeholders on atraumatic shoulder injuries, treatment strategies, and RTS criteria.

The Adolescent Athlete's Hip and Groin

Hip and groin pain in adolescents may encompass a wide range of disorders, including acute and chronic injuries, femoral acetabular impingement/labral tear, stress injuries, and inguinal-related groin pain. Other hip/groin disorders that cause pain may include hip dislocation, fracture, inflammatory or septic arthritis, nerve entrapment, and lumbar spine disease (14,15). Unique injuries in adolescent athletes are slipped capital femoral epiphysis (SCFE) and apophyseal injuries (i.e., avulsion and apophysitis).

Slipped capital femoral epiphysis (SCFE).

- SCFE is a common condition of the proximal femoral physis that leads to slippage of the metaphysis relative to the epiphysis. Causality is unclear.
- Incidence is approximately four times higher in African American children, 2.5 times higher in Hispanic children, more prevalent in males, and associated with elevated body mass index (BMI) (16).
- Patients with endocrine disorders, such as hypothyroidism, renal osteodystrophy, growth hormone deficiency, and panhypopituitarism, are at higher risk.
- Occurs bilaterally in up to 20% of affected adolescents.
- Subsequent osteonecrosis is a potential complication.

History.

- Presentation may be acute, severe, or insidious hip, groin, thigh, or knee pain exacerbated by physical activity. A painless limp is also common.
- Primary complaint of isolated knee pain may lead to misdiagnosis.

Physical examination.

- Evaluate for external foot rotation with gait or at rest.
- Gait abnormalities (antalgic or inability to bear weight).
- Limited motion and pain with hip internal rotation or flexion, adduction, internal rotation.
- Obligate hip external rotation occurs with hip flexion.
- Inability to bear weight may indicate unstable SCFE.
- Evaluate asymptomatic side due to high incidence of bilaterality.

Imaging.

- X-ray, including AP pelvis and lateral hip, is the diagnostic imaging modality of choice.
- Specific radiographic findings (e.g., Klein line and Southwick angle) aid in diagnosis.
- If X-ray is inconclusive, MRI and/or CT may be indicated. MRI may show edema around the physis in “preslip” conditions. CT may demonstrate subtle epiphyseal asymmetry.

Treatment.

- SCFE usually requires operative treatment to prevent further displacement and reduce risk of acute and long-term complications (e.g., osteonecrosis, osteoarthritis, and femoral acetabular impingement).

Prevention.

- In the case of unilateral SCFE, BMI reduction to lower than the 95th percentile was associated with lower risk of bilateral SCFE development (17).
- Prophylactic pinning of contralateral hip in a person with unilateral SCFE is controversial.

Apophyseal injuries.

- Apophyseal injuries include apophysitis and apophyseal avulsion injuries.
- These injuries are exclusive to skeletally immature athletes who have open physes.
- Apophysitis is due to repetitive traction on the apophysis, while avulsion injuries occur from sudden, forceful eccentric contraction (e.g., sprinting, jumping, and kicking).
- The most common injury sites around the hip and groin include the anterior inferior iliac spine (rectus femoris), anterior superior iliac spine (tensor fascia lata, sartorius), ischial tuberosity (hamstrings), lesser trochanter (iliopsoas), and pubic symphysis (rectus abdominis) (18).
- Most commonly present in male athletes aged 14–17 yr old.
- Risk factors include poor flexibility, rapid periods of growth, and abnormal biomechanics in sport/activity.

History.

- Apophysitis is often characterized by insidious onset, usually associated with a recent increase in activity.
- Avulsion injuries are typically acute and characterized by sudden, shooting pain and weakness. Athletes may report feeling or hearing a “pop” at the time of injury, with an inability to continue participation.

Physical examination.

- Gait abnormalities (antalgic or inability to bear weight).
- Evaluate for localized tenderness, decreased strength, and edema or ecchymosis.
- Passive or active stretching of the associated muscle group often reproduces pain.

Imaging.

- X-rays, including AP, lateral, and oblique of the pelvis, are the diagnostic imaging modality of choice (14).
- In apophysitis, X-rays are typically normal or may demonstrate a slightly widened apophysis.
- In apophyseal avulsion injuries, X-rays are usually definitive and demonstrate a displaced fracture. If there is a small degree of displacement, comparison with contralateral pelvic apophyses may be clarifying.
- MRI may be indicated if X-rays are not definitive.

Treatment.

- Apophysitis is typically treated nonoperatively with rest, ice, and non-steroidal anti-inflammatory drugs.
- Rehabilitation should focus on hip girdle strengthening and correcting flexibility deficits.
- Apophyseal avulsion injuries are typically treated nonoperatively with protected weight bearing with crutches until symptoms resolve.
- Indications for operative treatment of avulsion injuries include bony displacement >2 cm, symptomatic nonunion, or exostosis formation (19).

Prevention.

- The efficacy of prevention strategies is unknown, but neuromuscular training, flexibility exercise, dynamic warm-up before sports participation, proper technique education, and training load monitoring may be considered.

Bone stress injuries (BSIs).

- Athletes with a history of stress injuries are at high risk for subsequent stress injuries.
- There are multiple sites in the hip and groin for stress injuries.
- The femoral neck is considered a high-risk stress fracture.
- Relative energy deficiency in sport (REDs) (20) may be present in athletes with bone stress injury (BSI).

History.

- Pain is characterized by insidious onset and worsens with activity.
- Pain location varies by stress fracture site. Femoral neck stress fractures typically localize to the groin (may radiate to thigh). Sacral stress injuries localize to the sacral and gluteal region.

Physical examination.

- Evaluate for a limp, antalgic gait, point tenderness, and pain with provocative maneuvers (e.g., flexion, adduction, internal rotation; flexion, abduction, external rotation; fulcrum; and log roll).
- Hop test may be considered if other maneuvers are inconclusive.

Diagnostic testing/imaging.

- X-rays include standing AP pelvis and dedicated AP and lateral of the hip.
- MRI is recommended to grade injury severity and guide treatment.
- Diagnostic testing may include REDs assessment (21), bone mineral density testing, and laboratory studies (e.g., vitamin D, calcium, and thyroid panel).

Treatment.

- Most BSIs are treated nonoperatively with rest and protected weight bearing with crutches until symptoms resolve.
- Operative indications include tension-sided or high-grade compression-sided femoral neck stress (22).
- Address deficiencies identified in diagnostic testing.

Prevention.

- Address deficiencies identified in diagnostic testing.
- Address load management strategies supporting recovery (23) and other modifiable risk factors (e.g., negative effects of low energy availability).

It is essential that the team physicians understand:

- Hip and groin injuries are common and specific to the adolescent athlete.
- Apophyseal injuries include apophysitis and apophyseal avulsion injuries that are exclusive to skeletally immature athletes who have open apophyses.
- Referred knee pain can often be the presenting symptom for adolescents with hip pathology, including SCFE. Physical examination of the hip is necessary during evaluation of knee complaints.
- The role of REDs in BSI.

It is desirable that the team physicians:

- Perform a history and physical examination of the hip and groin.
- Understand that the apophyses are common sites of injury.
- Coordinate evaluation and treatment for REDs in BSI.
- Work with the athletic care network to educate athletes, parents, coaches, and additional stakeholders on load management strategies and other modifiable risk factors.

The Adolescent Athlete's Knee

Common knee injuries in the adolescent include physeal injuries, patellofemoral pain (PFP) and instability (PFI), anterior cruciate ligament (ACL) injuries, and osteochondritis dissecans (OCD). The presence of a discoid meniscus predisposes the adolescent athlete to a meniscal injury. Skeletal maturity/physeal status may influence injury patterns and treatment.

Physeal injuries.

- Physes are growth plates and vulnerable regions in the bone (24).
- Apophyses are the tendinous attachments to the physes.

- Physeal fractures are important injuries to recognize because potential complications may occur, including growth disturbance from physeal injury and compartment syndrome (e.g., proximal tibia physeal injury causing anterior compartment syndrome of the leg).
- A high degree of suspicion is warranted for physeal injuries because they can be missed on plain radiographs.

History.

- Typically involves a noncontact or contact traumatic event.
- Significant pain, swelling, discoloration, and inability to bear weight may be present.

Physical examination.

- Antalgic gait or inability to bear weight.
- Swelling, effusion, and/or deformity may be present.
- Neurovascular and compartment assessment.
- Tenderness to palpation.
- Often a decrease in active and/or passive ROM.
- Stability testing and provocative maneuvers based on location of pain (e.g., valgus stress test for distal femoral physeal injury).

Imaging.

- X-rays include weight bearing AP and lateral view; additional views when indicated may include axial patellar view at 30° or 45° of knee flexion (e.g., merchant, sunrise).
- Stress X-rays and/or contralateral comparison films may be utilized if diagnosis is unclear.
- MRI may be indicated if effusion is present and/or if X-rays are nondiagnostic.

Treatment.

- Management is influenced by fracture location, displacement, stability, and risk of growth disturbance.
- Repetitive closed reduction attempts can lead to increased risk of physeal arrest and growth disturbances.
- Early surgical consultation is recommended.

Prevention.

- There are no known prevention strategies.

Patellofemoral pain (PFP) and instability (PFI).

- PFP and PFI are common causes of knee pain in adolescent athletes.
- PFP is defined as pain around or behind the patella aggravated by weight-bearing activities (e.g., squats, stairs, running, or jumping) (25).

- Annual prevalence for patellofemoral pain in adolescents: 28.9% (25).
- Risk factors for PFP include female sex, activity profile (stairs, squatting), dynamic valgus, and weak hip abductors (26).
- PFI is associated with family history, patella alta, trochlear dysplasia, increased tibial tuberosity-trochlear groove, increased Q angle, femoral anteversion, genu valgum, foot pronation, previous dislocation, medial patellofemoral ligament incompetence, vastus medialis obliquus hypoplasia (27), and increased generalized laxity.
- Younger age is a risk factor for reinjury (28,29).

History.

- PFP typically has an insidious onset of anterior knee pain aggravated by flexed knee loading (25,26,30). Athletes may report grinding sensation, popping, clicking, and giving way/instability.
- PFI is typically associated with a specific event. Athletes may complain of pain, swelling, a “pop,” giving way/instability, and current/perceived dislocation.
- Determine the number of prior subluxations/dislocations and if reduction was manual or spontaneous.
- Family history.
- Bilateral versus unilateral.

Physical examination.

- Gait pattern may be normal, antalgic, or unable to bear weight.
- Standing lower-extremity alignment may demonstrate genu valgum and pes planus.
- Q angle may be increased.
- Visible inspection may demonstrate gross deformity if dislocated.
- Effusion is typically present after acute PFI, but is not common with PFP.
- Assess active and passive ROM; J-sign and hyperextension may be present.
- Point tenderness along patellar facets and/or inferior pole of patella.
- Patellar instability maneuvers (e.g., patellar apprehension, J-tracking with quadriceps activation) are positive in the case of PFI.
- Beighton score should be evaluated.

Imaging.

- X-rays include weight-bearing AP and notch, lateral view, and axial patellar view at 30° or 45° of knee flexion (e.g., merchant and sunrise); findings may include patella alta or baja, hypoplastic patella, trochlear dysplasia, lateral patellar displacement, and loose bodies.
- MRI after PFI can be used to characterize the anatomy (e.g., trochlear dysplasia, determine tibial

tuberosity-trochlear groove, tibial tuberosity to posterior cruciate ligament distance) and associated injuries (e.g., medial patellofemoral ligament tear, loose body).

- In PFP, MRI is typically not required and is usually normal.

Treatment.

- PFP is treated with rehabilitation with a focus on core, hip, and knee flexibility and strength (26,31).
- Patellar taping, foot orthotics is beneficial to correct alignment in PFP. Knee braces have not been shown to be beneficial over exercise (26).
- RTS for PFP involves advancing activity as tolerated with load progression and monitoring.
- Treatment (nonoperative vs operative) of first-time PFI is controversial (32).
- Nonoperative treatment for PFI includes bracing, activity modification, symptom management, early ROM, and quadriceps and hip girdle strengthening.
- Operative indications include first-time dislocation with loose body and recurrent instability. Surgical techniques and RTS progressions vary. Physeal sparing surgical techniques are recommended in athletes with open physes.

Prevention.

- There are no known prevention strategies.
- Prophylactic bracing has not been shown to reduce PFI injury risk and PFI reinjury after surgery (33).

Anterior cruciate ligament (ACL).

- Most ACL injuries are noncontact. Mechanism involves a loaded rotation, pivoting, or hyperextension (34).
- Incidence of ACL injuries among adolescent athletes continues to steadily rise (35).
- High-risk sports for adolescents include soccer, basketball, lacrosse, and football (35).
- Females have a higher incidence of noncontact ACL injury than males.
- ACL injuries in the adolescent may be tibial spine bony avulsions or ligament tears. Bony avulsion injuries require prompt referral for operative evaluation and treatment.
- Open physes require special attention in determining the treatment of ACL injuries.
- Nonmodifiable risk factors for ACL injury include age, sex, injury history, and unique anatomical findings (e.g., ligamentous laxity and Q angle).
- Modifiable risk factors include biomechanical and neuromuscular control, training loads, and BMI.
- Following pediatric and adolescent ACL reconstruction, approximately 32% may have a second ACL injury within the next 2 yr on the ipsilateral (19%)

or contralateral (13%) sides (36). Subsequent injury rates correlate with age and physal status.

- Screening an adolescent's psychological state surrounding ACL injury can offer insight and opportunity to customize treatment to improve overall surgical outcomes, RTS, satisfaction, and general mental well-being (addressing post traumatic stress, depression, athletic identity) (37–40).

History.

- Establish the mechanism of injury. Classical presentation is sudden deceleration or twisting injury with an audible/sensation of “pop,” immediate swelling, and inability to continue playing.
- Obtain menstrual history, maturation/puberty status, and family history of height.
- Obtain history of prior knee injuries and treatments.

Physical examination.

- Gait may be normal, antalgic, or unable to bear weight.
- Knee effusion is typically present.
- Assess for ligamentous stability (e.g., Lachman test, pivot shift, and lever test) (41) and ROM.
- Evaluate for other associated injuries, including ligamentous injury, patellofemoral instability, and meniscal injury.
- Neurovascular examination.

Imaging.

- X-rays include weight-bearing AP and notch, lateral view, and axial patellar view at 30° or 45° of knee flexion (merchant, sunrise).
- Noncontrast MRI is the imaging modality of choice to diagnose ACL tear and concomitant injuries (e.g., meniscal tears, tibial spine fractures, and collateral ligament injury) (34).

Treatment.

- Initial treatment involves ice, compression, and restoration of ROM, especially extension (not immobilization) and protected weight bearing as needed.
- Nonoperative management has shown poor results as activity modification in adolescents, and bracing provides little or no protection.
- Operative intervention is recommended when pain, swelling, and ROM have normalized.
- Operative technique and graft types vary; allografts are not recommended in adolescent athletes (42). Presence of open physes influences surgical decision-making.
- Postoperative rehabilitation and RTS are the same as in adults (14,40).
- Evidence supports early mobilization following operative treatment to improve ROM and avoid arthrofibrosis (34).

Prevention.

- Implement a sport-specific conditioning program with periodization (43,44), including motor control (including core and lower-extremity strength, balance, and flexibility): (45,46) technique training to include landing and sport-specific athletic skills programs; risk awareness education; and proper care of playing surfaces, and selection of shoe wear.
- Prophylactic bracing has not been shown to reduce noncontact ACL injury risk or risk of reinjury following operative treatment.

Osteochondritis dissecans (OCD).

- OCD is an acquired, potentially reversible alteration of subchondral bone and/or cartilage with risk for osteochondral instability and delamination, which may predispose to osteoarthritis.
- The knee is the most common site of OCD.
- Mostly occur in the lateral aspect of medial femoral condyle. More commonly unilateral but can present bilaterally (47–49).
- Unknown etiology that may have multifactorial contributors (vascularity, inflammatory, micro- and macrotrauma, genetic, biomechanical, obesity, and nutritional) (47).
- Most common in the preadolescent/adolescent age groups (age 10–15 yr) (47).
- OCDs differ from trauma-provoked osteochondral fractures; therefore, history is important in diagnosis (47).
- Symptoms do not always correlate with disease severity (47).
- Degree of skeletal maturity and stability of OCD guide treatment approach (47–49).
- Those with open physes and stable OCD have higher rates of success with nonoperative treatment and better overall outcomes.

History.

- Variable presentation: asymptomatic to vague generalized or focal pain (47–49).
- Swelling (stable or unstable lesions) and mechanical symptoms (unstable lesions) may be present (47–49).
- Symptoms aggravated with impact activities (e.g., running, jumping, squatting) (47,49).

Physical examination.

- Gait pattern may be normal, antalgic, or unable to bear weight.
- Effusion may be present (47).
- Point tenderness may be present.
- Wilson test may provoke pain.

Imaging.

- X-rays include weight-bearing AP and notch, lateral view, and axial patellar view at 30° or 45° of knee flexion (merchant and sunrise).
- OCD lesions are most commonly seen on the lateral aspect of the medial femoral condyle on the notch view. Also assess for loose bodies and physeal status.
- MRI provides additional detail about the lesion: location, size, and depth, and characteristics indicative of instability (e.g., loss of cartilage cap, cystic changes, and fluid tracking deep to OCD lesion) (47,50).
- CT is not indicated initially, but can prove helpful in postoperative healing assessment. US is not commonly used for OCD of the knee (47).
- Serial imaging can assist in determining stability and healing of OCD lesion (47).

Treatment.

- Aim of treatment is articular cartilage preservation and promotion of subchondral bone healing (47).
- Presence of symptoms, lesion stability/severity, chondral integrity, and physeal status are key factors in guiding treatment (47).
- In patients with stable lesions, a trial of observation, limited weight-bearing activities, and bracing are recommended. Observation for a period of 3–6 month is standard to monitor progression (47,48).
- Approximately 50%–65% of OCDs in children and adolescents will heal with nonoperative treatment (48).
- Progression of, or persisting pain, effusion, instability, or mechanical symptoms indicates failure of the nonoperative treatment (47).
- Operative treatment may be indicated for failed nonoperative treatment or unstable lesions.
- RTS for nonoperative treatment is controversial. General measures may include resolution of signs and symptoms and evidence of radiographic healing.
- RTS following operative treatment is based on the technique and procedure performed.

Prevention.

- There are no known prevention strategies.

It is essential that the team physicians:

- Understand common adolescent knee injuries.
- Conduct a history and physical examination of the knee.
- Understand the role of ACL prevention strategies.
- Understand that physeal status influences injury patterns, treatment, and prognosis.

It is desirable that the team physicians:

- Diagnose common knee injuries in the adolescent athlete.
- Understand risk factors and prevention strategies associated with adolescent knee conditions.
- Coordinate treatment.
- Work with the athletic care network to educate athletes, parents, and coaches regarding knee injuries and conditions.

The Adolescent Athlete's Elbow

Elbow conditions in the adolescent athlete are associated with overuse and/or traumatic injuries. The majority of elbow injuries occur in overhead/throwing athletes, but they can occur in numerous other sports/activities. Common conditions that affect the adolescent athlete's elbow include apophysitis, avulsion injury, ulnar collateral ligament (UCL) injury, OCD of the capitellum, and olecranon stress fracture. Panner disease is an osteochondrosis of the capitellum. It is a rare condition of the elbow that can occur in adolescent athletes and involves the entire capitellum.

Medial elbow pain (apophysitis, avulsion injury, and UCL sprain).

- Medial elbow injuries in adolescent athletes are increasing (51).
- Many injury patterns are based on the stage of osseous development.
- Areas susceptible to injury in the kinetic chain include the medial elbow apophysis, flexor/pronator group, and UCL.
- Valgus loads with rapid elbow extension produce tensile stress along the medial elbow, shear stress in the posterior elbow, and compression on the lateral structures.
- Traumatic injuries may occur from throwing, a fall or post on an outstretched upper extremity, or a direct impact to the elbow.
- Medial epicondyle apophysitis, fragmentation, widening, or avulsion may occur from trauma, overuse, poor kinetic chain mechanics, weak shoulder or arm muscles, and/or increased load (e.g., pitch count).
- UCL pathology may be acute or chronic.
- External load is affected by pitch/serve count, season length, number of seasons, number of teams played on, positions played, participating with pain/fatigue, competition/tournament frequency, and participation in/amount of private coaching.
- Excessive internal load is due to poor mechanics, core weakness, and lower-extremity strength deficits/ imbalances.

History.

- Determine the mechanism of injury.

- Medial elbow apophysitis may present with an insidious onset of medial elbow pain, with or without ulnar neuritis symptoms.
- Avulsion injuries typically have a sudden onset.
- UCL tears may occur insidiously or acutely and may or may not be associated with a “pop.” These tears may be associated with ulnar neuritis symptoms.
- Presence of numbness, tingling, weakness, pain radiation, loss of throwing velocity and endurance, and/or accuracy.
- For overhead/throwing athletes, questions about timing of pain, prodromal pain, volume and load, including alterations in technique, pitch count, number of teams played, positions played, and associated injuries in the kinetic chain.

Physical examination.

- Assess elbow carrying angle and ROM.
- Tenderness with palpation of medial elbow structures.
- Perform manual muscle testing, valgus stress testing (e.g., milking maneuver, moving valgus stress test), and ulnar nerve assessment.
- Evaluate neck, shoulder, and kinetic chain to include core stability, scapular motion and position, and GIRD.
- Identify weakness or injury to areas of the ipsilateral shoulder and upper extremity.
- Compare findings to the contralateral side.

Diagnostic studies.

- X-rays (AP, lateral, and oblique) with comparison views in athletes with open physes.
- Imaging may show fragmentation, physeal widening, or avulsion.
- US with dynamic imaging can identify UCL tears and laxity.
- MRI with or without intra-articular contrast is useful to better define injury, including ligamentous and osseous injuries, edema, physeal injury, and articular cartilage lesions.
- CT may be useful to better define osseous injury.

Treatment.

- Treatment options may vary based on skeletal maturity, activity (e.g., overhead athlete), and injury acuity/mechanism.
- Medial apophysitis is treated nonoperatively with activity modification, rehabilitation, addressing kinetic chain deficits, and modification of throwing demands. Athletes should complete an RTS program after full resolution of symptoms.
- Medial epicondyle avulsion fractures can be treated nonoperatively (e.g., period of immobilization followed by gradual RTS) or operatively depending on the degree of displacement.

- Nonoperative treatment of proximal UCL sprains and/or partial tears may be considered and includes activity modification, cessation of throwing, core strengthening, scapular stabilization, ROM shoulder/protected elbow, strengthening shoulder/elbow, evaluation of throwing mechanics, and throwing program based on position.
- Corticosteroid injection should be avoided.
- Orthobiologic treatment of UCL injuries is controversial.
- Operative treatment of UCL injuries involves reconstruction/repair of complete tears, some partial tears, and athletes who have failed nonoperative treatment.
- UCL reconstruction should not be considered in the uninjured athlete for performance enhancement (14).
- RTS following nonoperative treatment in UCL tears may take up to 12 wk with partial or proximal tears.
- RTS following operative treatment in UCL tears may take up to 12–16 month. Eighty percent to 90% of throwers return to preinjury levels (52).

Prevention.

- Follow established injury prevention strategies (53).
- Manage medial elbow loading (e.g., follow pitch counts).
- Work with the athletic care network to educate athletes, parents, and coaches on medial elbow injuries and prevention strategies.

OCD of the capitellum.

- Injury to articular cartilage and subchondral bone localized to capitellum from repetitive trauma secondary to high velocity valgus force.
- Skeletally immature, intact articular surface usually allows for healing in adolescents. Unstable lesions (e.g., separation, fragmentation, and loose bodies) usually require operative treatment.
- Typically presents with pain and/or swelling isolated to the lateral elbow.

History.

- Determine location of pain.
- Presence of mechanical symptoms.
- Determine if acute or chronic; traumatic or atraumatic.
- Presence of numbness, tingling, weakness, pain radiation, loss of throwing velocity and endurance, and/or accuracy.
- Determine volume and load (e.g., alterations in technique, pitch count, number of teams played, positions played, associated injuries in the kinetic chain).
- Presence or absence of prodromal pain.

Physical examination.

- Elbow joint effusion.
- ROM.
- Tender to palpation over the radiocapitellar joint.
- Positive radiocapitellar compression test.
- Mechanical block suggests a loose body.
- Compare findings to the contralateral side.

Diagnostic studies.

- X-ray: AP, lateral, and oblique views may show lucency of capitellum with flattened articular surface, possible sclerotic rim, and possible fragmentation or loose body.
- Consider contralateral images for comparison.
- MRI: may demonstrate bone marrow edema, fragmentation, and articular cartilage irregularities.

Treatment.

- Stable capitellar lesions with intact articular cartilage are treated nonoperatively with activity modification, rehabilitation, biomechanical analysis, throwing program per position.
- Increased rates of healing with nonoperative treatment in athletes with stable lesions and open physes (54).
- Indications for operative management include unstable lesions or failed nonoperative treatment.
- RTS for nonoperative treatment is controversial. General measures may include resolution of signs and symptoms.
- RTS following operative treatment is based on the technique and procedure performed.

Prevention.

- There are no known prevention strategies.

It is essential that the team physicians:

- Conduct a history and physical examination of the elbow.
- Understand common elbow injuries in the adolescent athlete.
- Understand the role of sport-specific issues on elbow injuries and conditions.
- Understand that most elbow issues in this population are related to overuse but can occur due to trauma.

It is desirable that the team physicians:

- Understand operative and nonoperative treatment indications.
- Understand the impact of kinetic chain deficits on adolescent elbow injuries.
- Work with the athletic care network to educate athletes, parents, and coaches regarding elbow injuries and conditions and prevention strategies.

The Adolescent Athlete's Spine

Common conditions in the adolescent spine include spondylolysis/spondylolisthesis, adolescent idiopathic scoliosis (AIS), and Scheuermann kyphosis. Lumbar disc herniations are an uncommon etiology of back pain in adolescents (55–57). Athletes report significantly higher rates of low back pain (LBP) than nonathlete counterparts. Most adolescent spine injuries are due to overuse/chronic repetitive trauma rather than acute injury. Adolescents with back pain are up to six times more likely to have back pain as an adult (58,59). Adolescents with poor trunk stability may be more likely to experience LBP (60). Persistent LBP and/or “red flag” symptoms (e.g., neurologic deficit, bowel/bladder dysfunction, and constitutional symptoms) in the adolescent athlete warrant evaluation.

Spondylolysis/spondylolisthesis.

- Spondylolysis is a unilateral or bilateral defect of the pars interarticularis (61), an isthmus of bone connecting the superior and inferior facet surfaces in the spine at a given level.
- Spondylolysis can be due to acute injury or chronic overload.
- BSIs occur along a spectrum ranging from stress reaction to fracture.
- It is the most frequent diagnosis made in adolescent athletes presenting with LBP (62), and the incidence may be much higher in specific sports with frequent flexion/extension motions combined with rotation (e.g., gymnastics, weightlifting, American football, and diving).
- Other risk factors include poor nutrition (63), scoliosis and spina bifida occulta (64–68), level of physical activity, and male sex.
- Spondylolysis most commonly occurs bilaterally at the L4/5 or L5/S1 level.
- The progression from spondylolysis to spondylolisthesis is uncommon, even with continuation of sporting activity. If progression occurs, it is often during the adolescent growth spurt and often occurs without symptoms (69).

History.

- Typically presents with insidious onset of axial LBP, often worsened with extension. However, the absence of pain with extension does not exclude the diagnosis of spondylolysis.
- Athletes may report a recent increase in volume of activities that involve extension, rotation, and axial loading.
- Neurologic symptoms are uncommon.
- Rule out “red flags.”

Physical examination.

- Tenderness to palpation at the site of the injury.
- A visible or palpable vertebral step-off may be present in spondylolisthesis (70,71).
- Hyperlordotic posture and tight hamstrings are commonly present.
- Standing single-leg hyperextension with rotation and axial loading (stork test) can accentuate pain. However, the predictive value of the stork test is poor (72).
- Neurologic examination is typically normal. If abnormal, a high-grade spondylolisthesis may be present.

Diagnostic studies.

- Standing AP and lateral X-rays of the lumbar spine can demonstrate spondylolysis/lolisthesis; oblique views do not improve diagnostic accuracy and are not recommended (73).
- MRI is commonly performed to diagnose because of a lack of radiation, ability to detect stress reaction, acute or chronic fracture, and spondylolisthesis, as well as other pathologies (e.g., disc herniation, discitis). However, in some cases of early stress reaction, SPECT CT may be more sensitive (72,74).
- CT may provide additional assessment of cortical defects, fracture status, and chronic sclerotic changes associated with pars injury (75).
- Consider bone mineral density testing and laboratory studies (e.g., vitamin D, calcium, and thyroid panel).

Treatment.

- Most symptomatic spondylolysis responds to nonoperative treatment.
- Nonoperative strategies may include a period of sport cessation/activity modification, flexion-based core stabilization exercises, correcting biomechanical and postural factors, and load management.
- Bracing is controversial. Regardless of bracing, outcome studies have similar results regarding return to play and bony healing.
- Surgical intervention is usually considered for grade two or more spondylolisthesis or spondylolysis/lolisthesis with intractable axial pain and/or significant neurologic findings.
- RTS may proceed based on pain, with or without radiographic evidence of bony healing.

Prevention.

- Early recognition and treatment of stress reaction may prevent progression to stress fracture (76–78).
- Proper load management and optimal technique in high-risk sports may have a role in prevention.

Adolescent idiopathic scoliosis (AIS).

- AIS is defined as a three-dimensional spine deformity with a curve greater than 10° developing between 10 yr of age and skeletal maturity without an identifiable cause.
- Typically develops before puberty, progresses during the adolescent growth spurt, and stabilizes after skeletal maturity.
- May be identified with screening tests (e.g., forward bend test, scoliometer, and Moire topography).
- The condition is more common in females and the thoracic spine; curves usually occur to the right.
- Genetics are thought to play a role, but genetic testing is not currently recommended.

History.

- If pain is present, it develops insidiously and does not equate to the degree of curve.
- Neurological symptoms are typically absent.

Physical examination.

- Visual inspection of the spine reveals an abnormal curve that does not resolve with flexion or extension.
- Neurologic examination is typically normal.
- Palpation may reveal tenderness in the paraspinal musculature. Spinous process tenderness is typically absent.

Diagnostic studies.

- Imaging involves standing posteroanterior and lateral spine radiographs to determine curve location and severity (i.e., Cobb angle).
- AP radiographs of the pelvis are used to determine the Risser grade of skeletal maturity.
- Advanced imaging is usually not indicated.

Treatment.

- Requires close monitoring (e.g., serial physical examination, radiographs) since curves may progress.
- Early consultation with a spine surgeon is recommended.
- For curves <20°, treatment involves scoliosis-specific physical therapy and monitoring for progression until skeletal maturity.
- For curves 20°–45°, treatment involves scoliosis-specific physical therapy, bracing, and monitoring for progression until skeletal maturity.
- For curves >45°, operative treatment may be considered.
- Sports participation is permitted as tolerated.

Prevention.

- There are no known strategies to prevent the onset of the condition.

- Scoliosis-specific physical therapy exercises and bracing slow progression or reduce scoliotic curvature more than generic exercises.

Scheuermann kyphosis.

- Scheuermann kyphosis is an idiopathic deformity of the thoracic/thoracolumbar spine that may develop before puberty, progress during the adolescent growth spurt, and stabilize after skeletal maturity.
- The condition may be more frequent in tall males.
- In rare cases, it may be associated with myelopathy (79–81).
- Long-term follow-up studies suggest increased back pain and lower health-related quality of life in adulthood (82–84).

History.

- Pain usually develops insidiously and is located at the apex of the kyphosis.
- Pain worsens with flexion, after activity, and at the end of the day; it improves with rest.
- Neurologic symptoms are typically absent.
- Symptoms may improve with skeletal maturity.

Physical Examination.

- Visual inspection of the thoracolumbar spine reveals an increased kyphosis that does not resolve with flexion or extension.
- Palpation may reveal tenderness in the paraspinal musculature. Spinous process tenderness is typically absent.
- Neurologic examination is typically normal.

Imaging.

- X-rays include a scoliosis series of the thoracolumbar spine.
- Diagnosis is defined by hyperkyphosis and wedging of $>5^\circ$ of three or more consecutive vertebral bodies at the apex of the deformity on a lateral radiograph in the thoracic or thoracolumbar spine (85,86).
- MRI is indicated if neurologic signs or symptoms are present.

Treatment.

- Requires monitoring (e.g., serial physical examination, radiographs) since curves may progress.
- Consultation with a spine surgeon is recommended.
- For kyphosis less than 50° , treatment is usually symptomatic, and most kyphoses rarely progress beyond 50° .
- For kyphosis between 50° and 75° , bracing should be considered in the skeletally immature athlete.
- For curves $>75^\circ$, surgical consultation is warranted.
- Sports participation is permitted as tolerated.

Prevention.

- There are no known strategies to prevent the onset of the condition.
- Bracing may slow progression.

It is essential that the team physicians:

- Obtain a history and perform a physical examination of the spine, including a neurologic examination.
- Understand that persistent back pain in the adolescent athlete warrants evaluation.
- Recognize “red flag” signs/symptoms.
- Understand treatment options and prevention strategies.

It is desirable that the team physicians:

- Recognize spondylolysis as the most frequent cause of back pain in the adolescent seeking treatment.
- Understand the indications for imaging.
- Coordinate the clinical treatment for athletes with spinal conditions.
- Understand RTS strategies for spinal conditions.
- Work with the athletic care network to educate athletes, parents, and coaches regarding spinal conditions and their treatment and prevention strategies.

MEDICAL ISSUES

Cardiac Issues in the Adolescent Athlete

Sudden cardiac death/sudden cardiac arrest (SCD/SCA) is the most common medical cause of death in adolescent athletes. There is some evidence that SCD is more prevalent in adolescent athletes than in their non-athletic counterparts (87–89). The most common cardiac conditions are cardiomyopathies (e.g., hypertrophic cardiomyopathy), channelopathies (e.g., Brugada syndrome, long and short QT), and anomalous coronary arteries. These conditions may be unmasked during adolescence. Commotio cordis may also cause SCD in a structurally and functionally normal heart.

The pre-participation examination should be routinely performed; it may be the only time an adolescent athlete sees a health care provider. Screening with history and physical examination alone has poor sensitivity for cardiac conditions. Electrocardiograms (ECGs) increase screening sensitivity and specificity, but general implementation is controversial because of factors including social determinants of health, expertise, equipment, and sport-specific issues. It is essential that the ECG is interpreted using athlete-specific criteria. Other diagnostic studies (e.g., echocardiogram [ECHO], exercise stress test, and cardiac MRI) also increase screening sensitivity and specificity, but are not recommended for general screening. Repeat screening (history, exam, ECG, and exercise stress testing) has been shown to increase detection of cardiac pathology (90).

Regardless of screening, SCD may still occur. In all sport settings, an emergency action plan (EAP) must be in place, which includes immediate initiation of cardiopulmonary resuscitation (CPR) and rapid access to defibrillation (91). EAP should be communicated with key stakeholders and practiced regularly.

Hypertrophic cardiomyopathy (HCM).

- HCM is the most common cause of adolescent SCD in the United States.
- It may present at any age but typically occurs in late childhood/early adolescence.
- Inherited in an autosomal dominant inheritance pattern.

History.

- The initial presentation of HCM may be SCD.
- Symptomatic athletes may present with dyspnea, presyncope/syncope with exercise, chest pain, palpitations, or exercise intolerance.
- Family history of unexplained SCD before the age of 50 or known HCM is important (92–94).

Physical examination.

- Systolic murmur exacerbated by decreased preload (e.g., lying to standing position).

Diagnostic studies.

- ECG remains crucial in the diagnosis and is abnormal in about 90% of cases (93).
- Potential findings with HCM include left ventricular hypertrophy, left axis deviation, Q-waves, ST-segment abnormalities, and T-wave inversion.
- ECG should be interpreted using athlete-specific criteria.
- When ECHO is utilized, there are adolescent-specific criteria for septal thickness (i.e., Z score greater than 2.5) (94).
- Exercise stress testing is recommended for functional capacity determination and prognosis.
- Cardiac MRI can measure septal thickness as well as show the magnitude and pattern of disease and associated cardiac fibrosis.
- Additional testing may include genetic testing, Holter monitoring, or stress ECHO.

Treatment.

- A diagnosis of cardiac disease should not necessarily disqualify adolescent athletes from sport participation. Expert assessment and shared decision-making should guide exercise prescription and engagement, even in high-intensity sports.

Prevention.

- Placement of implantable cardiac defibrillators (ICD) may reduce the risk of SCD.
- Annual or biennial screening is recommended from age 10 in children with a family history positive for HCM (95).

Channelopathies.

- Channelopathies are inherited cardiac ion channel disorders, commonly affecting the sodium (i.e., Brugada syndrome) and potassium (i.e., long and short QT syndrome) channels.
- They are frequently characterized by ventricular arrhythmias and SCD.
- Brugada syndrome is most commonly found in young Asian males and may be provoked by hyperthermia.
- QT interval can be affected by a variety of medications (e.g., antiarrhythmics, antimicrobials, antidepressants, and antipsychotics). This must be taken into consideration when evaluating and treating an athlete with long or short QT syndrome.

History.

- Initial presentation may be SCD.
- Symptomatic athletes may present with dyspnea, presyncope/syncope with exercise, chest pain, palpitations, or exercise intolerance.

Physical examination.

- Examination is typically normal.

Diagnostic studies.

- ECG should be interpreted using athlete-specific criteria.
- ECG findings for Brugada syndrome include right bundle branch block, J-point elevation, and ST-segment elevation in the precordial leads.
- ECG criteria for long QT syndrome include a QT interval corrected for heart rate (QTc) greater than 440 ms in men or greater than 460 ms in women. A QTc of greater than 500 ms is associated with increased risk of torsades de pointes.
- ECG criteria for short QT syndrome include a significantly shortened QTc, usually less than 330 ms in males and 340 ms in females.

Treatment.

- Options include medication, ICD, or surgical intervention (e.g., ablation).

Prevention.

- Placement of ICD may reduce the risk of SCD.

Anomalous coronary arteries.

- Anomalous coronary arteries are the second most common cause of SCD in adolescents (96).
- Congenital anatomic abnormality of the coronary arteries; the most common abnormality is the right coronary artery originating from the left coronary cusp.

History.

- The initial presentation may be SCD.
- Symptomatic athletes may present with dyspnea, presyncope/syncope with exercise, chest pain, palpitations, or exercise intolerance.

Physical examination.

- Examination is normal.

Diagnostic studies.

- ECG should be interpreted using athlete-specific criteria.
- ECG is usually normal but may demonstrate ischemic changes.
- ECHO, cardiac MRI, cardiac CT, or coronary angiography is diagnostic (96).
- Exercise stress tests can assess exercise tolerance and provide prognostic information for RTS (97).

Treatment.

- Operative treatment of the coronary arteries is indicated in symptomatic individuals (96).

Prevention.

- There are no known prevention strategies.

Commotio cordis.

- Commotio cordis occurs when there is a blow to the chest during cardiac repolarization (i.e., Q-on-T wave in the cardiac cycle), which results in ventricular fibrillation and SCD.
- It is more common in children and adolescents who have pliable chest walls.
- Most common in sports with projectiles (e.g., baseball, hockey, and lacrosse).
- Immediate recognition is critical with a high index of suspicion on the collapse of an athlete after a direct blow to the chest.

History.

- Athlete presents with collapse after sustaining a blow to the chest.

Physical examination.

- Seizure-like activity after collapse may occur.
- Pulseless, apneic, and unresponsive.

Treatment.

- The primary determinant of survival is early recognition, immediate initiation of CPR, and early defibrillation.
- Survival rates decline by 7%–10% per minute following cardiac arrest.

Prevention.

- Equipment advancements, including safety baseballs and chest protectors, decrease the incidence of commotio cordis.

It is essential that the team physicians:

- Understand common etiologies of SCD in adolescent athletes.
- Recognize noncontact collapse is due to SCA/D until proven otherwise.
- Consider commotio cordis when collapse occurs following a direct blow to the chest.
- Understand, practice, and be prepared to implement the EAP and medical protocols, including early access to defibrillation (91).
- Maintain CPR certification and automated external defibrillator training.

It is desirable that the team physicians:

- Participate in the development of the EAP.
- Participate in cardiac screening of athletes.
- Identify a subspecialty referral network for cardiac issues in athletes.
- Understand the role of protective equipment in preventing commotio cordis.
- Work with the athletic care network to understand SCA/D and provide CPR and automated external defibrillator training to all stakeholders.

The Adolescent Athlete and Infectious Disease

Infections in the adolescent athlete affect multiple systems, including the skin, respiratory system, gastrointestinal system, and others. Common considerations include RTS, prevention of transmission, and systemic involvement. Adolescent athletes may be affected by infectious mononucleosis (IM), skin infections (e.g., herpes, tinea, and methacillin-resistant staphylococcus aureus [MRSA]), respiratory infections (e.g., influenza, and COVID-19), and gastrointestinal infections (e.g., norovirus).

Blood-borne pathogens (e.g., hepatitis B/C and HIV) can occur in adolescent athletes. However, the transmission in sports is rare. Some infectious diseases are preventable through routine vaccination.

Infectious mononucleosis (IM).

- IM is primarily caused by the Epstein–Barr virus (EBV) but may be caused by other viruses (e.g., cytomegalovirus).
- EBV is known to have a long incubation period (30–50 d).
- Adolescents with lower socioeconomic status or who live in overcrowded environments or in communal living settings are at higher risk of exposure or previous infection.
- Transmission is primarily through saliva, even when asymptomatic.
- Coexistent bacterial and viral tonsillitis, often exudative, is common (e.g., Group A beta-hemolytic streptococcus is coexistent in up to 30% of cases).
- The spleen increases in size in most cases of IM, starting a few days after the onset of symptoms, with the peak occurring 1–3 wk after the beginning of symptoms.
- Athletes with acute IM actively participating in strenuous or contact sports carry a small, yet unquantifiable, risk of complications such as splenic rupture and death (98).

History.

- Manifestations of IM can be nonspecific or even asymptomatic.
- Most common presentations include sore throat, fever, fatigue, malaise, myalgia, headache, swollen lymph nodes, anorexia, abdominal pain, or jaundice.
- The presence of left upper quadrant or left shoulder pain (Kehr sign), particularly in the setting of recent exercise or acute trauma, should heighten concern for splenic injury.

Physical examination.

- Overall physical findings can be subtle or absent.
- Exudative tonsillopharyngitis is common.
- The presence of palatal petechiae, posterior cervical, axillary, and/or inguinal lymphadenopathy with splenomegaly significantly increases the likelihood of IM (99).
- Maculopapular, petechial, urticarial, or purpuric rashes are frequently present.
- Insensitive for detection of splenomegaly unless substantially enlarged or tender (100).

Laboratory assessment.

- A complete blood count demonstrates an absolute and relative lymphocytosis with a high percentage (>10%) of atypical lymphocytes (101).
- Serologic testing for nonspecific heterophile antibodies (Monospot) has a high false-negative rate in the first week of illness.

- EBV viral capsid antigen IgM and IgG antibodies have a high sensitivity and specificity and are more useful in confirming the diagnosis of IM (102,103).
- Confirmatory EBV and/or cytomegalovirus antibody testing should be considered in certain athletes, particularly those in high-risk sports or whose diagnosis is uncertain.
- A positive heterophile test, elevated liver transaminases, and the presence of EBV viral capsid antigen IgM antibodies support the diagnosis of IM with an approximate sensitivity of 87% and specificity of 91% (103).
- A small minority of patients will never develop seropositivity for heterophile antibodies.

Imaging.

- Routine imaging of the spleen has not been found to be necessary in the management of IM (98).
- CT is recommended if imaging is utilized to evaluate for splenic injury or rupture (98,104).
- Serial US imaging may be considered for trending spleen size or for early RTS (98).
- Interpretation of spleen size and its clinical significance is challenging in the absence of baseline data.

Treatment.

- IM is generally a self-limited disease that is managed conservatively with supportive care and observation.
- Systemic corticosteroid use is controversial and without proven benefit except in the setting of complications such as airway compromise or obstruction, severe thrombocytopenia, hemolytic anemia, or myocarditis (98,105).
- Antiviral therapy has not been shown to diminish the severity or duration of symptoms.
- Coexisting streptococcal infection should be treated with antibiotics other than penicillins to decrease the risk of developing pruritic maculopapular or morbilliform rashes as a sequela to IM.
- Athlete return is individualized. Return should involve shared decision-making between physicians and athletes and their parents/caregivers.
- Factors to consider in RTS are risk of contact/collision, age, timing within season, and other athlete-specific factors (medical comorbidities and psychological readiness) (98).
- The role of low- or moderate-intensity exercise and effects on IM are unclear. Athletes who are afebrile, with adequate energy level and improved clinical examination, can begin a trial of supervised, non-impact, low-intensity aerobic activity 2 wk after the beginning of symptoms.
- Full, unrestricted RTS should not be considered until symptoms have resolved.

- Contact/collision sports and heavy exertion should be avoided for at least 3 wk due to the risk of splenic rupture in that time period (98).

Prevention.

- Universal precautions can decrease transmission.
- Avoid contact with secretions (e.g., shared water bottles, food, kissing, and close exposure to sneezing or productive coughing).

Skin infections.

Community acquired MRSA (CA-MRSA).

- Community acquired MRSA (CA-MRSA) is a highly contagious, resistant variation of the common bacteria that does not respond to the traditional penicillin-based antibiotic.
- Athlete exposure is both direct contact (skin-to-skin and skin breaks) and indirect (improper hygiene, shaving, and sharing of personal items or equipment) (106).
- Most affected sports are weightlifting, wrestling, rugby, fencing, martial arts, and ball sports (107).
- Teams with athletes colonized with CA-MRSA increase the risk of person-to-person spread and team outbreaks (106). Approximately 6% of high school and college athletes are colonized with MRSA (108).
- Lesions occur most commonly in areas with skin breaks, maceration, trauma, or areas of occlusion, friction, or frequent perspiration (exposed skin, under equipment, or in skin folds).

History.

- Presents as impetigo, folliculitis, carbuncles, furuncles, cellulitis, or abscesses.
- Often confused with simple pustules or spider bites.
- Previous infection and/or exposure.

Physical examination.

- Athlete may or may not have systemic findings.
- May identify impetigo, folliculitis, carbuncles, furuncles, cellulitis, or abscesses.

Diagnostic studies.

- It is recommended to obtain sample(s) for culture and sensitivity to confirm diagnosis and direct treatment.

Treatment.

- Depends on the type of disease, local *Staphylococcus aureus* resistance patterns, antibiotic side effect profile, and comorbidities of the athlete.
- Antibiotics should begin immediately after cultures are obtained, with modifications based on sensitivities.

- Consider side effects of antibiotics for athletes (e.g., tetracycline class causing photosensitive reactions or fluoroquinolones causing QTc prolongation, arrhythmias, and tendonitis, and Achilles tendon rupture).
- Isolated lesions (less than 5 cm) can be treated with incision and drainage alone (109).
- Multiple and/or larger lesions necessitate oral antibiotics for 7–10 d. Antibiotic considerations include trimethoprim with sulfamethoxazole, doxycycline, clindamycin, or linezolid. Topical mupirocin 2% can be added to the above antibiotic regimens (109).
- More serious infections (systemic involvement or progressive lesions) may require emergent referral (e.g., emergency department and infectious disease) and intravenous antibiotics (e.g., vancomycin) (109).
- RTS requires completion of 72 h of antibiotics, no new skin lesions for 48 h, no active moist or draining lesions, and be in accordance with National Federation of State High School Associations state and local guidelines (110,111).

Prevention.

- Shower immediately after any sport activity, practice, or competition with hot water and soap. Routine use of skin cleansing materials, such as chlorhexidine washes, can dry skin and should not be used routinely.
- Do not share towels, uniforms, razors, nail clippers, other personal items, and equipment. Discourage body shaving.
- Policies and routine disinfection of equipment and playing surfaces should be in place. Research is emerging to study the link between disinfectants and increased bacterial flora in facilities and on equipment (107).
- Controversy remains over treating MRSA carriers via decolonization. If attempted, use chlorhexidine washes combined with 2% mupirocin ointment.
- Intermittent use of chlorhexidine for body washing can be effective against recurrent CA-MRSA skin and soft tissue infections (112,113).
- Daily skin checks (self or by medical personnel).
- The athletic care network should be proficient in recognizing lesions, have a clear schedule for body checks, and plan for intervention and treatment, including the use of infectious disease specialists.
- Educational programs for athletes and parents/guardians/caregivers/coaches on how to recognize lesions and emphasis on immediate intervention for suspected/confirmed lesions.

Tinea corporis/pedis/cruris/capitis.

- Tinea is a common infection of the skin spread through direct and indirect contact.

- Intensity of rash due to host cellular-based immune response. Spores may be carried by an athlete and not develop the rash.
- Infections are common in wrestling. Studies have shown that up to 60% of National Collegiate Athletics Association (NCAA) wrestlers and 52% of high school wrestlers had at least one infection during the season (114).

History.

- The athlete will present with a rash that may be pruritic but typically not associated with systemic symptoms.
- Previous infection and/or exposure.

Physical examination.

- Tinea corporis presents with erythematous, circular, and scaling plaques with central clearing.
- Tinea capitis typically is an erythematous scaly patch with hairs that break off 1–2 mm above the scalp.
- Tinea cruris lesions are similar to body lesions found in the inguinal folds and/or medial thighs.
- Tinea pedis is typically erythematous, scaly, pruritic skin along the sole of the foot with macerated, cracked skin in the toe web spaces.

Diagnostic studies.

- While diagnostic testing is not necessary, scraping of the leading edge of the skin plaque with KOH testing and microscopic evaluation can be performed.

Treatment.

- Primary treatment for tinea corporis, pedis, and cruris is with topical antifungal agents.
- Primary treatment for tinea capitis is with a prolonged course of oral antifungals (prolonged use may require monitoring of liver function tests) (115).
- Treat all areas simultaneously to decrease treatment failures.
- Topical corticosteroids should be avoided as this can exacerbate tinea infections.
- For RTS clearance, athletes in contact/collision sports should complete a minimum of oral or topical treatment for 72 h for skin infections and 14 d for scalp infections (111).
- Exposed lesions should be covered with a gas-permeable, secure dressing.

Prevention.

- Strict adherence to universal precaution principles.
- Promote good personal hygiene, limit cosmetic shaving, and avoid common tubs and shared equipment whenever possible.

- Encourage regular equipment and high-touch surface cleaning by following Centers for Disease Control cleaning protocols with bactericidal disinfectants registered by the Environmental Protection Agency (116).
- Daily skin checks (self or by medical personnel).
- Remove athletes with recent or new skin lesions from participation in contact sports while treatment is initiated.
- Oral antifungals and shampooing hair and body with selenium-containing products may be useful prophylaxis for tinea infections (117).

Herpes gladiatorum (HG).

- Herpes simplex virus (HSV) is common in athletes and consists of two types: HSV-1 and HSV-2. HSV-1 is associated with HG, cold sores and fever blisters; and HSV-2 is associated with genital herpes.
- Common locations are face (70%), head, neck, and upper body (113).
- Spread is via skin-to-skin via rash or rash fluid, fomites to skin, or from respiratory droplets or saliva.
- HG is the most common skin infection reported in NCAA wrestlers, making up 40.5% of all skin infections (114).
- Incubation period is 2–14 d (8-d average).
- Risk factors include abrasions and physical trauma to skin.
- Those with comorbid dermatoses, such as atopic dermatitis or contact eczema, are more at risk for infection (118).
- Recurrent infections can also be triggered by physical, environmental (sun), and psychological stressors.

History.

- May present with a rash or a prodrome of burning, stinging, or itching followed by eruption of clusters of vesicles on an erythematous base at the infected site. One in four infected with primary HG will begin with flu-like symptoms 2–24 h before rash.
- Determine initial or recurrent infection. Initial episode may present with systemic symptoms such as fever, localized cervical lymphadenopathy, malaise, myalgia, or pharyngitis, often before the rash eruption. Recurrent HG has fewer vesicles present for a shorter duration, and there is less of a chance of systemic symptoms.
- May report history of recent physical and psychological stressors (e.g., school, sleep loss, fatigue, weight loss/poor nutrition, emotional, competition, and coexisting infection) and/or sun exposure.
- Extensive history should be obtained, including constitution, location of lesion/s, date first appeared and appearance, lesion spread, treatment strategies, fomites shared, last competition/practice held, and travel history.

Physical examination.

- Rash appears as red bumps that form clusters of small vesicles filled with cloudy fluid on an erythematous base. After 2–4 d, vesicles collapse to form yellowish-brown scabs.
- In contact sports such as wrestling, lesions may be abraded, leading to misdiagnosis (114).

Diagnostic studies.

- Viral culture and HSV polymerase chain reaction (PCR) can be performed to confirm diagnosis and HSV type.
- Tzanck smear has fallen out of favor.

Treatment.

- Early recognition and initiation of treatment are important.
- National Federation of State High School Associations: primary—10 d of oral antiviral treatment for skin lesions only and 14 d with systemic symptoms, with no new lesions for 72 h, and all others crusted over and dried without discharge.
- Secondary—5 d of oral antiviral treatment with no new lesions for 72 h, and all others crusted over and dried.
- NCAA—Primary or secondary HG is after 5 d of oral antiviral lesions with no new lesions for 72 h, and all past lesions are dry and crusted with no secondary bacterial infection. With primary HG, no systemic symptoms can be present.
- Coverage of lesions alone is never appropriate for return.
- Topical antivirals are not effective when used in isolation.

Prevention.

- Strict adherence to universal precaution principles.
- Season-long prophylaxis with oral antiviral medication can prevent outbreaks in many cases (118,119). Consider prophylactic daily oral antiviral treatment for wrestlers, other high-risk sport athletes, those who have a history of HG, or during a team outbreak, to mitigate spread.
- Promote good personal hygiene, limit cosmetic shaving, and avoid common tubs and shared equipment whenever possible.
- Encourage regular equipment and high-touch surface cleaning by following Centers for Disease Control cleaning protocols with bactericidal disinfectants registered by the Environmental Protection Agency (116).
- Daily skin checks (self or by medical personnel).

- Remove athletes with recent or new skin lesions from participation in contact sports while treatment is initiated.

Respiratory infections.

- Respiratory infections in the adolescent athlete can be caused by several pathogens (e.g., rhinovirus, SARS-CoV-2, influenza, and streptococcus).
- Transmission is via inhalation, droplets, and touching contaminated surfaces, then introducing the virus to the mucus membranes.
- Athletes are at risk for inoculation due to certain conditions that are associated with sport:
 - Use of public and team transportation.
 - Interaction with large crowds at the event.
 - Shared housing/rooms at camps/competitions.
 - Intimate contact with an opponent (i.e., wrestling).
 - Heavy breathing among other athletes.
 - Shouting by teammates and opponents that increases airborne spread (120).
- Most respiratory infections are self-limited with 7–10 d of symptoms, including fever, cough, rhinorrhea, nasal congestion, sore throat, myalgias, and headache.
- With some infections, systemic complications can occur (e.g., myocarditis) and need consideration.

History.

- Complete history including onset, number and location of symptoms, whether cardiopulmonary symptoms are present, treatments attempted, contacts while infected, last competition/practices, and travel history.
- Symptoms may include rhinitis, sore throat and cough, fever, myalgias, headache, malaise, and shortness of breath.
- Severe symptoms can include respiratory distress, confusion, palpitations, dizziness, and collapse.

Physical examination.

- Findings may include fever, rhinorrhea, mucous membrane erythema, cobblestoning or swelling of the posterior pharynx, serous otitis, and cervical lymphadenopathy.
- Cardiac, pulmonary, and abdominal examinations are typically normal unless complications exist.

Diagnostic studies.

- Diagnostic studies are not always indicated but may assist in guiding disposition (e.g., isolation, masking), treatment, and RTS.

- While rapid tests may have a role, the most accurate testing is via reverse transcriptase PCR.
- Additional testing may be necessary if concerns for complications exist (e.g., chest X-ray for pneumonia, ECG for myocarditis, and blood tests).

Treatment.

- Most respiratory infections are viral and treated with supportive care (e.g., antipyretics, non-steroidal anti-inflammatory drugs, decongestants, nasal steroids, and cough suppressants).
- Nutrition and hydration status should be considered.
- Be aware of World Anti-Doping Agency and US Anti-Doping Agency-banned substances in OTC cold medicines.
- Antibiotic or antiviral medications may be considered if a specific pathogen is identified.
- Antibiotics may be considered in athletes who have sinusitis or suspected pneumonia for more than 10 d.
- If antiviral medications are indicated, they should be initiated within the first 72 h of symptom onset.
- Complicated cases, including respiratory distress, may require hospitalization, ventilation, steroids, and other treatment strategies.
- If an athlete is afebrile without the use of antipyretics for 24 h, consider mild-to-moderate exertion and progress as tolerated (121).
- For symptoms including severe cough, fever, myalgias, and gastrointestinal distress symptoms, athletes should not participate until symptoms improve and they can tolerate exercise progression.
- If cardiac symptoms or hemodynamic instability is present, no exercise should occur and subspecialty consultation is warranted.

Prevention.

- Universal precautions.
- Optimize vaccination status.
- Nutrition, hydration, and sleep status should be maximized.
- Hand washing with soap and water for at least 20 s or use of alcohol-based hand sanitizer.
- Cover mouth/nose with bent elbow or tissue when cough or sneeze and immediately dispose of tissue.
- Avoid crowded settings or settings with a closed environment, crowded, or associated with close contact.
- Clean and disinfect frequently used surfaces or fomites.
- Isolation of sick athlete until symptoms improve.
- Wearing a mask when traveling or when ill.

Gastroenteritis.

- Gastrointestinal infections in the adolescent athlete can be caused by several pathogens (e.g., norovirus, enterovirus, *Escherichia coli*, Salmonella, Campylobacter, *Clostridium difficile*, and Giardia).

- Transmission typically via fecal-oral route through contact with contaminated food/water and/or surfaces, or by utensils or food handled by an infected person.
- Incubation time varies based on the pathogen, and transmission can occur during both symptomatic/asymptomatic time periods.
- Some pathogens may require public health reporting.

History.

- Complete history including food/drink consumed, symptom onset and number, symptom location, treatments, contacts while infected, last competition/practices, and travel history.
- Common symptoms include diarrhea (e.g., bloody, watery), vomiting, nausea, and abdominal pain. Athletes may also have fever, headache, and myalgias.
- Mild-to-severe symptoms of dehydration may be present (e.g., lightheaded, dizziness upon standing, thirst, headache).

Physical evaluation.

- Evaluate vital signs and hydration status (e.g., mucous membranes and capillary refill) and assess for orthostatic hypotension.
- Abdominal palpation may reveal discomfort. Note rigidity, rebound, tenderness, or guarding.
- Auscultation may reveal increased bowel sounds.

Diagnostic studies.

- For mild cases, diagnostic studies may not be indicated.
- In more severe and/or persistent cases, additional studies and imaging (e.g., stool studies [reverse transcription-quantitative polymerase chain reaction assays, cell count with differential, culture, and sensitivities] and blood tests) may be indicated to identify the pathogen and guide treatment.

Treatment.

- In mild cases, supportive treatment is indicated with an emphasis on hydration status.
- Antibiotic or antiviral medications are typically not indicated unless moderate-to-severe symptoms are present and a specific pathogen is identified.
- RTS typically occurs 48 h after symptom resolution and normalization of hydration status.
- If clinical dehydration (e.g., orthostatic by pulse and/or blood pressure) is present, no exercise should occur until hydration status is corrected.
- If hemodynamic instability or evidence of sepsis is present, emergent referral (e.g., emergency department) is warranted.

Prevention.

- Handwashing.
- Proper food preparation.
- Clean and disinfect surfaces and fomites.
- Washing contaminated clothes, bedding in hot water.
- Isolate athletes until 48 h after symptoms resolve.

It is essential that the team physicians understand

- Signs, symptoms, and relative severity of common infectious diseases in adolescent athletes.
- Sport-specific restrictions exist for certain infectious diseases and may impact RTS.
- Certain infections require public health notification.
- Treatment and prevention strategies for infectious diseases.
- Hydration status and its role in infectious disease.
- Emergent issues in infectious disease.

It is desirable that the team physicians:

- Identify common infectious diseases and initiate treatment.
- Implement treatment and prevention strategies for infectious diseases.
- Manage and implement RTS restrictions that exist for certain infectious diseases.
- Coordinate referrals for subspecialties when indicated.
- Facilitate immunization.
- Work with the athletic care network to educate athletes, parents/guardians/caregivers, and other healthcare providers on common infectious diseases in adolescent athletes and prevention strategies.

The Adolescent Athlete and Pulmonary Conditions

Exercise-induced dyspnea is common among adolescent athletes and can have multiple causes, including physiologic (e.g., asthma, bronchospasm, allergy), anatomic (e.g., glottic), inhaled foreign objects (e.g., insects, debris), inhaled substances (e.g., vaping), and infections and masses. Exercise-induced asthma/bronchospasm (EIA/EIB) and exercise-induced laryngeal obstruction (EILO) are common conditions that may cause exercise-induced dyspnea. Symptoms can be similar and pose diagnostic challenges for the team physician. Dyspnea in EIA/EIB is characterized by expiratory wheezing and EILO by inspiratory stridor. Diagnosing and managing these conditions can be challenging.

Breathing pattern disorder is an increasingly recognized cause of breathlessness in athletes. It is an alteration in the normal breathing pattern or dysfunctional breathing resulting in breathlessness. While breathing pattern disorder also typically presents during peak exercise intensity, hyperventilation is more common than wheeze or stridor, but lightheadedness, dizziness, and

anxiety are also commonly reported. There is no definitive diagnostic test, but observing the athlete during an episode may assist with the diagnosis. Treatment often consists of breathing pattern retraining and focusing on diaphragmatic breathing (122).

Exercise-induced laryngeal obstruction.

- EILO is a condition where there is inappropriate vocal cord or glottic closure during exercise.
- Prevalence is estimated to be 7.1% in general pediatric population and 17.6%–35.2% in pediatric athlete population (123).
- Higher prevalence in females after puberty (124).
- May coexist with EIA/EIB with rates as high as 56% (124).
- During exertion, laryngeal obstruction can occur at supraglottic or glottic level.
- Supraglottic obstruction accounts for 71% EILO (124).
- Causes include laryngeal pathophysiology, aerodynamic mechanisms, and psychodynamic (125).
- Gastroesophageal reflux disease is a risk factor.

History.

- Often misdiagnosed as EIA, resulting in suboptimal treatment.
- Characterized by exercise-induced dyspnea.
- The most common symptoms are hoarseness and/or inspiratory stridor. May also have respiratory distress, prolonged inspiration, hyperventilation attacks, and panic reactions.
- Typically, symptoms occur at peak exercise intensity and quickly resolve spontaneously without medication within minutes.

Physical examination.

- Normal at rest.
- With exercise and symptom provocation, the athlete will have inspiratory stridor.
- Lung sounds are normal (126).

Diagnostic studies.

- Continuous laryngoscopy during exercise test is diagnostic (124).

Treatment.

- Nonoperative treatments include psychotherapy, speech therapy, botulin toxin, inhaled ipratropium, and breathing therapy.
- Operative treatments involve procedures such as endoscopic supraglottoplasty.

Prevention.

- There are no known prevention strategies.

Exercise-induced asthma/bronchospasm (EIA/EIB).

- Asthma is an acute reversible airway narrowing and is the most prevalent cause of breathlessness in athletes. EIB may be life-threatening.
- Other medical conditions (e.g., anemia, panic, or anxiety disorders) and medical emergencies (e.g., supraventricular tachycardia, ischemia, congestive heart failure, and pulmonary embolism) may present similarly.
- EIB may occur in individuals with and without asthma at rest. For an individual with spirometry-proven asthma that worsens with exercise, a diagnosis of exercise-induced bronchoconstriction with asthma is appropriate.
- For individuals who only have acute reversible airway narrowing with exercise, a diagnosis of EIB without asthma is most appropriate. EIB/exercise-induced bronchoconstriction with asthma has been characterized as more prevalent in cold-weather sport athletes.
- Athletes with well-controlled symptoms may participate in sports.
- The team physician should be aware that athletes from underresourced communities may be underdiagnosed with asthma, EIA/EIB, and other medical causes of breathlessness due to lack of access to medical care and lack of knowledge that their symptoms may be a medical condition. Greater asthma severity has been linked to indicators of poverty. Also, athletes in urban environments may be more likely to have EIB due to environmental triggers present in the air (127).

History.

- EIA/EIB may present with symptoms including dyspnea, expiratory wheeze, and cough that present during and/or after exercise.
- Symptoms may be exacerbated by cold, dry air, pollutants, altitude, and other irritants (e.g., pollen and chlorine).
- Symptoms may improve after an initial bout of exercise (refractory period/second-wind phenomenon).

Physical examination.

- At rest, physical examination is often normal.
- During or following exercise, when symptoms are provoked, an expiratory wheeze and/or cough and prolonged expiratory phase of respiration may be present.
- Accessory muscle use and diminished air movement may indicate a more emergent respiratory situation.

Diagnostic studies.

- Chest X-ray, posteroanterior and lateral, typically normal, may show hyperinflation of lungs, bronchial wall thickening, and a flattened diaphragm.

- A drop of at least 10% in forced expiratory volume in the first second on pulmonary function testing following bronchoprovocation (e.g., exercise and methacholine challenge) or an improvement of at least 12% of forced expiratory volume in the first second following administration of bronchodilator is considered diagnostic of asthma (127).

Treatment.

- EAP should address acute, severe asthma.
- An individual EIA/EIB action plan should consider the severity of the condition, the frequency of activity resulting in symptoms, the environment in which the activity is being performed, and any rules related to medication use by applicable governing bodies (128). Rescue inhalers should be available, with parameters for rescue medication use and when to initiate emergency transport.
- For EIB, there may be a role for nonpharmacologic management (e.g., reducing environmental exposures, warming and humidifying the air, or reducing circulating allergens).
- Other nonpharmacologic management techniques include improving fitness and using yoga breathing techniques (128).
- Performing a brief bout of high-intensity exercise for 10–15 min may lead to the release of prostaglandins in the airways that act locally, reducing the amount of airway constriction for 2–3 h (129).
- Prevention may include short-acting beta agonist 30 min before exercise (these may be ineffective in up to 20% of athletes) (128), daily leukotriene agonists, daily inhaled corticosteroids, or combination beta agonist/inhaled corticosteroid medications (130).
- The daily use of short- or long-acting beta agonists may result in tachyphylaxis or tolerance and should be discouraged (128).
- Well-controlled EIA/EIB should not restrict participation in sport/activity.

Prevention.

- Optimizing nonpharmacologic and pharmacologic management reduces the risk and severity of asthma symptoms.

It is essential that the team physicians:

- Recognize there are several potential causes of breathlessness in the athlete.
- Understand the role of rescue medications on the sideline for asthma and EIA/EIB.
- Understand asthma may be life-threatening and requires consideration in the EAP.
- Recognize respiratory emergency.

It is desirable that the team physicians:

- Distinguish between EILO and EIA/EIB and provide or refer for indicated treatment.
- Understand the role of pulmonary function testing in diagnosing EIA/EIB.
- Develop individual asthma or EIA/EIB action plans for athletes.
- Understand the role of environment and socioeconomic factors in asthma and EIA/EIB.
- Be aware of breathing pattern disorder and how it may mimic other conditions.
- Understand certain medications may be restricted or require completing a therapeutic use exemption for elite athletes.
- Work with the athlete care network to educate athletes, parents, coaches, and other stakeholders on causes, treatments, and prevention strategies of breathlessness in athletes.

The Adolescent Athlete and Nutrition/Supplements

Nutrition for health and performance is critical in the adolescent athlete. Athletes should be encouraged to follow a well-balanced diet. Athletes may be susceptible to improper sports supplementation and exploration of performance-enhancing substances (PES). Additionally, adolescent athletes may have goals to lose or gain weight that may or may not be healthy or realistic.

- A well-balanced diet typically meets nutritional requirements. Energy expenditure should be considered. Nutritional supplements are typically not required.
- Identified nutritional deficiencies should be addressed.
- Motivators for PES use include enhancement of athletic performance and body appearance.
- Common supplements used in this age group include sports drinks, vitamins, sports bars, protein powders (54.5%), caffeine and creatine (25%–40%), and other stimulants (131).
- Creatine use significantly increases between 9th and 12th grades.
- Factors associated with the use of PES are elite athletes, male sex, age (older), history of depression, weight training, and belief that weight affects athletic performance and body appearance (132).
- Athletes who report legal supplement use are significantly more likely to report anabolic steroid use (133).
- More than half of all anabolic steroid use begins in high school (133).
- About 3%–6.5% of boys and 1%–2% of girls reported current or past use of anabolic steroids (134).
- Athletes have limited knowledge about PES and obtain information primarily from coaches, friends, and the Internet (135) and are highly influenced by marketing (131).

Evaluation.

- Inquire about diet, use of supplements, and illicit substances (e.g., alcohol and marijuana).
- Inquire about pre-existing medical conditions that may adversely affect nutrient absorption or require special diets (e.g., Crohn disease, malabsorption diseases, and diabetes).
- Inquire about motivation for supplement use (e.g., performance, body image, peer and coach pressure).
- Inquire about the history of or risk factors for REDs and anemia.
- Consider diagnostic studies to evaluate for nutritional deficiencies and REDs (20,136).

Treatment/prevention.

- Educate the athlete on a well-balanced diet and the lack of evidence to support nutritional supplement use without nutritional deficiencies.
- Treat identified nutritional deficiencies.
- Consider prophylactic supplementation (e.g., iron and vitamin D) in at-risk athletes (e.g., sport and diet/dietary restrictions).
- Treat REDs if identified (20).
- Provide alternatives for performance enhancement, including nutrition, training, and sports psychology techniques.
- Counsel regarding illicit substance use (e.g., alcohol and marijuana), which are related to high risk of PES use.
- Educate athletes, the athletic care network, and stakeholders regarding risks of supplements and PES, banned and illegal supplements, and issues related to fair play and ethics.

Weight loss.

Patient populations.

- Obesity is defined as a BMI at or above the 95th percentile for age and sex (137).
- Prevalence of obesity is approximately 22% in U.S. adolescents (138).
- Complications of obesity include hypertension, insulin resistance, type 2 diabetes, hypercholesterolemia, and orthopedic conditions (e.g., SCFE).
- Multifactorial etiology (e.g., sedentary lifestyle, poor nutrition, genetics, and psychosocial factors).
- Weight loss may be the goal for adolescents in weight-restricted sports (e.g., wrestling, lightweight rowing), aesthetic sports (e.g., diving), and sports that favor leanness (e.g., gymnastics, figure skating, distance runners).

Treatment.

- Weight loss in obese athletes begins with BMI and body composition determination and evaluation for medical

causes (e.g., polycystic ovary syndrome, hypothyroidism, and genetic syndromes), medical conditions (e.g., insulin resistance, cholesterol abnormalities, and liver disease), and orthopedic conditions (e.g., SCFE).

- Athletes in weight-restricted sports should have a measurement of percent body fat and hydration status.
- Athletes at risk should be screened for REDs and treated with a multidisciplinary approach if identified.
- Determine if weight loss is needed and/or appropriate.
- Set a goal for weight loss; athletes should lose no more than 1.5% of their body weight per week.
- Provide individualized nutrition and exercise recommendations.
- Counsel against weight-loss medication use (e.g., stimulants, laxatives, and diuretics), excessive fluid/food restrictions, purging, vapor impermeable suits, and other pathogenic weight-control behaviors.
- For the obese athlete, provide behavioral and family counseling as needed.
- Monitor BMI to aid in primary and secondary prevention strategies.
- Primary prevention of obesity should be initiated in early childhood.
- Work with the athletic care network to educate athletes, parents, and coaches regarding weight-loss issues.

Weight gain.

Patient populations.

- Adolescents who desire weight gain related to strength and performance.
- Adolescents who desire weight gain related to appearance and body image.

Treatment.

- Review dietary intake and training program.
- Determine BMI and body composition.
- Screen by history for performance-enhancing agent use.
- Assess reasons for desiring weight gain (i.e., performance versus body image).
- Determine if weight gain is needed and/or appropriate.
- Set a goal for weight gain; athletes should gain no more than 1.5% of their body weight per week.
- Provide individualized nutrition and exercise recommendations.
- Counsel regarding weight gain medication and supplements.

Prevention.

- Monitor BMI and body composition.
- Work with the athletic care network to educate athletes, parents, and coaches regarding weight gain.

It is essential that the team physicians:

- Understand that a well-balanced diet typically meets nutritional requirements.
- Understand that nutritional supplements are typically not required.
- Recognize obese and underweight athletes.
- Understand that adolescent athletes are more susceptible to PES and nutritional supplements use.
- Understand REDs.
- Understand that some supplements and PES are prohibited in certain sports.

It is desirable that the team physicians:

- Perform evaluations to assess for metabolic and nutritional status and supplement/substance use.
- Emphasize health and performance over weight change.
- Manage nutritional requirements and deficiencies.
- Make recommendations related to nutrition and exercise for obese and underweight athletes.
- Counsel the athlete and athlete care network regarding the risks of supplements and PES.
- Make nutrition recommendations and guidance related to medical conditions, strength training for the athlete who desires strength and weight gain.
- Make recommendations related to minimum weight, nutrition, and exercise for weight-restricted sports.
- Understand the impact of pathogenic weight behaviors on normal growth and development, athletic performance, and psychological well-being.
- Understand the role of sports dietitians in providing education and dietary plans.
- Work with the athletic care network to educate athletes, parents, and coaches regarding nutrition, weight-loss, and weight-gain issues.

THE ADOLESCENT ATHLETE AND OVERTRAINING/SPORTS SPECIALIZATION

Overtraining and overuse injury are risks for the adolescent athlete, particularly in those who specialize in a single sport at an early age. There has been an increase in sport specialization with emphasis on athletic success in the adolescent athlete. This has resulted in more intensive training and increased psychological pressure on these athletes, which can result in negative ramifications, including overuse injuries and burnout.

- The research dedicated to overtraining/sports specialization in the adolescent athlete has increased.
- There has been an increase in the number of surgical procedures and complex medical problems seen in the adolescent athlete over the past decade.
- Early specialization is composed of three components on a point system (139–141):

- Year-round training (greater than 8 month a year).
- Choosing a main sport.
- Quitting all other sports to focus on one.
- This point system predicts increasing risk of overuse injury and serious overuse injury (at least 1 month time loss away from sport) (141) related to the degree of specialization (142).
- Injury risk is increased by participating in greater than 16 h per week of chosen sport or hours per week of sport greater than the athlete's age (139).
- Early sport specialization is correlated with increased injury risk and is a risk factor for burnout and decreased future sport participation (143).
- Many overuse injuries can be related to an excessive increase in the intensity, volume, or frequency of practice and game participation in adolescents (144,145).
- Sport-specific injury prevention guidelines exist in multiple sports (e.g., pitch limits in youth baseball); literature shows that up to 83% of caregivers are not aware of guidelines (142).
- There is a risk of overuse and serious-use injury in adolescent athletes who have a high degree of specialization, train for more hours per week than their age, and have a sports training ratio >2:1 (organized sport hours/week: free play hours per week) (140). An accumulation of risk factors may predict overuse injury (141).
- The developmental stage of the youth athlete should be used to provide anticipatory guidance, athlete development, and RTS guidance.
- The adolescent female athlete may be at higher risk for sport specialization, overuse injury, and negative impacts on overall quality of life (146).
- Rest and recovery are important in preventing overuse injury. The current recommendation suggests taking off 2–4 month annually from organized competition and training in a single sport. Considerations include the type of sport, age, and phase of development. Cross-training and participating in different sports or activities should be considered (140, 146–151).
- The effect of an increase in volume, intensity, and frequency of training and competition on the mental health of the adolescent is unclear.
- Review of training logs can be useful in evaluation for overtraining.

It is essential that the team physicians:

- Understand the potential effects of sports specialization and exceeding training guidelines on the adolescent athlete in the development of overuse injuries.
- Understand that injury patterns are different based on an adolescent athlete's phase of development.
- Understand that sport-specific injury prevention guidelines exist.

It is desirable that the team physicians:

- Understand the role of rest and recovery in preventing overuse injury.
- Understand the role of psychological stressors as a response to injury (38).
- Understand that an adolescent's developmental phase may impact recommendations for injury prevention and sport training strategies.
- Work with the athletic care network to educate athletes, parents, and coaches regarding the importance of appropriate rest and recovery.

SPORT-RELATED CONCUSSION (SRC) IN THE ADOLESCENT ATHLETE

Sport-related concussion (SRC) is a significant injury in the adolescent athlete population. It is defined as “a traumatic brain injury caused by a direct blow to the head, neck, or body resulting in an impulsive force being transmitted to the brain” (152).

- SRC involves a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change, and inflammation affecting the brain.
- SRC results in a range of clinical symptoms and signs that evolve over time and may or may not involve loss of consciousness.
- The clinical symptoms and signs of concussion cannot be explained solely by drug, alcohol, medication use, other injuries, or other comorbidities.
- Standard neuroimaging studies are normal, so are not typically indicated.
- Diagnostic criteria for concussion have been published (153).
- An estimated 400,000 SRCs occur in high school athletes (154,155).
- SRC is under-reported in the adolescent population (156).
- Management considerations may differ in the adolescent age group (157).
- Athletes with suspected SRC should be removed from play and not allowed to return the same day. This prevents a same-day injury and decreases the risk for prolonged recovery.
- Adolescent athletes who continue to play with signs and symptoms of SRC have been shown to have delayed recovery; they were 8.8 times more likely to demonstrate delayed recovery (≥ 21 d) (158).
- Prolonged rest may be associated with poorer outcomes and delayed recovery in adolescent athletes (159–161).
- Access to healthcare providers is associated with faster recovery (162).
- Risk factors for SRC in high school and college athletes include prior SRC, attention-deficit/hyperactivity disorder, and/or learning disabilities (163–166).

- There is no difference in recovery between sexes (162).
- Immediate and early postinjury symptoms remain the most powerful predictor of recovery (162).
- Complications of SRC in adolescents include persisting symptoms, posttraumatic headache disorder, and rarely second impact syndrome (152,154,167).

History

- There will be a history of a direct or indirect blow to the head followed by SRC signs and/or symptoms. Typical symptoms listed in the Sport Concussion Assessment Tool-6 (SCAT-6) (168) checklist are often present.
- “Red flags” (i.e., symptoms that warrant urgent referral to an emergency department include weakness or paresthesias in arms or legs, severe or progressively worsening headache, loss or deteriorating level of consciousness, repeated vomiting, combative nature, and seizures or convulsions).

Physical Examination

- A standardized assessment tool such as the SCAT-6 (168) for the first 48–72 h or the Sport Concussion Office Assessment Tool-6 (SCOAT-6) (169) thereafter can be useful to guide the physical examination.
- Assessment of observable signs and symptoms, orientation, ocular motor screen, cervical spine and neurologic examination, memory, concentration, and coordination, balance (e.g., SCAT-6 and SCOAT-6).

Diagnostic Studies

- Radiologic imaging is not necessary unless “red flags” and/or persistent symptoms are present. A CT scan is indicated to exclude intracranial hemorrhage; MRI can be considered for persisting symptoms.
- Neuropsychological testing may be useful for additional information regarding cognitive functioning status and return-to-learn (RTL)/RTS decision-making.

Treatment

- An EAP needs to be in place for all practices and competitions where SRC may occur (91,170).
- If “red flags” are present, emergency transport is warranted.
- Athletes with suspected SRC should be removed from play and not returned same day, even if symptoms resolve. Athletes with suspected SRC must be supervised.
- Adolescent athletes should be managed on an individual basis, accounting for specific factors that may affect their recovery trajectory, such as pre-existing

factors (e.g., migraine history and anxiety) or postinjury factors (e.g., aggravation of injury, psychological stress, and social factors) (152).

- In the first 72 h, the SCAT-6 may be used to guide treatment. A multimodal evaluation tool (e.g., SCOAT-6) can be used to monitor recovery, engage a multidisciplinary team, and guide RTS.
- Persisting, worsening, or symptoms that are not resolving 2–4 wk postinjury should be considered for referral to a multidisciplinary team for management and treatment (167,171).
- RTL and RTS strategies should incorporate an individualized, stepwise approach with a gradual increase in both physical and cognitive demands and risk for contact (162).
- Early symptom-limited (no more than mild or brief: an increase of no more than two points on a Likert 0–10 scale for less than an hour) exercise, even within the first 24–48 h, is associated with improved recovery (152,162,172,173).
- The first stages of the RTS progression (151,161) include an incremental increase in exercise and non-contact sport-specific activities.
- Once the athlete is back to preinjury level of symptoms, cognitive function, balance, and physical examination, they should be evaluated by a healthcare provider to provide supervision over the last steps of the RTS progression.
- The final stages of RTS progression include return to contact practice and unrestricted return to contact sport.
- Full RTL should occur before unrestricted RTS.

Prevention

- Prevention strategies include policy (e.g., laws/protocols regarding removal from play for suspected concussion, gradual RTS progression, clearance to RTS by a health care provider) or rule changes (e.g., disallowing body checks in adolescent ice hockey), personal protective equipment (e.g., football helmet and mouthguard), modification in training (e.g., neuromuscular training), and management strategies (174,175).
- The majority (60%) of prevention strategies apply to children and adolescents (175).
- Work with the athletic care network to educate stakeholders regarding the common signs and symptoms and the importance of early reporting, removal from play, and managing SRC is important (e.g., Concussion Recognition Tool-6) (176).

It is essential that the team physicians:

- Recognize the symptoms and signs of SRC.
- Identify “red flags” that may warrant emergency management.

- Understand, practice, and be prepared to implement the EAP and medical protocols (91), including recognition of SRC and emergency transportation options.
- Prohibit athletes with any signs or symptoms of SRC from same-day return to participation, even if symptoms resolve.

It is desirable that the team physicians:

- Perform SRC evaluation.
- Participate in the development of an EAP for SRC.
- Understand that full RTL and RTS are accomplished using a stepwise program while monitoring symptoms.
- Understand that a delay in seeing a healthcare provider and continuing to play while concussed is associated with prolonged recovery.
- Understand that exercise, cognitive load, and sport-specific activities can be initiated early in the management of concussion as part of treatment, as long as symptoms are only mildly and briefly exacerbated.
- Work with the athletic care network to educate athletes, parents, and coaches regarding SRC recognition, management, treatment, and prevention strategies.

The authors would like to thank Shelby Mandla, Christa Dickey, and Laura Young, PhD, for their contributions to this paper. Margot Putukian is a paid consultant, chief medical officer at Major League Soccer; paid for travel and stipend by NFL Head Neck and Spine and General Medical Committees; paid consultant for FIFA, venue medical officer (CWC, FWC); and receives royalties for chapter (UpToDate) and book editor (Netter's Sports Medicine, Elsevier). The remaining authors have no conflicts of interest to disclose. S. A. H., M. P., and L. E. L. created the outline. All authors contributed to the literature review, and then S. A. H., M. P., and L. E. L. contributed to compiling the sections of the paper. M. P., L. L., and J. T. F. met in person and reviewed the draft paper, after which all authors contributed to revisions during an in-person meeting. All authors have approved the final manuscript. The consensus statement results are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results presented do not constitute endorsement by the American College of Sports Medicine.

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