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Assessment of sports-related concussion in children and adolescents

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ABSTRACT

Advances in research on sports-related concussions have led to updates in diagnostic and management protocols. This article reviews the recommendations from the Sixth International Consensus Conference on Concussion in Sport (Amsterdam, 2022), focusing on children (ages 8-12) and adolescents (ages 13-18). It highlights preventive strategies, such as identifying risk factors, using protective equipment, implementing regulatory changes, and engaging in neuromuscular training.

Up-to-date clinical tools are recommended for identification and monitoring. Initial management includes relative rest for 24-48 hours, with limited screen time, followed by subthreshold physical exercise. Specific rehabilitation is indicated if symptoms persist. This comprehensive, evidence-based approach optimizes recovery and minimizes long-term effects, promoting the safety and well-being of young athletes.

The proposed protocol aims to guide pediatricians and sports professionals in clinical decision-making.

Keywords: *concussion; sports injuries; pediatrics; disease prevention; rehabilitation.*

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INTRODUCTION

A concussion is a mild traumatic brain injury that is common among pediatric athletes. It results from the brain's acceleration and deceleration within the skull, although the pathophysiological mechanisms are still being investigated. Clinically, it presents with a variety of symptoms,[1] such as dizziness, nausea, vomiting, attention difficulties, sleep disturbances, and headaches. Despite the severity of symptoms, conventional neuroimaging is usually normal.[2,3] However, structural and functional abnormalities may persist after initial clinical resolution, underscoring the importance of early diagnosis and management to optimize recovery and prevent long-term sequelae.

In recent decades, research on concussion has advanced considerably. Since 2001, periodic international statements have been published; the Berlin Consensus Statement (2017) is a landmark document that synthesizes the evidence and establishes recommendations for management in sports.[4] The most recent update, published in June 2023, incorporates the findings of the 6th International Conference on Concussion in Sport[5] and introduces updated tools for recognition, assessment, and clinical follow-up.[6-8]

This document reviews the identification and management of sports-related concussions in children (ages 8-12) and adolescents (ages 13-18), emphasizing the critical role of the physician in clinical decision-making across all age groups.

DEFINITION

Sports-related concussion[1,5] is a traumatic brain injury caused by a direct impact to the head, neck, or body, which transmits an impulsive force to the brain during sports activities. This event triggers a neurochemical and metabolic cascade, potentially leading to axonal injury, altered blood flow, and inflammation. Symptoms may appear immediately or gradually, and while they usually resolve within days, they may persist in some cases.

Standard structural neuroimaging (CT or MRI) generally does not reveal any abnormalities, although functional techniques can detect abnormalities. Loss of consciousness is not required for diagnosis, and symptoms should not be attributed solely to other conditions or comorbidities (such as psychological factors or coexisting medical conditions).

PREVENTION OF SPORTS-RELATED CONCUSSIONS

Preventive strategies aim to reduce incidence and morbidity through interventions in policy, education, regulation, and equipment:[9]

- **Helmet use:** It reduces the incidence of concussions in American football, although this effect is not observed in rugby. A properly fitted helmet reduces the severity and duration of symptoms, as well as the likelihood of their occurrence.
- **Ban on body checking** (an offensive technique involving physical contact)**:** In youth and junior ice hockey, this measure reduces the incidence of concussions by 58%, without affecting future competitive performance.
- **Mouthguards:** Using them reduces concussions by 26% in ice hockey and rugby.
- **Limiting contact drills:** In youth football, this intervention reduces concussions by 64%.
- **Neuromuscular warm-up:** In rugby, regularly performing (≥3 times per week) neuromuscular warm-up routines—including neck strengthening exercises—reduces concussions by 32% to 60%.
- **Specific laws and policies:** mandatory removal from play and a doctor's authorization to return to play reduce the recurrence of concussions in adolescents.
- **Restrictions on heading:** Both the U.S. Soccer Concussion Initiative and the English Football Association have implemented bans on heading in youth soccer for players under the ages of 10 and 12, respectively.

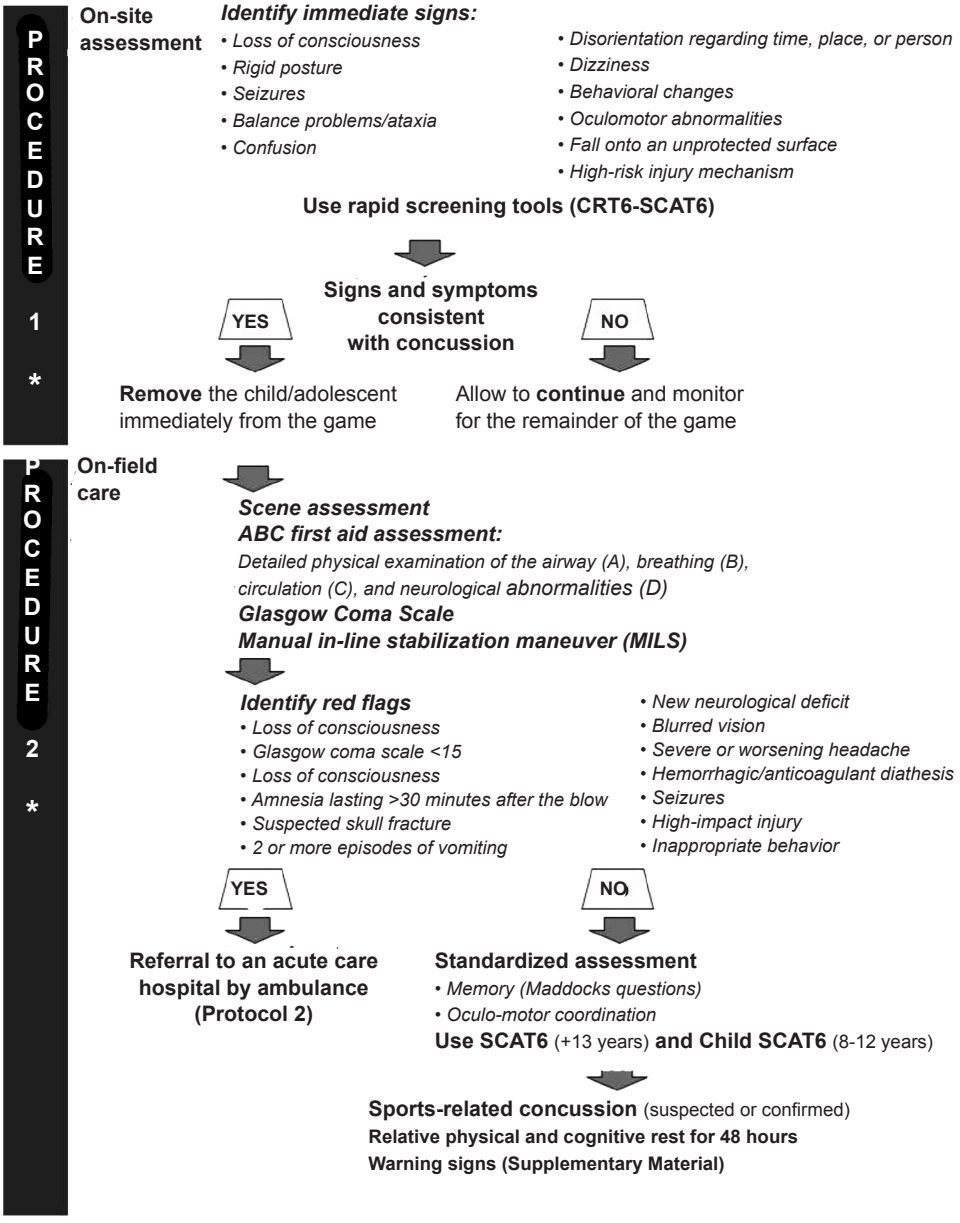
FIELD SERVICE

When a concussion is suspected in a sports setting, early recognition by healthcare professionals, coaches, teachers, parents, family members, or teammates is essential (*Figure 1*). Identification is based on the presence of signs and symptoms, guided by tools[7,8,10,11] such as the Sport Concussion Assessment Tool 6 (SCAT6), the Child Sport Concussion Assessment Tool 6 (Child SCAT6), and the Concussion Recognition Tool (CRT6).

The main observable neurological signs of a concussion are as follows:

- Player lying motionless on the playing surface.
- Unprotected fall to the ground.
- Stumbling and trying to keep playing.
- Difficulty with balance or walking.
- Disorientation or confusion.

Figure 1. On-field assistance



- Staring or blank gaze.
- Limited responsiveness or lack of an appropriate response.
- Facial injury following a head injury.

The diagnosis is primarily clinical, as there is no specific confirmatory test.[12] On the field, the initial assessment should follow first-aid principles: securing the scene, assessing the athlete's responsiveness, and evaluating the airway, breathing, and circulation, including an assessment of the Glasgow Coma Scale and the identification of warning signs (red flags). It is important to record the Glasgow Coma Scale score along with the date and time, as it is a standard measure.

RED FLAGS (*FIGURE 2*)

- Neck pain or tenderness
- Seizures
- Loss of consciousness (only 10% of concussions involve loss of consciousness).
- Impaired consciousness
- Vomiting
- Double vision
- Severe or worsening headache
- Numbness or weakness in one or more limbs.

- Increased restlessness or aggression
- Glasgow Coma Scale <15
- Visible skull deformity

If these signs are present, the possibility of a cervical spine injury must always be considered; maintain manual in-line stabilization, apply a rigid cervical collar until the injury is ruled out, and proceed with immediate transport by ambulance.[12]

If no warning signs are identified, the following is recommended on the field:

1. A basic neurological evaluation.
2. An examination of coordination and eye movement:
   - Coordination: Finger-to-nose with eyes open and closed.
   - Ocular/motor: Without moving the head or neck, look to the sides, up, and down without experiencing double vision.
   - Normal or abnormal eye movements.
3. A memory assessment using the Maddocks questions,[8] which consist of 5 questions tailored to each sport.

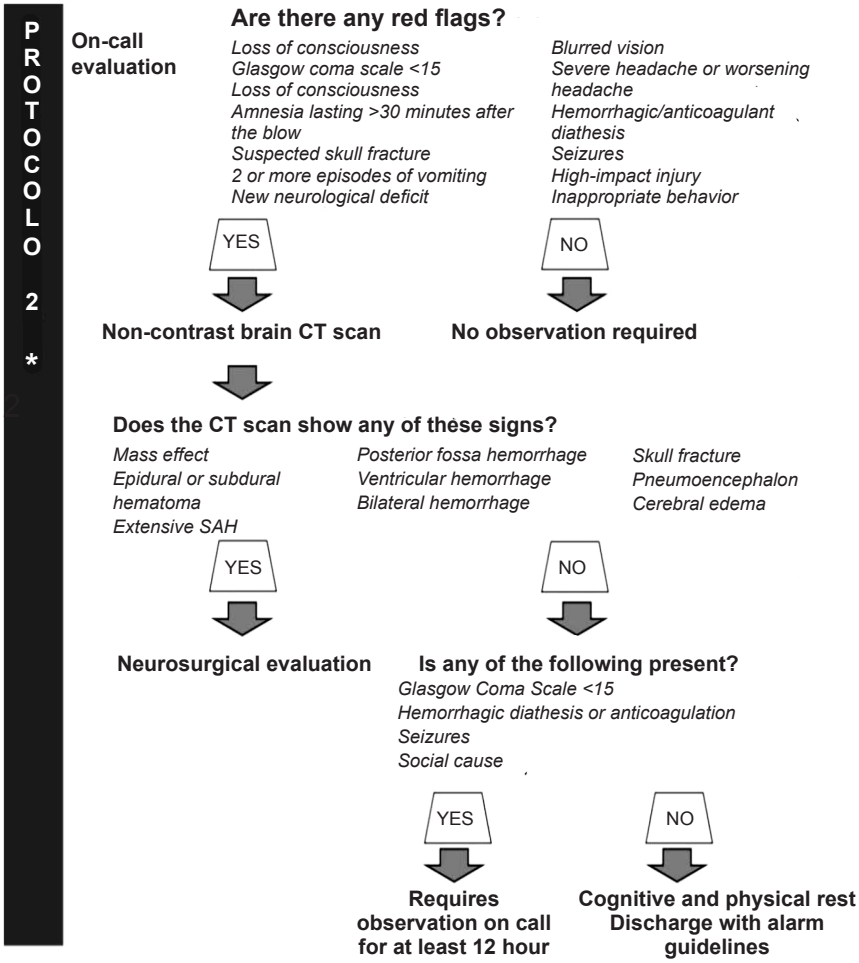
At the slightest suspicion of a concussion, the athlete must be removed from the field of play. Only a healthcare professional can diagnose a concussion. Continuing to participate in the activity can worsen the condition, significantly delay recovery, and, in the event of another head injury, lead to a more serious injury and, in rare cases, death. Therefore, it is crucial to immediately remove anyone suspected of having a concussion from any high-risk activity.[13]

OUTPATIENT OR EMERGENCY DEPARTMENT CARE

The medical evaluation (*Figure 3*), both in the acute phase (<72 hours) and the subacute phase (≥72 hours), the primary objectives should be:

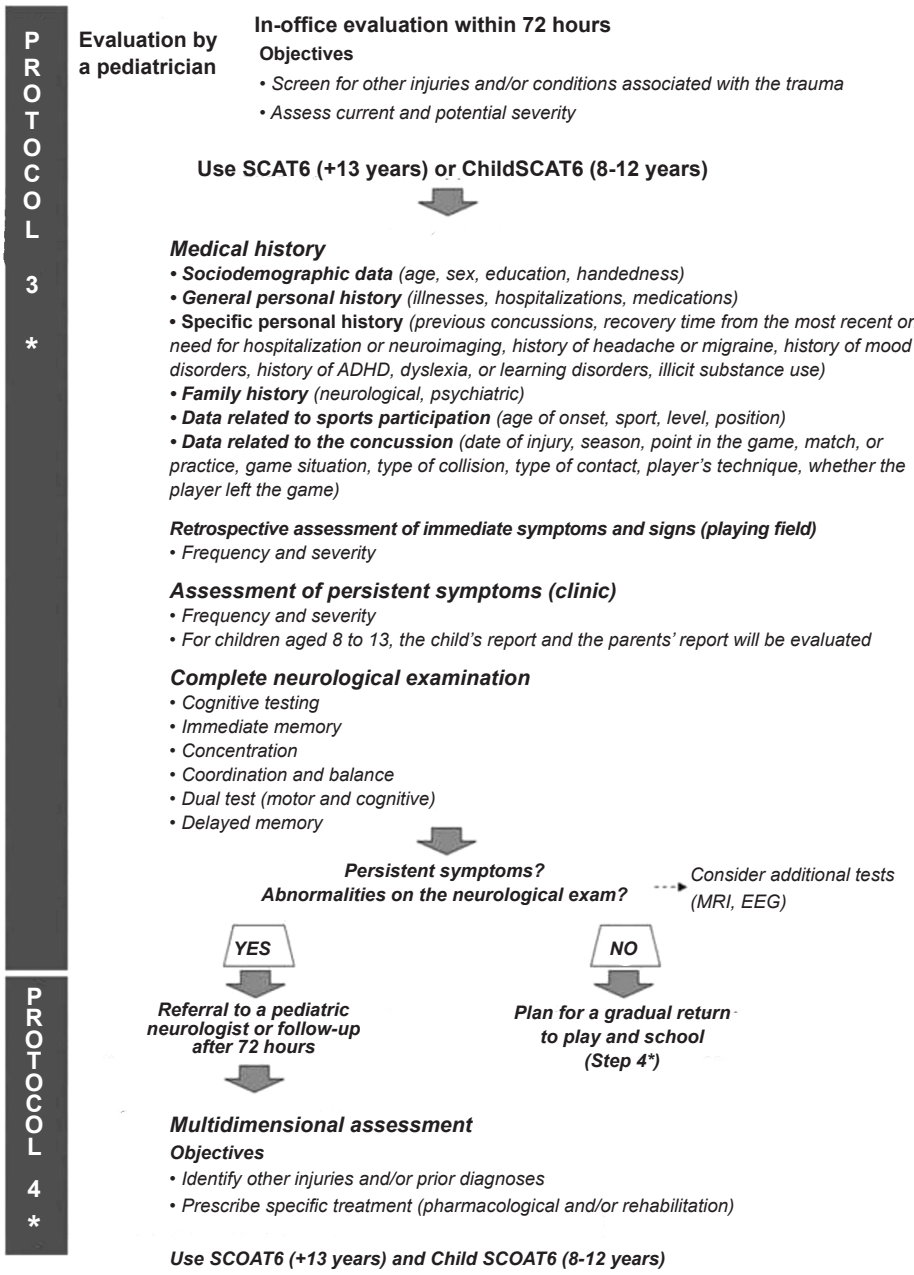
• Identify patients at risk of severe traumatic injury, while limiting the use of diagnostic tests in

Figure 2. Red flags



CT: computed tomography, SAH: subarachnoid hemorrhage.

Figure 3. In-office care or emergency room care



children who are not at risk.

- Investigate other injuries and/or previous or concomitant diagnoses associated with the head injury.

In any of these circumstances, the treating physician should keep in mind that most concussions result in a Glasgow Coma Scale score of 14 or 15.

Ideally, this should be accompanied by a report from the healthcare professional who treated the patient during the acute episode, including details of the initial assessment; otherwise, we must rely on the account provided by the affected person and their companion (parent, friend, coach).

The initial office evaluation (<72 hours) should include:

- A medical history typical of any other pediatric consultation.
- A medical history specific to the diagnosis of concussion.
- Retrospective review of neurological symptoms and signs on the field.

- Assessment of the persistence or onset of new symptoms at the time of the consultation.
- Clinical examination, including measurement of blood pressure and heart rate, both while standing and lying down.[5]
- Assessment of the range of motion of the cervical spine.
- Neurological examination, including a cognitive assessment (orientation, immediate memory, and concentration) and an assessment of coordination and balance (modified balance failure test, timed tandem walk).[8]
- Use of standardized tools (Child SCAT-6)[10,14] for children aged 8 to 12 or the SCAT6[8,15] for adolescents aged 13 to 18, ideally within 72 hours and up to 7 days after the injury, is recommended to facilitate assessment and follow-up, allowing for the adaptation of interventions and monitoring of recovery.

The history should identify the mechanism of injury. Most commonly, these include head-to-head, head-to-body (e.g., elbow, knee, shoulder), head-to-ground, or head-to-object (e.g., pole, disc, stick) impacts. Less frequently, these injuries involve transmitted or indirect forces (e.g., whiplash). The relationship between the mechanism, signs, symptoms, and severity is an emerging area of interest.[2] No direct relationship has been identified between the biomechanics of the impact and symptoms or scores reflecting changes in cognitive performance. However, cellular, metabolic, and molecular changes in the brain increase the brain's vulnerability to a second impact, a condition clinically known as second-impact syndrome.[16,17]

After 72 hours, it is recommended to use another tool, the Sport Concussion Office Assessment Tool and the Child Sport Concussion Office Assessment Tool (SCOAT6 and Child SCOAT6),[18,19] for players aged 13 and older and for children aged 8 to 12, respectively. These tools were designed to help physicians assess key clinical manifestations during concussion follow-up, identify potential individualized therapeutic interventions, determine the need for specialist referral, and monitor recovery. If the SCAT6 or Child SCAT6 was administered close to the time of the acute injury, comparing the recorded symptoms and signs will be valuable.

In some cases, the SCOAT6/Child SCOAT6 may be the initial assessment used to inform the diagnosis and treatment of sports-related concussions. All four tools include an initial form for the athlete's personal information, history of previous concussions, history of neurological disorders, mental health conditions, learning disabilities, etc. In addition, they provide a guide for conducting the following assessments:

- Symptoms: For children aged 8 to 12, the children's and parents' reports will be evaluated.
- Cognitive assessment.
- Coordination and balance.
- Dual assessment (motor and cognitive).

The SCOAT6 and Child SCOAT6 tools include additional assessments:

- Orthostatic vital signs.
- Evaluation of the cervical spine (muscles).
- Examination of cranial nerves and deep reflexes.
- Ocular-vestibular examination.
- Sleep evaluation.
- Mental health.

In the final section, both tools include a protocol for a "gradual return to school" and a "gradual return to play". They emphasize the importance of returning to school as part of the recovery process, collaboration with the school, and gradual progression from simple tasks at home to shorter school hours at school until normal school activities can resume, given the onset of symptoms.

REST AND EXERCISE

Previously, the traditional management of sports-related concussions was based on strict cognitive and physical rest until symptoms had completely resolved.[20] However, current evidence shows that complete rest not only lacks benefits but may also delay recovery.[21,22] Instead, relative rest is recommended during the first 24-48 hours, which includes basic daily activities and reducing screen time (phones, computers). After this initial period, it is suggested to gradually reintroduce physical activities, such as walking and low-intensity exercises, provided they do not exacerbate symptoms beyond a mild and brief increase.

Research strongly supports the benefits of early physical activity and aerobic exercise as key interventions.[21] Aerobic exercise, started between 2 and 10 days after the injury, is associated with faster recovery and a lower incidence of persistent symptoms. This exercise should be subthreshold, meaning it should not increase symptoms by more than 2 points on a scale of 0 to 10 and should last less than one hour. Aerobic exercise started within 14 days of the injury significantly reduces the incidence of symptoms persisting

beyond 30 days. The amount and intensity of the exercises will gradually increase; the final step will be a full return to their sport.

Sleep disorders are associated with an increased risk of persistent symptoms.[21]

INTERVENTIONS AIMED AT ATHLETE REHABILITATION

Rehabilitation, and particularly neurorehabilitation as applied to sports, combines neurology and sports medicine to address injuries or neurological conditions in athletes of all ages.[23] The following may be considered:

- **Vestibular or cervicovestibular rehabilitation:** For adolescents with dizziness, neck pain, or headaches that last longer than 10 days.[6]
- **Active, interdisciplinary rehabilitation:** For children and adolescents with symptoms lasting longer than 4 weeks.[6] This approach includes subthreshold exercise, combined with other treatments if necessary.

Table 1. Risk factors for post-concussion syndrome

Type	Risk factors
Persistence of symptoms	Persistence of physical, cognitive, or emotional symptoms beyond 4 weeks after the concussion, and especially when they last longer than 3 months, is associated with a poorer prognosis and a higher risk of a prolonged course. **Pre-injury:** • Previous concussions • Female gender • Mood disorders • Learning disorders • Attention-deficit/hyperactivity disorder • Personal or family history of migraines • Younger age • Pre-existing sleep problems **Post-injury:** • Severity of the initial injury • High symptom score on initial assessment • Retrograde amnesia • Delay in reporting • Sleep disturbances • Concomitant cervical injuries • Balance problems and eye movement abnormalities • High early cognitive activity
Longitudinal assessment of symptoms	An early indicator of the risk of persistent symptoms following a concussion. Systematic monitoring of symptoms at rest, during cognitive activities, and during physical exertion, as the presence or recurrence of symptoms under these conditionsis associated with an increased risk of persistent post-concussion syndrome.
Third-party report	A sign of persistent symptoms that the athlete has not recognized. Information provided by family members, close friends, coaching staff, or club personnel regarding changes in behavior, performance, or subjective complaints, which may reveal persistent symptoms that have been underestimated or not reported by the athlete themselves and, therefore, indicate a higher risk of a prolonged course of the condition.
Abnormalities in complementary tests	Abnormalities in static and dynamic balance tests, vestibulo-ocular and oculomotor assessments, and cognitive and dual-task tests (cognitive + motor), which suggest objective dysfunction and are associated with a higher likelihood of persistent symptoms.
Functional limitations during the gradual return-to-play protocol	Difficulty completing the stages of the protocol for a gradual return to sports or regaining pre-injury performance levels indicates incomplete recovery and an increased risk of long-term symptoms.
Emerging biomarkers potentially associated with risk and prognosis	Serum, neuroimaging, or neurophysiological markers that, although not yet part of routine clinical practice, show potential for identifying an increased risk of persistent symptoms and providing prognostic information in the context of research.

Table 2. Factors to consider when recommending discontinuation of sports participation

Types	Factors to consider
Patient factors	History of previous concussions, their severity and frequency, the presence of persistent symptoms, and their impact on quality of life, mental health (such as anxiety or depression), and potential comorbidities.
Injury factors	Severity of the current concussion, duration of symptoms, and presence of persistent neurological deficits.
Sport-specific factors	Sport-related risk of concussion, physical and cognitive demands of the sport, playing position, and prevention strategies.
Ethical factors	The obligation of healthcare professionals is to prioritize the athlete's long-term wellbeing.
Psychosocial factors	The athlete's wishes and perspectives, as well as family and social support, and the potential impact of retirement on their identity and emotional well-being.

- **Other strategies:** Neurocognitive, cognitive-behavioral, oculomotor, therapeutic support.

The effects of different rehabilitation regimens, the optimal timing for initiating rehabilitation, and modifying factors still require further evaluation.[5]

RECOVERY PATTERNS AND PREDICTION

Recovery trajectories vary significantly among individuals. Although there are no universal time frames, arbitrary parameters are established to guide clinical management. A recent systematic review evaluated the time it takes for athletes to return to sports after a concussion. A key finding of the study was that the median time to return to sports was 21 days in 80% of the published studies.[24] *Table 1* lists the risk factors to consider.[5,25-27]

POTENTIAL LONG-TERM NEUROLOGICAL EFFECTS OF CONCUSSIONS

Concussions not only have immediate consequences but are also associated with long-term neurological and psychiatric risks.[5,28] Some of these effects include:

- **Mental health and mood disorders:** Increased risk of anxiety and depression.[29] Pre-existing conditions increase the likelihood of developing persistent symptoms.[30]
- **Prolonged cognitive impairments:** Difficulties with concentration, memory, attention, and executive function.[28,31]
- **Neurodegenerative diseases:** There is a possible link between exposure to head impacts and an increased risk of developing neurodegenerative diseases, such as chronic traumatic encephalopathy, Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis.[5] However, the evidence on this matter remains controversial.
- **Second-impact syndrome:** A rare but life-threatening complication, with a 50% mortality rate due to cerebral edema following a second concussion before full recovery.

PERMANENT WITHDRAWAL FROM CONTACT OR COLLISION SPORTS

The decision to discontinue sports participation is a complex process that requires an individualized and interdisciplinary approach,[5,32] integrating scientific evidence, clinical context, and psychosocial factors. This may involve sports medicine physicians, neurologists, neuropsychologists, physical therapists, and other health professionals, and must take into account various aspects detailed in *Table 2*.

For child and adolescent athletes, additional concerns include a successful return to school and the maintenance of healthy levels of physical activity. This typically requires a multidisciplinary approach that involves the child or adolescent, parents or caregivers, healthcare professionals, school administrators, and teachers in the discussions.

CONCLUSION

Sports-related concussion injuries are a common clinical challenge in the pediatric and adolescent population. Diagnosis is primarily clinical and requires a systematic evaluation in both the field and the clinic. Early identification, immediate removal from play, and the implementation of individualized management protocols are essential for optimizing recovery and preventing complications.

Current evidence does not support complete rest; rather, it favors a gradual, controlled return to physical activity and school. An interdisciplinary approach and the use of standardized tools

improve assessment and follow-up, enabling athlete-centered care based on the best available scientific evidence. ■

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