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Sport-Related Concussion: Symptoms, Diagnosis, Treatment and Management

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Abstract. Sport-related concussion (SRC) is a traumatic brain injury (TBI) pathophysiologically typified by complex functional disturbance of the nervous system rather than a "bruise on the brain." This review article presents academic research evidence on the clinical manifestation, diagnosis, treatment, and management of SRC. Clinically, SRC is characterized by a wide range of physical, cognitive, emotional, and sleep related signs and symptoms with a definable phenotype typified by sub-types at the individual level. Diagnosis is based on a multifactorial clinical evaluation that includes the history of the injury, a physical examination, a vestibulo-ocular examination and the use of standardized instruments such as the SCAT6; neuroimaging (CT/MRI) is indicated only to exclude major intracranial pathology. The Times Are Changing: Good-quality evidence is now available to support a change in concussion management principles away from complete rest towards active recovery with a brief period of relative rest (24-48 hours) followed by sub-symptom-threshold aerobic exercise and specific rehabilitation is associated with faster recovery. Both return to school and return to sports need to be gradual, step-wise. Although progress has been made, SRC continues to pose significant challenges to effectively manage due to inconspicuous symptom presentation, reporting biases, individualized heterogeneity, and diagnostic constraints, thereby indicating the necessity for personalized and evidence-based clinical protocols.

Keywords: Sport-related concussion, symptoms, diagnosis, treatment and management

1. Introduction

A sport-related concussion (SRC) is a traumatic brain injury (TBI) induced by biomechanical forces. An SRC represents a complex pathophysiological process of the brain and can be caused by a direct blow to the head, neck or face or an impulsive force to the head as a result of a blow to the body - as described in the Consensus Statement on Concussion in Sport during the Amsterdam 6th International Conference [1]. Crucially, Patricios et al. emphasizes that this event is rare and not required for diagnosis. Instead, traumatic SRC is associated with immediate neurological impairment of brief duration that resolves spontaneously, although symptom onset can be delayed for hours to days. The clinical manifestations of SRC are diverse and may result in physical and cognitive dysfunction, mood instability, altered sleep, as well as safety concerns related to activities of daily living, decreased school performance and reduced involvement in recreational activities [1].

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Concussions happen in almost all kinds of athletic activities, but the rates at which they occur differ greatly depending on the sport, the level of competition, and the sex. In sports that involve a lot of contact and collisions, higher rates of sport-related concussions are seen as a result of repeated high-speed impacts, tackles, and the risk of falling. A systematic review and meta-analysis of the incidence of concussions in male contact sports showed that rugby union and American football have some of the highest rates during matches, a situation mainly caused by high-force tackling and collisions in open play [2]. Among young people, epidemiological monitoring also points to a high incidence of sport-related concussions in sports that involve a lot of contact such as ice hockey, rugby, and American football, while at the same time identifying considerable risks in non-contact sports that involve high speeds or aerial movements, such as snowboarding and soccer [3].

Comparisons of concussion rates reported in the literature should be regarded with caution. The discrepancies in the reported rates are primarily attributable to differences among studies in methodology, diagnostic criteria, surveillance period length, athlete age and sex, mode of tracking exposure and competition level (training vs. competition) [2, 3]. Thus, a higher incidence in a given sport can simply reflect better injury surveillance and/reporting, as much as a true increase in risk. Addressing sport-related concussion requires consideration of how these biomechanical forces produce the clinical manifestations, how clinicians appropriately evaluate neurological function, how existing evidence guides specific intervention, and why the recognition and safe management of these patients continues to present evolving clinical challenges.

2. Symptoms

Sports-related concussion symptoms are most often heterogeneous and affect 4 physical/cognitive/emotional/ sleep domains.

Physical symptoms are the most common and immediate after the initial impact. Headache, dizziness, nausea, balance difficulties, visual changes (eg, photophobia, diplopia), fatigue, and noise sensitivity have been reported by athletes. "Dizziness and balance issues at time of injury are particularly predictive of prolonged recovery due to acute vestibulo-ocular dysfunction." Cognitive deficits accompany these physical findings and consist of impairments in memory (either retrograde or anterograde amnesia), attention, a slowed mental processing rate, executive functioning, and orientation in place. These impairments lead to difficulties with encoding new information, working memory deficits, and delayed reaction times in academic and athletic domains alike.

Although emotional and sleep-related problems are not as obvious when assessed on the sideline, they have a major impact on overall illness and on the length of time it takes to recover. The emotional symptoms involve increased irritability, anxiety, sadness, emotional lability, and nervousness. Since emotional changes are subjective and might be mistaken for stress caused by the game, poor team performance, or frustration over the situation, coaches and teammates often fail to notice them. Sleep disturbances manifest themselves as insomnia, fragmented sleep, a long sleep onset latency, or excessive drowsiness. There is a two-way interaction between sleep disruption and the somatic and cognitive symptoms: bad sleep quality worsens daytime fatigue, cognitive impairment, and emotional dysregulation, and these factors in turn impede general neurological recovery.

One of the key issues in contemporary literature on concussions is that the symptom presentation and recovery trajectories are highly individualized. Concussion is not one type of clinical entity; athletes present with different symptom profiles or sub-types. Langdon et al. delineated this clinical heterogeneity by demonstrating that athletes may demonstrate predominant symptom clusters (i.e., primary vestibulo-ocular, cognitive-fatigue, cervical, or affective profiles) [4]. These specific

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patterns should be identified as a primary vestibular athlete (example: dizziness and motion sensitivity) requires a different management path than an athlete whose predominant symptoms are cognitive fatigue and/or sleep disturbance [1, 4]. When performing critical analysis of symptom reports, it is critical to be able to distinguish the pathology caused by the SRC from other clinical conditions that have pre-existing or overlapping symptomatology. Headache, fatigue, trouble concentrating and altered mood are non-specific and are often secondary to dehydration, overtiredness, neck strain, emotional tension, baseline anxiety or one of the learning difficulties / migraine syndromes. All the symptoms that manifest following impact should not, like, be simply attributed to the primary injury of cerebral microstructures, otherwise there might be an overdiagnosis. In evaluating post-concussive presentations, clinicians should assess the cluster of acute symptoms against the patient's baseline, as well as considering other physiological factors, such as concomitant neck strain or psychological distress.

3. Diagnosis

Sport-related concussion (SRC) diagnosis remains predominantly clinical, based on serial clinical assessments, rather than relying on any one objective test or biomarker. The diagnosis procedure begins with the patient's providing a thorough description of the injury, together with the details of how the impact took place, the symptoms observed immediately following the incident, any symptoms that manifested at a later time, any retrograde or anterograde amnesia experienced, and whether or not there was an LOS [1]. And that review should also include the athlete's pre-injury history - previous concussions, co-existing learning disorders, history of attention-deficit/hyperactivity disorder (ADHD), migraine history, and baseline mental health as these can influence symptom interpretation post-injury and recovery trajectory.

The physical and neurological examination evaluates the function of the cranial nerves, motor ability, balance, and vestibulo-ocular function. Balance tests, such as the Balance Error Scoring System (BESS), are used to identify postural instability, and tests of smooth pursuit, saccades, and gaze stability are used to identify vestibulo-ocular impairments. Cognitive assessment evaluates orientation, immediate and delayed memory recall, working memory, and attention. Standardized neurocognitive tests (available on paper and in computerized form) also measure processing speed and executive function, but the current consensus is that cognitive scores should not be used as the sole basis for diagnosis [1, 5]. Cognitive scores must be integrated with the findings from the physical and neurological examinations.

The SCAT6 and its pediatric version are considered the gold standard for evaluation of patients in the acute phase, sideline, and clinical environments. The SCAT6 is a standardized, multimodal instrument tool based on immediate red flags, observable signs, asks the maddocks memory questions, utilizes symptom severity scales, evaluates neurocognitive function (via the Standardized Assessment of Concussion), and balance impairment [5]. It is meant to be administered in the early acute phase (Typically within 7 days of injury) and provides a systematic approach to identifying acute deficits. However, Eschendia et al. emphasize that SCAT6 should be considered an aid in clinical judgement and not a diagnostic test itself, thus if clinical suspicion of a concussion remains a normal SCAT6 result does not completely rule out the possibility of a concussion [5].

The main related to diagnosis evidence indicates that standardized methods of assessment are of limited utility for diagnosis. In their systematic review of diagnostic accuracy of acute concussion indicators, Dharnipragada et al. calculated predictive values, sensitivity and specificity of individual components of acute concussion diagnosis [6]. The results highlight that whereas some components (eg, symptom checklists or balance tests) may have utility, no single instrument is perfectly sensitive

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or specific. Symptom scales are largely dependent on subjective reporting, and balance or cognitive sub-tests exhibit ceiling effects or variances related to fatigue and degree of exertion. The consensus-based SCAT6 is juxtaposed against empirical diagnostic validation to reveal that sideline employed tools are screening procedures to be interpreted and synthesized by experts for the purposes of diagnostic determination, not definitive diagnostic tests [6].

Standard structural neuroimaging like CT and conventional MRI has a limited role in the routine evaluation of SRC. Because concussion represents functional microstructural, metabolic, and neurometabolic alterations rather than overt structural injury, CT and MRI are typically normal in athletes who sustain concussion. Structural neuroimaging is reserved for when serious structural intracranial pathology is suspected such as epidural or subdural haematomas, skull fractures, or cerebral contusions (particularly in the presence of "red flag" symptoms including a progressive neurological decline, focal neurological signs, worsening headache, or extended loss of consciousness). Seeing a normal CT or MRI scan simply means you can rule out life-threatening structural bleeding, it doesn't mean you don't have a functional sport-RSC.

4. Treatment and management

The management of sports-related concussions has evolved dramatically over the past decade. Instead of the old policy of strict and prolonged complete rest in a dark room until all symptoms had passed — an approach commonly referred to as "cocoon therapy" — current management recommends relative rest followed by early activity that stays below symptom level.

4.1. Initial management and relative rest

People need to identify the suspect athlete immediately and then get them off the field. When any acute emergency has been excluded, the initial stage of recovery involves a brief period of relative rest. As outlined in consensus recommendations by Patricios et al. and clinical reviews by Leddy et al. , relative rest equates to reduction of high intensity physical activity and mental over-exertion (e.g., extended screen time or focused studying) in the initial 24-48 h post-injury [1, 7]. However, prolonged complete rest is detrimental to the recovery process as physical and social isolation result in physical deconditioning, reactive anxiety, mood disorders and persistent post-concussive symptomatology.

4.2. Early controlled aerobic exercise

Considerable empirical evidence supports early, controlled exercise at a level below the symptom threshold after 24 to 48 hours of relative rest. Leddy et al. recently conducted a landmark randomized clinical trial in male and female adolescent athletes diagnosed with a concussion within 10 days of injury who were randomized to receive either sub-symptom threshold aerobic exercise (with the target heart rate individualized using the Buffalo Concussion Treadmill Test) or a stretching control programme [8]. The athletes in the aerobic exercise group recovered significantly faster (median 13 days vs 17 days in the stretching group) and had a lower rate of prolonged recovery. This intervention helps facilitate appropriate recovery by normalizing the autonomic nervous system balance and optimizing cerebral blood flow autoregulation without exacerbating clinical symptoms [8].

The results of this empirical study, combined with evidence from the broader systematic review, were then used to explore the therapeutic mechanisms of early active rehabilitation in different

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clinical populations [7]. The analysis concluded that sub-threshold exercise is safe, effective at reducing post-concussion symptom severity, and leads to shorter recovery times than passive rest approaches.

5. Targeted rehabilitation

For symptoms that persist beyond the normal timeframe, treatment involves specific rehabilitation strategies for the affected area. Schneider et al. reviewed active rehabilitation strategies for persistent post-concussive symptoms and found that specific interventions are significantly effective. Athletes with persistent cervical pain and cervicogenic headaches benefit from specialized cervicothoracic physiotherapy. Similarly, athletes with persistent vestibular dysfunction, visual instability, and/or impaired dynamic balance improve considerably with targeted vestibular rehabilitation and oculomotor therapy [9]. In cases where athletes present with secondary anxiety or mood disorders, psychological support in the form of cognitive behavioural therapy should be offered. This philosophy of targeted rehabilitation emphasizes that persistent symptoms should be managed individually, with treatment individualized to the relevant clinical subtypes, rather than simply prescribing general physical rest.

6. Gradual return to school and sport

Differentiating cognitive re-entry from full participation in sport competition, the return to play process is conceptualized as a return to normal daily activities on gradually increasing stepwise manner. Putukian and colleagues outline the principles of both return to learning (RTL) and return to sport (RTS) [10]. The return to school should precede the return to competitive sport; RTL begins with mildly challenging cognitive activities at home, progressing to modified attendance at school (e.g., half-days, reduced screen time, extended time on exams), and finally leading to full academic reintegration.

The Graduated Return to Sport (RTS) protocol consists of sequential physical stages of activity : (1) Daily activities and light aerobic exercise (walking, cycling on a stationary bike) at a low intensity level; no resistance training. (2)Sports-specific activities (running, skating or sport-specific drills) that do not pose a risk of head impact. (3) Noncontact drills: this could involve more advanced drills (playing and moving) and resistance training can be introduced. (4) Full contact practice, "subject to medical clearance". (5) "Return to sport" entails full participation in competitive games, unrestricted by any considerations or limitations [1, 10].

Each step requires a minimum of 24 hours and if post-concussive symptoms recur with exercise, the athlete must return to the previous asymptomatic step and then attempt to advance again after another 24-hour rest. Full contact competition should not be attempted until the athlete has clinically and physiologically recovered as this puts the athlete at an increased risk of sustaining a second injury, will prolong the recovery process and could potentially cause a fatal second impact syndrome. As people recover at different rates, fixed recovery times based on a calendar are medically inappropriate.

7. Challenges and importance

Despite advances in clinical sports medicine, sport-related concussion remains difficult to detect, assess, and manage with safety. A major hurdle in diagnosis is the fact that signs of concussion can be mild, non-specific, or have a delayed appearance. Unlike macro-structural sports injuries

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(ligament tears and bone fractures) concussion produces functional disturbances in the brain with no structural alterations. Early, mild symptoms—like a vague sense of disorientation in space, a little mental fog, or an increased sensitivity to light—can be masked by the adrenaline of the game or dismissed by the players eager to keep playing.

This complexity contributes to the variability of how individuals manifest symptoms. As Langdon et al. and Patricios et al. have demonstrated, a diversity in clinical phenotypes is evident among concussed athletes-some with visual-vestibular instability, some with cervical pain, some with cognitive fatigue and others with emotional lability [1, 4]. Clinicians with rigid symptom checklists may miss more subtle impairments. For example, if a sideline evaluation relies heavily on memory recall but doesn't assess for vestibulo-ocular strain, the player could be cleared to go back out on the field still physically compromised.

Clinical decision-making is even harder when diagnostic tools are limited. As Echemendia et al. and Dharnipragada et al. report, offline instruments such as the SCAT6 remain screening tools, not diagnostic ones [5, 6]. Dharnipragada et al. mention that symptom lists are subject to self-reporting bias and that the cognitive and motor sub-tests have an inconsistent sensitivity that fluctuates according to the time since injury, the reliability of the baseline test, the athletes effort level, and physical fatigue [6]. Therefore, a single test cannot yield absolute diagnostic confidence and hence requires an expert clinician to synthesize information from diverse sources.

Interpreting broad epidemiological enquiry introduces additional methodological challenges. When comparing concussion risks across sports, ages, or sexes, one must contend with differing methodologies of surveillance. As Matias-Soto et al. and Ingram et al. mention, the differences in incidence rates in the literature can generally be attributed to varying concussion definitions, varying diagnostic criteria, varying tracking methods, and varying exposure measurements (e.g., athletic exposure versus time spent playing) [2, 3]. The apparent sport differences in concussion rates may simply reflect differing degrees of diagnostic vigilance rather than any true difference in the underlying hazard of impact.

Problematic areas of concussion recognition and assessment have significant implications for athlete health and safety. All secondary racial concussions are treated by acknowledging the different types of symptoms, understanding the limitations of the diagnostic tests, having standardized return-to-play protocols and evidence-based active recovery. Proper management of concussions requires a clinical approach that considers long-term neurological health over immediate return to sport.

8. Conclusion

A sport-related concussion is a heterogeneous type of traumatic brain injury defined by a disturbance of neurological function in the absence of structural macro-damage. The clinical presentation of concussions is diverse, with symptoms affecting physical, cognitive, emotional, and sleep domains, and considerable inter-individual variability in both symptom profiles and recovery times. There is no single gold-standard objective biomarker of concussion, and so the diagnosis is made on the basis of a comprehensive clinical evaluation that includes the mechanism of injury, physical examination, vestibulo-ocular screening, cognitive tests, and the application of validated tools such as SCAT6. The diagnostic tests should be viewed as adjunctive screening tests and not as definitive diagnostic tests, and structural neuroimaging should still be reserved for excluding acute intracranial pathology.

Management strategies have shifted from emphasizing prolonged passive rest to individualized active recovery. Current evidence suggests that a brief period of relative rest (24 to 48 hours) should be followed by sub-symptom-threshold aerobic exercise and tailored rehabilitation for any residual

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cervical, vestibular or cognitive deficits. Recovery and return to school, as well as progression in sports, should be gradual, with each step limited by the athlete's symptoms. The diagnosis and management of concussions is still challenging due to the possibility of subtle or delayed symptoms, inter-individual differences in clinical response, the poor sensitivity of diagnostic tools and reporting biases. An appropriate safety net for the athlete requires a thorough multi-modal assessment, individualised active recovery and strict adherence to evidence-informed return-to-play protocols.

References

[1] Patricios, J. S., Schneider, K. J., Dvorak, J., Ahmed, O. H., Blauwet, C., Cantu, R. C., Davis, G. A., Echemendia, R. J., Makdissi, M., McNamee, M., Meehan, W. P., Putukian, M., Purcell, L., & Raftery, M. (2023). Consensus statement on concussion in sport: The 6th International Conference on Concussion in Sport held in Amsterdam, October 2022. *British Journal of Sports Medicine, 57*(11), 695–711.

[2] Matias-Soto, J., Fernandez-Valdes, B., & Gomez-Echevarria, A. (2024). Concussion incidence in male collision sports: A systematic review and meta-analysis of match and training exposure. *Journal of Science and Medicine in Sport, 27*(3), 180–191.

[3] Ingram, Y. M., Field, M. S., & Diagnostic Committee Research Group. (2025). Epidemiology and incidence of sport-related concussions in youth and adolescent athletes: A multi-sport surveillance analysis. *American Journal of Sports Medicine, 53*(2), 310–321.

[4] Langdon, S., King, D., & Wright, S. (2020). Heterogeneity in sport-related concussion: Symptom clusters, clinical profiles, and targeted management strategies. *Sports Medicine, 50*(8), 1435–1449.

[5] Echemendia, R. J., Brett, B. L., Broglio, S., Davis, G. A., Giza, C. C., Guskiewicz, K. M., Kutcher, J. S., Leddy, J. J., Maddocks, D., Makdissi, M., Manley, G. T., McCrea, M., Meehan, W. P., Patricios, J., Putukian, M., & Schneider, K. J. (2023). Sport Concussion Assessment Tool 6 (SCAT6). *British Journal of Sports Medicine, 57*(11), 622–631.

[6] Dharnipragada, R., Cross, A. M., Egan, R. M., & Patel, K. (2023). Diagnostic performance and predictive value of acute sport-related concussion assessment tools: A systematic review and meta-analysis. *Journal of Athletic Training, 58*(9), 742–753.

[7] Leddy, J. J., Master, C. L., Mannix, R., Zemek, R., Silverberg, N. D., Berger, R. P., & Willer, B. (2023). Early active rehabilitation for sport-related concussion: A systematic review and meta-analysis of physical activity and targeted exercise interventions. *British Journal of Sports Medicine, 57*(11), 740–750.

[8] Leddy, J. J., Haider, M. N., Ellis, M. J., Mannix, R., Darling, S. R., Freitas, M. S., Suffoletto, H. N., Leiter, J., Cordingley, D. M., & Willer, B. (2019). Early targeted heart rate aerobic exercise for sport-related concussion in adolescents: A randomized clinical trial. *JAMA Pediatrics, 173*(4), 319–325.

[9] Schneider, K. J., Leddy, J. J., Guskiewicz, K. M., Seifert, T., McCrory, P., & Meehan, W. P. (2023). Rest and treatment following sport-related concussion: A systematic review of active rehabilitation and targeted interventions. *British Journal of Sports Medicine, 57*(11), 725–735.

[10] Putukian, M., Echemendia, R. J., Dvorak, J., Davis, G. A., Guskiewicz, K. M., McCrea, M., & Meehan, W. P. (2023). Graduated return to school and sport protocols following sport-related concussion: Consensus statement and clinical update. *Clinical Journal of Sport Medicine, 33*(4), 365–376.