

REVIEW

Advances in rehabilitation post-concussion: managing return-to-sport decisions

Sri Valli Chekuri¹, Mohammed Sheeba Kauser^{2*†} and Subhasis Karmakar³¹Department of Physiotherapy, Austin, TX, United States²Department of Physiotherapy, SV College, Nellore, India³University of East London, London, United Kingdom***Correspondence:**Mohammed Sheeba Kauser,
sheebaishaq.doc@gmail.com**†ORCID:**Mohammed Sheeba Kauser,
0000-0001-5301-3559**Received:** 04 June 2025; **Accepted:** 07 July 2025; **Published:** 30 July 2025

In recent decades there has been a rapid shift in the way concussions are being managed, especially in drawing back to sports decisions being made and judgments about how to return back to the game on the field. After a close reading with different studies involved, there is growing evidence that active, customized rehabilitation techniques that promote neuronal repair and improve functional independence after extended periods of rehabilitation and rest. This post-concussions rehabilitation included the importance of early sub-symptom threshold aerobic exercise, vestibular and ocular motor treatment, and cognitive behavioral approaches. Specified recovery programs, which include multidisciplinary approaches and sport-specific recovery programs including clinical trajectories, are presented as strategies to increase decision-making accuracy and the chance of early return to their respective sports.

Keywords: concussion, mild traumatic brain injury (mTBI), rehabilitation, return-to-sport (RTS), neurocognitive testing

Introduction

Overview of concussion in sport

Concussions have always been a point of concern in health. They are generally referred to as mild traumatic brain injury (1). In sports, especially in contact injuries, they are very alarming for on-field players. They occur with a sudden biomechanical force and powerful blow overhead most probably sudden forces, which gradually sets off deterioration in physiological activities that affects the brain's ability to function normally (2). General symptoms are usually unnoticed, like mild headaches, memory issues, disorientation, and mild balance issues (3). Athletes more likely to play soccer, rugby, hockey are more likely to have this concussions (4).

Evolving paradigms in concussion management

From rest to active rehabilitation

Resting physically and mentally until all symptoms subsided was the most widely used treatment for concussions for a long time (5–7). Although this approach was designed to lessen the metabolic stress on the wounded brain and avoid symptom exacerbation, recent evidence suggests that extended rest may lead to delayed recovery, deconditioning, and even more mental suffering. A paradigm shift toward active rehabilitation has resulted from recent research acknowledging that recovery can be facilitated by adequate levels of cognitive and physical engagement (8). Stationary

walking, balance training are more likely to be involved in the early stages of rehabilitation.

Although earlier models used rigid concussion grading systems (e.g., Cantu or Colorado guidelines), modern concussion management has moved away from strict classification. Instead, symptom burden, progression, and resolution over time are prioritized (9). This shift reflects the variability in individual recovery trajectories and discourages reliance on a single-time-point assessment.

Neurocognitive testing tools

Neurocognitive testing provides objective data on brain function, particularly in areas commonly affected by concussion—such as attention, memory, reaction time, and processing speed. Both **baseline** and **post-injury comparisons** can be valuable in determining the extent of cognitive impairment and readiness for return-to-learn or return-to-play (10).

Computer-based tools like **Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)**, **Central Nervous System (CNS) Vital Signs**, and **CogSport** are widely used in sports medicine settings. These tests, however, should never be used in isolation; rather, they complement clinical judgment and should be interpreted within the broader clinical context.

Role of objective biomarkers

The search for reliable, objective biomarkers to aid in concussion diagnosis and management is an active area of research. Biomarkers may offer the potential to reduce reliance on subjective reporting and improve diagnostic accuracy. Key areas of exploration include:

- **Blood-based biomarkers:** Proteins such as **Glial Fibrillary Acidic Protein (GFAP)** and **Ubiquitin C-terminal Hydrolase L1 (UCH-L1)** have shown promise in identifying brain injury and are being integrated into point-of-care testing in some clinical environments.
- **Neuroimaging:** While conventional Computed Tomography (CT) and Magnetic resonance imaging (MRI) scans are typically normal in concussion, advanced imaging techniques such as **diffusion tensor imaging (DTI)** and **functional MRI (fMRI)** are being explored to detect subtle brain changes associated with mild traumatic brain injury (mTBI).
- **Oculomotor and vestibular testing:** Devices that objectively assess **eye tracking**, **pupil reactivity**, and **balance** (e.g., the **King-Devick test** or **Vestibular/Ocular Motor Screening [VOMS]**) are increasingly utilized as functional biomarkers.

Individualized rehabilitation approaches

A “one-size-fits-all” approach has been replaced by targeted, symptom-specific rehabilitation treatments that address each patient’s unique limitations. The objective is to reduce the chance of protracted symptoms and a delayed return to sports while promoting a safe and effective recovery (11).

Controlled sub-symptom threshold aerobic activity may aid in concussion recovery, according to recent studies. It has been demonstrated that improving brain autoregulation, reducing symptom intensity, and speeding up recovery can be achieved by starting light aerobic exercise, such as stationary cycling or brisk walking, within a few days after injury and maintaining exertion levels below the threshold that aggravates symptoms (12).

Under the guidance of qualified physiotherapists or specialists, vestibular rehabilitation treatment (VRT) includes exercises to enhance gaze stability, balance, and spatial orientation. Impairments, including smooth pursuit anomalies, saccadic dysfunction, and convergence insufficiency, are addressed by oculomotor rehabilitation (13). Techniques include computer-based visual training, pencil pushups, and visual tracking activities. Particularly in sports that demand a high degree of visual-vestibular integration, early detection and treatment of these deficiencies can greatly shorten the duration of symptoms and enhance functional performance.

Particularly in contact sports or sports requiring whiplash-like mechanics. Symptoms including headache, lightheadedness, and visual abnormalities that resemble or exacerbate concussions can be caused by cervical spine dysfunction. The evaluation includes an examination of the cervical range of motion, postural control, muscle discomfort, and feeling of joint position. Proprioceptive exercises, manual therapy, and posture correction are possible treatment approaches (14). Addressing cervical contributions early in the rehabilitation process can enhance recovery and reduce symptom overlap.

Functional testing particular to sports

Athletes should demonstrate sport-specific functional readiness prior to full return to play to ensure that they can withstand the physical, cognitive, and sensory demands of their sport without exhibiting symptoms. This includes:

- Sprinting, cutting, and agility drills for field athletes.
- Stickhandling and shooting for hockey players.
- Heading and rapid directional changes in soccer.
- Tumbling or flipping in gymnastics or cheerleading.

Monitoring symptom recurrence

Even after an apparent recovery, symptoms may resurface if an athlete returns too soon or participates in high-intensity exercises. Continuous observation is crucial as return-to-sport (RTS) develops, particularly when unfettered play is introduced (15).

Clinicians should inform coaches, parents, and players about warning signs and the significance of reporting new or recurring symptoms (16). This approach can be aided by resources like symptom diaries, smartphone monitoring applications, or planned follow-up appointments.

If symptoms reappear during RTS, reevaluate for underlying causes (e.g., vestibular dysfunction, psychological stress, or cervical involvement) and modify the rehabilitation approach accordingly (17).

Multidisciplinary team involvement

A multidisciplinary, collaborative approach is required for effective concussion management and RTS decision-making. The full range of concussion-related physical, cognitive, and psychological challenges cannot be addressed by a single doctor. Instead, coordinated input from various healthcare professionals ensures a holistic, patient-centered recovery process (18).

The Parts Played by doctors, physical therapists, neuropsychologists, and athletic trainers, physicians (typically sports medicine physicians or neurologists) play a central role in the diagnosis, medical clearance, and overall management of concussion. They keep an eye on the symptoms, rule out more serious brain injuries, and decide if the patient is ready to progress through the RTS stages. Balance, mobility, neck dysfunction, and dizziness are all issues that physiotherapists, particularly those with expertise in vestibular and cervical spine rehabilitation, address. They are crucial in modifying exercise programs that target sub-symptom thresholds and correcting physical impairments that may delay recovery (19). Neuropsychologists specialize in cognitive, emotional, and behavioral symptom assessment and treatment. Sideline assessment, daily monitoring, symptom tracking, and communication between athletes and the broader healthcare team are all crucial responsibilities of athletic trainers, who frequently act as the first responders in sport settings (20).

Early pharmacological interventions

Early pharmacological interventions in the rehabilitation of sport-related concussion (SRC) are emerging as a complementary approach to traditional conservative management, which primarily involves physical and cognitive rest followed by a gradual return-to-play protocol. While most concussions resolve within a few weeks, a

subset of athletes experience prolonged symptoms that may benefit from targeted pharmacologic support. In the early stages post-injury, medications such as acetaminophen are sometimes used for headache relief, while melatonin or trazodone may be prescribed to manage acute sleep disturbances, which can negatively impact recovery. Though not typically used immediately post-injury, agents like amantadine or stimulants have been explored for early cognitive support in selected cases. Experimental neuroprotective agents, such as N-acetylcysteine (NAC), are also under investigation for their potential to reduce oxidative stress and neuronal damage if administered shortly after concussion. However, caution is essential, as early pharmacologic treatment may mask symptoms critical for monitoring recovery and determining safe return-to-play. Therefore, early medication use should be individualized, symptom-targeted, and integrated within a multidisciplinary rehabilitation plan (21).

Conclusion

RTS decision-making and concussion therapy have changed dramatically in recent years, moving away from passive rest and toward active, customized recovery plans. Current best practices place a strong emphasis on targeted rehabilitation based on clinical presentation, early, restricted physical exercise, and cautious, step-by-step advancement through RTS regimens.

A comprehensive clinical assessment that includes vestibular, ocular, and cervical dysfunction evaluation, cognition testing, and symptom inventories is the first step in comprehensive care. Addressing the various and frequently overlapping aspects of post-concussive symptoms requires tailored therapies, which can range from vestibular therapy and cognitive-behavioral support to sub-symptom threshold aerobic activity.

Optimizing recovery outcomes and improving care coordination are two benefits of multidisciplinary collaboration between doctors, physiotherapists, neuropsychologists, and athletic trainers. Safe reintegration into sport depends on open communication between all parties involved, including the athlete, family, school, and team personnel.

Author contributions

Sri Valli Chekuri: Editing and paraphrasing. Mohammed Sheeba Kauser: Context development, content creation, and writing. Subhasis Karmakar: Results verification.

Funding

No funding received for this article.

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