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Prajna Paramita Rout
Department of Physiotherapy, MPT student, Abhinav Bindra Sports Medicine and Research Institute Utkal University Bhubaneswar, Odisha, India

Debasis Behera
Department of Physiotherapy, Lecturer, Acharya NR Institute of Physiotherapy Rajiv Gandhi University of Health Sciences Bangalore, Karnataka, India

Corresponding Author:
Debasis Behera
Department of Physiotherapy, Lecturer, Acharya NR Institute of Physiotherapy Rajiv Gandhi University of Health Sciences Bangalore, Karnataka, India

Advanced assessment approaches in sports related concussion

Prajna Paramita Rout and Debasis Behera

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Abstract
The term "sports-related concussion" (SRC) refers to a mild traumatic brain injury (mTBI) that can cause a variety of intricate neurological function deficits, many of which are difficult to detect or conceal and can worsen quickly without warning. An increased dialogue about player safety and welfare has resulted from an increase of SRCs in both professional and amateur contact sports. Even though concussions are well known in sports at all levels, there is uneven and fragmented concussion management and assessment from youth to college. A key deficiency that leads to uneven treatment is the absence of a scalable, methodical method for recording the initial characteristics of injuries after concussions. As a result, there are difficulties with off-field evaluation and return to play (RTP) protocols. The majority of the traditional, subjective methods used today are based on sporadic snapshot assessments. There is ample evidence to support the need for a multimodal strategy in the assessment and treatment of concussions connected to sports. For this reason, several evaluation criteria have been created. It's critical to comprehend the current and upcoming diagnostic testing methods for concussions sustained in sports. In this review we provide insights into off-field digital techniques to identify critical SRC indicators. We also offer insights on digital technologies' translational utility and SRC clinical assessment methodologies.

Keywords: Concussion, sports related injury, assessment

1. Introduction
One of the main causes of sports-related concussions, or SRCs, in athletes is direct head or neck impact(s) during contact sports. In several contact sports, the prevalence of SRC has increased. For instance, concussion rates in rugby union might reach up to one every game [1].
As a result, SRC poses a serious risk to the health of athletes who play contact sports, where high-impact collisions, for example, are frequent and diagnosis and monitoring are extremely difficult to come by. This makes RTP difficult to determine [2].
In order to prevent detrimental effects on the nervous system, timely detection of SRC is essential to SRC management. Participants who get appropriate SRC care are protected from premature RTP, which may result in a secondary brain injury [3].
Thus, it is critical to diagnose SRC as soon as possible by precise and prompt assessment in order to reduce the hazards to one's short-term health. Evidence demonstrating the possible long-term effects of improper SRC management on brain function and chronic traumatic encephalopathy (CTE) supports this hypothesis. The need for evidence-based monitoring and treatment has grown as a result of long-term neurological abnormalities linked to head trauma and growing public health issues (in many sports) [1, 4].
The prompt and precise identification and handling of SRC in the field continue to pose challenges. Professional teams and sports are examples of this, as they frequently have enough medical personnel on staff to keep an eye out for any odd mechanisms of injury that could result in an SRC. Therefore, accurately identifying SRC is especially difficult in settings with little medical support, such amateur sports teams, where there might just be one coach or first responder [1].
The signs and symptoms of SRC presentation are varied and can include minor ones that are easily overlooked or ones that show up hours or days after the injury.

As a result, difficulties still exist in the RTP protocols and the assessment that comes after SRC (off-field). This is complicated by the fact that standard methods of diagnosing and tracking SRC frequently arise during sporadic snapshot assessments [1].

Digital technologies that are less expensive have been created recently to measure and track results for assessments that are better informed. The efficiency and accuracy of healthcare evaluation could be improved by using such methodologies, which could offer scalable, robust data for better informed and integrated SRC diagnosis to better inform RTP. This narrative review looks at SRC clinical assessment techniques in four main domains (cognitive, visual, motor, and symptom), offering an understanding of the practicality of easily accessible digital techniques. As those digital approaches strive to go from novel technologies to effective, valid, reliable, and integrated clinical tools for SRC, we look at the shared advantages and difficulties they face.

2. Materials and Methods

The approach for this review was developed based on previously reported suggestions and results. The all-original data that included in this review, collected from published articles in Research Gate, Google Scholar, and PubMed. Articles that published in English language are included in the study. The published articles search was done by using the topics of sports related concussion, sports related injury, assessment in concussion. After a thorough assessment of the abstract, introduction, results and discussions, the suitable articles were chosen. References were used to identify additional articles in order to obtain more details and results.

3. Results and Discussion

3.1 Approaches for cognitive assessment

A thorough evaluation of cognitive performance outside of athletics usually entails in-depth interviews that delve into a patient's medical history, educational background, and social circumstances. SRC is limited to concentrating on certain aspects such as executive function, working memory, and short-term memory. Pen and paper assessments include the Standardised Assessment of Concussion (SAC), which is currently a part of the fifth version of the SCAT (SCAT5), the digit span (forward and/or reverse), and the short-blessed test [5].

Compared to pen-and-paper approaches, the introduction of digital-based cognitive exams offers several advantages, such as the ability to calculate objective cognitive metrics (such reaction times) and to randomly assign test trials while automating data collection and processing. The scalable computerised neurocognitive instrument Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) (figure 1) evaluates verbal memory, response time, visual-motor speed, and visual memory [5, 6].

Fig 1: How ImPACT works in assessment

3.2 Approaches for visual assessment

Oculomotor dysfunction has been found to be present in as many as 90% of cases with SRC, which can lead to deficits in both visual and oculomotor speed. The Visual Occulomotor evaluation (VOMS), an eye-tracking examination that uses self-report to evaluate deficits, is one example of a traditional subjective visual evaluation. Other visual exams include the King-Devick (K-D), which measures attention, language function, and quick eye movements indirectly. When it comes to diagnosing athletes with concussions, the K-D test has shown reasonable sensitivity (60%) but poor specificity (39%) [1, 7].

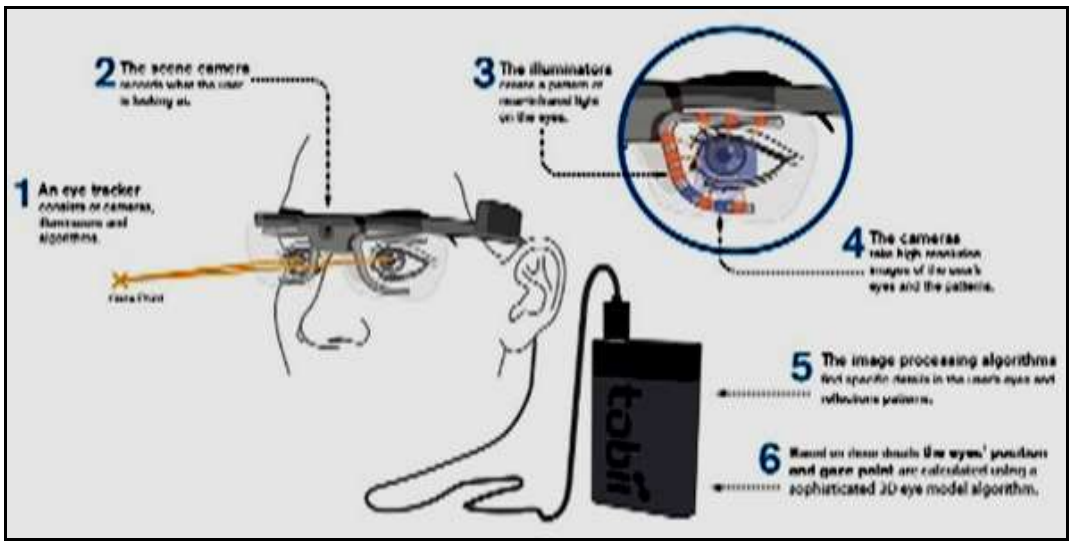

Fig 2: Tobii eye-tracker

Digital non-invasive devices, like eye trackers, can measure visual and cognitive processes by objectively tracking eye movements during lab tasks. Khalife *et al.* emphasise the advantages of utilising the Tobii eye-tracker (figure 2) to investigate fast and dependable eye-movement impairment in SRC assessment for the few research that have sufficient information reported. The latter produces a reflection in the eye by shining a light on it; a high-resolution camera then takes a picture of the reflection-filled eye, which is used to determine the look direction [1, 8].

3.3 Approaches for motor assessment

The Balance Error Scoring System (BESS) is a commonly used evaluation tool for postural stability and balance disorders. It involves asking participants to assume particular positions designed to test their vestibular and motor systems. The BESS is timed with a stopwatch and manually recorded errors (e.g., participant removing hand from waist during single leg stance) to determine the assessment's subjective nature. Because of this, assessor experience has a significant impact on the BESS sensitivity, and research indicates that it is only sensitive during the acute period [9].

The advent of wearables with inertial sensors, like as gyroscopes and accelerometers, has made it easier to do practical instrumented testing of more established techniques, such BESS and Timed-Up-and-Go (TUG). A multi-wearable strategy was used by Celik *et al*. to fully instrument SCAT5. Eight inertial wearables (wrists, legs, lower back) are used to segment-specific components (tandem walk, static balancing, etc.) to provide rich spatial and temporal data with excellent/millisecond resolution connected with each SCAT5 component [10].

3.4 Approaches for symptom assessment

The Post-Concussion Symptom Scale (PCSS), which has been reduced and modified for the 5th edition of the SCAT (SCAT5), evaluates a range of symptoms (0-6 of increasing severity) to provide an overall score. It can be difficult for clinicians, players, and patients to determine whether a patient is ready to resume play because of the wide variation in the severity of symptoms and signs that players describe after an SRC (immediate or delayed onset). In addition to the difficulties associated with subjectivity in self-reported symptomatology, there are major logistical and practical obstacles [11].

Numerous smartphone apps are available to register injuries and track the recovery of SRC patients by reporting symptoms. Applications include the Cleveland Clinic Concussion Application (C3), which collects data on information processing, memory, vision, and response time, and CSX, which is used, for example, by World Rugby. According to Linder *et al.*, using an Electronic Injury Reporting (IR) software offers a helpful digital platform for demographic analysis related to injuries [12].

4. Conclusion

The increasing incidence of SRC and challenges of current diagnosis approaches has illuminated the scale of the problem facing clinicians for routine diagnosis and monitoring. Traditional and subjective assessment will remain a crucial component of SRC assessment. Digital approaches have the potential to transform the way player data can be objectively captured, processed and analyzed enhancing current health care practice in SRC.

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