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Fédération Internationale de Football Association World (FIFA) cup 2018 is over and there are other sports competitions which are happening almost every day in different parts of the world in different countries, level, age, gender, type and duration. Some of the major incidents of head injury during this FIFA 2018 are, Peru's Renato Tapia was knocked flat against Denmark, allowed to play to be substituted 13 minutes later, Morocco's Nordin Amrabat suffered concussion and memory loss following a blow to the head against Portugal, Iceland defender Ragnar Sigurdsson went down being struck in the back of the head against Nigeria, playing with a bandage and then substituted in the 65th minute and Peru's Jefferson Farfan was left temporarily paralyzed during the World Cup training.

Injuries related to sports are mainly seen in hockey, football, rugby, basketball, cycling, boxing, snowboarding, horse riding and soccer. One of the common problems faced during sports is concussion and hence this article aims to define its epidemiology, pathophysiology and management along with a short review of literature.

Concussion in sports (CIS) is a common type of injury related to sports which must be recognized and treated quickly with a decision whether the sportsperson can return to play or not.² The simplest definition of CIS will be trauma leading to symptoms of mild head injury. This definition will though not tell of any internal injuries, future neuro-psychological problems or any other future complications. The earliest description of concussion was done by the Persian Physician Rhazes who defined transient neurological syndrome secondary to head shaking.²³ There are now many studies and scales available in literature that have defined the severity of concussion many of which have not been scientifically proven.¹⁶ It is well known now that the symptoms causing CIS varies from different individuals and the type of injury and its effect too depends on the kinetics of the brain movement inside in relation with the fixed structures like bone and dura. Many different articles

Concussion Injury In Sports: Brief Review Of The Epidemiology And Initial Management

have investigated the characteristics of CIS in relation to mild head injury and the type of sports with different bodies having different methods of diagnosis and criteria for further play (**Figure 1**).^{15,20}

Definition and Epidemiology: Concussion is defined by Merriam-Webster dictionary as, **a:** a stunning, damaging, or shattering effect from a hard blow; especially: a jarring injury of the brain resulting in disturbance of cerebral function. **b:** a hard blow or collision. It means to "shake violently" from the Latin word *Concutere*. In the USA alone around 3.8 million concussions are reported each year and the many still go unreported. Concussion can occur in upto 14% of all sports related injuries with 700,000 concussion between 2005 -2010 and 13% of them being recurrent concussion.⁵ It is more common in female sports, younger age, and in actual matches than during training and certain type of sports as stated above.^{10,21} In males its due to player to player contact injury and in females due to trauma by fall, equipment or surface.⁶ Most of the symptoms last less than 72 hours and the majority will resolve within a week and brief loss of consciousness or seizure may not lead to delay in recovery.⁴ The majority (80%) will be asymptomatic within 10 days and the rest may exhibit symptoms for few weeks.

Pathophysiology: Unlike head injury direct impact to the head is not needed for concussion which is caused by rotational and angular forces leading to neuronal disruption leading to potassium efflux, release of calcium and excitatory amino acids leading to paradoxical blood flow.^{14,18} This leads to neuronal injury that may persist for weeks and hence delaying the recovery of the patient. Studies have shown that mild head injuries can lead to increases in hyperphosphorylated paired helical filament 1 tau in the hippocampus that produces long term behavioral deficits.⁸ Another study showed that a panel of biomarkers, increases in NF-L and Tau markers, TNF α and IL8 markers, [SYP]CD11b+/[CD81]CD11b+, have the potential to surrogate chronic neural damage in CIS.^{12,27}

Diagnosing CIS: The first step is to make the diagnosis of concussion which will help in early recovery, risk of further complications, reduce other musculoskeletal injuries, and other neurological or psychiatric illness. Due to the lack of a proper clinical or diagnostic pattern it is often a clinical diagnosis.¹⁹ CIS diagnosis will depend on the severity of the injury, the complaints by the athlete and the signs seen by the attending medical person. The common symptoms are given in Table 1.

Common symptoms of concussion
Confusion
Slurred speech
Headache
Clumsiness
Blurring of vision
Nausea
Disorientation
Inappropriate behavior or response
Memory loss
Lack of concentration
Tinnitus
Convulsions
Decreased or increased sleep
Sadness
Depression
Anxiety/nervousness
Vacant stare
Fatigue

Table 1: Some of the common symptoms of concussion.

Concussion can also be defined as mild, moderate or severe. **Grade 1** concussion, symptoms last for less than 15 minutes. There is no loss of consciousness. **Grade 2** concussion, there is no loss of consciousness but symptoms last longer than 15 minutes. **Grade 3** concussion, the person loses consciousness, sometimes just for a few seconds. A history of CIS is associated with sustaining another concussion and the number of CIS, children and adolescents, duration or Grade and severity often will prolong the recovery. Other factors like headache more than 60 hours, presence of more than three symptoms are associated with prolonged recovery.

The initial examination starts with airway, breathing and circulation followed by cervical spine injury assessment. Most of these findings are normal in CIS and may need some form of assessment form to rule out severe concussion. The athlete must be barred from return to play till concussion is ruled out.

Signs of concussion and check tools:

Assessment tools:

There is no single method to diagnose CIS and in literature there are many tools that have been described. The following Table gives the presently available tools (Table 2).²⁶

Management of CIS

Sport-specific challenges for CIS

Second impact injury: this was first described by Schneider in 1973 and then used in an example of a football player who died with no apparent trauma but had sustained an injury 4 days earlier by Saunders and Harbaugh.^{24,25} Classically the athlete suffers a concussion and before the symptoms resolve they return to the sport during which they suffer a relatively minor trivial injury. This leads to a stunned athlete who can resume the play but then suddenly they collapse with dilated pupils and respiratory failure. Pathologically it is due to cerebrovascular dysregulation with edema and herniation. This term means that a person is prone to repeated concussion after the first injury and hence must be carefully observed and prevented to play, to prevent further complications.

Using video in CIS

With the use of more and more technology in sports it is common to find and record an impact or injury that can be replayed again and again to study the nature of the severity of injury. Application of such in sports has led to the better understanding of CIS which can allow to individual or organizational policy making and management. Although video recording helps one must still understand its limitations in recording, showing the angle of impact or response from the athletes.¹³

The initial examination will either confirm or rule out CIS and hence the athlete can either return to play/ home care with observation or will need further medical attention in a hospital. Rest is the most important prevention and precaution to be taken in CIS. In case of Grade 2, 3 concussion the athlete needs to be taken to a medical center with neurosurgical facilities. Repeated waking up is controversial in the detection of CIS.⁹ Some patients may need neuroimaging to further diagnose severe head injury the guidelines of which have been laid down by the American College of Emergency Physicians, American Academy of Pediatrics and the American Association of Family Physicians (Table 3).^{11,26,28}

Table 3. The present guidelines for neuroimaging in concussion from American Association of Family Physicians, American Academy of Pediatrics and the American Academy of Family Physicians.^{11,26,18}

Type / examples	Characteristics
Symptom checklists <i>Postconcussion Symptom Scale</i> <i>Graded Symptom Checklist</i> <i>Head Injury Scale</i> <i>McGill Abbreviated Concussion Evaluation (ACE)</i> <i>postconcussion symptom scale</i> <i>HeadMinder</i> <i>Concussion Symptom Inventory</i>	<ul style="list-style-type: none"> The most commonly used type of concussion assessment tool Quick, easy, cost-effective tool with good sensitivity; allows athletes to self-report symptoms Cautions: symptoms may be delayed, may not be reported, or were already present at baseline Most checklists developed using clinical judgment; the Concussion Symptom Inventory is the only empirically derived symptom checklist
Neuropsychological tests Written <i>Trail Making Test</i> <i>Digit Symbol Substitution Test</i> <i>Controlled Oral Word Association Test</i> <i>Hopkins Verbal Learning Test</i> <i>Stroop Color and Word Test</i> Computer-based <i>HeadMinder</i> <i>CogSport</i> <i>ImPACT</i> <i>Automated Neuropsychological Assessment Metrics</i>	<ul style="list-style-type: none"> Designed to identify subtle cognitive deficits Written tests are labor intensive and must be interpreted, whereas computer-based tests can be administered rapidly and to multiple patients simultaneously Results best interpreted when compared with baseline data; affected by psychiatric disorders, physical symptoms, cultural factors, and motivation/effort These tests are not validated, and no data demonstrate that they affect outcomes when used to guide return to play There are limited baseline data in children younger than 12 years; child-specific computerized tests are under development
Postural stability testing <i>BESS (and modified version</i> <i>SOT</i>	<ul style="list-style-type: none"> Very sensitive for concussion diagnosis, but there are limited data regarding its use in monitoring recovery SOT is the preferred test, but it is not portable; BESS is inexpensive and easy to administer on the sideline of a sporting event Instability usually lasts three to five days after a concussion occurs
Sideline assessment tools <i>SAC</i> <i>SCAT</i> <i>SCAT2</i>	<ul style="list-style-type: none"> A single, simple tool to assess a variety of domains in the initial concussion assessment Often used to monitor the recovery process SAC can be used immediately after injury to evaluate orientation, memory, concentration, and delayed recall; validated as a sideline tool for athletes junior high school-aged and older; emergency department version is validated in adults SCAT2 combines multiple assessment tools (symptom checklist, concentration and memory tasks [Maddock's questions], SAC, BESS, and Glasgow Coma Scale); it is not validated but is widely used and the most sophisticated sideline tool available
BESS = Balance Error Scoring System; SAC = Standardized Assessment of Concussion;	SCAT = Sport Concussion Assessment Tool; SOT = Sensory Organization Test.

Table 2: Common tools to examine concussion along with their characteristics.²⁶

CIS Management at the field

When an athlete sustains an injury then the medical professional, trainer or coach should immediately examine with one of the CIS assessment tools. If it suspected the athlete should be barred from further play and continuous observation should be done and the index of medical

center referral or neuroimaging should be kept low. Unless the symptoms have remitted they should not be allowed to return to sports.

Treatment of CIS

All CIS athletes are followed with a graduated play protocol each step of which requires 24 hours. At the end

Indications for Neuroimaging

Guidelines from the American College of Emergency Physicians

Imaging is indicated in patients with a loss of consciousness or amnesia if at least one of the following is present: headache (diffuse), vomiting, age older than 60 years, intoxication, deficits in short-term memory, evidence of trauma above the clavicle, seizures, GCS score of less than 15, focal neurologic deficits, coagulopathy.

Imaging is indicated in patients with no loss of consciousness or amnesia if at least one of the following is present: focal neurologic deficit, vomiting, severe headache, age older than 65 years, signs of basilar skull fracture, GCS score of less than 15, coagulopathy, significant mechanism of injury (e.g., ejection from vehicle, pedestrian struck by vehicle, fall from a height greater than 3 ft or five stairs).

Guidelines from the American Academy of Pediatrics and the American Academy of Family Physicians

Perform imaging in patients with loss of consciousness of greater than 60 seconds, evidence of skull fracture, or focal neurologic findings.

Consider imaging or observation if patient has brief loss of consciousness.

Note that nonspecific signs (e.g., immediate seizures, headache, vomiting, lethargy) increase the likelihood of intracranial injury, but have very limited predictive value.

the athlete needs a detailed checkup and then only allowed to play (Table 4).¹⁷ recent studies with functional MRI has shown that even with minor head injury players can have abnormal neuropsychological results which are called as subconcussion that can progress to chronic traumatic encephalopathy.³ Although well documented for adults the efficacy of this graduated scale is unknown in younger children.

There are no medications for CIS and most are used for symptomatic treatment of headache, nausea, vomiting, sleep disturbances or psychological problems. Rehabilitation, Buffalo concussion treadmill test, aerobics, exercises may be beneficial in CIS.²²

Recovery in CIS²²

The definition of recovery is ill defined for CIS with delayed recovery upto a month after injury. The cognitive or academic recovery may take time and needs to be further studied. 15% of the athletes may return to play within one day and the same number took a month to return across younger age, high school and college groups. Adolescents may have longer recovery from CIS leading to altered academic performance which may suggest the younger brain may be more susceptible to injury. All aspects of the athlete's activity including, school, work, and daily activities must be assessed thoroughly before release from medical care. Neuropsychological, neurocognitive, motor, balance and physical examination must be made to avoid missing important signs of CIS.

Concussion awareness and education

All the sports can lead to CIS injury and awareness and education for the athlete, coach, organization, family and

schools is important to avoid this injury. Some sports like football which has heading as part of the game it is difficult to control impact injury and presently there are no devices available to protect form CIS. Protective equipment like helmets, padding and covers can theoretically lower the risk of CIS injuries by 85% if it is worn properly. Children must always be supervised, rules of the game or the pool or outdoor park must be followed, and diving is discouraged in less than 12 feet deep pool/river/ponds. Avoid sports if ill, be aware of neighboring players and proper maintenance of the equipment can reduce injuries. Use of alcohol or other neuro depressant medication is to be banned and seat belts must be worn in all high speed activities. Few studies have though shown no benefit of using helmets to prevent concussion, subconcussion or rotational injuries and thus strict rules implementation, avoidance of impact, preventing fights or collision can reduce CIS injuries.²⁶

Education and awareness training including information on the risk of each sport is important not only to the athletes and the coach but also to the public. Teaching should be started as a curriculum in schools regarding the dangers of concussion and the importance of safe play will definitely help to reduce CIS injuries. The coach and the supporting team must be regularly appraised regarding new developments in the management of concussion.

Current and future research

Although much has been studied in CIS pathology yet its exact cause remains unknown. Future studies in animal models and artificial dummy models could help prevent CIS injuries.^{1,7} The current research of MRI on

Concussion in sports

Organisation, year published	Definition of concussion	Domains assessed	Key features	Definition mTBI? Link concussion - TBI?	Notes
Concussion in sports group, ¹² 28–30 2002, 2005, 2009, 2013	<p>'A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces' that 'may be caused by a direct blow to the head, face, neck or elsewhere in the body with an impulsive force transmitted to the head'.</p> <p>Common features include:</p> <ul style="list-style-type: none"> ▶ Rapid onset of short-lived impairment of neurological function that resolves spontaneously ▶ May result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury ▶ Graded set of neurological syndromes that may or may not involve an LOC. Resolution of the clinical and cognitive features typically follows a sequential course. In some cases symptoms may be prolonged. ▶ Typically associated with grossly normal structural neuroimaging studies. 	<ul style="list-style-type: none"> ▶ Clinical symptoms (physical, cognitive, emotional) ▶ Physical signs ▶ Cognitive impairment ▶ Neurobehavioural features ▶ Sleep disturbances 	<i>Onset:</i> rapid <i>Duration:</i> short-lived <i>Mechanism of impairment:</i> functional disturbance rather than structural injury <i>LOC:</i> may or may not <i>Resolution:</i> sequential <i>Neuroimaging:</i> no abnormalities on standard structural neuroimaging	No (concussion is considered as subset of TBI)	This definition also comments on typical neuroimaging features in concussion.
American Medical Society for Sports Medicine, ³¹ 2013	'A concussion is defined as a traumatically induced transient disturbance of brain function and is caused by a complex pathophysiological process. Concussions have also been referred to as mild traumatic brain injuries (mTBI). While all concussions are mTBIs, not all mTBIs are concussions. Concussions are a subset of mTBIs, on the less-severe end of the brain injury spectrum and are generally self-limited in duration and resolution'.	<ul style="list-style-type: none"> ▶ Symptoms and signs (physical, cognitive, emotional, sleep) 	<i>Onset:</i> not specified <i>Duration:</i> transient, self-limited <i>Mechanism of impairment:</i> functional disturbance <i>LOC:</i> may or may not <i>Resolution:</i> not specified <i>Neuroimaging:</i> not specified	No (concussion is considered as subset of mTBI)	
National Athletic Trainers' Association, ^{33 34} 2004, 2014	'Trauma-induced alteration in mental status that may or may not involve loss of consciousness'	Not specified	<i>Onset:</i> not specified <i>Duration:</i> not specified <i>Mechanism of impairment:</i> not specified <i>LOC:</i> may or may not <i>Resolution:</i> not specified <i>Neuroimaging:</i> not specified	No (concussion and mTBI are used interchangeably)	
American Academy of Neurology, ^{32 46} 1997, 2013	'Concussion is a trauma-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion. The confusional episode and amnesia may occur immediately after the blow to the head or several minutes later'.	<ul style="list-style-type: none"> ▶ Clinical symptoms (physical, cognitive, emotional) ▶ Physical signs ▶ Cognitive impairment ▶ Sleep disturbances 	<i>Onset:</i> immediate or within mins <i>Duration:</i> not specified <i>Mechanism of impairment:</i> not specified <i>LOC:</i> may or may not <i>Resolution:</i> not specified <i>Neuroimaging:</i> not specified	No (concussion and mTBI are used interchangeably)	1997 definition was used as the 2013 revision provided a shortened definition only.
Team Physician Consensus statements (AAFP, AAOS, ACSM, AMSSM, AOSSM, AOASM), ^{35 36} 2006, 2011	<p>'Concussion or mild traumatic brain injury (mTBI) is a pathophysiological process affecting the brain induced by direct or indirect biomechanical forces'.</p> <p>Common features include:</p> <ul style="list-style-type: none"> ▶ Rapid onset of usually short-lived neurological impairment, which typically resolves spontaneously ▶ Acute clinical symptoms that usually reflect a functional disturbance rather than structural injury ▶ A range of clinical symptoms that may or may not involve LOC ▶ Routine neuroimaging studies are typically normal 	<ul style="list-style-type: none"> ▶ Clinical symptoms and signs (cognitive, somatic, affective, sleep disturbances) 	<i>Onset:</i> rapid <i>Duration:</i> short-lived <i>Mechanism of impairment:</i> functional disturbance rather than structural injury <i>LOC:</i> may or may not <i>Resolution:</i> spontaneous <i>Neuroimaging:</i> no abnormalities on standard structural neuroimaging	Combined definition for mTBI and concussion	This definition also comments on typical neuroimaging features in concussion.
Congress of Neurological Surgeons, ³⁷ 1966	'a clinical syndrome characterized by the immediate and transient post-traumatic impairment of neural function such as alteration of consciousness, disturbance of vision or equilibrium due to mechanical forces'.	Not specified	<i>Onset:</i> immediate <i>Duration:</i> transient <i>Mechanism of impairment:</i> not specified <i>LOC:</i> may or may not <i>Resolution:</i> not specified <i>Neuroimaging:</i> not specified	Not specified	

*In case of revised concussion definitions from the same group, the most recent version was considered if not stated otherwise.

AAFP, American Academy of Family Physicians; AAOS, American Academy of Orthopaedic Surgeons; ACSM, American College of Sports Medicine; AMSSM, American Medical Society for Sports Medicine; AOSSM, American Orthopaedic Society for Sports Medicine; AOASM, American Osteopathic Academy of Sports Medicine; LOC, loss of consciousness; mTBI, mild traumatic brain injury.

Figure 1: Definition of different bodies of Concussion.

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective(s) of each stage
1. No activity	Symptom-limited physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming, or stationary cycling, keeping intensity, 70% of maximum permitted heart rate; no resistance training	Increase heart rate
3. Sport specific exercise	Skating drills in ice hockey, running drills in soccer; no head-impact activities	Add movement
4. Noncontact training drills	Progression to more complex training drills, e.g., passing drills in football and ice hockey; may start progressive resistance training	Exercise, coordination, and cognitive load
5. Full-contact practice	After medical clearance, participation in normal training activities	Restore confidence and assessment of functional skills by coaching staff Return to play Normal game play

Table 4. The graduated return to play protocol.¹⁷

subconcussion and in specific cohorts of athletes can help increase our knowledge of CIS.

Summary

CIS is a complex injury the pathogenesis of which is yet to be fully understood. If not recognized early, it can lead to disastrous consequences including death. The entire supporting team should be aware of such injury and its clinical manifestations which if suspected the athlete must be barred from further play and given medical care. Recovery must be closely followed in a graduated step wise manner and made clear not to take part in physical impact sports. Proper education of the public, precautions taken during sports can help reduce CIS injury.

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