52 Sport-related Concussion: Experience from the National Football League

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52.1 Preseason Baseline Evaluation

Prior to the start of football season, all players are required to review educational materials on concussion and undergo a preseason physical examination. Educational resources assist players in identifying signs and symptoms of concussion and emphasize the importance of removal from play after injury. Preseason physical examinations include a comprehensive interview of past medical and concussion history, neurological examination, and baseline testing [1]. The NFL has adopted a baseline assessment model for managing concussion [2], in which athletes are required to complete mental status testing and neuropsychological baseline testing when noninjured that is used as a "control" should a player sustain a concussion in the future. Baseline testing is particularly important for individuals with a history of a neurodevelopmental disorder such as attention deficit hyperactivity disorder [3, 4] or who have above average intelligence [5] who are not well represented by available normative data [6, 7]. The NFL does not require it, but it is often recommended that all baseline testing includes validity indicators to prevent athletes from "gaming" their baseline testing [8–10].

52.2 Sideline Assessment and Management of Concussion

Players suspected of sustaining a concussion on field must adhere to a strict concussion management protocol outlined by the NFL's Head, Neck, and Spine Committee. The NFL's sideline concussion protocol focuses on (1) detection of the injury and (2) evaluation of the player for concussion or other neurological pathologies [1].

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Players suspected of a concussion are immediately removed from play for further evaluation to ensure the safety of the athlete [11–14].

52.2.1 Detection of Concussion

Identification of on-field concussion is executed by the team medical staff, coaches, teammates, and/or player. Given the tendency for athletes to underreport their symptoms of concussion or for a general lack of player awareness [15–18], the NFL has implemented an organized team of medical personnel to watch closely for concussions during games. Personnel required include the team physician, club athletic trainer, booth athletic trainers (also known as the "eyes in the sky"), and an unaffiliated neurotrauma consultant (UNC) [1]. Personnel are trained to monitor players for acute signs and symptoms of concussion, as outlined in Table 52.1, after sustaining a traumatic blow to the head or body. With increasing education around concussion, it is common for coaches and/or teammates to report a suspected concussion as well, especially if the player in question is not exhibiting obvious or outward signs/symptoms.

Fact Box 1
A loss of consciousness is not required for a diagnosis of concussion.

Contrary to popular belief, a loss of consciousness (LOC) is not required for a diagnosis of concussion [13, 19–21], and LOC or posttraumatic amnesia [22–24] at the time of injury does not always equate to a more severe concussion [22, 23, 25–27]. On-field endorsement of dizziness [25, 27] and posttraumatic migraine [28–30] may be better clinical indicators of length of recovery time from concussion. If a player is suspected of sustaining a concussion, the player is immediately removed from play and evaluated by medical personnel. There are six "Go/No-Go" criteria that require immediate removal of the NFL player from the field without chance of return. They include LOC, confusion, amnesia, new or persistent symptoms (e.g., headache, nausea, dizziness), abnormal neurological findings, and progressive or worsening symptoms [1].

Table 52.1 On-field acute signs and symptoms of concussion

Acute (observable) signs of head injury	Concussion symptoms (player report)
Loss of consciousness	Headache
Incoordination/imbalance	Nausea
Dazed	Photosensitivity/ phonosensitivity
Disorientation/confusion	Dizziness
Clutching head	Balance/coordination problems
Physically slow	Tinnitus
Vomiting	Cognitive slowness
	Visual disturbance
	Amnesia (retrograde or anterograde)

It is important to remove players immediately after a potential injury to rule out critical neurological pathology and prevent from additional blows to the head while the brain is in a vulnerable state of neurometabolic crisis [19, 21] from concussion [31–34]. Football players who continue to play immediately after sustaining a concussion are at an increased risk of a prolonged recovery. In fact, a recent manuscript shows that athletes who continue to play after experiencing concussion symptoms may double their recovery time [35].

Fact Box 2
Athletes who continue to play after sustaining a concussion may double their recovery time from the injury.

52.2.2 Evaluation of the Player for Concussion

Once removed from play for a concussion evaluation, sideline assessment of the athlete includes an evaluation of concussion signs and symp-

Table 52.2 Modified Maddock's questions in NFL concussion checklist

Modified Maddock's questions
1. Where are we?
2. What quarter is it right now?
3. Who scored last in the practice/game?
4. Who did we play last game?
5. Did we win the last game?

toms, a focused neurological examination, and a modified Maddock's questioning [1, 36] for evaluation of orientation and recent memory. Traditional orientation questions (e.g., person, place, and time) have been demonstrated to be unreliable for sideline assessment of sports concussion when compared to recent memory questioning (Table 52.2) [13, 36, 37]. If a player is suspected of having a concussion or there are abnormal findings on the sideline assessment, then the player is taken to the locker room for further evaluation.

The NFL utilizes an NFL-specific tailored version of a standardized sideline assessment tool for concussion, known as the Sideline Concussion Assessment Tool – 3rd Edition (SCAT3), for brief cognitive and mental status testing once an athlete is removed from play [1, 37, 38]. Results of testing are compared with the player's preseason baseline testing. The player is not permitted to return to the same game or practice if suspected of a concussion and is required to enter the NFL concussion protocol for return to football participation. To return to contact football, the player must be cleared by his team physician and an independent concussion specialist in accordance with international guidelines [1, 11–13, 39, 40].

52.3 In-Office Evaluation of Concussion

Initiation of the NFL concussion protocol first results in the player receiving education surrounding the expected signs and symptoms of concussion. Injured players are then managed by their team medical staff and/or in-office by a licensed concussion specialist. The NFL requires concussed players to return to their baseline functioning in terms of their report of symptoms and neurological/neurocognitive exam before reengaging in physical activity [1]. Aside from the recommendation of serial neuropsychological testing to track players' neurocognitive recovery [1, 2] post-injury, there is little direction provided by the NFL and international concussion consensus statements regarding the in-office management and treatment of concussion to facilitate concussed players' return to baseline functioning [11–14, 39].

Current guidelines requiring a return to baseline status are helpful for preventing a premature return to play. The recommendations vary among team physicians and athletic trainers in the NFL. The role of "active rehabilitation" from concussion is in evolution and being studied. A "one-size-fits-all" approach to concussion management is no longer embraced [41]. In the recent past, to promote recovery post-injury, most players are prescribed physical and some form of cognitive rest until asymptomatic; however, there is sparse evidence to support strict rest for managing concussion [42–45]. A randomized control study [46] demonstrated that strict rest after concussion may actually lead to a slower recovery and worsened symptoms [46–49]. A recent consensus meeting held in Pittsburgh, Pennsylvania, among leading concussion experts, including NFL physicians and concussion consultants, on the "Targeted Evaluation and Active Management (TEAM) Approaches to Treating Concussion," indicated that 97% of experts believed that strict rest may have detrimental effects after concussion and may not be an effective strategy for all concussions. Furthermore, 100% of these experts advocated for an individualized, active treatment approach to concussion, in which treatment was matched to the individual clinical profile of the concussed athlete [41]. To improve treatment approaches, the NFL, in collaboration with other institutions, has launched a $60 million Head Health Initiative to expedite development of better diagnostic tools, improved protective gear, and better treatment techniques for concussion [50].

52.3.1 Diagnostic Assessment of Concussion

To develop an individualized treatment plan for concussion, a comprehensive, multimodal diagnostic assessment is warranted in order to delineate the clinical profile of the concussed player [13, 51–53]. The NFL currently employs a neurological exam with mental status, neuropsychological, and balance testing for their initial assessment [1] and has recently started to implement other cutting-edge measures sensitive to concussion [50]. Traditional neurodiagnostic techniques (e.g., computed tomography, magnetic resonance imaging), although helpful in ruling out intracranial bleeds and/or skull fracture, are not recommended for determining diagnosis of concussion. They are typically not sensitive to concussion and may involve potentially harmful radiation exposure [54, 55]. International guidelines recommend that the in-office assessment of concussion includes a thorough clinical interview, a subjective report of symptoms, and the use of empirically established, objective tools sensitive to concussion [13, 51]. Table 52.3 provides an overview of a multimodal approach to concussion diagnosis and evaluation utilized by concussion consultants for the Pittsburgh Steelers [13, 51, 52, 56, 57]. The multimodal assessment includes a clinical interview, symptom report, cognitive testing, and vestibular-oculomotor screening.

Table 52.3 Multimodal diagnostic assessment of concussion

Assessments	Brief description
Clinical interview	Establish rapport, determine mechanism of injury, acute markers of injury, acute and chronic symptom presentation, detailed personal and family medical history, review of medical records, identify concussion risk factors, psychosocial history
Symptom report	Self-report symptom questionnaires
Cognitive testing	Computerized neurocognitive testing/paper-and-pencil neuropsychological testing
Vestibular-oculomotor screening	Balance testing, vestibular-ocular reflex, visual motion sensitivity, oculomotor screening, near point of convergence

52.3.1.1 Clinical Interview

Establishing a trusting relationship with the player and team organization is important for gaining an understanding of the player and facilitating comprehensive care. Sideline evaluations conducted by the team medical staff are useful in identifying the mechanism of injury, acute signs and symptoms of concussion, and performance on mental status testing in order to gain an appreciation for the severity and nature of the injury. Detailing the personal and family medical history is important for identifying risk factors of concussion. Records from the player's medical history collected in the preseason evaluation by the team medical staff should be utilized when possible for verification of medical history.

A thorough review of concussion risk factors is vital in order to prognosticate recovery time. Most athletes are expected to recover within 1 to 3 weeks of injury; however, 10–20% of athletes in the general population do not recover in this timeframe [23, 53, 58]. The presence of multiple prior concussions [27, 59–61] or a personal or family history of the following preinjury conditions have been identified as potential risk factors for a protracted recovery: neurodevelopmental/neurological condition [27, 62–64], psychiatric condition such as anxiety/depression [65–69], migraine [28–30], and/or sleep disturbance [70, 71]. Other suspected risk factors that have yet to be fully established include a personal or family history of oculomotor dysfunction [72, 73] or motion sensitivity such as vertigo [53, 74–76]. An understanding of these risk factors can set the stage for conceptualizing a player's clinical profile and necessary treatment.

Psychosocial history is also pertinent to conceptualizing the functional challenges and limitations a player may experience after a concussion. Players may endorse different types of symptoms in specific environments (e.g., being in the locker room, riding a bus, and watching film) that can provide useful information about the deficits and functional impairments from the concussion. For instance, a player who experiences a headache while watching film may suggest the presence of oculomotor dysfunction due to the visual demand involved in this task. There may also be environ-

mental stressors that can play a role in the player's response to injury, including a lack of social support in the nearby area, external pressures to return to play quickly, and fears surrounding long-term health. The overall goal of the clinical interview is to establish concussion risk factors, address the player's concerns, and determine specific functional limitations from the injury.

52.3.1.2 Symptom Report

A concussion can result in a myriad of physical, cognitive, sleep, and mood symptoms. Table 52.4 details some of the most common symptoms of concussion that are often reported on post-concussion symptom questionnaires [77–79]. The pattern of symptom reporting can provide useful information regarding the clusters of symptoms most bothersome to the player [30, 51–53, 73]. Athletes who report a higher total symptom score upon initial evaluation tend to take a longer time to recover from concussion [24, 80, 81]. Although evaluating symptoms is an important aspect of the assessment, objective measures should also be utilized in conjunction with self-report data given athletes' tendency to underreport their symptoms of concussion [15, 18, 82–84].

Table 52.4 Common symptoms of concussion

Common symptoms
Headache
Nausea
Vomiting
Balance problems
Dizziness
Fatigue
Trouble falling asleep
Sleeping more than usual
Sleeping less than usual
Drowsiness
Sensitivity to light
Sensitivity to noise
Irritability
Sadness
Feeling more emotional
Numbness or tingling
Feeling slowed down
Feeling mentally "foggy"
Difficulty concentrating
Difficulty remembering
Visual problems

Fact Box 3
Athletes who report a greater number of symptoms upon initial evaluation tend to take longer to recover from concussion.

52.3.1.3 Cognitive Testing

Neuropsychological testing has been recognized by international guidelines as a valid and reliable tool for the objective evaluation of concussion [11–14]. Neuropsychological testing can be administered one on one through paper-and-pencil tests or in a computerized format with all test instructions embedded within the computer program. Computerized neurocognitive testing is recognized as one of the most widely used assessments for concussion management [85, 86], and one tool, ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing), has recently become the first device for concussion assessment approved by the Food and Drug Administration (FDA) [87]. It is sensitive in detecting concussed from non-concussed athletes, can be serially administered to track recovery over time, and has prognostic value in estimating length of recovery time [18, 81, 84, 88]. Athletes who are reportedly asymptomatic can still demonstrate deficits on computerized neurocognitive testing [18, 84].

52.3.1.4 Vestibular-Oculomotor Screening

The vestibular system is a complex sensory system that allows for neural maintenance of balance/postural control and stabilization of vision during movement. When this sensory system is disturbed after a concussion, it can result in subjective complaints of dizziness, vertigo, nausea, light-headedness, unstable vision, imbalance, and motion discomfort [89–93]. Given that nearly 40% of athletes report balance impairment [78] and 50%

Table 52.5 Vestibular/Ocular Motor Screening (VOMS) for concussion

	Headache (1–10)	Dizziness (1–10)	Nausea (1–10)	Fogginess (1–10)
Baseline symptoms (at rest)				
Smooth pursuits				
Saccades – horizontal				
Saccades – vertical				
Convergence (near point)[a]				
Vestibular-ocular reflex (VOR) – horizontal				
Vestibular-ocular reflex (VOR) – vertical				
Visual motion sensitivity test				

[a]Near point of convergence measurements are averaged across three measurement trials

endorse dizziness [80] after a concussion, a thorough evaluation of the vestibular-oculomotor system is recommended [51, 93]. Balance testing is currently utilized by the NFL to assess disturbance of the vestibulospinal tract [1, 91, 94, 95], and some teams have begun to implement screening of dynamic vestibular functions (e.g., vestibular-ocular reflex, visual motion sensitivity) that are involved in the stabilization of vision and tolerance of dynamic movement [50, 93]. Disruption of vestibular reflexes can be a contributor to players' intolerance of exercise post-injury and is associated with increased recovery time following sport-related concussion [74, 89, 90].

Oculomotor abnormalities in which there is a deficit in the neural control of eye movements are also common following concussion. There are multiple oculomotor abnormalities that can occur after a head injury, including abnormal eye movement and function [96]. For example, a convergence insufficiency occurs when there is a reduced ability for the eyes to team toward each other upon near vision. Athletes with a sport-related concussion are 10 times more likely to demonstrate a convergence insufficiency when compared to the general population [72, 73]. Athletes with oculomotor dysfunction often report increased symptoms when engaging in visually demanding tasks such as watching film, engaging in computer work, and reading [72, 73]. Concussion consultants for the Pittsburgh Steelers have developed and validated a brief vestibular-ocular screening tool that can be used for in-office or sideline assessment of vestibular-oculomotor dysfunction; see Table 52.5 [74, 78, 93]. This Vestibular/Ocular Motor Screening (VOMS) tool evaluates multiple vestibular-oculomotor functions and has athletes endorse their experience of headache, dizziness, nausea, and fogginess on a scale from 1 to 10 at rest and with each assessment. The VOMS can be serially administered to track recovery over time.

52.3.2 Individual Clinical Profiles and Targeted Treatment for Concussion

Multimodal assessment of concussion as outlined above facilitates conceptualization of the player's clinical profile and trajectory from the injury. Establishment of the clinical profile allows for targeted, active rehabilitation from concussion rather than a "one-size-fits-all" approach. In the first few days of injury, athletes may demonstrate a global concussion presentation that includes primarily cognitive deficits, fatigue, and migraine symptoms [78]. It is suggested by experts that beyond the acute stage of injury, athletes begin to demonstrate a more delineated clinical profile/s from the concussion [41, 51, 52, 56].

Utilizing information gleaned from sideline assessments, clinical interview, preexisting risk factors, record review, symptom report, cognitive

testing, and vestibular-oculomotor screening, a comprehensive and targeted rehabilitation program can be initiated for more active treatment and rehabilitation of concussion. Conceptualization of the clinical profile/s should incorporate a careful consideration of concussion risk factors, mechanism of injury, symptoms, functional deficits, and abnormalities on objective examination. Summarized in Table 52.6 are emerging clinical profiles from concussion. Each profile is associated with specific symptoms, objective test findings, and rehabilitation recommendations [41, 53]. Establishment of these clinical profiles is in its infancy and requires further empirical investigation which is underway by multiple institutions, including studies funded by the NFL [41, 50–53]. Once a player's profile is determined, treatment can begin to actively rehabilitate the player for return to football.

Fact Box 4
Concussion is an individualized injury that has different clinical profiles that require targeted treatment rather than a "one-size-fits-all" approach.

52.3.3 Return to Play Criteria

International return to play (RTP) guidelines are standardized in order to protect athletes from returning to sport participation prematurely. A player is never returned to play on the same day as a concussion is diagnosed. In order to receive full clearance back to contact football, these guidelines require an athlete to be (1) asymptomatic at rest, (2) asymptomatic with noncontact exertion, and (3) at their neurocognitive baseline. These criteria protect and prevent athletes who still demonstrate signs and symptoms of concussion from returning to football while the brain is still recovering from injury [13]. If an athlete has not met these criteria or there is a question of criteria being met, then holding an athlete from RTP is warranted as additional head insult while the player is still concussed can have potentially deleterious outcomes [31, 32].

Fact Box 5
A player is never returned to play on the same day as a concussion is diagnosed. In order to receive full clearance back to play, international guidelines require an athlete to be (1) asymptomatic at rest, (2) asymptomatic with noncontact exertion, and (3) at their neurocognitive baseline.

The NFL's Head, Neck, and Spine Committee's Return to Participation Protocol [1] and International Consensus Statements [13] advocate for a graduated, stepwise return to physical exertion. The NFL exertion protocol is initiated once the player returns to their baseline status in terms of symptoms and neurological examination. Stepwise exertion protocols such as the NFL's often require an athlete to start with low-level physical activity and (suggest but do not require) the athlete remain asymptomatic for 24 h at each stage before progressing to the next level.

This stepwise, homogenous approach for returning to physical activity can be problematic in select athletes. Firstly, as noted in the treatments for different concussion trajectories, some players can tolerate physical activity early after the injury. Participation in exercise may actually expedite some players' recovery time, while players with different concussion trajectories may be highly symptomatic with certain types of exertion [49, 56, 89, 90, 97, 98]. The clinical profile of the athlete plays a role in their tolerance of particular physical activity (e.g., heavy aerobic activity versus dynamic movement). A "one-size-fits-all" approach is again not uniformly successful for prescribing exertion activities and treatment approaches in concussion management given the individualized nature of the injury. Secondly, preventing players from exercising after injury may have deleterious effects on their mood and physical conditioning [47, 99]. Lastly, requiring a player to follow a structured, stepwise exertion protocol when they can tolerate exercise

Table 52.6 Clinical trajectories and targeted treatment for concussion

Clinical trajectory	Common symptoms	Objective findings	Treatment
Cognitive/fatigue	Fatigue Decreased energy Nonspecific headache Sleep disruption Worse symptoms at the end of the day Trouble concentrating	Global deficits on cognitive testing Declines in functional cognition	Behavioral regulation Pharmacological intervention (stimulants, sleep aids) Cognitive therapy if protracted Allow for moderate physical activity
Vestibular	Dizziness Fogginess Nausea Feeling of being detached Anxiety Overstimulation in complex environments Motion sensitivity	Symptom provocation with vestibular-ocular reflex or optokinetic sensitivity Imbalance Processing speed/reaction time deficits on cognitive testing	Vestibular therapy by a neuro-rehabilitation specialist Pharmacological intervention (if mood or migraine overlay)
Oculomotor	Localized, frontal headache Fatigue Distractibility Pressure behind eyes Trouble focusing Headache with visual tasks	Abnormal oculomotor exam Convergence insufficiency Accommodation insufficiency Global deficits on cognitive testing	Neuro-optometry for vision therapy Vestibular-ocular therapy by a neuro-rehabilitation specialist Allow for physical activity
Anxiety/mood	Anxiety Ruminative thinking Hypervigilance Feeling overwhelmed Sadness Hopelessness Sleep disturbance Somatic symptoms with stress	Mild symptom provocation with vestibular screening	Treatment of vestibular dysfunction if present Heavy, dynamic physical activity Behavioral regulation Pharmacological or behavioral treatment of anxiety/mood
Posttraumatic migraine	Unilateral headache Moderate/severe headache Pulsating headache Nausea Photosensitivity Phonosensitivity Dizziness	Verbal or visual memory deficits on cognitive testing	Behavioral regulation Pharmacological therapy (tricyclic antidepressants, anticonvulsants, beta or calcium channel blockers, or triptans) Aerobic, structured physical activity
Cervical	Headache (suboccipital location) Neck pain Numbness/tingling in extremities	Abnormal decreased range of motion, muscle weakness, ligamentous instability, limited musculature flexibility in the neck	Range of motion exercises Manual cervical and thoracic mobilization Soft tissue mobilization Posture reeducation Biofeedback Pain management Trigger point injections Pharmacological therapy if protracted (analgesics, anti-inflammatories, muscle relaxants)

early after injury may potentially delay their return to full health.

Once a player has successfully returned to their baseline status and completed the exertion protocol, clearance is required from multiple members of the NFL concussion management team. The player must have baseline scores returned to normal as interpreted by a team's neuropsychological consultant, receive clearance from the team physician, and receive clearance from an independent neurological consultant with expertise in concussion. Full clearance allows the player to return to full sport participation, including competition and contact activities.

Take-Home Message

The NFL's Head, Neck, and Spine Committee has evolved their guidelines for concussion identification and management to protect the health of players. Standardized protocols designed by the NFL for return to football participation prevent concussed players from being prematurely returned to play. Individualized clinical profiles after concussion have started to emerge and are being studied to potentially allow for targeted treatment from the injury rather than a "one-size-fits-all" approach.

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