

Establishing a Clinical Service for the Management of Sports-Related Concussions

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The clinical management of sports-related concussions is a specialized area of interest with a lack of empirical findings regarding best practice approaches. The University of Pittsburgh Medical Center Sports Concussion Program was the first of its kind; 13 years after its inception, it remains a leader in the clinical management and research of sports-related concussions. This article outlines the essential components of a successful clinical service for the management of sports-related concussions, using the University of Pittsburgh Medical Center Sports Concussion Program as a case example. Drawing on both empirical evidence and anecdotal conclusions from this high-volume clinical practice, this article provides a detailed account of the inner workings of a multidisciplinary concussion clinic with a comprehensive approach to the management of sports-related concussions. A detailed description of the evaluation process and an in-depth analysis of targeted clinical pathways and subtypes of sports-related concussions effectively set the stage for a comprehensive understanding of the assessment, treatment, and rehabilitation model used in Pittsburgh today.

KEY WORDS: Concussion, Mild traumatic brain injury, Ocular-motor, Rehabilitation, Vestibular

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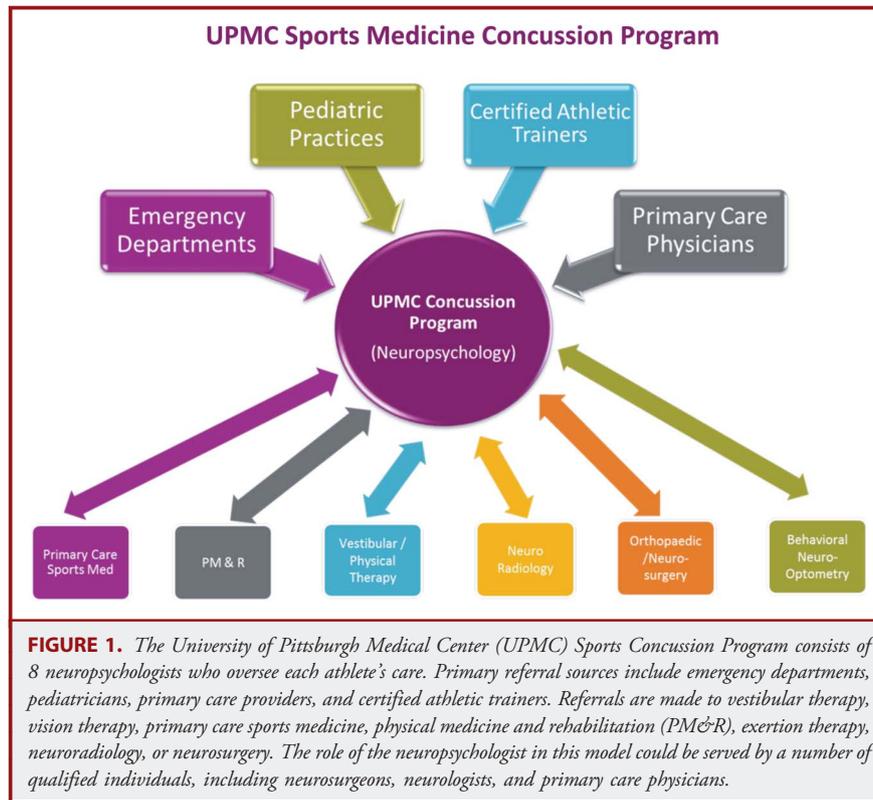
The field of sports-related concussions has grown rapidly over the past decade, with concussion-specific clinics becoming more commonplace and concussion specialties becoming recognized among neuropsychology, neurosurgery, neurology, and sports medicine physicians. Although primary care physicians and pediatricians continue to treat a large number of these patients, stand-alone clinics and clinics housed within hospital systems are increasing in number and magnitude. Given the recent growth in the field, there is a lack of research investigating best practices for care. This article outlines the essential components of a successful, multidisciplinary treatment model for the diagnosis and rehabilitation of sports-related concussion. Using the University of Pittsburgh Medical Center

(UPMC) Sports Concussion Program as an example, this article provides a foundation on which to begin building a comprehensive model of care for athletes of all ages.

Established in 2000, the UPMC Sports Concussion Program was the first program of its kind; more than a decade later, it remains the largest clinical and research program focused on the assessment, treatment, and rehabilitation of sports-related mild traumatic brain injury (mTBI) in athletes of all levels. The nucleus of this program consists of 8 neuropsychologists who oversee each athlete's care from the initial evaluation through the final appointment in which the return-to-play decision is made. Primary referral sources include emergency departments, pediatricians, primary care providers, and certified athletic trainers (ATCs). Once an athlete has undergone an initial evaluation with a neuropsychologist, a number of referrals may be made, including vestibular therapy, vision therapy, primary care sports medicine, physical medicine and rehabilitation, exertion therapy, neuroradiology, or neurosurgery. It is important to note that the central role of the neuropsychologist in this model could be served by a number of qualified individuals,

ABBREVIATIONS: **ImPACT**, Immediate Post-Concussion Assessment and Cognitive Testing; **mTBI**, mild traumatic brain injury; **UPMC**, University of Pittsburgh Medical Center

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including neurosurgeons, neurologists, sports medicine physicians, and primary care physicians (Figure 1). This article provides an overview of this unique and successful model of care. A detailed description of the evaluation process and an in-depth analysis of targeted clinical pathways and subtypes of sports-related mTBI will effectively set the stage for a comprehensive understanding of the assessment, treatment, and rehabilitation model used in Pittsburgh today.

Although the majority of athletes with appropriate management recover from concussion within 1 to 2 weeks after injury,¹⁻³ research shows that approximately 1 in every 5 athletes experiences a prolonged (>21 days) recovery.⁴ Given the estimated yearly incidence rate for sports-related mTBI of 1.6 to 3.8 million,⁵ this suggests that prolonged recovery from sports-related mTBI may occur in 320,000 to 760,000 athletes each year in the United States alone. Considering this statistic within a clinical framework, it is clear that a comprehensive understanding of the factors that lead to prolonged recovery after concussion is critical.

PREDICTING PROTRACTED RECOVERY

Researchers have identified a number of postconcussion symptoms that are associated with protracted recovery. After injury, on-field dizziness is associated with an increased risk of a protracted recovery,⁶ whereas subacute (within 3-7 days) foggy, difficulty concentrating, vomiting, dizziness, nausea,

headache, slowness, imbalance, photosensitivity or phonosensitivity, and numbness predicted a recovery of ≥ 14 days.⁷ The presence of posttraumatic migraine is also associated with a more severe and protracted recovery.^{8,9} It is important to differentiate between posttraumatic headache and posttraumatic migraine. Posttraumatic headache is defined by the *International Classification of Headache Disorders, 2nd edition*¹⁰ as a secondary headache that occurs in close temporal proximity to a head injury. Whereas >80% of individuals experiencing posttraumatic headache are categorized as having tension-type headaches, a subset of individuals will experience typical migraine-type headaches. The International Headache Society defines migraine as a unilateral, moderate- to severe-intensity headache with a pulsating quality that is associated with nausea or sensitivity to light and sound and is aggravated by routine physical activity.¹⁰

In addition to relying on symptom reports, athletes are often administered a computer-based neurocognitive assessment such as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). At 3 days after injury, if an athlete exhibits ≥ 3 Reliable Change Index changes relative to baseline, there is a 94% chance that recovery will require >10 days.¹¹ In addition, there are specific cutoff scores for each clinical composite that predict recovery times of >1 month with up to 85% sensitivity.⁹

Using these indicators of potential protracted recovery, the neuropsychologist or other managing provider is able to develop an individualized, comprehensive clinical evaluation that includes

providing the athlete with a more robust understanding of what his or her recovery may entail. The UPMC Sports Concussion Program evaluation consists of 3 components: a detailed clinical interview, a vestibular/ocular-motor screening, and computerized neurocognitive testing, including a self-report symptom scale. All 3 components are vital, and none may stand alone in determining diagnosis or treatment. Before concluding their first appointment, all athletes are provided with a detailed analysis of the severity of the injury, their prognosis for recovery, whether they need additional neuroimaging, what referrals will be provided, the level and type of physical and cognitive exertion allowed, what academic (or work) accommodations will be provided, and finally whether the athlete will be returning to play at that time. In addition, communication between the attending neuropsychologist and primary care providers, team physicians, certified athletic trainers, or other referring providers on the outcome of the evaluation is initiated at that time.

CLINICAL INTERVIEW

The clinical interview is the first step in beginning to understand both the athlete and the injury itself. The goals of the clinical interview are to establish an understanding of the mechanism of injury, acute and current (potentially chronic) symptoms, to obtain a detailed biopsychosocial history, including a family medical history, and to establish the framework for understanding the potential clinical trajectories an individual may experience.

An important goal of the clinical interview is to assess premorbid risk factors, which will delineate the course of treatment. Premorbid risk factors include a history of prior concussions,^{12,13} history of migraine,^{8,14} diagnoses of learning disability or attention-deficit/hyperactivity disorder,^{15,16} sex,^{17,18} and age.^{19,20} Once risk factors have been identified, the clinical trajectory and course of treatment should become clearer. Although many athletes present with multiple and overlapping symptom trajectories, identifying and parceling out specific groupings help target specific rehabilitation pathways.

Current return-to-play guidelines specify 3 requirements for return to contact sports: asymptomatic at rest, asymptomatic with

exertion, and neurocognitive test scores that are commensurate with baseline performance.²¹ Determining asymptomatic status requires a clinical interview that includes specific and individualized questions. This does not mean asking the athlete “How are you feeling?” or “Do you have a headache?” but rather asking a series of questions inquiring about the subtleties of the injury. Asymptomatic is not an easily defined term; however, it is at the core of proper concussion management. Table 1 provides examples of questions used within the UPMC Sports Concussion Program.

VESTIBULAR/OCULAR-MOTOR SCREENING

The vestibular system is a complex sensorimotor system that, in addition to maintaining visual and spatial organization, manages balance function via pathways linking sensory organs of the inner ear with central processing areas in the brainstem, cerebellum, midbrain, and cerebral cortex. The information provided from the vestibular system is then used to adjust eye movements to stabilize vision (vestibulo-ocular reflex) and to mitigate muscle responses of the head and body to stabilize balance (vestibulo-spinal reflex). Current research suggests that vestibular dysfunction is common after concussion,^{22,23} with as many as 50% of athletes reporting dizziness as an initial postconcussion symptom and 43% reporting balance impairments.²⁴ Dysfunction in either the peripheral or central structures of the vestibulo-ocular system typically causes dizziness, vertigo, blurred or unstable vision, or nausea; involvement in either the peripheral or central structures of the vestibulo-spinal system results in balance impairment. Balance dysfunction after concussion is often due to abnormal central processing of sensory information (vestibular, visual, somatosensory) needed to maintain postural control. In particular, the ability to use and process vestibular information appears to be affected in concussed athletes.^{25,26} The standard balance assessment tool in concussion management is the Balance Error Scoring System (BESS).²⁷ In a recent study,²⁸ the BESS was found to differentiate concussed from non-concussed adolescents, with conditions of tandem stance and double-support stance on compliant foam being the most discriminating.

TABLE 1. Sample Interview Questions

Do Not Ask	Do Ask
Do you have a headache?	Do you experience a pressure sensation in your head that increases as the day progresses?
Do you feel fatigued?	Do you feel more fatigued than normal at the end of the day?
Are certain environments worse than others?	Do busy environments cause you to feel foggy, anxious, or tired?
Is reading or doing computer work difficult?	Do you have blurred or fuzzy vision while reading or difficulty reading?
Are you easily distracted?	Do you feel a frontal pressure in your head when reading or doing computer work?
How are you sleeping?	Do you feel more distractible than normal?
How is your mood?	Do you have difficulty falling or staying asleep? Are you napping?
	Have you or your parents or family noticed changes in mood such as irritability or anxiety?

In addition to vestibular symptoms, ocular-motor deficits are common after injury. It is estimated that 90% of concussed individuals presenting with vision-related symptoms in a clinic setting are later diagnosed with ocular-motor dysfunction.²⁹ Two of the most common ocular-motor findings in a concussed population are convergence insufficiency and accommodative insufficiency.^{30,31} Convergence insufficiency is the inability to maintain visual fusion with reading or close work. Normal individuals should be able to maintain focus on a midline object brought toward the nose (ie, converge) without diplopia to at least 6 cm.³² Symptoms of convergence insufficiency may include eye strain, headaches with reading, double vision, and frequent loss of place when reading.³³ In a retrospective analysis of 160 patients with mTBI, Ciuffreda et al²⁹ found that 56.3% were diagnosed with a vergence abnormality, with convergence insufficiency representing the most common type of dysfunction at 36.7%. Visual accommodation refers to the curvature of the crystalline lens of the eye that occurs when an individual attempts to focus on an object or to adjust focus from a particular distance.³⁴ Accommodative insufficiency results in blurred vision when an object is viewed at near distances. Research suggests that 10% to 40% of individuals experiencing mTBI present with accommodative insufficiency.^{31,32,34} In addition to vergence and accommodative dysfunction, concussion frequently results in disturbances to coordinated activation of pursuit and saccadic eye movements.^{29,31} Abnormal pursuit and saccadic eye movements have been reported in 30% to 60% of individuals after mTBI.³¹

The UPMC Sports Concussion Program has considered the implications of vestibular and ocular-motor dysfunction in recovery from concussion and has established a vestibular/ocular-motor screening assessment to identify athletes who may have underlying vestibular or ocular-motor impairments and associated symptoms. If potential impairment is detected, the athlete is then referred for more comprehensive vestibular and ocular-motor assessments and therapies. Table 2 gives an outline of the UPMC vestibular/ocular-motor screening for concussion. In addition to providing referral information, the information gathered from this screening is used by the neuropsychologist to begin formulating specific school and work accommodations. For example, difficulties with saccadic eye movements may provoke headache, fatigue, and difficulty concentrating. Appropriate accommodations may include reduced computer work and reading, limited television, and elimination of video games. Difficulties with horizontal or vertical gaze stability may provoke dizziness, blurred vision, or nausea. Appropriate recommendations in this case may include reduced note taking and avoidance of busy environments such as hallways, cafeterias, and gymnasiums.

NEUROCOGNITIVE TESTING

The third component of the UPMC evaluation is neurocognitive testing. The UPMC Sports Concussion Program uses the ImPACT program; however, a number of computer-based programs are available, including CogSport, Headminders,

ANAM,³⁵ and CNS Vital Signs. ImPACT includes the 22-item Post-Concussive Symptom Scale, 8 neurocognitive measures, 4 clinical composite scores, and a detailed clinical report that provides demographic information, symptom profile, and neurocognitive data. Extensive normative data are available for patients 11 to 60 years of age, and extensive data have been published on the reliability, validity, added value, and prognostic ability of the test. The UPMC Sports Concussion Program recommends baseline testing athletes of all ages. Although it is possible to interpret postinjury ImPACT scores without a baseline for comparison, having that information available contributes to a more individualized assessment.

ImPACT composite scores have been shown to be stable across a 2-year time period, with intraclass correlation coefficients ranging from 0.47 to 0.75 for composite scales.³⁶ Stability across a 1-year time period surpassed these data, with intraclass correlation coefficients ranging from 0.57 to 0.85.³⁷ A comparison of preseason, midseason, and postseason neurocognitive test scores in uninjured collegiate football players, all of whom engaged in contact practices or games, revealed no significant changes in composite scores despite repetitive contact.³⁸ This finding suggests that any significant decline in ImPACT scores compared with baseline data, should be interpreted as evidence of a concussive event. Reliable Change methodology was designed in that regard to identify cutoff scores that can be used for meaningful comparisons of test scores that are independent of practice effects and other sources of variance.³⁹

Using a computer-based neurocognitive test allows the neuropsychologist or other managing provider to make better-informed decisions about an athlete's return to play. A 2012 study revealed that when computer-based neurocognitive testing was used, athletes were less likely to return to play within 10 days of injury (38.5%) compared with those in whom it was not used (55.7%).⁴⁰ In addition, these athletes were more likely to be returned to play by a qualified physician (instead of an athletic trainer or other provider). This highlights the importance of including computer-based neurocognitive testing in determining both prognosis and recovery. The data gathered from neurocognitive testing may also be used to support difficult or controversial return-to-play decisions when the symptom profile may be ambiguous. A recent study revealed that when asked to rate their "percent back to normal," athletes 12 to 18 years of age demonstrated low correlations between their subjective perception of recovery and neurocognitive test scores.⁴¹ Athletes demonstrated a tendency to focus on somatic symptoms (such as headache, nausea, and vomiting) and overlooked other key symptom clusters. A 2012 study revealed that, when athletes are not candid about the presence of symptoms, specific patterns of performance on ImPACT can detect neurocognitive deficits with a sensitivity of 94.6% and a specificity of 97.3%.⁴² These findings emphasize the importance of including objective measures in making return-to-play decisions, with computer-based neurocognitive testing serving as the industry standard.

TABLE 2. University of Pittsburgh Medical Center Vestibular/Ocular-Motor Screening for Concussion

Vestibular/Ocular Motor Test	Headache, Dizziness, Nausea, Fogginess,					Comments
	NT	0-10	0-10	0-10	0-10	
Baseline symptoms	X					
Smooth pursuits						
Saccades—horizontal						
Saccades—vertical						
Convergence (near point)						(Near point in cm) Measure 1: _____ Measure 2: _____ Measure 3: _____
Accommodation						Distance in cm: Right: _____ Left: _____
VOR—horizontal						
VOR—vertical						
Visual/vestibular suppression test						
Balance screening from Balance Error Scoring System: foam/EC/feet together						No. of errors (20 s): _____ (maximum = 10)
Error types						
<i>Hands lifted off chest</i>						
<i>Opening eyes</i>						
<i>Step, stumble, or fall</i>						
<i>Moving hip into >30° abduction/flexion</i>						
<i>Lifting forefoot or heel</i>						
<i>Remaining out of test position >5 s</i>						

Instructions

Interpretation: This test is designed for use with subjects 9–40 y of age. When used with patients outside this age range, interpretation may vary. Abnormal findings or provocation of symptoms with any test may indicate dysfunction and should trigger a referral to the appropriate healthcare professional for more detailed assessment and management.

Equipment: Airex foam pad; tape measure (cm); metronome; target with 14-point font print. Optional: Bernell Fixation Stick.

Baseline symptoms: record headache, dizziness, nausea, and fogginess on a scale of 0–10 before beginning screening.

Smooth pursuits: Test the ability to follow a slowly moving target. The patient and the examiner are seated. The examiner holds a fingertip at a distance 3 ft from the patient. The patient is instructed to maintain focus on the target as the examiner moves the target smoothly in the horizontal direction 1.5 ft to the right and 1.5 ft to the left of midline. One repetition is complete when the target moves back and forth to the starting position; 2 repetitions are performed. The target should be moved at a rate requiring approximately 2 s to go fully from left to right and 2 s to go fully from right to left. The test is repeated with the examiner moving the target smoothly and slowly in the vertical direction 1.5 ft above and 1.5 ft below midline for 2 complete repetitions up and down. Again, the target should be moved at a rate requiring approximately 2 s to move the eyes fully upward and 2 s to move fully downward. Record headache, dizziness, nausea, and fogginess ratings after the test.

Saccades: Test the ability of the eyes to move quickly between targets. The patient and the examiner are seated.

Horizontal saccades: The examiner holds 2 single points (fingertips) horizontally at a distance of 3 ft from the patient and 1.5 ft to the right and 1.5 ft to the left of midline so that the patient must gaze 30° to left and 30° to the right. Instruct the patient to move his/her eyes as quickly as possible from point to point. One repetition is complete when the eyes move back and forth to the starting position; 10 repetitions are performed. Record headache, dizziness, nausea, and fogginess ratings after the test.

Vertical saccades: Repeat the test with 2 points held vertically at a distance of 3 ft from the patient and 1.5 ft above and 1.5 ft below midline so that the patient must gaze 30° upward and 30° downward. Instruct the patient to move his/her eyes as quickly as possible from point to point. One repetition is complete when the eyes move up and down to the starting position; 10 repetitions are performed. Record headache, dizziness, nausea, and fogginess ratings after the test.

(Continues)

TABLE 2. Continued

Instructions

Convergence: Measure the ability to view a near target without double vision. The patient is seated and wearing corrective lenses (if needed). The examiner is seated in front of the patient and observes his/her eye movement during this test. The patient focuses on a small target (approximately 14-point font size) at arm's length and slowly brings it toward the tip of the nose. The patient is instructed to stop moving the target when he/she sees 2 distinct images or when the examiner observes an outward deviation of 1 eye. Blurring of the image is ignored. The distance (in cm) between the target and tip of the nose is measured and recorded. This is repeated a total of 3 times with measures recorded each time. Record headache, dizziness, nausea, and fogginess ratings after the test. Abnormal: Near point of convergence ≥ 6 cm from the tip of the nose.

Accommodation: Measure the near point at which a visual image becomes blurry. The patient is seated, wearing corrective lenses for near vision (if needed). Identify the smallest letter that can be seen at normal reading distance (a Bernell Fixation Stick may be used) as the target. The patient is instructed to cover the left eye while bringing the target in toward the uncovered right eye. The patient stops moving the target when it is no longer in focus. The distance between the target and the nose (in cm) is recorded for right accommodation. The process is repeated with the right eye covered to measure left accommodation. Record headache, dizziness, nausea, and fogginess ratings after the test. This gross screen for accommodation is considered abnormal when the image becomes blurry at ≥ 15 cm from the nose.

Vestibular-ocular reflex test: Assess the ability to stabilize vision as the head moves. The patient and the examiner are seated. The examiner holds a target of approximately 14-point font size in front of the patient in midline at a distance of 3 ft.

Horizontal VOR test: The patient is asked to rotate his/her head horizontally while maintaining focus on the target. The head is moved at an amplitude of 20° to each side, and a metronome is used to ensure that the speed of rotation is maintained at 180 beats per minute (1 beat in each direction). One repetition is complete when the head moves back and forth to the starting position; 10 repetitions are performed. Record headache, dizziness, nausea, and fogginess ratings 10 s after the test is completed.

Vertical VOR Test: The test is repeated with the patient moving their head vertically. The head is moved in an amplitude of 20° up and 20° down and a metronome is used to ensure the speed of movement is maintained at 180 beats per minute (1 beat in each direction). One repetition is complete when the head moves up and down to the starting position; 10 repetitions are performed. Record headache, dizziness, nausea, and fogginess ratings 10 s after the test is completed.

Visual/vestibular suppression test: Test visual motion sensitivity and the ability to inhibit vestibular-induced eye movements using vision. The patient stands with feet shoulder width apart, facing a busy area of the clinic. The examiner stands next to and slightly behind the patient so that the patient is guarded but the movement can be performed freely. The patient holds arm outstretched and focuses on his/her thumb. Maintaining focus on the thumb, the patient rotates, together as a unit, his/her head, eyes, and trunk at an amplitude of 80° to the right and 80° to the left. A metronome is used to ensure the speed of rotation is maintained at 50 beats per minute (1 beat in each direction). One repetition is complete when the trunk rotates back and forth to the starting position; 5 repetitions are performed. Record headache, dizziness, nausea, and fogginess ratings 10 s after the test is completed.

Balance screening: Test the ability to use vestibular information to maintain balance. Whenever possible, the entire Balance Error Scoring System should be performed.

For minimum screening purposes, the following condition from the Balance Error Scoring System is used:

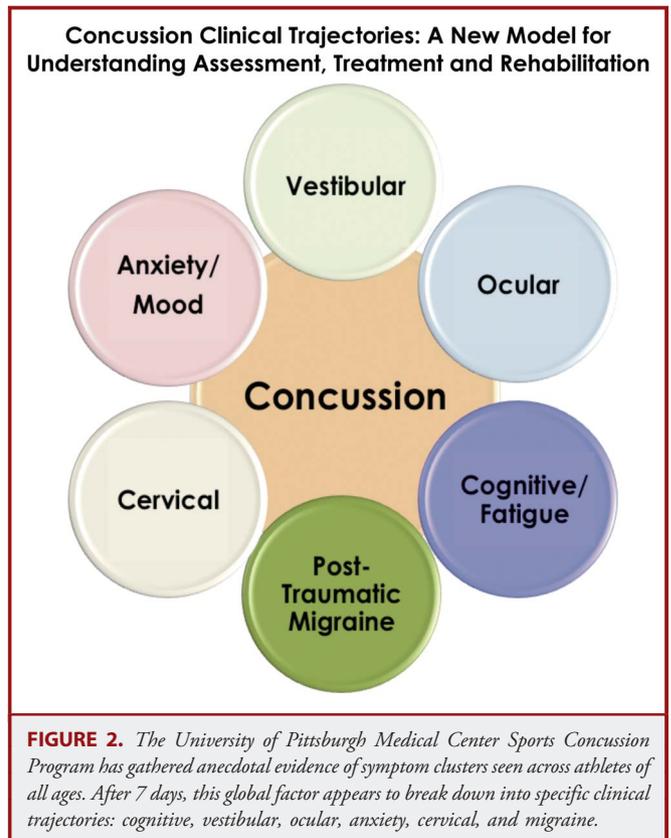
Double-leg stance/foam surface: The patient is instructed to stand, shoes off, on an Airex foam pad (0.5 × 30.4 × 30.06 m; Somersworth, New Hampshire) with feet together and arms folded across the chest. The examiner guards the patient closely and instructs the patient to close his/her eyes. This test is timed for 20 s. Record the number of errors committed in the 20-s trial (see below), as well as headache, dizziness, nausea, and fogginess ratings immediately after the test. Abnormal: >1 error.

HA, headache; EC, eyes closed; NT, not tested; VOR, vestibular ocular reflex.

Regarding validity, there has been discussion in the media regarding an athlete's ability to "sandbag" his or her baseline, or intentionally perform below expectation on baseline testing to "lower the bar" for return-to-play standards. A 2012 study addressed this concern when 75 college-aged former athletes were asked to intentionally perform poorly on baseline testing without reaching the threshold on built-in validity indicators.⁴³ All participants had previously taken a valid baseline test during their athletic career and were therefore familiar with the structure of the test. A monetary incentive was offered for successful sandbagging. This study revealed that only 11% of participants were successful and determined that sandbagging is difficult to accomplish successfully, despite instruction, motivation, and experience with the structure of the test.⁴³ A 2013 study addressed sandbagging by examining 3 groups: 1 group instructed to perform to the best of their ability, 1 group instructed to perform poorly (naïve group), and 1 group instructed to perform poorly with specific instructions indicating that they should perform as poorly as possible without reaching the threshold for validity indicators (coached group).⁴⁴ The group instructed to perform to the best of their ability was found to be 100% valid, with existing validity indicators accurately identifying 65% of the coached group and 70% of the naïve group. When the forced-choice measure of Word Memory Correct Distractors was incorporated as a potential additional validity indicator, the performances of 95% of the naïve group and 100% of the coached group were accurately identified as invalid.⁴⁴ Although sandbagging continues to be a concern at all levels of play, these studies suggest that intentionally underperforming on baseline ImPACT testing is extremely difficult to achieve successfully without detection.

CONCUSSION CLINICAL TRAJECTORIES

A 2012 factor analysis of the Post-Concussive Symptom Scale revealed different symptom factors at baseline and after injury.⁴⁵ After injury (<7 days), symptoms grouped into a global concussion factor, including cognitive, fatigue, and migraine symptoms. Although further research is warranted to investigate specific symptom clusters after 1 week, the UPMC Sports Concussion Program has gathered anecdotal evidence of symptom clusters seen across athletes of all ages. After 7 days, this global factor appears to breakdown into specific clinical trajectories: cognitive, vestibular, ocular, anxiety, cervical, and migraine (Figure 2). Considering the future of sports-related concussion management, this information may begin to change the way concussion is conceptualized. Rather than characterizing concussion as a general, global injury, clinicians may use this information to begin thinking in clinical subtypes, which may lead to better-informed treatment and rehabilitation decisions. Each clinical trajectory can be broken down into specific assessment and treatment protocols. Although an athlete may fit the profile for multiple subtypes, identifying the individual mechanisms for symptoms allows a more comprehensive rehabilitation protocol



and reduces the risk of overlooking important clinical data (Figure 3). An overview of each of the 6 identified subtypes is given below.

Cognitive/Fatigue

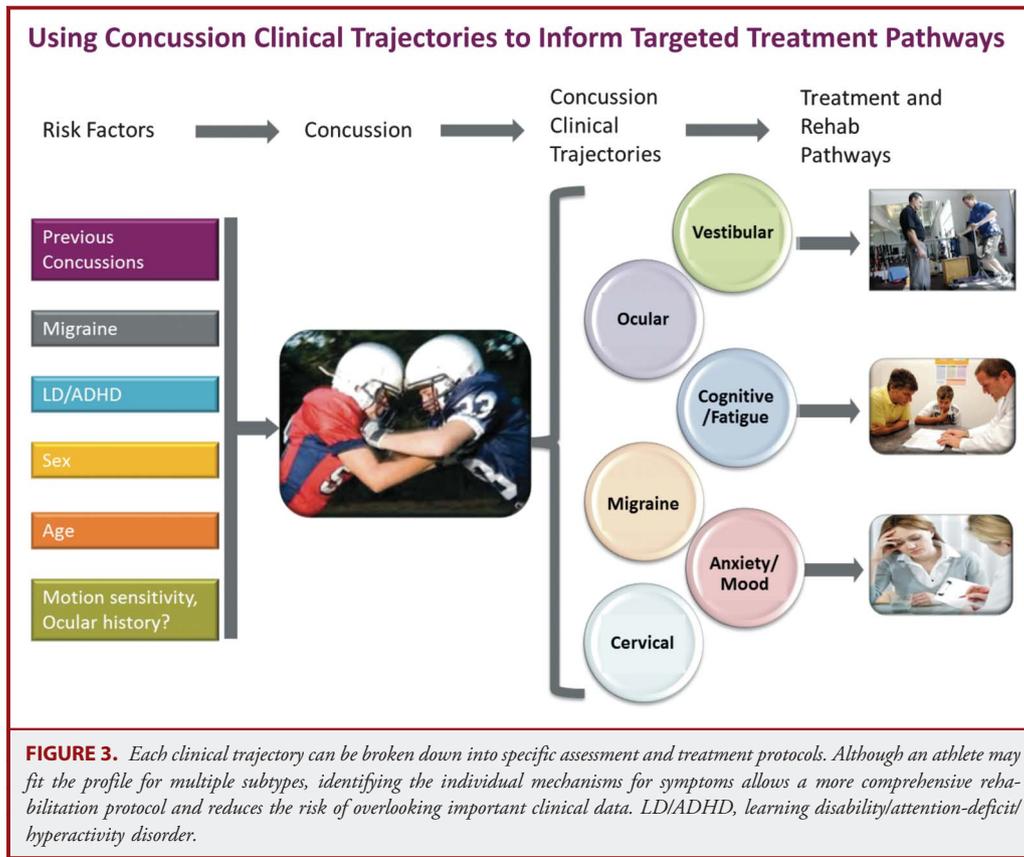
Symptoms include fatigue, anergia, generalized headache, end-of-the-day increase in symptoms, and potential sleep deficits. Some questions to ask in the interview include the following:

“Do you have a generalized headache that increases as the day progresses?”

“Do you feel more fatigued than normal at the end of the day?”

“Do you feel more distractible in school than normal?”

Vestibular/ocular-motor screening may be normal; however, neurocognitive test data may reveal mild global deficits across composites. These athletes may demonstrate deficits with retrieval rather than encoding. Treatment for the cognitive/fatigue subtype includes cognitive and physical rest with a regulated schedule (ie, no napping). Cognitive therapy may be warranted in more protracted cases. Pharmacological treatments, including neurostimulants and sleep aids, may be considered when symptoms persist beyond the expected concussion recovery window.



Vestibular

As noted above, vestibular symptoms may include dizziness, fogginess, nausea, feeling of being detached, anxiety, and overstimulation in more complex environments. Some questions to ask in the interview include the following:

- “Do busy environments cause you to feel dizzy, off balance, or nauseated?”
- “Do you become dizzy when looking up/down, turning your head, lying down in bed, rolling over in bed, or getting out of bed?”
- “Are you experiencing motion sickness?”
- “Does moving quickly make you dizzy?”

Vestibular/ocular-motor screening may reveal difficulties with horizontal and/or vertical gaze stability, optokinetic sensitivity, and balance deficits. Neurocognitive test data may include deficits in processing speed and reaction time composites. Treatment pathways for the vestibular subtype include vestibular therapy and potential pharmacological intervention if there is overlay with emotional changes, migraine symptoms, or dysregulated sleep.

Ocular-Motor

Ocular-motor symptoms include localized, frontally based headache, fatigue, distractibility, difficulties with visually based classes (such as mathematics), pressure behind the eyes, and

difficulties with focus. Following are some questions to ask in the interview:

- “Do you feel a frontal pressure in your head/behind your eyes when reading, doing computer work, or taking notes in class?”
- “Do you have blurred or fuzzy vision while reading or difficulty reading?”
- “Are you having more difficulty in mathematics and science?”

Vestibular/ocular-motor screening may reveal difficulties with smooth pursuits and saccadic eye movements, as well as abnormal near point of convergence or accommodation. Neurocognitive test data may reveal deficits in visual memory and reaction time. There may be evidence of difficulties with encoding rather than retrieval. Because isolated binocular vision dysfunction typically will not result in symptoms with standard exertion practices, a dynamic physical exertion protocol may be prescribed for patients fitting this clinical trajectory.

Anxiety/Mood

Symptoms of the anxiety subtype include ruminative thoughts, hypervigilance, fastidiousness, feelings of being overwhelmed, sadness, hopelessness, and sleep disturbance. Some questions to ask in the interview include the following:

TABLE 3. University of Pittsburg Medical Center 5-Stage Exertion Protocol for Concussion^a

Stage of Rehabilitation	Physical Therapy Program
<p>Stage 1 Target heart rate: 30%-40% of maximum exertion \times (maximum HR – resting HR \times 0.30) + resting HR Recommendations: exercise in quiet area (treatment rooms recommended); no impact activities; balance and vestibular treatment by specialist (PRN); limit head movement/position change; very limited concentration activities</p>	<p>Light aerobic conditioning Static balance exercises Exercises that limit head movements (weight machines, squats or lunges with focusing)</p>
<p>Stage 2 Target heart rate: 40%-60% of maximum exertion \times (maximum HR – resting HR \times 0.40) + resting HR Recommendations: exercise in gym areas recommended; use various exercise equipment; allow some positional changes and head movement; low-level concentration activities (counting repetitions); 20-30 min of cardiovascular exercise</p>	<p>Core exercises without head movements Light to moderate aerobic conditioning Balance activities with head movements Resistance exercises with head movements (example: lateral squats with head movement)</p>
<p>Stage 3 Target heart rate: 60%-80% of maximum exertion \times (maximum HR – resting HR \times 0.60) + resting HR Recommendations: any environment (indoor, outdoor) is okay for exercise; integrate strength, conditioning, and balance/proprioceptive exercise; can incorporate concentration challenges (counting exercises, visual games)</p>	<p>Low-intensity sport-specific activities Core exercises with head movements (example: side planks with arm/head turn, bicycles, Russian twists) Moderately aggressive aerobic exercise (intervals, pyramids, stair running) All forms of strength exercise Dynamic warm-ups</p>
<p>Stage 4 Target heart rate: 80% of maximum exertion \times (maximum HR – resting HR \times 0.80) + resting HR Recommendations: continue to avoid contact activity but resume aggressive training in all environments, resume noncontact practices</p>	<p>Impact activities; running; plyometrics (no contact) Challenge positional changes (burpees, mountain climbers) More aggressive sport-specific activities (80% maximum HR) 80% maximum exertion sport-specific activities avoiding contact</p>
<p>Stage 5 Target heart rate: 100% of maximum exertion \times (maximum HR – resting HR \times 1) + resting HR Recommendations: initiate contact activities as appropriate to sport activity; full exertion for sports activities</p>	<p>Full physical training activities with contact</p>

^aHR, heart rate.

“Do you have a history of anxiety? Family history?”
 “How often do you take inventory of your symptoms?”
 “Do you have difficulty turning off your thoughts?”
 “Do you have difficulty falling asleep at night because of rumination or an inability to stop thinking?”

Vestibular/ocular-motor screening may be mildly provocative if there is vestibular overlay. Neurocognitive test data may be within normal limits if there is no vestibular component. Treatment of the anxiety subtype includes treating any underlying vestibular component first. Once vestibular symptoms have resolved, supervised exertion should begin. For athletes with an emotional component, regulation is a critical component. Incorporating a regulated sleep schedule, with consistent diet, hydration, exercise, and stress management, is crucial. Many of these athletes will benefit from psychotherapy. Pharmacological treatment in the form of antidepressants also may be warranted.

Cervical

Symptoms of the cervical subtype include headache and neck pain. Assessment is completed by a certified physical therapist and includes cervical range of motion, strength evaluations, testing for cervical ligamentous instability, and assessment of cervical musculature flexibility. Interview questions should focus on characterization of headache, including the onset and course of daily headache. Management of the cervical subtype includes range-of-motion exercises, manual cervical and thoracic mobilization, soft tissue mobilization, posture re-education, biofeedback, modalities as warranted for pain management, and trigger-point injections. Pharmacological interventions include analgesics, anti-inflammatories, and muscle relaxants.

Migraine

Symptoms include variable headache with intermittent severity, nausea, and photosensitivity or phonosensitivity. Migraine symptoms may be exacerbated by stress, sleep dysregulation, dietary triggers, and anxiety or emotional changes. Following are some questions to ask in the interview:

“Did you get migraines before the injury?”
 “Do you have a family history of migraines?”
 “Are you having difficulty falling asleep/staying asleep/sleeping during the day?”
 “Are you experiencing more stress than usual?”

Vestibular/ocular-motor screening may be within normal limits. Neurocognitive test data commonly reveal verbal or visual memory deficits. Treatment for posttraumatic migraine includes pharmacological interventions such as tricyclic antidepressants, anticonvulsants, β -blockers or calcium channel blockers (as preventive) or triptans (as abortive). Increased cardiovascular activity is recommended, as is regulation of sleep, diet, hydration, and stress management.

REHABILITATION PATHWAYS

The UPMC Sports Concussion Program has developed an extensive network of providers who specialize in postconcussion rehabilitation protocols. Currently, the program includes 25 vestibular therapists, 17 physical therapists specializing in exertion therapy, >100 certified athletic trainers, and >45 contracted high schools and colleges and universities. All athletes are provided with individualized rehabilitation protocols that may include structured exertion therapy or simply working with certified athletic trainers through a 5-stage exertion progression (Table 3). Before returning to sport, all athletes undergo a 60-minute exertion test that includes generalized exercises and sport-specific movements. All providers communicate on a regular basis and provide feedback to the treatment team about the athlete's progress.

With the clinical model outlined above, it is our experience that the number of athletes required to retire from sport because of multiple concussions is significantly reduced. To date, concussion has never been conceptualized in terms of clinical trajectories, which allow us to focus on specific pathways of rehabilitation. When individual treatment plans are constructed in this manner, each athlete's injury can be understood as a separate entity, with complete recovery occurring before the athlete returns to play. It is our hope that by using this model we may begin to change the way in which concussion is conceptualized and therefore treated, leading to more enduring, successful athletic careers.

CONCLUSION

The field of sports-related concussion management has expanded rapidly during the past decade. Moving forward, clinicians and researchers are presented with both opportunities and challenges regarding the ongoing development of treatment and rehabilitation protocols. Consensus statements that shape clinical care and policies are vague and are not driven by empirical evidence, leaving clinicians to determine best practices of care within their own hospital or rehabilitation systems. Although this allows some creativity programmatically, it may also lead to programs that lack critical care components. To that end, developing a strong clinical team with an identified clinical leader helps to facilitate both communication and effective treatment plans. Using a comprehensive clinical interview, vestibular/ocular-motor screening, and computer-based neurocognitive testing allows one to gather information sufficient to make informed treatment decisions. Flexible treatment protocols allow individualized care and may increase compliance among athletes because they are able to modify rehabilitation plans as dictated by their progress. Most important, using a comprehensive rehabilitation program with a strong treatment team decreases clinical ambiguity and allows athletes to return to play with confidence and, we hope, a better understanding of their own injury and recovery process.

A podcast associated with this article can be accessed online (<http://links.lww.com/NEU/A666>).

Disclosure

Dr Collins is coowner and codeveloper of ImpACT Applications, Inc. The authors have no other personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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