

CLINICAL COMMENTARY

COMPREHENSIVE ASSESSMENT AND MANAGEMENT OF ATHLETES WITH SPORT CONCUSSION

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ABSTRACT

Currently, the popular approach to post-concussion management of the athlete relies upon the use of a multi-disciplinary team of healthcare providers, all typically coordinated by a physician. That core team is often supplemented by nurses, psychotherapists, coaches, teachers, the athletic director, and, of course, family members. However, access to such a model is frequently limited by financial, geographical, and numerous other factors. In the absence of such resources, a thorough clinical evaluation and management by an available, ongoing healthcare provider, quite often the sports physical therapist, becomes necessary.

The authors recommend that the professional who coordinates the athlete's post-concussion healthcare should focus efforts upon a comprehensive assessment and tailored treatment plan specific to the athlete's post-concussive symptoms. Assessment of both pre-morbid function and post-injury physical, cognitive, psychosocial, emotional, and behavioral issues, including the patient's support system, can assist the clinician with identifying specific constraints to sport, academic, social, and vocational activity participation. Hence, the assessment provides structure to the athlete's individualized treatment plan. Successful specialized interventions that address the multi-faceted impairments of sport related concussion frequently require knowledge of resources in a variety of other healthcare professions, in order to facilitate appropriate and necessary treatment referrals.

Initial assessment should be followed by repeat monitoring throughout treatment, and spanning a variety of environments, in order to ensure the athlete's full recovery prior to return, not only to sport participation, but also to involvement in social, academic, and/or employment related life activities.

Level of Evidence: 5

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BACKGROUND

The Centers for Disease Control and Prevention estimates that over three million traumatic brain injuries related to sport injuries occur annually.¹ Concussion, or mild traumatic brain injury (mTBI), describes the majority of these occurrences. This injury is defined as a complex, pathophysiological process, affecting the brain, induced by traumatic biomechanical forces to the head, in the form of a blow and/or subjection to acceleration/deceleration forces that may or may not involve loss of consciousness.²⁻⁴

However, obtaining sound data concerning the global incidence of sport concussions is complicated by incongruence in injury reporting and diagnosis. Many athletes with concussions never make it to the emergency room, but are treated on the sideline and in the clinic. Further, research suggests that athletes frequently underreport concussive symptoms and/or that the symptoms are unrecognized.⁵⁻⁷ Injury reporting and diagnostic inconsistencies produce challenges for the health care providers who manage athletes with sport concussion. Athletes with concussion rapidly develop short-term impairment of neurologic function; among those, 80 to 90% resolve spontaneously within the first ten days,^{8,9} although the recovery timeframe may be longer in children and adolescents than in their adult counterparts.¹⁰

However, a small percentage of patients experience prolonged, physical, behavioral, neuropsychological, and/or personality changes frequently termed post-concussive syndrome (PCS).¹¹⁻¹³ However, PCS are not unique to mTBI. For example, the symptoms occur frequently in day to day life among healthy individuals and persons with other conditions such as chronic pain or depression.¹⁴⁻¹⁷ Reports of incidence and prevalence of individuals who suffer with PCS vary, due in part to the disparities in defining PCS. For example, the outcome measure(s) for PCS are often symptom checklists¹⁸ rather than uniform, criterion based diagnoses. Researchers remain inconsistent in their efforts to define the point in time at which initial concussion symptoms become post-concussive syndrome. For purposes of the current concussion management recommendations contained in this clinical commentary, the authors discourage the use of post-concussion syndrome as a diagnosis. Rather, the clinician(s) should identify

and document the unique patterns of persistent post-concussion symptoms (defined as the cluster of symptoms persisting beyond the first ten days post-injury) exhibited during physical, psychological, and neuropsychological examinations and focus on amelioration of the symptoms.

Evidence is evolving toward establishing the efficacy of medical and behavioral interventions for post-concussive symptoms. Concussion management is moving toward an individualized, patient centered approach to assessment and treatment.² A wide range of health and other professionals are involved in the care and the provision of services of athletes after concussion, including the physician, sports physical therapist, athletic trainer, neuropsychologist, and speech-language pathologist, functioning as a core medical team. Academic and employment personnel are also crucial to concussion management, including the nurse, social worker/guidance counselor, teacher, coach, athletic director, and family.

One of the most critical and controversial questions within the medical community is when an athlete should be allowed to safely return to sport after a concussion. Another vital issue often neglected in the literature of sport concussion management is the decision making process used to support the athlete's successful return to academic, employment, and social activities. In this clinical commentary, the authors synthesize the current literature pertaining to on-field/sideline and clinic management of athletes with sport concussion. Specific dilemmas in the context of return to play and return to play decision making and resource allocation are also explored. Recognizing that this analysis is restricted, the authors hope to encourage future dialogue regarding comprehensive management of athletes with sport concussion(s).

Preseason Baseline Testing

Baseline concussion testing is often mandated for participation in many sports, including football and hockey, from elementary school to the professional level. Such testing is intended to be brief and to measure selected brain processes such as balance, somatic and neurobehavioral symptoms, attention span, working memory, and reaction time.^{8,9,19-25} Clinical tools for baseline assessment include the

Sport Concussion Assessment Tool-2 [SCAT2],² Clinical Reaction Time,^{19,20,26} the Digit Symbol Substitution Test,²⁷⁻³⁰ and, most recently, computerized tests. In the event that an athlete suffers a concussion, he/she then retakes the test(s). Baseline test performance is next compared to scores obtained post-concussion, in an effort to determine the extent of the injury and the athlete's level of brain function recovery. Typically, the patient is not allowed to return to participation until the score returns to baseline.

However, the reliability, validity, and feasibility of baseline testing remain questionable. Bailey and colleagues³¹ suggest that athletes may perform below their highest potential during pre-season baseline neuropsychological testing, creating a low threshold for comparison if they are then re-evaluated for return to play, post-concussion. Biopsychosocial factors such as age,³² gender,^{33,34} headache,³⁵ education level,³⁶ learning disability/attention deficit disorder,³⁷ and psychiatric conditions^{37,38} have been suggested to influence baseline scores. In addition, testing environment, for example, distracted, isolated, or supportive settings, may also affect baseline scores.^{20,26} Therefore, obtaining valid baseline and comparative post-injury scores that are interpreted in a clinical context is crucial for sport concussion management. However, many leagues may not have access to the appropriate resources to conduct baseline testing; hence, concussion management protocols should be employable without baseline data. Schmidt and colleagues³⁹ have reported on the clinical utility of standardized normative scores when baseline data is unavailable.

On-field/Sideline Assessment

The timeline for the initial assessment of concussion begins with the onset of the injury. The brain, head, and neck are the involved body structures in a concussion, and should all be evaluated. The medical team that is first to assess the injured athlete should always remember that the unconscious athlete must be treated as having a possible cervical spine injury. Experts agree that no single instrument should be used in isolation to diagnose concussion, nor should one be used to evaluate the athlete's recovery.^{2,40,41} When a player demonstrates any feature of a concussion, he/she should be removed from play and assessed by a healthcare provider trained in acute concussion management.^{2,42,43} Subsequently,

the "On-field or sideline evaluation of acute concussion" (pp. 756-757) guidelines from the Consensus Statement on Concussion in Sport² should be implemented.

The suspected diagnosis of concussion may include one or more of the five clinical domains, (a) somatic (e.g., headache) and/or emotional symptoms (e.g., lability), (b) physical signs (e.g., loss of consciousness or amnesia), (c) behavioral changes (e.g., irritability), (d) cognitive impairment (e.g., slow to answer questions or follow instructions and/or slowed reaction time), and/or (e) sleep disturbance (e.g., drowsiness).^{2,44} A panel of experts² in sports medicine and concussion management have recommended specific tests, appropriate for use during the sideline evaluation, including the Sports Concussion Assessment Tool (SCAT 2),¹⁸ or the Maddocks questions,⁴⁵ and the Standard Assessment of Concussion (SAC).^{2,46-48}

Although the SCAT 2 has not yet been validated, use of this instrument for field assessment of concussion is the international norm, and clinicians are encouraged to use the tool to promote consistency in clinical concussion assessment.² Following administration of the SCAT 2, the team physician must decide whether there is any indication for referral to a hospital, or whether the player may be adequately managed at home. Specific neurological indicators that warrant emergent referral to a hospital include vomiting, dizziness, worsening headache, severe neck pain, double vision, difficulty recognizing people or places, weakness/numbness in limbs, increasing confusion or irritability, slurred speech, seizure, or excessive drowsiness.^{2,43,49-51} Home supervision requires that a responsible adult be present to monitor the athlete over the next 24 to 48 hours.

The athlete's symptoms should be monitored regularly using a symptom checklist and red flag indicators such as those indicated on the *Acute Concussion Evaluation* (ACE).⁵⁰ It should be recognized that the appearance of symptoms can be delayed for several hours following a concussive episode. Concussion diagnosis is often complicated by the athlete's attempt to mask his or her condition, in order to continue to play; therefore, a medical team with experience in sports medicine and sport related concussion management should be consulted.^{7,42} Current principles of sport concussion in the sport concussion management

protocol indicate that return-to-play decisions require serial medical evaluations and should not be made merely after the initial sideline and/or emergency room evaluations.^{2,42,52} Contemporary medical management, including many state laws⁵³ that represent the main principles of the Zachery Lystedt model legislation,⁵⁴ prohibits the return of a concussed athlete to participation on the day of injury.

Follow-Up/Referral

Often, no appropriate healthcare provider is present on the field to perform the initial evaluation. As an additional point of first contact following injury, the athlete may present to the emergency room, physician's office, or another care provider (e.g., the sports physical therapist).² Typically, multiple systems are affected by sport concussion; hence, a comprehensive assessment by a rehabilitation specialist is crucial to determine the athlete's individual needs and to rehabilitate the athlete.

A contemporary approach to sport concussion management is the use of a multi-disciplinary network of medical professionals with skills in assessment and rehabilitation of individuals with head injury, coordinated by a primary care sports medicine physician. Input from physiatrists, neurologists, neurosurgeons, neuropsychologists, speech-language pathologists and, of course, sports physical therapists should be accessed for specific indications.

Although symptoms of concussion may appear mild, they can significantly negatively impact the individual's ability to function physically, cognitively, and psychosocially.^{3,55} A careful clinical interview concerning premorbid functioning is needed to determine previous learning disabilities, concussion history, academic history, any history of problems with social behavior, work history, any history of concomitant substance abuse, and the athlete's level of competence and independence prior to the injury.^{4,56-59} Such factors can assist the clinician in providing better estimates of the athlete's functional capacity and limitations.⁴

Both recreational and professional athletes participate in a variety of activities, including sport, academia, employment, and social events. Research suggests that athletes often report dizziness, reduced balance, headache, and reduced physical activity tolerance

following concussion, any of which can interfere with participation in a myriad of activities.^{8-10,22,25,60-63} Hence, sports physical therapy consultation is frequently warranted.

A comprehensive assessment of the athlete, post-concussion, should include not only an assessment of function(s) and activity participation, but also an evaluation of that patient's support systems (e.g., family, friends, academia, employment, and access to technology). Such systems may provide necessary resources and/or hinder the athlete's successful return to participation in sport, cognitive, and psychosocial activities. Specific questions to guide the assessment of activity participation are presented in Activity Participation Assessment VA mTBI management reference.

The comprehensive assessment will guide the sports physical therapist's management of not only neuromusculoskeletal, balance, vestibular, and/or visual functions, but also the host of cognitive and psychosocial symptoms associated with concussion. Initiation of early intervention and education is essential to the athlete's recovery. During initial and subsequent contact with the athlete, the clinician should provide that patient and his/her family with education concerning typical post-concussive symptoms, transient effects of head injury, signs of stress, suggestions regarding how to cope with them, and a plan for supervised, gradual resumption of pre-injury activities.^{3,4} When the injured athlete's needs exceed the scope of practice of the sports physical therapist, referrals for consultations with appropriate specialists such as neuropsychologist, speech-language pathologist/cognitive therapist, audiologist, neuro-ophthalmologist/optometrist, and/or psychiatrist, should be recommended in the plan of care. Sports physical therapists who manage athletes post-concussion should be competent in assessment and intervention techniques associated with vestibular function, headache management, postural stability, balance, and physical activity, not only to support return to play, but also to facilitate return to life participation.

Postural Stability and Balance Assessment

Impaired postural control is common among athletes with post-concussion symptoms.^{8,22} Postural stability testing is a useful tool for objectively assessing the

motor domain of neurologic functioning. One possible etiology of postural dysfunction is disruption of the ability to utilize and process vestibular information.^{8,62} Specific assessments for postural function include dynamic posturography, the Sensory Organization Test,⁶⁴ and the Clinical Test for Sensory Interaction in Balance⁶⁵ which require the SMART Balance Master®. The Balance Error Scoring System is also an assessment of postural function and requires minimal inexpensive equipment compared to the SMART Balance Master®.^{22,24} Feasible balance measures include the Dynamic Gait Index,⁶⁶⁻⁶⁹ the Functional Gait Assessment,⁷⁰ the HiMAT,⁷¹⁻⁷³ Dual Cognitive Task paradigms,^{74,75} and Five Times Sit to Stand.⁷⁶

The body functions that directly influence postural stability and balance include the vestibular system, sensations associated with hearing and vestibular functions, the proprioceptive system, mobility of joints, muscle power, muscle tone, and gait pattern.^{60,63-65,70,77-79} Examples of activities subject to disruption from postural instability include ambulation safety and endurance, climbing, some employment related activities and, of course, most, if not all, forms of sport participation. Intervention techniques that may improve postural stability across activities include sensory integration exercises, balance training, oculomotor training, eye-head coordination training, visual motion sensitivity training, neuromuscular control, and body mechanics and posture.^{64,80} However, there is limited evidence in the rehabilitation literature in support of the positive effects of physical therapy interventions on balance and mobility outcomes.⁸⁰ Further, there is considerable variability in the intensity, duration, and frequency of the interventions reported in the literature, therefore, presenting a considerable challenge to extrapolating meaningful clinical guidelines.

Post-Concussion Dizziness

More than 23 percent of patients with acute sport concussion present with the complaint of dizziness.^{8,77,81} The etiology of dizziness in concussion includes inner ear disorders (e.g., benign paroxysmal positional vertigo, labyrinthine concussion, and/or perilymphatic fistula), central nervous system disorders (e.g., post-traumatic migraine, brainstem concussion, autonomic dysregulation/postural hypotension, oculomotor abnormalities and/or seizures), and psychological

and/or musculoskeletal disorders⁷⁸ Clinical presentation of dizziness may include dysfunction of the vestibular system, muscle power, gait pattern, proprioception, perception, vision, and blood pressure regulation.

Thus, in order to identify appropriate intervention modalities, it is essential to determine the primary cause of dizziness. Physical therapists can assist in differential diagnosis by performing thorough neuromusculoskeletal and vestibular assessments. Activities that can be affected by dizziness include ambulation safety and endurance, academic performance, ability to socialize, work tolerance, and sport participation. Vestibulo-ocular reflex training (gaze stability training) and various canalith repositioning maneuvers are among the interventions used in treatment of dizziness.^{10,77,81,82} However, such management programs are few, with sparse, and often contradictory, findings which interfere with translation to clinical practice.

Headache

Post-traumatic headache is the most common post-concussive symptom of sport-related concussion.^{10,30,57} The International Headache Society's classification category involves secondary headaches, associated with head and neck trauma.⁸³ The four most common patterns of post-traumatic headache are tension-type headaches (including a cervicogenic component), migraine headaches, combined migraine and tension-type headaches, and headache due to cognitive fatigue.⁸³⁻⁸⁵

Body dysfunctions that may exacerbate/trigger a headache include cervical spine injury, impaired sleep, higher-level cognition, vision, hearing sensitivity, and exercise.⁸⁶⁻⁹⁰ Headaches may then impair other body functions and activities, including energy and drive, sleep, attention, emotion, thought, higher-level cognition, exercise tolerance, and appetite.^{35,63} Sports physical therapists who provide comprehensive assessment of the neuromusculoskeletal system for the athlete complaining of headache can facilitate differential diagnosis of the pattern of the headaches and expedite tailored intervention for that individual. However, confirmatory studies of specific guidelines for post-traumatic headache management among athletes are lacking.⁹¹ Currently, guidelines are offered for post-traumatic headache management based upon primary headache categories and treatments.^{84,85} It is imperative that well-designed clinical studies be

conducted to inform clinicians concerning the management and prevention of chronic, post-traumatic headache, in order to minimize the athlete's disability.

Physical Activity Tolerance

Managing athletes with post-concussive symptoms in order to achieve and maintain optimal physical function presents a considerable challenge due to sparse scientific evidence to guide clinical practice. Current international guidelines indicate physical activity should be avoided until an athlete is asymptomatic at rest.² However, inactivity can contribute to the disease process of several of the co-morbidities that are associated with concussion, such as vestibular disorders, depression, posttraumatic stress disorder, chronic fatigue, and pain disorders.⁹² Three to six days of bed rest can result in an athlete's complaint of headache, restlessness, and difficulty sleeping, which may complicate the treatment of the patient with persistent post-concussion symptoms.⁹³ As with many other medical conditions, the role of physical activity in the treatment of concussion needs to be reconsidered.⁹²

There are legitimate reasons to refrain from activity after a concussion. First and foremost the injured athlete should be removed from play and examined for the presence of life threatening injuries, such as bleeding in the brain.² After life-threatening injuries have been ruled out and the diagnosis of a concussion has been made, restricted activity is prescribed to avoid re-injury. There appears to be a 7-10 day period of a heightened susceptibility to re-injury.^{57,94} Removal from activity during this timeframe is essential to reduce the risks of persistent symptoms and the development of second impact syndrome that can accompany repeat concussions.⁵⁷ The authors recommend that clinicians respect this period of decreased activity. No sport participation should occur during this time; however, general physical activity deserves further consideration.

Recently, the utility of the universal recommendation for complete rest until asymptomatic after concussion has been questioned.⁹² Theoretically, after an athlete suffers a concussion, the sympathetic nervous system activity is exaggerated and heart rate is increased, possibly due to disrupted cerebral blood flow. Such factors can contribute to the re-expression and/or exacerbation of post-concussion symptoms with physical exertion or other stressors

that result in an increase in blood pressure.^{95,96} Sub-symptom threshold exercise may be a method to treat the disrupted blood flow and alleviate the dysfunctional sympathetic nervous activity.

Research suggests that sub-symptom threshold cardiovascular exercise and gradual progression of exertion with heart rate monitoring may be effective interventions in order to rehabilitate an athlete with persistent concussion symptoms.⁹⁶⁻⁹⁸ The majority of medical and activity tolerance guidelines pertain to sporting activities, and not necessarily to exercise.² It has been suggested that returning to pre-injury activities within days to weeks post-injury, regardless of symptoms, is likely to speed up, rather than slow down recovery.⁹² Current recommendations regarding the role of physical activity in concussions are as follows:⁹²

- Bed rest exceeding 3 days is not recommended
- Gradual resumption of preinjury activities should begin as soon as tolerated
- Contact and activities with high concussion exposure should be avoided for at least 1 week (7 days)
- Patients should take part in activity as guided by their symptoms. If symptoms are exacerbated, then a reduction in the physical and/or cognitive demands should occur and the return to activity should take place at a slower pace
- 1 month post injury, a supervised exercise program should be considered as part of the treatment plan for individuals who are symptomatic

Clearly, the aforementioned recent physical activity recommendations conflict with the current internationally accepted guidelines of concussion management.² However, the recommendations can also be viewed as the evolution of concussion management that fully supports a patient centered method of rehabilitation. What follows is a summary of the current literature for the assessment and progression of physical activity among athletes post-concussion and clinical application.

Physical Activity Tolerance Assessment

Prior to initiation of any physical activity (walking, biking, jogging, running, etc.), an athlete who has

suffered a concussion should participate in detailed, serial examinations with the medical team to determine readiness for physical activity. In all cases the managing physician should medically clear physical activity participation before any initiation of activity is started. In the situation where the patient has demonstrated recovery from symptoms, and the goal is to return to play, the authors have found previously published gradual return to play protocols to be effective.² However, the small portion of patients who develop persistent post-concussive symptoms do not fit into current guidelines, thus necessitating the development of new assessment and intervention strategies. The authors recommend that clinicians who treat those with persistent post-concussive symptoms consider a physical activity assessment and intervention approximately one month post-injury.

The suggested protocol for the activity tolerance assessment includes the use of the Balke treadmill test with ratings of perceived exertion (the Borg 15 point scale).⁹⁹⁻¹⁰¹ Ideally, a heart rate monitor and treadmill that can be inclined are the equipment requirements for the initial assessment of exercise activity tolerance. The athlete's baseline of perceived exertion rating and number of concussion symptoms should be recorded prior to physical activity.

The Balke treadmill protocol differs for males and females and is as follows. For males, the treadmill is set at 3.3 MPH at a grade of 0%. After one minute of activity the grade is increased to 2% and every minute thereafter the grade is increased 1%. Females begin with the treadmill set at 3.0 MPH and a grade of 0%. The grade is increased 2.5% every 3 minutes. For both sexes the grade is increased until the patient is unable to continue activity due to symptom exacerbation or fatigue, at which point the test is terminated. The clinician should record the speed, grade, and heart rate associated with symptom exacerbation and/or fatigue. Hence, the heart rate associated with symptom exacerbation and/or fatigue provides the athlete's heart rate threshold (HRT) to guide physical activity interventions.

Realistically, the Balke protocol may not be a feasible option due to equipment limitations. For example, the authors have initiated pilot investigations of the feasibility of using the Balke protocol with concussed athletes in a clinical setting. Preliminary data sug-

gests the Balke protocol is impractical because the athlete's physical activity tolerance post-concussion exceeded the equipment capabilities. Specifically, the incline limitation of the treadmill was 10%, which was insufficient for the patients to reach fatigue, heart rate maximum, and/or symptom exacerbation. Subsequently, the clinician modified the Balke protocol by increasing the walking speed by 0.5 MPH after every 3 minutes in order to obtain the requisite heart rate threshold.

Physical Activity Tolerance Intervention

After medical clearance is obtained, and using the HRT determined from the steps above, a cardiovascular exercise prescription can be formulated. The authors suggest that exercise intensity can begin at <70% of the HRT for 15 minutes.² Initially exercise time should be increased 5 minutes each session until a total time of 30 minutes is reached. After a total of 30 minutes of exercise is reached exercise intensity can be increased by approximately 5% increases in heart rate each session. These are general guidelines. The most important principle is to tailor the exercise to the individual and progress only when appropriate. The challenge to clinicians is determining the point when progression is appropriate, especially when symptoms may be present. The authors suggest that exercise may be continued and progressed as long that there is no symptom increase above baseline.

Clinicians should also keep in mind alternative exercise protocols and not simply continuous cardiovascular exercise. There may be times when individuals tolerate interval training better than continuous exercise. This would allow for a rest period or decreased activity rather than simply exercising through symptoms, which may not increase during exercise, but interfere with the patients exercise adherence.

The individual undergoing physical rehabilitation needs to be supervised and monitored during and after activity for the development of neurobehavioral and somatic symptoms. If symptoms develop during the exercise, the clinician should guide the athlete to immediately decrease the demands of the exercise until symptoms resolve. When symptoms persist with a decrease in activity intensity, the activity should be terminated. The exercising heart rate and

the duration of exercise when symptoms develop should be recorded, and used to tailor future exercise prescriptions. Future exercise should be modified so who has the HRT and the time of exercise is lowered, or divided into intervals. The athlete should also be monitored for 30 minutes post exercise for the development and/or exacerbation of any symptoms.

While exercise in general is suggested as a treatment modality,^{92,96,97} there is sparse evidence to support the use of resistance training. Clearly, cardiovascular exercise can be helpful in the treatment of many of the comorbidities associated with concussion. Resistance training may also support recovery; however, current guidelines do not exist and are beyond the scope of this article. Currently, the authors recommend cardiovascular exercise rather than resistance training, with the acknowledgement that future research may find a benefit of resistance training.

Future studies should identify effective and feasible HRT protocols to investigate the applicability of HRT to measure physical activity tolerance after brain trauma, specifically among athletes who endure one and/or repeated concussions. Further research should also evaluate athletes' HRT during pre-participation physicals to establish normative data. Moreover, investigations of the effects of resistive training on the recovery rate of an athlete after sustaining concussion(s) are warranted in order to guide effective, comprehensive medical management.

Cognitive Activity Assessment

Cognitive symptoms typical of mTBI include difficulty with concentration and attention, memory problems, executive dysfunction, and slowed mental processing.^{9,30,102,103} Typically, the neuropsychologist is responsible for the comprehensive evaluation of cognitive functioning, attempting to relate cognitive and behavioral findings to the underlying brain systems involved. The Zurich guidelines state that trained neuropsychologists are in the best position to interpret neuropsychological tests, but stress that this may not always be possible.² Consequently, other medical professionals, such as the speech-language pathologist, may provide an assessment of cognitive-communication function and provide appropriate intervention recommendations. However, multidisciplinary input from neuropsychologists and/or speech-language pathologists is not

always available. Therefore, the involvement of sports physical therapists is critically important to recognize and address cognitive and motor impairments associated with sport related concussion. Prior to initiation of any cognitive training exercise, an athlete that suffered a concussion should be evaluated by his/her physician and obtain medical clearance to participate in cognitive training exercise.

One method of examining cognitive function involves conducting a structured interview with the athlete, in order to elicit a list of cognitively based problems that may be interfering with everyday function. For example, the athlete may report difficulty driving, frequently forgetting information in conversations, difficulty tolerating distractions, slowness or errors in academia or the workplace, and/or fatigue.^{4,104} From the problem list, the sports physical therapist can garner insight into the individual's awareness of his/her impairments, determine the extent and nature of functional problems, and develop strategies for responding to the problems. Hence, goals can be tailored to functional terms that are mutually discussed and agreed upon.⁴ Specific clinical tasks used to examine attention and other executive functions among athletes include the Trail Making Test,^{41,102} cancellation tasks,²⁸ the Digit-Symbol Substitution Test,²⁸⁻³⁰ and dual-task paradigms.^{8,74,75,105,106}

Dual-task paradigms are particularly relevant for the physical therapist due to their association with abnormalities in gait and other functional limitations.^{62,74,75,105} With reliable and valid outcome measures using dual-task conditions, therapists can accurately identify dual-task performance problems and fall risk, establish guidelines for intervention, and judge whether the intervention is effective in improving dual-task performance. Dual-task paradigms also share theoretical principles with the divided attention clinical model.⁴ The disruptions in task performance observed during dual-task conditions are thought to be due to insufficient executive capacity to share attention between the demands of the tasks.¹⁰⁷ The equation for calculating the dual-task cost is $[(\text{dual-task performance} - \text{single-task performance}) / \text{single-task performance}] \times 100$.¹⁰⁸ Dual-task costs represent the percent difference between single-task and dual-task conditions.

Gentile¹⁰⁸⁻¹¹⁰ and McCulloch¹¹¹ suggest that therapists should match the patient's motor, visual, and cognitive

abilities to the types of tasks used for dual-task performance, so that the tasks are feasible for patients to perform in the single-task condition. A structured approach to monitoring errors in performance of motor and cognitive tasks can guide decision making regarding when to increase task difficulty. For example, the authors initiated a pilot investigation of the dual-task cost or divided attention function among high school and collegiate athletes who suffered one or repeated concussions. The dual-task paradigm was defined as tandem stance on a solid surface maintained by the student-athlete for 20 sec with his/her eyes closed while completing simple calculations by subtracting seven from 100 and then from his/her subsequent answers. Outcome measures included balance errors using the Balance Error Scoring System^{17,19} and correct number of subtractions. Preliminary results suggest that the student-athletes demonstrated an increase in the number of balance and cognitive errors with slower processing speed during dual-task compared to single-task performance. During the dual-task assessment, the student-athletes also provided subjective reports of significant difficulty attending to class lectures and to assignments. Subjective reports also included increased level of stress associated with the change in academic activity tolerance/participation compared to performance prior to the concussion. What follows is a brief summary of one specific dual-task paradigm developed by a speech-language pathologist to support a student-athlete's successful return to academic participation.

The necessary equipment to complete the dual-task paradigm assessment includes a structured interview and ratings of attention function,⁴ neurobehavioral and somatic graded symptom checklist,^{18,25,40,112,113} two copies of functional reading material selected by the athlete (e.g., articles and books from class assignments), pencil, and timer. The dual-task design could be defined as a functional reading task (articles and books from enrolled classes) for comprehension and simultaneously scanning for a target word (*and*). Baseline symptoms were recorded prior to initiating the reading task for comprehension and simultaneously scanning for a target word (e.g., while reading, the athlete counted the number of *ands*). Single-task was defined as reading comprehension in a quiet clinical setting. Outcome measures for the single and dual task included efficiency and accuracy measures. Specifically, the number of pages read, tolerance duration (e.g., duration until trigger or

exacerbation of neurobehavioral and/or somatic symptoms), the number of correct targets (*ands*), the number of errors (errors of omission and commission), and the number of correct responses to concrete comprehension questions. Dual-task costs were calculated and analyzed to estimate the magnitude of attention impairment during a divided attention task. The athlete's tolerance duration was also recorded.

Results from all of the assessment components (e.g., questionnaires, ratings of attention, and dual-task cost) were utilized to guide the prescribed tailored interventions to gradually increase asymptomatic attention capacity across various settings (clinic, school, social events). Baseline attention capacity varied among each student athlete ranging from five minutes to 30 minutes, which supports the patient centered approach for rehabilitation of function after suffering a concussion. However, confirmatory studies that support specific tasks for dual-task assessment are lacking. This problem is due in part to the paucity of literature addressing dual-task performance among athletes, and to the disparity in study designs (e.g., variables measured and outcome measures chosen). Additional research that targets clinical dual-task measures among athletes (amateur and professional) who have suffered a concussion is vital to guide effective clinical management.

Cognitive Activity Intervention

Most guidelines for management of concussion in sport use vague, graded exercise approaches, with a focus upon return to play, often neglecting guidelines that support return to cognitive and psychosocial activities.^{2,3,96-98} The sports physical therapist should be able to include cognitive tasks within the athlete's plan of care in order to facilitate the athlete's care and comprehensive rehabilitation post-concussion. In some instances, cognitive impairments may require restricted activity or reduced environmental challenges in order to maintain safety, facilitate participation, and/or optimize therapy activity. For example, Table 1 provides examples of accommodations to support successful return to school and/or work following concussion, with a focus on minimizing the trigger of somatic and neurological symptoms.^{114,115}

Currently, limited information exists to guide treatment addressing the use of cognitive tasks as a part of the physical intervention. The use of dual- or multi-

Table 1. School and Work Accommodations After a Concussion.	
Symptoms	Accommodations
Sleep Disturbance Fatigue Headache	Late starts/Early dismissals Rest periods during the day Partial attendance Excuse from non-essential assignments Excuse from attending sport practices
Difficulty Concentrating	Exams/Work in small/quiet rooms eBooks/etextbooks Record lectures/meetings Provide note-taker/scribe Provide classroom/meeting notes/PowerPoint prior to lecture/meeting Preferential classroom seating
Photophobia Sonophobia	Ball cap Sunglasses Dimmer lights Excuse from assemblies, band, orchestra, woodshop, conferences Earplugs Lunch in a quiet area
Slow to answer/follow directions	Extra time for assignment completion Extra time testing
Difficulty Remembering	Postpone or stagger testing Excuse from standardized testing Assistive Technology: Smartphone/Electronic Notebooks/Software Applications Alarms Minimize the number of academic courses/work assignments and projects

ple-task conditions simulates real life, so that patients can learn strategies to attend to safety, even in the presence of distractions. For example, Gentile's taxonomy¹⁰⁸⁻¹¹⁰ is a useful tool to assist the sports physical therapist in the development an environment for successful skill practice at individual skill levels. The taxonomy consists of sixteen sequenced task categories. The demands of the athlete generally become increasingly complex with manipulation of the environmental context in which the skill takes place and the function the motor skill must fulfill. The ability to generalize novel, dual-task conditions to real life has not been demonstrated for athletes with sport related concussion, so choosing therapy activities that simulate real life is a reasonable approach.

For example, reconsider the pilot investigation of a dual-task paradigm during the speech-language session. The same equipment that was used during assessment was utilized during intervention with a gradual, tailored increase in the duration of the activity. Specifically,

attention training capacity during the divided attention task started at the sub-threshold cognitive activity tolerance. The formula for calculating sub-threshold cognitive activity tolerance is (tolerance duration during dual-task × 60%). Sixty percent was derived from the graded return-to-play recommendations.²

Based on the structured interview, the student-athletes reported significant difficulty with daily class participation. Typically, classes were reported to last for 60 min in duration. Hence, a long-term goal of 60 min of cognitive activity using dual-task design was set. Initially, the athletes completed the same dual-task with different reading material for the sub-threshold duration. Gradually the duration was increased by 5% thereafter, guided by the athlete's activity tolerance. If the athlete demonstrated and/or reported trigger or exacerbation of symptoms during task participation, the clinician immediately decreased the duration and cognitive load (e.g., transitioned to less cognitive-demanding task). For example, the cognitive task was aborted and teaching of

cognitive behavioral techniques (e.g., neck stretches, mobility, and relaxation techniques) to ameliorate the symptoms. The student-athlete was trained to initiate cognitive behavioral techniques upon symptom onset to support carry-over of the strategies in natural environments. Symptoms were monitored until they returned to baseline status. Once symptoms returned to baseline status, the dual-task intervention was initiated again using the last asymptomatic cognitive activity tolerance and increased as tolerated.

Other dual-task treatments may include combinations of motor tasks specific to the athlete's sport participation (walking and carrying items or walking while performing dribbling drills) and combinations of motor tasks with other cognitive tasks (conversation, list making or way finding) within various environments (clinic, gym with few individuals or gym during team practice). Cognitive rehabilitation can also be integrated into physical therapy sessions through training and practice of functional multistep routines, and use of external cognitive aids (smart phones, electronic notebooks or alarms) to assist with the athlete's organization, management of events, deadlines, medication, metacognitive strategies, and social skills training.^{4,115,116} Undoubtedly, additional study of patients with neurologic involvement, specifically athletes who have suffered one or more concussions, is necessary to understand how attention and allocation of attention affect community, academia, and employment participation. As knowledge of the extent and nature of these problems expands, appropriate intervention strategies should also become evident.

SUMMARY AND CONCLUSIONS

The brain is a complex and complicated organ. No two mTBIs are the same and, consequently, no two treatment programs can be identical. We have outlined a comprehensive approach to post-concussion management of the athlete, designed to return him/her not only to sport, but also to school, vocation, and active socialization with family and friends. Realistically, scarcity of financial resources, lack of internet access, and geographical remoteness may interfere with access to a multi-disciplinary team. In these cases, a systematic and thorough clinical evaluation, with repeated monitoring across multiple environments (e.g., academia, work, social, and home) and including psychosocial and cognitive

tasks, will ensure that the player has recovered fully before returning to play and life participation.

The athlete's long-term goals typically target environments and roles that they are expected to resume (academia, work, social, and sport). When the athlete becomes asymptomatic at rest, or presents with chronic symptoms, he or she should be assessed while performing symptom provoking movements and activities, in order to ensure full recovery, or to assess status in recovery. The sports physical therapist should initiate gradual return, with the athlete remaining symptom free, not only to sport activities, but also to social and academic and/or employment related activities. Nonetheless, the investigation of multidisciplinary treatment for post-concussion symptoms is in its infancy. It is imperative for future research to investigate consistent application of methods to obtain quantifiable results that can add evidence to the efficacy of specific assessment and therapeutic techniques for athletes who suffer one or repeated concussion(s).

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