ABSTRACT

Sports-related concussions are receiving growing attention in healthcare. Most concussions resolve spontaneously with little or no treatment, but twenty percent of concussions take longer than three weeks to resolve. In some cases, symptoms can last for five years following a traumatic brain injury. Physical Therapists have unique skills that can assist patients experiencing protracted recovery.

The purpose of this clinical commentary is to describe a new conceptual model that provides a framework for Physical Therapy management of patients with protracted recovery following a sports-related concussion. The end product is a visual diagram that represents the full scope of clinical practice that Physical Therapy can provide to an athlete following a concussion.

*Level of Evidence: 5*

*Key Words: Conceptual Model, Post-Concussion Management, Sports*
INTRODUCTION

Background

A concussion is a mild traumatic brain injury caused by a direct or indirect biomechanical force to the brain.1 This initial injury is followed by a secondary insult on the brain due to a metabolic cascade that places increased energy demands on the brain.2,3 Each year 1.6 to 3.8 million sports-related concussions occur in the United States.4 Eighty percent of concussions have been observed to recover within 7-10 days.1 Twenty percent of the sports-related concussions take longer than three weeks to resolve.5,6 Symptoms such as headaches (54%), dizziness (37%), and anxiety (63%) may persist for five years after a head injury, regardless of the severity of the injury.7

Predictors for having a protracted recovery include: loss of consciousness,8 post-traumatic amnesia and retrograde amnesia,8 and elevated symptom scores early after concussion.8,9 Females have been shown to have increased risk of longer recovery compared to their male counterparts in the same sports.8-11 Those with a prior history of migraine and those with post-traumatic migraines are slower to recover.9,12 In collegiate football players, a statistically significant association exists between history of multiple concussions and a longer recovery time.13 High school athletes took longer to recover from neurocognitive deficits than collegiate athletes following a concussion.14

THE ROLE OF PHYSICAL THERAPY

Those who have protracted recovery can experience symptoms, impairments and functional losses that can be managed by Physical Therapists. These include headaches, dizziness, neck pain, fatigue, balance disturbances, oculomotor changes, and decreased coordination.15,16 Physical Therapists are part of the multidisciplinary team that has the ability to manage patients with vestibular rehabilitation, spine rehabilitation and controlled activity progression.15-20

Vestibular-Ocular Rehabilitation

The forces that cause a concussion can disrupt the neurons that run along the vestibulospinal tracts, control the vestibular-ocular reflex, and link central vestibular pathways.21,22 The peripheral vestibular receptors can also be injured during a concussion.21,23 Physical Therapists can provide treatment for balance dysfunctions, gaze stabilization activities, vestibular habituation activities, and canalith repositioning.24-26 In the same way, oculomotor control can be compromised through axonal injury or blunt trauma to the visual control systems.27-32 Physical Therapists can provide treatments that are directed towards addressing impairments in oculomotor control such as convergence,33-37 smooth pursuits,38-43 saccades,41-45 and ocular fixation.42-44

Cervical Rehabilitation

Dysfunctions of the neck, particularly the upper cervical spine, can be responsible for producing neck pain and headaches,46-50 dizziness,51-53 oculomotor disturbances,54-56 and postural dysfunctions.53,57-59 There are multiple isolated impairments that can potentially exist in the cervical spine following a concussion. Each of these impairments can be responsible for producing one or more of the symptoms noted above.

Physical Therapists can refine their cervical-based care into three broader components of treatment that address:

- Cervical mobility dysfunctions
- Neuromuscular control
- Strengthening

Cervical Mobility Dysfunctions

The first component to address is cervical mobility, which can be influenced by intra and extra articular factors. Although all segments of the cervical spine should be considered, the mobility of C1/C2 should be of particular importance. This area of the upper cervical spine can produce pain, loss of rotational mobility, headaches, and alter postural control.46,51,52,60 Manual Therapy has been shown to have positive benefits for treatment of hypomobile segments in the cervical and thoracic spine for individuals following a concussion and whiplash associated disorders.50,51,61,62 Since the thoracic spine can influence the cervical spine, it should also be considered with evaluation and treatment of the cervical spine.63
Neuromuscular Control
The rapid acceleration/deceleration of the head can result in trauma to the mechanoreceptors in the cervical spine. The deep cervical flexor muscles are richly innervated with muscle spindles that provide proprioceptive and kinesthetic feedback. Altered proprioceptive input in the neck can result in altered perceived head position. Higher rates of joint position error are noted in subjects with chronic whiplash-associated disorder compared to controls without cervical injury. This is consistent with altered proprioceptive function observed after injuries in other areas of the body.

Treatment for neuromuscular control needs to include activities that involve the ability to coordinate muscle contraction in order to maintain a cervical posture. Cranio cervical flexion (CCF) with pressure biofeedback is a low load exercise approach that helps refine the individual's ability to grade muscle activity of the deep neck flexors (longus capitus and longus colli), while inhibiting the sternocleidomastoid and anterior scalene muscles. A randomized controlled trial by Jull, found this training technique helpful in treating cervicogenic headaches.

Joint reposition sense is another component for normal cervical function. A head mounted laser and a target can be used to track relocation accuracy after active horizontal head movements. In individuals with chronic neck pain, improvements in cervical kinesthesia (head reposition accuracy) was associated with decreased neck pain, improved cervical range of motion, and improved self-reported functional improvement.

Good postural alignment helps improve muscular function by maximizing length tension relationships. Suboccipital and anterior chest wall tightness should be addressed with stretching to help facilitate improved cervical spine posture. Addressing body mechanics and posture during school, activities of daily living and work can reduce strain on the spine that can lead to headaches and neck pain.

Strengthening
The final component of overall cervical treatment is strengthening the cervical and periscapular muscles. The Deep Neck Flexor Endurance (DNFE) Test is a way to measure the strength of the neck stabilizers. Hold time durations for the DNFE test were statistically and clinically significantly different between individuals without and with neck pain. Mean time for those without neck pain was 39 seconds. Normative times for asymptomatic men and women have been documented (Men = 39 seconds, Women = 29 seconds). It is reasonable to use these outcomes as goals for muscle strength during the late phase of deficit management or early return to sports phase of recovery.

Smaller mean neck circumference, smaller mean neck to head ratio and weaker mean overall neck strength were significantly associated with concussion. Collins reported for each one pound increase in neck strength, there was a 5% reduction in the risk of concussion. A program of general muscular strengthening for the neck and periscapular muscles should be considered during late phase rehabilitation.

Exertional Activity Progression
There are three strategies for Physical Therapists to organize exertional aerobic activities:

- Light to moderate aerobic exercise
- Controlled graded aerobic exercise
- Exercise as an Adjunct to Managing Anxiety, Depression, and Sleep Disturbances

Light to Moderate Aerobic Exercise
Gagnon noted that children and adolescents who participated in light aerobic exercise had improved post-concussion outcomes compared to those who did not. Their patients exercised at 50-60% of their predicted max heart rate (220-age). Reed also found similar improvements with light aerobic activity in youth athletes done at the same intensities. In college athletes, mild to moderate activity was found to be a safe adjunct to care.

Graded Aerobic Exercise
Some athletes may experience exercise intolerance following a concussion that has not resolved within 7-10 days. These athletes may be experiencing dysfunctions in their autoregulatory control of heart
rate responses attributed to imbalances in sympathetic/parasympathetic activity.\textsuperscript{83-88} Leddy initially proposed a system of subsymptom threshold exercise that was based on the Balke Protocol. Exercise for individuals with post-concussion syndrome was prescribed at 80\% of the heart rate at which concussion symptoms were provoked during exercise testing.\textsuperscript{89} Interrater reliability for performing the Balke protocol was found to be high in a follow up study.\textsuperscript{90} Leddy refined the testing procedures by modifying the protocol treadmill speed, and incorporating thresholds for changes in symptoms and rate of perceived exertion (RPE). This new protocol is known as the Buffalo Concussion Treadmill Test and is recommended for patients with noted exercise or autonomic sensitivity.\textsuperscript{91}

**Exercise as an Adjunct to Managing Anxiety, Depression, and Sleep Disturbances**

Following a concussion an athlete is at risk of secondary conditions such as anxiety, depression, and sleep disturbances. A Cochrane Review on exercise and depression for adults 18 years and older, reported a small effect over control interventions in reducing depression symptoms. It was also shown to be no more effective than standard psychological or pharmacological treatments.\textsuperscript{92} The Cochrane Review reported that exercise was a good adjunct to treating depression due to its associated benefits and having very few associated negative side effects.

Another Cochrane Review examined the effect of exercise on treating anxiety and depression in children, adolescents and young adults no older than 20 years old. Again, a small effect was noted in the ability of exercise to lessen anxiety and depression in this population.\textsuperscript{93} This benefit was maintained regardless of whether the exercise was performed at low or high intensity levels. Exercise therapy has a place in mitigating the effect of depression due to withdrawal from normal daily activities, and as an adjunct to typical medical care in those patients that are experiencing clinical anxiety and depression.\textsuperscript{16}

Sleep can often be disrupted in the post-concussion populations. The Clinical Practice Guidelines for Concussion/Mild Traumatic Brain Injury and Persistent Symptoms recommends considering exercise as part of sleep management.\textsuperscript{16}

**Addressing Challenges Facing Physical Therapists**

A concussion is a functional disturbance to the brain without observable structural injury.\textsuperscript{94} The lack of a pathoanatomical model, the multitude of non-specific symptoms, and the potential for confounding influence from co-morbidities is a challenge for Physical Therapists in developing appropriate treatment plans.

Conceptual models can be used to organize physical and abstract information. This can assist the clinician to synthesize complex clinical information into meaningful groups or patterns.\textsuperscript{95} Well-developed models can allow the user to visualize complex relationships into simple and discrete visual forms.\textsuperscript{85} The initial concepts for a conceptual model for the Physical Therapy management of protracted recovery were proposed by the author.\textsuperscript{96} These concepts were refined and expanded as part of this commentary.

**Purpose**

The purpose of this clinical commentary is to describe a new conceptual model that provides a framework for Physical Therapy management of patients with protracted recovery following a sports-related concussion.

**CONCEPTUAL MODEL**

This conceptual model is for post-concussion patients that do not recover spontaneously within 7-10 days. This model is made up of four levels of treatment considerations. The levels of treatment consideration are: Recovery Time Line, Phases of Recovery, Progression of Treatment, and Physical Therapy Treatment Domains. (Figure 1)

**Recovery Time Line**

The Recovery Time Line is on the bottom of the model. It starts with the onset of the concussion and moves right with the passage of time. The time line ends with unrestricted return to sports. The time line does not provide any discrete time intervals, since the recovery time from a concussion can be variable.

**Phases of Recovery**

The next level of treatment above the Recovery Time Line is Phases of Recovery. There are three phases that run from left to right. The first phase is termed...
the Protection Phase. It is represented by a red circle. The color strengthens the concept of protection and stresses preventing additional trauma and avoiding overtaking the neurometabolic recovery process.\textsuperscript{2,3,97-99} It does not represent absolute rest.\textsuperscript{100-104} The second phase is represented by a yellow circle and is named the Deficit Management Phase. This phase is focused on addressing impairments, neuroplasticity, and normalizing full function. The last phase in this model is the Return to Sport Phase and is represented by a green circle. This phase represents progressive return to safe sporting activities. The Return to Sports Phase ends when the athlete safely returns to full and unrestricted sports participation. There is overlapping between the Deficit Management Phase and the two other phases, since there is no clear indication when one phase ends and the next starts.

**Progression of Treatment**

The third level of treatment consideration is termed Progression of Treatment. As time passes from the initial injury, there needs to be an evolving focus on the goals of treatment and the types of treatment activities emphasized. There are five treatment progressions that move from left to right, also using the red, yellow, green color coding.

Relative Rest is the initial treatment focus in the progression of care. Relative Rest is controlled...
activity and “rest as needed”. Symptoms are closely monitored and patient clinical status is assessed to determine appropriate activities. The patient is educated regarding which activities should be avoided and which activities should be modified.

Symptom Management is the second treatment focus in the progression of care. There is a proactive shift towards managing potential symptom triggers. These triggers may arise from an underlying autonomic dysfunction from the concussion or developing deconditioning from reduced activity levels. Triggers can also exist from impairments to the cervical spine or vestibular system. Physical Therapy should focus on progressing activity level and function by mitigating existing barriers.

Neuoplasticity is the third treatment focus in the progression of care. Treatment activities incorporated should stimulate neurological plasticity in order to maximize long term neurological recovery. Multi-sensory activities in situations that are purposeful and meaningful result in neuoplasticity.

Complex Functional Activities is the fourth treatment focus in the progression of care. Treatment should emphasize maximizing full functional recovery. Full functional recovery rehabilitation would involve real-life functional movements, occurring in a variety of sensory environments, and incorporating dual task activities that would approximate normal daily function for the individual.

Guided Return to Sports is the last treatment progression of care. Sports-specific activities that are determined to be safe are emphasized. Each sport and position has a different relative risk to the athlete that must be considered when selecting appropriate activities. The individual's prior history of concussions and baseline function must also be considered before the patient is released back to their sport without restrictions.

Physical Therapy Domains:
The Physical Therapy Domains are situated at the top of the conceptual model. They are the areas of Physical Therapist practice through which the clinician can directly impact the care of an athlete following a concussion. Previous discussion in this commentary supports their place within this model.

Specific treatment activities selected for any domain are dependent on the residual deficits and the point of recovery on the time line.

There are three domains in which Physical Therapist can impact the residual deficits that remain during protracted recovery:

1. Vestibular-Ocular Rehab
2. Cervical Spine Rehab
3. Exertion Activity Progression

A Physical Therapist may encounter patients with multiple deficits that require multiple domains of care. If one type of treatment domain is outside the therapist's knowledge base, they should consider collaborating with another therapist that is able to address the specific deficit that cannot be appropriately managed by a single therapist.

CONCLUSION
This conceptual model was developed from a thorough review of the literature to specifically describe the full scope of care that Physical Therapy can provide to patients recovering from a sports-related concussion. The conceptual model is made up of four levels of treatment consideration oriented vertically. Each level is dependent on the level of treatment consideration below it. The model progresses vertically, the levels become more specific to the role of Physical Therapy in the management of the recovering athlete. Horizontally, as the time line moves away from the onset of concussion, the model provides a pathway for progressing treatment.

This model can help an individual therapist organize their treatment plan, and improve their understanding of when they may need to collaborate. In addition, this model can be used by physicians and other healthcare professionals to recognize which deficits are best managed by Physical Therapy in order to make appropriate referrals. The end product of this commentary is a visual representation of Physical Therapy management of protracted recovery following a sports related concussion.

REFERENCES


