Neuropsychological Dysfunction and Treatment Recommendations following Concussion by Megan Glasmann, M.Ed. and Janiece Pompa, Ph.D.

In the United States, 1.6 to 3.8 million sports-related concussions annually occur across all age groups, with still more occurring outside of the sports arena (Langlois et al., 2005). Among children and adolescents, close to 175,000 sports- and recreationally-related traumatic brain injuries, including concussions, were treated annually, as reported in 2011 by the National Centers for Disease Control and Prevention, or CDC (Gilchrist et al., 2011). Since then, this incidence has increased by an estimated 15% each year (Lincoln et al., 2011), with a 60% increase in the number of concussions diagnosed across all age groups between 2007-2014 (Zhang, Sing, Rugg, Feeley, & Senter, 2016). Individuals aged 10-19 years accounted for 32% of diagnosed concussions in this seven-year time period, with the highest incidence of concussion (1.65%) among individuals aged 15-19 years (Zhang et al., 2016). Although efforts have been made to research the management of concussion, little to no evidence exists at present to guide the rehabilitation of children under the age of 12 who sustain concussion injuries. Currently, practitioners and researchers are advised to use the same principles of adult concussion management for children and adolescents, and to maintain these principles when treating patients with concussion or head injury caused by mechanisms other than sport- or recreation-related trauma (Meehan & O'Brien, 2017).

Given that concussions occur most frequently among school-aged children and young adults, this type of injury and neuropsychological dysfunction is very relevant to psychologists who treat children. Without proper diagnosis and treatment, concussive symptoms may be prolonged beyond the expected 7-10 day resolution of 80-90% of concussion complaints, as

described by the International Concussion Organization (McCrory et al., 2017). Cases in which symptoms are prolonged beyond the expected time frame of recovery are termed post-concussion syndrome (PCS).

Although much research is still required to understand the neuropsychological structures and processes that are disrupted after concussion injury, data has suggested that chronic white-matter tract deterioration may occur following sport-related concussion, particularly in the (1) superior longitudinal fasciculus (SLF), (2) corticospinal tract, and (3) anterior thalamic radiations (Multani et al., 2016). These areas are important for the integration of auditory and speech nuclei, fine motor control, alertness, learning, memory, and emotional regulation.

Additional research has indicated that symptoms experienced after concussion injury may be due to poor modulation or gating of incoming sensory information by the temporoparietal cortex, prefrontal cortex, and hippocampus (Kumar et al., 2005). Still other data suggest that sub-concussive impacts alter neuro-metabolism in the dorsolateral prefrontal (DLPFC) cortex and the primary motor area (M1) (Aron et al., 2004; Diamond, 2013; Poole et al., 2014). These areas are responsible for the voluntary control of behavior and higher cognition. Together, this research would suggest that the prefrontal cortex, primary motor area, basal ganglia, and limbic system, as well as white matter tracts, are implicated in the etiology of concussion symptoms.

Although these preliminary findings suggest that the brain is broadly affected by PCS, there is limited understanding or evidence basis for treating concussions and the neuroanatomical areas affected. That said, the International Concussion Organization has identified physical and cognitive rest as the cornerstone of concussion management (McCrory et al., 2017). The CDC has followed suit, endorsing a period of 24 to 48 hours of cognitive and physical rest following

concussion. These recommendations are based on retrospective research that suggest that rest reduces symptoms experienced following concussion injury (Moser et al., 2012; Gibson et al., 2013; Moser et al., 2015; Taubman et al., 2016). However, recovery is to be expected whether or not concussed individuals rest following concussion, and without a control group for comparison, the rationale for this recommendation is questionable. In addition, the International Concussion Organization has not defined the term "rest", instead suggesting only that "in the absence of evidence-based recommendations, a sensible approach involves the gradual return to school and social activities (prior to contact sports) in a manner that does not result in a significant exacerbation of symptoms" (McCrory et al., 2013; p. 3).

Other researchers have attempted to provide more explicit guidelines, defining rest as "the avoidance of mental activities that may trigger symptoms, such as watching television, using the computer, listening to music, exercising, reading or talking on the phone" (Varner et al., 2016, p. 4) and "(1) time off from school or work; (2) no homework; (3) no reading; (4) no visually stimulating activities, such as computers, video games, texting, or use of cell phones, and limited or no television; (5) no exercise, athletics, chores that result in perspiration/exertion; (6) no trips, social visits in or out of the home; and (7) increased rest and sleep" (Moser et al., 2012, p. 922). Although rest guidelines for concussed individuals by researchers and practitioners have attempted to reduce cognitive load, exposure to stimuli, and physical exertion, some studies have indicated that rest does not reduce symptoms, and strict rest may even prolong post-concussive symptoms in individuals (Thomas et al., 2015; Varner et al., 2016; Buckley et al., 2016)

In contrast, active rehabilitation has been described as the gradual reintegration of concussed athletes/students to activity, including low-level exercise (Leddy et al., 2010, 2013). Multiple researchers in the field (Baker, et al., 2012; Leddy et al., 2010, 2013; Howell et al. 2016) have indicated that a higher frequency of exercise, rather than rest, following concussion may reduce recovery time, especially for individuals experiencing PCS. It is important to note that these recommendations emphasize "liberal noncontact activity […] and subsymptom threshold aerobic exercise" (Leddy et al., 2016, p. S91-S92).

In a similar vein, cervicovestibular rehabilitation therapy, or a combination of cervical and vestibular physiotherapy, has recently received attention as a means of reducing concussion symptoms. This therapy is based on the role that cervical musculoskeletal dysfunction can play in post-concussional headaches following cervical spine trauma that may co-occur during the concussion impact (Treleaven et al., 1994). Cervical spine physiotherapy intervention may include cervical and thoracic spine joint mobilization, cervical neuromotor retraining exercises, and sensorimotor retraining exercises. Vestibular rehabilitation may include gaze stabilization, standing and dynamic balance exercises. When combined, these treatments have been shown to be 3.91 times more effective in reducing symptoms, compared to rest and stretching (Schneider et al., 2014). In one study, 73% of individuals receiving cervicovestibular therapy were medically cleared within 8 weeks of initiation of treatment, compared with only 7% in a control group where rest and stretching were recommended (Schneider et al., 2014).

Overall, considerable research still needs to be done to determine the most effective treatment for concussion. It is likely, however, that an interdisciplinary approach, including a temporary reduction of cognitively loaded activities, light aerobic exercise, active rehabilitation,

and cervicovestibular therapy, would be helpful in reducing symptoms. Youth with concussion injuries may benefit from consultation and support from a school psychologist, including the use of accommodations under Section 504 (of the Rehabilitation Act of 1973), when necessary; a physical therapist or physiologist for rehabilitation and strengthening exercises to reduce headache and vestibular problems; and a general practitioner for possible alternative or auxiliary treatments, such as medication. Until more evidence is provided with regard to the efficacy of different treatments, it is important to closely monitor the trajectory of the concussed individual's progress with regard to symptom reduction. Although the expectation is that a person's concussion symptoms will remit over time regardless of chosen therapy, his or her recovery may be facilitated by more active therapies rather than by complete rest and inactivity, as has traditionally been recommended in the past.

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