AquaJogging the brain: An early intervention in concussion management?

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Mild traumatic brain injury has been shown to result in decreased cerebral blood flow. Water-based exercise has recently been shown to increase cerebral blood flow when compared to land-based exercise. It seems reasonable that the initial introduction of water-based exercise may improve the recovery and return to activity of patients who have sustained a concussion.

Key Words: *Concussion management; Water-based exercise; Return to activity; Cerebral blood flow*

Concussions have garnered attention in the popular media and scientific literature during the last several years. The understanding of the pathophysiology and diagnosis of concussion has improved with the increased attention but management and treatment remain a difficult endeavor. A recent article (1) hints at a modification to current concussion management protocols. An extrapolation of Pugh et al's (1) findings suggests that the use of water aerobic exercise may be a useful initial step in return-to-activity protocols in concussion management.

A cerebral concussion is a traumatically induced alteration in brain function (2-5) that can be summarized as a disorder of information processing. A concussion results in a complicated cascade of physiologic events at the cellular level that involve bioenergetics, cytoskeletal and axonal alterations, and impairments in neurotransmission (6-8). The initial injury alters membrane permeability with excessive neurotransmitter release and an abnormal distribution of ions across the axon. Restoration of neurotransmitter and ion distribution requires a large amount of energy from adenosine triphosphate (ATP) to supply the sodium potassium pump (6-9). Increases in calcium concentration cause mitochondrial dysfunction, and disrupt neurofilaments and microtubules, impairing neural connectivity (6-9). The time course of this cascade is illustrated in a well-known figure (6,7).

Of particular importance within the pathophysiology of concussion is the change in cerebral blood flow. Neurons, glia and blood vessels are integrated into a neurovascular unit. Alterations in the neurovascular coupling will cause neuronal dysfunction (10). Decreases in cerebral blood flow have been shown to occur and persist in mild traumatic brain injury in adults (6,8,11,12) and children (13). This decrease may amount to 50% of normal cerebral blood flow and may persist for 10 days (6). Abnormalities in 1) neurovascular coupling (distribution of cerebral blood flow proportional to functional activity present in various brain regions), 2) cerebral vasoreactivity (response to CO_2, which is the most influential modulator of cerebral blood flow), and 3) cerebral autoregulation (maintenance of steady cerebral blood pressure in spite of changes in systemic blood pressure) are each postulated as mechanisms (10).

In healthy subjects, submaximal exercise may cause cerebral blood flow to increase 10% to 30% (1,14). Aerobic exercise training may engage the mechanisms of cerebrovascular control. Muscle engagement during exercise causes cortical activation in the motor and sensorimotor areas, increasing cerebral metabolism to engage neurovascular coupling. Increased CO_2 production in aerobic exercise affects cerebral vasoreactivity to regulate blood flow in response to hyper- and hypocapnea (10), which is disrupted following mild traumatic brain injury (15). Increases in blood pressure seen with exercise are countered by cerebral autoregulation to prevent overperfusion (10), which may also be disrupted following mild traumatic brain injury (12).

A recent study showed an increase in cerebral blood flow with exercise in acutely concussed (within 72 hours) patients compared to controls (14). Subjects were exercised at 30% and 70% heart rate reserve. Overall symptom scores did not worsen with exercise in the concussed subjects, but headache scores did with exercise at 70% heart rate reserve (14). Physiologic stress produced differences in cerebral blood flow between concussed patients and control subjects. This may explain increasing symptomatology with increasing activity (15). Inability to tolerate the stress persisted for 3-7 days following injury (15). After the acute phase of concussion, submaximal threshold exercise is safe and may be beneficial (16).

The article of interest investigated the effects of water-based exercise compared to land-based exercise on cerebral blood flow (1). The water- and land-based exercise bouts were matched for oxygen consumption and heart rate in fifteen healthy subjects. The principal finding of the investigation was that water-based exercise is associated with higher middle cerebral artery and posterior cerebral artery flow velocity than during land-based exercise in healthy humans (1). An intriguing hypothesis is whether this increase in flow velocity can be helpful in counteracting the decreased cerebral blood flow seen with concussions. Subsequent questions will be whether any increased blood flow will translate to improved outcomes in recovery and symptom management.

The management of sport-related concussion must balance the medical recovery of the patient with the timely return of a conditioned athlete. Several lines of evidence suggest a beneficial effect of mild to moderate exercise on cerebrovascular function, hinting that exercise may be useful in dysfunction. Current management protocols utilize a graduated exercise protocol that hinges on reported symptoms, under the assumption that improvement in pathophysiologic processes accompany the reduction of symptoms. Legislation in most states now makes this medical algorithm a judicial requirement.

I suggest that water-based exercise should be further studied as part of the protocol for return to activity in a concussion patient. This could potentially improve the decreased cerebral blood flow associated with mild traumatic injury and ease the transition into full physical

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activity. The currently available literature suggests this will be most effective as submaximal exercise at the 30% heart rate reserve range after 72 hours has elapsed since the injury. The available literature does not constitute a definitive investigation of this hypothesis however. This will require investigation by independent researchers in a properly designed study. Improvement in evidence-based concussion management is sorely needed.

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