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Sports-related concussion: ongoing debate

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Research in mild traumatic brain injury (mTBI), also known as concussion, has increased significantly within the past decade parallel to the increased attention being given from injured athletes on high school, collegiate and professional sports teams. These patients have focused the research community's efforts into further understanding the pathophysiological underpinnings of the injury as well as its both short-term and long-term effects.[1] Widespread media coverage and several high-profile cases have raised the issue of possible severe and devastating long-term consequences of repetitive sports-related brain trauma that may involve the acquisition of a proteinopathy[2] as well as an increased risk for developing neurodegenerative diseases associated with repetitive concussive and subconcussive blows.[3]

Following a concussive episode there is a destructive pathophysiological and biochemical response that initiates a chain of neurometabolic and neurochemical reactions that include activation of inflammatory response, imbalances of ion concentrations, increase in the presence of excitatory amino acids, dysregulation of neurotransmitter synthesis and release, imbalance in mitochondrial functions and energy metabolism, and production of free radicals.[4] Most of these molecular changes resolve spontaneously but, since cells are highly vulnerable, a second concussive event during this period of altered cell functions may have catastrophic consequences up to cell death. So, as the name may lead you to believe, *there is nothing mild about mTBI at the cellular level*. Ignoring what is basic research in mTBI has shown in the last decade, given the high rates of sports-related brain injury, the clinical community has been hesitant to directly address, modify or research its diagnostic or treatment approach for nearly two decades.

Clinical management of concussion is mainly regulated by position statements released by experts in the field of concussion management. These position statements are revisited and released on a quadrennial basis and are typically adopted as clinical gold standard in the management of concussion by all regulating bodies within the medical community. As such, the recommendations themselves become the foundation for mTBI or sport-related concussion management. Medical doctors, athletic trainers and neuropsychologists as well as other allied health professionals treating concussed young people have been using the same clinical approach with little noticeable change for the past 20 years.

According to recently published American Medical Society for Sports Medicine position statement: 'Concussion in Sport'[5] and endorsed by the National Trainers' Athletic Association and the American College of Sports Medicine, "Concussion is defined as a traumatically induced *transient disturbance of brain function* and involves a complex *pathophysiological process*."

The term 'transient' has historically been used to describe the spontaneous alleviation of clinical findings upon examination. We believe that the use of this term is contradictory to biological findings in animal models of injury,[6] and neurophysiological[7] and neuroimaging findings in humans which suggest high risk for long lasting, both *ultrastructural* and functional brain alteration induced by even a single concussive blow. It should be noted that even with the multitude of signs and symptoms, alterations in the neurochemical environment, and disruption of normal neurometabolic reactions, conventional neuroimaging techniques and neuropsychological tests fail to adequately detect these alterations in the subacute phase of injury.[8] However, utilising susceptibility-weighted imaging , functional MRI, diffusion tensor imaging, magnetic resonance spectroscopy and positron emission tomography advanced neuroimaging techniques have demonstrated structural, and metabolic alterations after a single and multiple concussions.[9–18] Several researchers have now detected similar abnormalities after multiple head blows that DO NOT result in concussion.[19 20] These studies underscore the sensitivity of these progressive imaging techniques for detecting the subtle changes and nuances in brain morphology, physiology and function caused by concussive and, perhaps, even subconcussive blows to the head.

The definition of concussion in this position statement is limiting in the sense that it restricts the discussion of concussion to a group of 'clinical symptoms' and 'functional disturbances'. Thus 'recovery' from concussion is defined by the resolution of 'clinical symptoms' and 'functional disturbances'. Along these lines, current best practice suggests that the recovery of clinical symptoms and resolution of cognitive function as measured through various neuropsychological testing methods would be demonstrative of recovery from injury. However, this clinical process is lacking in one specific domain as outlined by the AMSSM definition of concussion. Without the inclusion of diagnostic tools designed to directly evaluate the underlying "complex pathophysiological processes affecting the brain…" our true understanding of recovery from concussion will continue to remain incomplete at best. Sports medical personnel diagnosing, treating and releasing patients back to the field of play may consider to include diagnostic procedures aimed at measuring the aberrant

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physiological processes in such a way as to confirm the evolution of physiological processes in the brain and 'true return-to-normal'.

We understand that at present, such sophisticated studies are often not easily accessible, and the full implication of them is not yet established. Continuing research should indicate what will be cost effective in determining safe return-to-play.

We believe that if concussion indeed, is a *complex pathophysiological processes affecting the brain*, proper (physiological, brain imaging etc.) diagnostic tools have to be clinically validated and implemented in practice to directly and accurately assess these *complex pathophysiological processes*. However, this continues NOT to be the case within the guidelines of the AMSSM Position Statement and/or previous other accepted statements on concussion in sport. Rather, this recent statement suggests that a 'graded symptoms checklist provides an *objective tool* for assessing a variety of symptoms related to concussion while also tracking the severity of those symptoms over serial evaluation'. While we do not currently understand the true pathophysiology of concussion and/or contributing factors for permanent versus transitory physiological damage, the graded symptoms checklist will never bridge the knowledge gaps at the junction between neuroscience and clinical management of sport-related concussions.

Correction notice This paper has been corrected since it was published Online First. The fifth reference has been added.

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