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Constructing a Dynamic Model of Concussion

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1 Tracking: Complexity in Biological Systems

Aim

To construct a causal-loop diagram and corresponding system dynamics model of concussion pathology and recovery at the individual scale. These models will contribute to a greater understanding of the factors involved in concussion recovery and will inform the development of a new classification system for traumatic brain injury.

Problem

- Traumatic brain injury has been called "the most complicated disease of the most complex organ of the body" (Marklund and Hiljed 2011).
- In the United States, an estimated 1.7 million people suffer a traumatic brain injury per year (Paull et al. 2018). Seventy to ninety percent of these cases are mild TBI, or concussion (Cassidy et al. 2004). Concussion is vastly underreported; one study found that at least 86% of cases might go unrecognized (Delaney et al. 2005).
- No single definition of concussion (also known as mTBI) is accepted across disciplines, though several different definitions are available (Comper et al. 2005; Hawryluk & Manley 2015).
- Injury occurs in context. Traumatic biomechanical forces in the brain can occur from direct (to the head) or indirect (to the body) impact (e.g., motor vehicle accidents), or intra-cranial changes in pressure (e.g., blast exposure) (Patterson & Hovda 2005).
- Following a concussion many people become symptomatic within a short period of time. However, an estimated 15% of people experience longer-term symptoms and deficits, although this number has been disputed (Zaider et al. 2007). These impairments can cause significant distress and debilitation.
- The medical field currently lacks reliable and accessible means of identifying individuals at risk for more prolonged or complicated recoveries from concussion.
- The current classification system for traumatic brain injury (mild, moderate, severe – based on the Glasgow Coma Scale) lacks precision and does not reliably predict recovery. The field is engaged in developing a new classification system.
- No clinically useful biomarker or imaging technique has been identified for concussion, although several show promise.
- A wide variety of medical disciplines and specialties study and treat individuals with concussions.

Methods

- Model development led by methodology team in cooperation with a large team of researchers and clinicians gathered by the Brain Trauma Evidence-Based Consortium (B-TEC)
- Conducted extensive review of relevant literature, interviewed many key researchers, clinicians and athletic trainers, and conducted focus groups with young athletes suffering from prolonged recovery from concussion and their parents
- Iterative model development with frequent review by experts

Next steps

- Enhance conceptual model based on information from interviews and literature review
- Acquire reference behavior data (recovery trajectories at the individual level)
- Develop system dynamics computational model that will generate estimated recovery trajectories based on individual inputs for key parameters. The model will assist in the development of a new classification system for TBI, identify research gaps, aid in the design of successful clinical trials (especially appropriate inclusion/exclusion criteria), and promote discussion among experts
- Collaborate with a related B-TEC project that is creating data-driven models using OCCAM reconstructability analysis software