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INVESTIGATING TIME-DEPENDENT STRAIN-BASED CUMULATIVE HEAD IMPACT EXPOSURE IN CANADIAN VARSITY FOOTBALL

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ABSTRACT

Repeated subconcussive head impacts (rSHI) in contact sports like American football are linked to changes in brain white matter (WM) microstructure, commonly assessed through imaging, with changes in fractional anisotropy (ΔFA) serving as a marker of changes in WM structural integrity over time. Understanding how head impact exposure (HIE) influences these changes is critical for identifying injury mechanisms. While HIE has traditionally been quantified with kinematic metrics, recent studies suggest that strain-based metrics—like the 95th percentile maximum principal strain (95MPS), estimated via finite element modeling—better correlate with imaging changes, offering a more biologically relevant measure of brain tissue response. Cumulative strain over time has been associated with ΔFA, with the time between hits (TBH) further modulating this relationship, as closely spaced impacts may increase vulnerability. Given WM's region-specific injury susceptibility, incorporating regional strain metrics may strengthen the connection between HIE and ΔFA. This study compares WM whole-brain and WM region-specific 95MPS using two cumulative HIE schemes: summation and TBH-weighted summation.

Impact kinematics were recorded for a defensive back during a Canadian varsity football season using a Vector instrumented mouthguard. Linear and rotational impact acceleration waveforms were leveraged to estimate strain responses via the Total Human Model for Safety (THUMS v4.02) head finite element model (hFEM), scaled to the player's brain volume. Strain was quantified using 95MPS in both whole-brain and regional WM. The brain of the hFEM was segmented into 49 WM bundles based on diffusion tensor imaging tractography of the player, enabling region-specific strain calculations. WM whole-brain and region-specific cumulative HIE were assessed: (1) WM whole-brain 95MPS cumulative HIE, summing strain across all impacts; (2) WM whole-brain 95MPS TBH-weighted cumulative HIE, where strain accumulation is weighted by the time between hits; (3) WM region-specific 95MPS cumulative HIE, summing strain within each WM bundle independently; and (4) WM region-specific 95MPS TBH-weighted cumulative HIE, incorporating TBH weighting within individual WM bundles. The cumulative HIE schemes will be compared and analyzed at different time points (e.g., game or practice). These comparisons will evaluate how the cumulative HIE schemes, including summation and TBH-weighted summation, influence strain accumulation over time, determine if WM region-specific 95MPS accumulates differently than whole-brain 95MPS, and explore how TBH weighting affects the identification of the most vulnerable WM regions.

Analysis is ongoing, but it is believed that identifying the contribution of regional strain and TBH weighting will help guide future studies correlating rSHI exposure with ΔFA.