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Relationship Between Brain Morphology and Head Dimensions in Varsity Canadian Football Players

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ABSTRACT

It is widely accepted that impact-induced brain strain is a primary cause of sports-related concussions. Validated finite element head models (FEHM) offer a reliable method to estimate brain strain associated with injury, particularly when the model's morphology is subject-specific. Typically, a generic FEHM is scaled or morphed using neuroimaging-based methods. Alternatively, subject-specific models can be directly built from neuroimages using conventional techniques. However, neuroimaging data is not always readily available in practice. To overcome this limitation, Wu et al. (2024) recently developed simple regression models to scale a generic FEHM without relying on neuroimages. These models use external head dimensions as predictors, enabling subject-specific brain scaling based on easily measurable anatomical features. This novel approach is particularly appealing for generating subject-specific FEHMs for Varsity Canadian football players, who often have limited access to neuroimaging systems.

This study aims to evaluate the applicability of the regression models developed by Wu et al. (2024) for estimating brain outer surface morphology parameters of Canadian varsity football players based on their head dimensions. These parameters can then be leveraged to scale a generic FEHM and achieve player-specific FEHMs in future applications. Structural T1-weighted magnetic resonance (MR) images were acquired from 19 football players using a Siemens PRISMA 3.0T scanner (Siemens Healthcare, Germany). To ensure measurement standardization and reproducibility, the MR images were processed in Slicer 3D software, where an automated script was developed to extract four key head dimensions – head circumference, head length, head breadth and tragion-to-top of the head distance – as well as three brain morphological features – brain length, brain width and brain volume. The brain morphological parameters for the 19 players were estimated from the external head dimensions using the Wu et al. (2024) regression models - 1) a model with all head dimensions, 2) a model excluding the tragion-to-top distance and 3) a model using only age and sex (without head measurements). The estimated brain morphology parameters were then compared with those measured from the MR images to assess model accuracy. Results showed that the mean absolute percentage error for regression models 1, 2 and 3 were respectively 5.4, 3.2 and 4.3% for the brain length, 4.1, 4.6 and 3.5% for brain width and 7.6, 9.1 and 5.2% for brain volume. Future work will determine whether this level of accuracy is sufficient for predicting subject-specific brain strain with an acceptable degree of precision.

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