Title: A Decision Tree Framework for Clinically Intuitive Prediction of Persisting Symptoms After Concussion

Authors: Mathew J. Wingerson, Joshua R. Kniss, Julie C. Wilson, David R. Howell

Author affiliations:

University of Colorado Anschutz School of Medicine, Aurora, CO, USA

Children's Hospital Colorado, Aurora, CO, USA

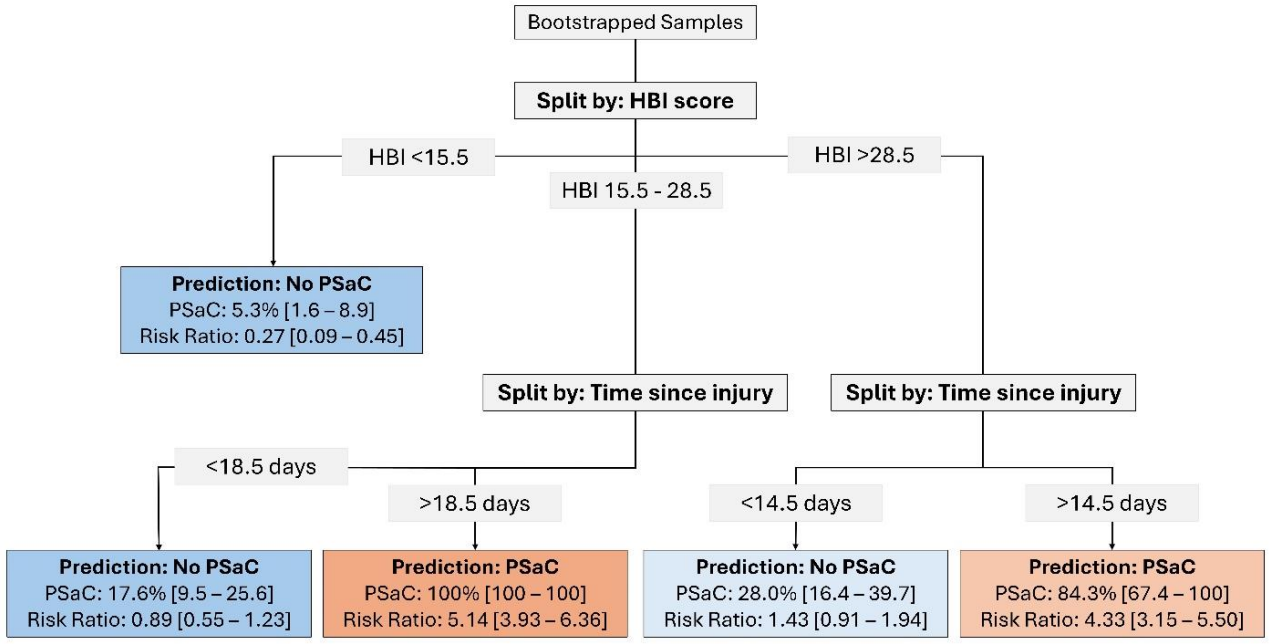
Higher initial post-concussion symptom burden is a known risk factor for Persisting Symptoms After Concussion (PSaC: symptoms lasting ≥28-days). Symptoms change variably in the weeks following concussion; thus, at initial post-injury assessments, clinicians intuitively account for time since injury when determining how patient-reported symptoms contribute to PSaC risk. **PURPOSE:** To develop a decision tree identifying clinical cut points for post-concussion symptom scores and time since injury that distinguish adolescents at risk for developing PSaC.

METHODS: We conducted a retrospective review of adolescent athletes presenting to a specialty care concussion clinic ≤21-days of concussion. Patients were 10-18 years old, reported post-concussion symptoms via the Health and Behavior Inventory (HBI; 0=no symptoms, 60=highest symptom burden) at initial evaluation, and were followed until self-reported symptom resolution. Gini index scores, a standard method for developing decision trees, identified cut points for predicting PSaC development, based on both patient-reported HBI score and time since injury (days between injury and initial evaluation). Bootstrapping was used to estimate risk ratios for PSaC in terminal nodes of the tree, with values >1.0 indicating greater risk.

RESULTS: Of 305 patients (14.5±2.3 years; 37% female; initial evaluation 8.7±5.4 days post-concussion), N=60 (20%) developed PSaC and N=245 (80%) did not. Our decision tree correctly predicted PSaC status in 81.9% of patients, with an Area Under the Curve of 0.71. Patients seen >14 days post-concussion with an HBI score >28 points had 4.3x (95% CI: 3.2x – 5.5x) the expected risk of PSaC compared to the rest of the sample (Figure).

CONCLUSION: As a rule-of-thumb guide supporting existing clinical reasoning, our decision tree contextualizes how stratifying patients based on just two factors – self-reported symptoms and time since injury – can effectively estimate PSaC risk.

Figure. Clinical cut points for HBI score (range: 0-60) and time since injury (days post-concussion, range: 0-21) when predicting PSaC development. Also included are bootstrapped means [95% confidence intervals] for the percentage of patients with PSaC and relative PSaC risk in each terminal node. Bootstrapping was conducted with replacement for 1,000 iterations.



Risk ratios are calculated with respect to the overall bootstrapped samples prevalence of PSaC. A risk ratio of 1.0 indicates that the risk of PSaC in that node is equal to the probability of PSaC in the sample as a whole. A risk ratio <1.0 indicates a lower risk compared to the remaining sample. A risk ratio >1.0 indicates a greater risk.

Quick interpretation: *Our decision-tree framework indicates that a patient presenting with an HBI score >28.5 and who was >14.5 days post-concussion (pathway furthest right in the Figure) is expected to develop PSaC; 84% (Confidence Interval: 67-100%) of patients with their same characteristics developed PSaC; and their expected risk of developing PSaC is 4.3 (CI: 3.15 – 5.50) times greater than other patients.*