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Sport Concussion Assessment Tool: Interpreting day-of-injury scores in professional ice hockey players

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ABSTRACT

Objectives: To characterize the clinical utility of Sport Concussion Assessment Tool 3 (SCAT3) baseline and normative reference values for the assessment of acute concussion; and to identify the sensitivity of each SCAT3 subcomponent to the acute effects of concussion.
Design: Prospective cohort.
Methods: The day-of-concussion SCAT3 results (n = 27) of professional male ice hockey players (mean age = 27, SD = 4) were compared to athlete's individual baseline and to the league's normative reference values. Normative cutoffs corresponding to 10th percentile and natural distribution change cutoffs corresponding to 90th percentile cumulative frequency were considered uncommon.
Results: The percentages of the players with uncommon day-of-injury performance, when post-injury scores were compared to individual baseline versus (vs.) normative values, were as follows: symptoms: 96% vs. 100% (post-injury score: M = 12, Md = 12, SD = 4; severity M = 26, Md = 23, SD = 13); Standardized Assessment of Concussion (SAC): 33% vs. 27% (post-injury M = 25, Md = 26, SD = 3); modified-BESS (M-BESS): 46% vs. 46% (post-injury M = 7, Md = 5, SD = 7); Tandem Gait: 18% vs. 31% (post-injury M = 11, Md = 12, SD = 4); coordination: both 8%. The number and severity of post-injury symptoms were significantly greater, with extremely large effect sizes (Cohen's d = 2.44–3.92), than normative values and individual baseline scores. The post-injury SAC score was significantly lower relative to both baseline (d = 0.68) and normative values (d = 0.88). The post-injury M-BESS performance was significantly worse when compared to both individual baseline (d = 1.06) and league normative values (d = 1.46). No significant day-of-injury Tandem Gait deficits were observed using either comparison method.
Conclusions: SCAT3 league normative values were as sensitive as individual baseline scores during day-of-injury assessments. Symptoms were the most sensitive post-concussion component of the SCAT3.

1. Introduction

Acute concussion recognition leading to immediate removal from play reduces the likelihood of more severe injuries and prolonged recovery in sports.[1,2] However, recognition remains challenging due to the lack of an explicit definition of the lowest threshold[3] of a clinically, radiologically, neurometabolically, or neuropsychologically significant concussion. Deficits in cognitive functioning,[4] postural stability,[5] and dynamic balance control[6] have been reported after concussion, along with diverse physical, cognitive, and emotional symptoms.[7] Therefore, on an individual level, effects from concussion manifest in diverse clinical presentations.

Concussion is defined as a clinical syndrome arising from a traumatically induced time-limited disturbance of brain functions.[8] A concussion diagnosis relies on clinician judgment. Multi-modal

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clinical assessments have been designed to measure the diverse acute effects of concussion. The Sport Concussion Assessment Tool (SCAT; third edition SCAT3)[9] is used widely by sports medicine clinicians for the acute assessment of athletes with suspected concussion. The standardized approach documents injury mechanism, presence of amnesia, signs of concussion (e.g. disorientation or confusion), and level of consciousness. Several tests compose the SCAT3, including a symptom rating scale, a postural stability test (Modified Balance Erroring System, M-BESS), a timed Tandem Gait test, a finger-to-nose coordination test, and a cognitive screen (Standardized Assessment of Concussion, SAC). The SCAT5, a modification of the SCAT3, was released in 2017.[10] There were some small modifications, such as including an option to use a list of 10 words, instead of 5 words, in immediate and delayed word recall. In addition, the timing (in seconds) of Tandem Gait task was replaced with only an examiner's subjective evaluation if the athlete performs the test with or without any error.

No formal SCAT interpretation guide has been published, leaving clinicians to develop their own interpretive approach. Following a suspected concussion, clinicians can compare post-injury SCAT results to individual baseline performance (obtained when uninjured; e.g. pre-season),[11] to published normative reference values,[12] or to both.[11–13] When using individual baseline data as a comparison to post-injury performance, the relatively low test–retest reliability for the SCAT should be considered,[12] along with the few studies discussing change interpretation on each SCAT component.[14,15] In contrast, if using normative reference values as a comparison to post-injury performance, clinicians are limited by the characteristics of athletes (e.g., age, sport, sex) used for dataset development.[16]

The purpose of the present study was to improve the clinical methodology for interpreting acute post-injury SCAT3 performance. We recently developed SCAT3 normative reference values, using preseason (2013–2014) baseline data from a large sample of Finnish professional hockey league athletes.[17] We also examined test–retest reliability and developed a method for interpreting change on the SCAT3 in professional hockey players.[14] We had two aims in the current study: (i) to describe day-of-injury performance on the SCAT3 and (ii) to determine the ability of pre-injury individual SCAT3 baseline scores and normative reference values to detect acute deficits resulting from concussion.

2. Methods

The Finnish Ice Hockey league uses a concussion protocol that recommends day-of-injury SCAT3 testing for all players with suspected concussion and subsequent follow-up evaluations. Of the reported day-of-injury SCAT3s, between seasons 2013–2016, a total of 29 concussion diagnoses were made for 27 different players. The final diagnosis and return to play (RTP) day were recorded for each athlete by the team physician. Two players had two concussions. Regarding these two players, only their first concussion was included in the statistical analyses of this study. Additionally, four cases who underwent day-of injury SCAT3 testing were diagnosed with other injuries [cervical sprain (n = 2) and facial contusion (n = 2)]; they did not sustain a concussion. The SCAT3 scores of these four non-concussed athletes are not included in the statistical analyses. They are presented in Tables S4 and S5 for comparison to the scores of athletes who sustained a concussion.

Athletes diagnosed with a concussion (n = 27) were between 19 and 35 (M = 27, SD = 4) years of age on the day of injury; all were Caucasian. The Finnish translation[18] of the SCAT3 was used with Finnish players (n = 22, 81%), all others were tested in English. The SCAT3 translation was performed by a professional translator and reviewed by the authors to maintain the original denotation and connotation of items instead of exact literal or syntactical equivalence. The day-of-injury SCAT3 was administered by the team medical provider. Team medical staff members were trained by the authors to administer both baseline and post-injury SCAT3s in accordance with the SCAT3 instructions (in sideline settings, 10 or more minutes post-exercise). Barefoot performance in M-BESS and Tandem Gait tests were recorded. Eight teams and 14 examiners were involved in post-injury testing. Of the athletes, 44% (n = 12) were tested by the same person during preseason and post-injury testing sessions. Baseline to post-concussion test administration time intervals varied from 1 to 560 days (M = 127, Md = 79, SD = 122). Of the concussed athletes, 88% (23 of 26) reported a prior concussion history; 22% (6 of 27) reported prior hospitalization or neuroimaging following head trauma; 11% (3 of 27) reported a prior history of headache or migraine; and none reported a history of learning, attention, or psychiatric problems. The median time to RTP was 8 days (M = 21, SD = 48, range = 4–248) with 33% of the players remaining out of play for more than 10 days. Potential signs of concussion (loss of consciousness, balance/motor incoordination, disorientation/confusion, loss of memory, or blank or vacant look) were observed in 10 (37%) cases.

The league normative data and a large test–retest sample of uninjured players were used to calculate the cutoff scores for uncommon SCAT3 performance in this study. The league normative data are based on preseason 2013–2014 baselines of 304 players who were between the ages of 16 and 40 years (M = 25.3 years, SD = 5.2). The normative data are described in detail in a prior publication.[17] A large test–retest sample of 179 players, baseline tested a second time prior to the 2014–2015 season, were also used in this study. This test–retest sample has been described in detail in a prior publication.[14]

The comparison between the two interpretation methods (i.e., comparison to normative reference values and comparison to baseline scores) was performed by selecting the 10th percentile cutoff as a limit of uncommon performance for each method. We selected the 10th percentile in an attempt to improve sensitivity and maintain specificity at a reasonable level. That is, we were willing to accept a possible 10% false positive rate in order to detect a possible concussion-related deficit on each component of the SCAT3. Accordingly, post-injury values that were identified as uncommon were defined in two ways. First, according to normative values as previously described[17]: Symptom Score = 4 or greater, Symptom Severity = 6 or greater, SAC = 24 or lower, M-BESS = 6 or greater, and Tandem Gait = 12.9 or greater. Second, uncommon change in performance was defined according to the change from baseline to post-injury[14] as: Symptom Score = +3 or greater, Symptom Severity = +5 or greater, SAC = −3 or lower, M-BESS errors = +3 or greater, and Tandem Gait = +4 s or greater, when post-injury scores were compared to personal baseline scores.

The individual post-injury to baseline change score, hereafter referred to as "baseline-adjusted post-injury score", was calculated by subtracting the players' most recent preseason baseline score from the day-of-injury score. The two-season test–retest change score, hereafter referred to as "test–retest difference score", was calculated by subtracting the season 1 baseline score from the season 2 baseline score. This was done to illustrate normal test-retest variability in the sample, and to ensure that test–retest variability among the current sample of participants was similar to the variability reported for the league.[14]

Descriptive post-injury characteristics [M, Md, SD, interquartile range (IQR)] for concussed athletes were calculated. Variable distribution normality was assessed with Kolmogorov–Smirnov and Shapiro–Wilk tests. Because of skewed distributions, non-parametric Mann–Whitney U tests were used to examine between-group (day-of-injury vs. league normative value) differences and Wilcoxon Signed Ranks tests for within-subject

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