



## Rapid sideline performance meets outpatient clinic: Results from a multidisciplinary concussion center registry



G. Kyle Harrold<sup>a</sup>, Lisena Hasanaj<sup>a</sup>, Nicholas Moehringer<sup>a</sup>, Isis Zhang<sup>a</sup>, Rachel Nolan<sup>a</sup>, Liliana Serrano<sup>a</sup>, Jenelle Raynowska<sup>a</sup>, Janet C. Rucker<sup>a,c</sup>, Steven R. Flanagan<sup>d</sup>, Dennis Cardone<sup>e</sup>, Steven L. Galetta<sup>a,c</sup>, Laura J. Balcer<sup>a,b,c,\*</sup>

<sup>a</sup> Department of Neurology, New York University School of Medicine, New York, NY, USA

<sup>b</sup> Department of Population Health, New York University School of Medicine, New York, NY, USA

<sup>c</sup> Department of Ophthalmology, New York University School of Medicine, New York, NY, USA

<sup>d</sup> Department of Physical Medicine and Rehabilitation, New York University School of Medicine, New York, NY, USA

<sup>e</sup> Department of Primary Care Sports Medicine - Orthopaedics, New York University School of Medicine, New York, NY, USA

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### ABSTRACT

**Objective:** This study investigated the utility of sideline concussion tests, including components of the Sports Concussion Assessment Tool, 3rd Edition (SCAT3) and the King-Devick (K-D), a vision-based test of rapid number naming, in an outpatient, multidisciplinary concussion center treating patients with both sports-related and non-sports related concussions. The ability of these tests to predict clinical outcomes based on the scores at the initial visit was evaluated.

**Methods:** Scores for components of the SCAT3 and the K-D were fit into regression models accounting for age, gender, and sport/non-sport etiology in order to predict clinical outcome measures including total number of visits to the concussion center, whether the patient reached a SCAT3 symptom severity score  $\leq 7$ , and the total types of referrals each patient received over their course. Patient characteristics, differences between those with sport and non-sport etiologies, and correlations between the tests were also analyzed.

**Results:** Among 426 patients with concussion, SCAT3 total symptom score and symptom severity score at the initial visit predicted each of the clinical outcome variables. K-D score at the initial visit predicted the total number of visits and the total number of referrals. Those with sports-related concussions were younger, had less severely-affected test scores, had fewer visits and types of referrals, and were more likely to have clinical resolution of their concussion and to reach a symptom severity score  $\leq 7$ .

**Conclusions:** This large-scale study of concussion patients supports the use of sideline concussion tests as part of outpatient concussion assessment, especially the total symptom and symptom severity score portions of the SCAT3 and the K-D. Women in this cohort had higher total symptom and symptom severity scores compared to men. Our data also suggest that those with non-sports-related concussions have longer lasting symptoms than those with sports-related concussions, and that these two groups should perhaps be regarded separately when assessing outcomes and needs in a multidisciplinary setting.

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### 1. Introduction

Although there is a substantial literature investigating concussions and concussion testing, these studies have largely been in specific populations, such as athletes, military personnel, or children. Most studies have also specifically looked at concussions in the immediate post-concussion setting, often taking place on the sidelines of sporting events or

in emergency departments. However, the CDC estimates that outpatient providers are the first to see over 200,000 concussions annually [1]. They also manage the 5.3 million Americans living with concussion and traumatic brain injury-related disability [2]. Unfortunately, there is little clinical guidance for the outpatient provider who sees patients of all ages, with concussions of varied etiologies, in the days to weeks, or even months to years, after their concussive event.

Two of the more widely utilized concussion assessment tests are the Sports Concussion Assessment Tool 3 (SCAT3) and the King-Devick (K-D) test. The SCAT3 consists of multiple components that were each investigated as part of the present study, including the Total Symptom Score, the Symptom Severity Score, the Standardized Assessment of

\* Corresponding author at: Department of Neurology, NYU School of Medicine, 240 East 38th Street, 20th Floor, New York, NY 10016, USA.

E-mail address: [laura.balcer@nyumc.org](mailto:laura.balcer@nyumc.org) (L.J. Balcer).

Concussion (SAC), the modified Balance Error Scoring System (mBESS), and the timed tandem gait (TTG). The K-D test is a vision-based assessment of rapid number naming. These tests have been shown to be useful in diagnosing concussions on the sideline [3–10]; however, use of these tests in the outpatient setting has not been thoroughly examined. These tests were used at an outpatient, urban-based, multidisciplinary concussion center to track the clinical course of patients with concussions.

This study aimed to investigate the characteristics of patients who present to a multidisciplinary concussion center and the relationship between these characteristics and patients' clinical course. The use of the sideline concussion tests in the outpatient setting and how testing results at the initial visit predict patients' clinical courses were also examined.

## 2. Subjects and methods

### 2.1. Study participants

Patients six years of age or older that had received care for a diagnosis of concussion at the Concussion Center at NYU Langone Medical Center were invited to participate in data collection for the NYU Concussion Center Registry. The Institutional Review Board (IRB) at the NYU School of Medicine approved all study protocols. Informed consent and/or age-appropriate assent were obtained from each participant.

The diagnosis of concussion was established at the time of all initial patient visits using the standard definition of witnessed or reported impulse blow to the head or body followed by any new or otherwise unexplained neurological symptom(s) [11]. Judgements about whether a concussion occurred were made for each patient by physician experts; this was applicable at the initial evaluation and at the time of data capture for these analyses.

Data that related directly to concussion diagnoses were obtained from patient electronic medical records. This information included the patient's age at the time of concussion, gender, the time that elapsed between the concussion event and each appointment with the Concussion Center, and specialty of each physician seen at the Concussion Center. Also captured were the sub-specialty services to which patients were referred (such as vestibular rehabilitation), the total number of referrals given, and mechanism of concussive injury (sports- vs. non-sports-related and nature of injury itself).

Outcome data obtained included the total number of concussion-related visits, whether a physician noted clinical resolution of the concussion, whether the physician recommended no further or as needed follow-up, and whether the SCAT3 total symptom severity score was less than or equal to 7. This cutoff of 7 points was chosen as prior literature has used this as a marker of recovery on the Post-Concussion Symptom Scale (PCSS), which is identical to the rating scale of the SCAT3 Symptom Evaluation [12–16]. Despite no firmly established PCSS score criteria for symptom recovery, Lovell and colleagues [13] demonstrated that PCSS scores less than or equal to 7 may be successfully utilized as criteria for symptom recovery by the PCSS in the absence of pre-season or other baseline scores [12,14–16].

Scores for the K-D, TTG, mBESS, SAC, and Symptom Evaluation (including symptom severity score and total number of symptoms) were also recorded from each visit at which they were documented. It is important to note that the tests were performed by a non-physician tester who was masked to etiology for the concussion, referrals made by the physician, and other study outcomes. As such, the tests were generally performed at the end of each patient visit when decisions regarding referrals and etiology had been made by the physician. Descriptions of each of these tests are outlined below.

Written informed consent was obtained from each participant; the Institutional Review Board (IRB) at New York University School of Medicine approved all study protocols.

### 2.2. Rapid number naming: King-Devick (K-D) test

The K-D test is based on the speed of rapid number naming and requires saccadic (fast to a target) and other eye movements [3–5,9]. The test involves reading aloud a series of single-digit numbers on three test cards. Standardized instructions are used; participants are asked to read the numbers from left to right as quickly as possible without making errors. K-D is scored by adding the times in seconds required to read each card; the sum of the three card times is the summary time score. When obtaining a baseline, the test is administered twice, with the faster time recorded as the patient's score. Total K-D test times for college students during pre-season baseline testing are generally close to 40 s [4,5]. As such, the K-D test requires <2 min to administer for most patients.

### 2.3. SCAT3 symptom evaluation

The Symptom Evaluation, a component of SCAT3, is comprised of 22 symptoms, each of which is rated on a 0–6 scale (0 indicates absence of a symptom; 6 is most severe). A symptom is counted towards the total number of symptoms if it has a non-zero score. The total number of symptoms thus has a maximum of 22. The symptom severity score is the sum of the individual scores for each of the symptoms; this scale has a maximum score of 132. Patients are asked to rate their symptoms based on how they feel at the time of test administration.

### 2.4. Standardized Assessment of Concussion (SAC)

Also a component of SCAT3, the SAC is a brief cognitive battery that captures domains of Orientation (score 0–5), Immediate Memory (score 0–15), Concentration (score 0–5), and Delayed Recall (score 0–5). The maximum total score for the SAC is 30. Unlike the K-D, Symptom Evaluation and BESS, lower scores indicate worse performance for the SAC.

### 2.5. modified Balance Error Scoring System (mBESS)

To perform the mBESS, patients are asked to stand with their hands on their hips and their eyes closed for 20 s. Three stances are examined, including feet together, non-dominant foot only, and tandem (heel-to-toe) stance. Any time the patient moves from the stance or opens his or her eyes, an error is recorded by the examiner. There is a maximum of 10 errors per 20-s period of stance, with a total maximum of 30 errors.

### 2.6. Timed tandem gait (TTG)

The TTG is performed by having patients walk using a tandem, or heel-to-toe, gait. Patients are instructed to walk with this tandem gait for 3 m, turn 180°, and return 3 m to the starting point, again using the tandem gait. Patients are asked to complete this as quickly as possible. This is repeated for 4 trials; the fastest time is counted as the TTG score.

### 2.7. Statistical analyses

Statistical analyses were performed using Stata 14.1 software. Logistic regression and linear regression models were used to assess the relation between test scores and dichotomous patient characteristics (such as gender, sport/non-sport etiology) and between test scores and patient outcomes as continuous variables, accounting simultaneously for age. Pearson linear correlations were also used to examine the relation of test scores to patient characteristics and the inter-relation between scores for each test.

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