Journal of the Neurological Sciences 356 (2015) 97–101

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Evaluation of the King–Devick test as a concussion screening tool in high school football players

Daniel H. Seidman [a], Jennifer Burlingame [a], Lina R. Yousif [a], Xinh P. Donahue [a], Joshua Krier [a], Lydia J. Rayes [a], Rachel Young [a], Muareen Lilla [b], Rochelle Mazurek [b], Kristie Hittle [b], Charles McCloskey [a], Saroj Misra [a], Michael K. Shaw [c,*]

[a] Department of Family Medicine, St. John Macomb-Oakland Hospital, St. John Providence Health System, United States
[b] Department of Physical Rehabilitation, St. John Macomb-Oakland Hospital, St. John Providence Health System, United States
[c] Department of Medical Education and Research, St. John Macomb-Oakland Hospital, St. John Providence Health System, United States

ARTICLE INFO

Article history:
Received 20 November 2014
Received in revised form 10 June 2015
Accepted 11 June 2015
Available online 12 June 2015

Keywords:
Traumatic brain injury
Diffuse axonal injury
Neuropsychological tests
Post-concussion syndrome
Visual motor coordination
Football

ABSTRACT

Objective: Concussion is the most common type of traumatic brain injury, and results from impact or impulsive forces to the head, neck or face. Due to the variability and subtlety of symptoms, concussions may go unrecognized or be ignored, especially with the pressure placed on athletes to return to competition. The King–Devick (KD) test, an oculomotor test originally designed for reading evaluation, was recently validated as a concussion screening tool in collegiate athletes. A prospective study was performed using high school football players in an attempt to study the KD as a concussion screening tool in this younger population.
Methods: 343 athletes from four local high school football teams were recruited to participate. These athletes were given baseline KD tests prior to competition. Individual demographic information was collected on the subjects. Standard team protocol was employed to determine if a concussion had occurred during competition. Immediately after diagnosis, the KD test was re-administered to the concussed athlete for comparison to baseline. Post-season testing was also performed in non-concussed individuals.
Results: Of the 343 athletes, nine were diagnosed with concussions. In all concussed players, cumulative read times for the KD test were significantly increased ($p < 0.001$). Post-season testing of non-concussed athletes revealed minimal change in read times relative to baseline. Univariate analysis revealed that history of concussion was the only demographic factor predictive of concussion in this cohort.
Conclusion: The KD test is an accurate and easily administered sideline screening tool for concussion in adolescent football players.

1. Introduction

Concussion is the most common type of traumatic brain injury, and results from impact or impulsive forces to the head, neck or face. Athletes in certain contact sports may be especially vulnerable to concussion [1]. Symptoms can include amnesia or loss of consciousness, and symptomatic changes in three areas: physical (drowsiness, loss of balance, weakness in extremities), cognitive (feeling in a fog, slurred speech), and emotional (irritability) [2,3]. Due to the variability and subtlety of symptoms, concussions may be unrecognized or even ignored, especially with the pressure placed on athletes to return to competition. As demonstrated in animal models [4,5], and suggested in human studies [6,7], athletes who have had one concussion may be susceptible to another, especially if the new injury occurs before symptoms from the previous concussion has completely resolved. A phenomenon known as second impact syndrome [6,8], while rare, is also a risk of repetitive concussion. The neurobiology of concussion has been described by Giza et al. as a neuro-metabolic cascade of events that involves bio-energetic challenges, cytoskeletal and axonal alterations, impairments in neurotransmission, vulnerability to delayed cell death and chronic dysfunction. In the acute setting, this increased demand for energy occurs in a setting of normal or reduced cerebral blood flow, resulting in an uncoupling, or mismatch, between energy supply and demand [9].

Sport-related concussion has received increased scrutiny recently with the realization that repetitive brain injury may lead to consequences later in life — including anxiety, depressive disorders and chronic traumatic encephalopathy (CTE). Per Gardner et al., CTE has recently been redefined from the original condition resembling Alzheimer's disease in

Abbreviations: KD, King–Devick; ImPACT, immediate post-concussion and cognitive testing; MACE, military acute concussion evaluation; LOC, loss of consciousness; SCAT, sport concussion assessment tool; SAC, standardized assessment of concussion; PCSS, post-concussion symptom scale; SAC, standardized assessment of concussion.

* Corresponding author at: St. John Macomb-Oakland Hospital, 12001 E. Twelve Mile Road, Warren, MI 48093, United States.
E-mail address: michael.shaw@stjohn.org (M.K. Shaw).

http://dx.doi.org/10.1016/j.jns.2015.06.021
0022-510X/

professional boxers to a new condition observed in athletes and others that shares many features with known psychiatric disorders and other forms of dementia [10]. It has also been realized that prompt diagnosis of sport-related concussion can allow athletes to be removed from competition for recovery, potentially preventing long-term sequelae of repetitive head trauma [11,12]. The King–Devick (KD) test was recently validated as an accurate and reliable concussion screening test in mixed martial arts fighters, rugby players and collegiate athletes [13–15].

Originally designed as an oculomotor test for reading evaluation, the KD test is based on performing rapid number naming which requires eye movements, concentration, attention and language [14]. The test subject reads a series of numbers in right-to-left and up-to-down order on three test cards. The test is available in a physical spiral bound test or electronic iPad application. The accuracy of the reading and the time taken to read the cards is recorded. A baseline is established and used for comparison. Worsening of cumulative read time from baseline has been noted in players diagnosed with concussion [13–16]. The test can be administered on the sideline during competition in less than 2 min, by a layperson [17], and may aid in the detection of athletes with concussion.

2. Methods

337 varsity football players from four Southeast Michigan high schools were enrolled in this prospective study, which took place during the Fall 2013 season. The St. John Providence Health System IRB committee approved the study. All participants signed a written consent to be a part of the study. If participants were minors at the time of enrollment, written consent by their parent/legal guardian was obtained along with assent of the minor. The administration and head coaches of each of the high schools approved participation in the study. Inclusion criteria included all high school athletes from participating schools participating in football. Subjects were willing and able to give informed consent according to the guidelines established by the St. John IRB or those minors with signed informed consent from their parent or legal guardian. Subjects were excluded from the study if their English language skills were insufficient to understand the written informed consent or the testing procedures. Athletes with diagnosed reading difficulties were also excluded from the study. Two athletes with diagnosed dyslexia were thus excluded.

Permission to use the King–Devick test was purchased from the King–Devick Test Inc. (Oakbrook Terrace, IL). The KD test consists of a series of three numbered cards that the participant reads while being timed. The cumulative read time of all three cards was recorded as a baseline measurement. The KD tested was administered by a research team consisting of athletic trainers, physicians, scientists and medical students, all of whom received prior training on test administration. These trained personnel were routinely available for testing at each practice and game during the season.

Baseline tests were administered at a team practice to simulate the noisy sideline environment that would be encountered during competition. The test maker's recommendations for baseline testing were followed. In brief, the athlete was asked to read each test card as quickly as possible without making an error. If an error was made that was not quickly corrected, the test was restarted. The fastest cumulative test time of two attempts was recorded as the athlete's baseline time. Individual demographic information on the subjects was collected as well. Concussion history was self-reported by answering 'yes' to the question 'Have you ever been diagnosed with a concussion?' All four teams employed ImPACT testing as part of their concussion policy. Although ImPACT testing can be utilized with normative values for this age group, baseline testing was conducted instead as it has been suggested that this is preferable [18]. Since ImPACT testing is not designed for sideline evaluation of concussion, in the event of an on-field injury, standard team practice was employed to determine if a concussion had occurred. St. John Providence Sports Medicine concussion policy is based upon the recommendations of the Concussion in Sport Group (CISG) first position statement and subsequent statements [1]. In general, concussion was evaluated when an athlete presented with a mechanism of injury—direct or indirect forces to the head, neck or face. Forces may include direct forces with the ground, another player, or other objects in the playing area; indirect forces are most common with whiplash type injuries such as a blow to the shoulders. If an injury mechanism existed, then the tests of the SCAT3 assessment tool were employed by the medical professional present to assess for concussion. Diagnosis of concussion was left to the professional with all diagnosed athletes having a deficit of at least 30% on SCAT3 tests. All athletes diagnosed in this manner were subsequently tested with ImPACT within 72 h of the event.

Study personnel were on field for all practices and games to assure prompt KD testing of diagnosed players. After on-field concussion diagnosis, the KD test was re-administered to all injured athletes within 30 min of removal from play, and the scores were recorded for comparison to baseline. Time, date, and symptomatology were also noted.

At the end of the season, the KD test was re-administered to all players to determine the extent of learning effects as well as any deviation from baseline. This testing was again done on the sidelines during a game-like practice session.

Descriptive statistics were generated to characterize the study populations with respect to demographic factors such as age, weight, height, race and position played. Continuous variables were described using the mean ± standard deviation. Categorical variables were described using frequency distributions. Univariate between group comparisons were performed using Chi squared tests for categorical variables. The normality of distribution was tested using the Shapiro–Wilk test. For comparison of read times, non-parametric statistical tests were used given the small sample size ($n = 9$) for athletes with concussion and sideline testing. Differences in KD time scores from pre- to post-season were calculated, and pre- and post-season KD scores were compared within athletes using the Wilcoxon signed-rank test. For athletes with concussion, sideline KD scores were compared similarly with pre-season baseline scores. Logistic regression analysis was performed to determine predictors, if any, of concussion by study group, age, gender, and other collected factors. All statistical analyses were performed using SPSS v. 22.0. A two tailed p-value of 0.05 or less was considered to indicate statistical significance.

3. Results

Demographic data for the concussed and non-concussed cohorts is shown in Table 1. The population of high school football athletes

Table 1
Study population demographics.

	Players without concussion	Players with concussion	p value
n	328	9	
Ethnicity			
Caucasian	236 (72%)	9 (100%)	0.63
African American	79 (24%)	0	
Other	13 (4%)	0	
Age (years)	15.4 ± 1.3	15.6 ± 1.0	0.65
Height (inches)	69.8 ± 3.4	71.7 ± 3.8	0.11
Height (centimeters)	177.3 ± 8.6	182.1 ± 9.7	
Weight (pounds)	175.6 ± 42.2	179.1 ± 29.3	0.80
Weight (kilograms)	79.7 ± 19.1	81.2 ± 13.3	
History of concussion	26 (8%)	4 (44%)	0.002
Player position			
Lineman	134 (41%)	3 (33%)	1.0
Defensive back	45 (14%)	2 (22%)	.63
Wide receiver	62 (19%)	1 (11%)	1.0
Linebacker	41 (13%)	1 (11%)	1.0
Running back	29 (9%)	1 (11%)	.58
Quarterback	15 (5%)	1 (11%)	.38
Kicker	2 (.6%)	0	1.0