

King-Devick Test for Concussion



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Saccades and Memory: Baseline associations of the King-Devick and SCAT2 SAC tests in professional hockey players

Matthew S. Galetta^a, Kristin M. Galetta^a, Jim McCrossin^c, James A. Wilson^a, Stephen Moster^a, Steven L. Galetta^{a,b}, Laura J. Balcer^{a,b,c,*}, Gary W. Dorshimer^d, Christina L. Master^{f,g}

a Department of Neurology, *b* Ophthalmology, *c* Epidemiology, *d* Medicine, University of Pennsylvania, Perelman School of Medicine, Philadelphia, *e* Philadelphia Flyers, Philadelphia, PA

f Department of Pediatrics, Children's Hospital of Philadelphia, University of Pennsylvania, Perelman School of Medicine, Philadelphia, PA

g Department of Sports Medicine, Children's Hospital of Philadelphia, University of Pennsylvania, Perelman School of Medicine, Philadelphia, PA

OBJECTIVE: The Sports Concussion Assessment Tool 2 (SCAT2) and King-Devick (K-D) tests have both been proposed as sideline tools to detect sports-related concussion. We performed an exploratory analysis to determine the relation of SCAT2 components, particularly the Standardized Assessment of Concussion (SAC), to K-D test scores in a professional ice hockey team cohort during pre-season baseline testing. We also examined changes in scores for two athletes who developed concussion and had rinkside testing.

METHODS: A modified SCAT2 (no balance testing) and the K-D test, a brief measure of rapid number naming, were administered to 27 members of a professional ice hockey team during the 2011-2012 pre-season. Athletes with concussion also underwent rinkside testing.

RESULTS: Lower (worse) scores for the SCAT2 SAC Immediate Memory Score and the overall SAC score were associated with greater (worse) times required to complete the K-D test at baseline. On average, for every 1-point reduction in SAC Immediate Memory Score, we found a corresponding increase (worsening) of K-D time score of 7.3 s (95% CI 4.9, 9.7, $p < 0.001$, $R^2 = 0.62$, linear regression, accounting for age). For the overall SAC score, 1-point reductions were associated with K-D score worsening of 2.2 s (95% CI 0.6, 3.8, $p = 0.01$, $R^2 = 0.25$, linear regression). In two players tested rinkside immediately following concussion, K-D test scores worsened from baseline by 4.2 and 6.4 s. These athletes had no differences found for SCAT2 SAC components, but reported symptoms of concussion.

CONCLUSION: In this study of professional athletes, scores for the K-D test, a measure for which saccadic (fast) eye movements are required for the task of rapid number naming, were associated with reductions in Immediate Memory at a pre-season baseline. Both working memory and saccadic eye movements share closely related anatomical structures, including the dorsolateral prefrontal cortex (DLPFC). A composite of brief rapid sideline tests, including SAC and K-D (and balance testing for non-ice hockey sports), is likely to provide an effective clinical tool to assess the athlete with suspected concussion.



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Concussions in amateur rugby union identified with the use of a rapid visual screening tool

Doug King, Matt Brughelli, Patria Hume, Conor Gissane

Sports Performance Research Institute New Zealand, School of Sport and Recreation, Faculty of Health and Environmental Science, Auckland University of Technology, New Zealand; School of Sport, Health and Applied Science, St Mary's University College, Twickenham, Middlesex, United Kingdom

AIM: To use the King-Devick (KD) test and Sports Concussion Assessment Tool 2 (SCAT2) in amateur rugby union players to identify witnessed and unrecognised episodes of concussion that occurred from match participation.

METHODS: A prospective observational cohort study was conducted on a premier club level amateur rugby union team during the 2012 competition in New Zealand. Every player completed a pre-competition questionnaire on concussion history, a baseline PCSS and two trials of the KD before they participated in any match activities.

RESULTS: For players reporting a concussion in the previous three years there was an average of 4.0 ± 2.8 concussions per player. There were 22 concussive incidents recorded over the duration of the competition (46 per 1000 match hours). Five concussive incidents were witnessed (11 per 1000 match hours) and 17 unrecognised concussive incidents were identified with the KD (37 per 1000 match hours). Witnessed concussions recorded, on average, a longer KD on the day of injury (5.5 ± 2.4 s) than unrecognised concussions (4.4 ± 0.9 s) when compared with their baseline KD.

DISCUSSION: The KD was able to identify players that had not shown, or reported, any signs or symptoms of a concussion but who had meaningful head injury. The current rate of concussion reported was a ten-fold increase in previously reported concussion injury rates. This makes the KD suitable for rapid assessment in a limited time frame on the sideline such as a five-minute window to assess and review suspected concussed players in rugby union.

Sports-Related Concussion Testing

Dziemianowicz MS, Kirschen MP, Pukenas BA, Laudano E, Balcer LJ, Galetta SL.

Department of Neurology, University of Pennsylvania, Perelman School of Medicine, 3 E. Gates Building 3400 Spruce Street, Philadelphia, PA, 19104, USA, mark.dziemianowicz@gmail.com.

Due to the recent focus on concussion in sports, a number of tests have been developed to diagnose and manage concussion. While each test measures different brain functions, no single test has been shown to quickly and reliably assess concussion in all cases. In addition, most of the current concussion tests have not been validated by scientific investigation. This review identifies the pros and cons of the most commonly used noninvasive tests for concussion in order to provide a more complete picture of the resources that are available for concussion testing. The potential utility of research tools such as the head impact telemetry system, advanced magnetic resonance imaging protocols, and biomarkers are discussed in the context of the currently employed tools.

"The King–Devick (K–D) Test is a rapid number naming test that captures impaired eye movements and saccades, attention, and language. These involve integration of functions of the brainstem, cerebellum, and cerebral cortex. Impaired eye movements and saccades have been shown to correlate with suboptimal brain function, particularly in patients following concussion. Because the K–D test does not require a medical professional and can be administered in 1–2 min, it is practical for sideline use at all levels of sports. While the K–D test has not been as thoroughly studied as other concussion tests, a study of collegiate athletes found that, on average, concussed athletes performed 5.9 s slower than their baseline, whereas controls performed, on average, almost 3 s faster. In another study of boxers and mixed martial arts fighters, those suffering a concussion showed a worsening of the times required to read the three test cards of 5 s or more, as compared with their own baseline. At this time, any worsening of the K–D score from baseline should suggest the presence of a concussion. In addition, K–D scores in studies of collegiate athletes were not negatively affected by prolonged exercise in the form of intense 2-h scrimmage. One important consideration identified with the K–D test was a learning effect associated with repeated testing. Nevertheless, the K–D test has the potential to capture brain impairment not observed in standard neurocognitive testing."



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Use of a rapid visual screening tool for the assessment of concussion in amateur rugby league: a pilot study

King D, Clark T, Gissane C.

Sports Performance Research Institute New Zealand, School of Sport and Recreation, Faculty of Health and Environmental Science, Auckland University of Technology, New Zealand. dking@aut.ac.nz

AIM: This study undertook to use the K-D sideline test with the SCAT2 to see if concussions could be identified in amateur rugby league players over a representative competition period.

METHOD: A prospective cohort study was conducted on two teams participating in an amateur rugby league. All players were tested for signs of concussion utilising the K-D test and players with longer times than their baseline scores undertook a further concussion assessment with the SCAT2.

RESULTS: Five athletes with suspected concussion were evaluated by K-D testing. Three concussions were associated with witnessed events during the matches and two athletes were identified by the team medic as having longer K-D time scores incidentally post-match compared to baseline. Post-match K-D scores for all concussed athletes were worse than baseline for those with reported or witnessed concussion events (7s; 5.0-7.1; $p=0.025$) and for those identified incidentally ($>5s$; 8.9-9.1s). Both groups also reported more symptoms on the PCSS (a part of the SCAT2) post-match.

DISCUSSION: In this rugby cohort, the K-D test was not only useful in identifying changes in players with witnessed head trauma, but in identifying changes in players with an un-witnessed suspected concussion.

"The K-D test was able to identify players with a suspected concussion, players with a concussion that was not reported or witnessed. The ease-of-use of the K-D Test made it more acceptable to team management and players and, as it provided immediate feedback to the player and coach. The K-D Test served to provide support for the decision made by the team medic to rule out the player from further match participation."

The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort

Galetta KM, Brandes LE, Maki K, Dziemianowicz MS, Laudano E, Allen M, Lawler K, Sennett B, Wiebe D, Devick S, Messner LV, Galetta SL, Balcer LJ

Department of Neurology, University of Pennsylvania School of Medicine, Philadelphia, PA 19104, USA.

OBJECTIVE: Concussion, defined as an impulse blow to the head or body resulting in transient neurologic signs or symptoms, has received increasing attention in sports at all levels. The King-Devick (K-D) test is based on the time to perform rapid number naming and captures eye movements and other correlates of suboptimal brain function. In a study of boxers and mixed martial arts (MMA) fighters, the K-D test was shown to have high degrees of test-retest and inter-rater reliability and to be an accurate method for rapidly identifying boxers and mixed martial arts fighters with concussion. We performed a study of the K-D test as a rapid sideline screening tool in collegiate athletes to determine the effect of concussion on K-D scores compared to a pre-season baseline.

METHODS: In this longitudinal study, athletes from the University of Pennsylvania varsity football, sprint football, and women's and men's soccer and basketball teams underwent baseline K-D testing prior to the start of the 2010-11 playing season. Post-season testing was also performed. For athletes who had concussions during the season, K-D testing was administered immediately on the sidelines and changes in score from baseline were determined.

RESULTS: Among 219 athletes tested at baseline, post-season K-D scores were lower (better) than the best pre-season scores (35.1 vs. 37.9s, $P=0.03$, Wilcoxon signed-rank test), reflecting mild learning effects in the absence of concussion. For the 10 athletes who had concussions, K-D testing on the sidelines showed significant worsening from baseline (46.9 vs. 37.0s, $P=0.009$), with all except one athlete demonstrating worsening from baseline (median 5.9s).

CONCLUSION: This study of collegiate athletes provides initial evidence in support of the K-D test as a strong candidate rapid sideline visual screening tool for concussion. Data show worsening of scores following concussion, and ongoing follow-up in this study with additional concussion events and different athlete populations will further examine the effectiveness of the K-D test.



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The King-Devick test as a determinant of head trauma and concussion in boxers and MMA fighters

Galetta KM, Barrett J, Allen M, Madda F, Delicata D, Tennant AT, Branas CC, Maguire MG, Messner LV, Devick S, Galetta SL, Balcer LJ

Department of Neurology, University of Pennsylvania School of Medicine, 3400 Spruce Street, Philadelphia, PA 19104, USA.

OBJECTIVE: Sports-related concussion has received increasing attention as a cause of short- and long-term neurologic symptoms among athletes. The King-Devick (K-D) test is based on measurement of the speed of rapid number naming (reading aloud single-digit numbers from 3 test cards), and captures impairment of eye movements, attention, language, and other correlates of suboptimal brain function. We investigated the K-D test as a potential rapid sideline screening for concussion in a cohort of boxers and mixed martial arts fighters.

METHODS: The K-D test was administered prefight and postfight. The Military Acute Concussion Evaluation (MACE) was administered as a more comprehensive but longer test for concussion. Differences in postfight K-D scores and changes in scores from prefight to postfight were compared for athletes with head trauma during the fight vs those without.

RESULTS: Postfight K-D scores ($n = 39$ participants) were significantly higher (worse) for those with head trauma during the match (59.1 ± 7.4 vs 41.0 ± 6.7 seconds, $p < 0.0001$, Wilcoxon rank sum test). Those with loss of consciousness showed the greatest worsening from prefight to postfight. Worse postfight K-D scores ($r(s) = -0.79$, $p = 0.0001$) and greater worsening of scores ($r(s) = 0.90$, $p < 0.0001$) correlated well with postfight MACE scores. Worsening of K-D scores by ≥ 5 seconds was a distinguishing characteristic noted only among participants with head trauma. High levels of test-retest reliability were observed (intraclass correlation coefficient 0.97 [95% confidence interval 0.90-1.0]).

CONCLUSIONS: The K-D test is an accurate and reliable method for identifying athletes with head trauma, and is a strong candidate rapid sideline screening test for concussion.



AMERICAN ACADEMY
of OPTOMETRY

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The King-Devick test for Sideline Concussion Screening in Collegiate Football

Danielle Leong, OD¹, Greg Evans, MA, ATC², Laura Balcer, MD, MSCE³, Steven Galetta, MD³

¹ King-Devick Test, LLC, Oakbrook Terrace, IL, USA; ² Wheaton College Sports Medicine, Wheaton, IL, USA; ³ Department of Neurology, New York University Langone Medical Center, New York, NY, USA

Purpose: Sports-related concussion has received increasing attention as a result of neurologic sequelae seen among athletes, highlighting the need for a validated, rapid screening tool. The King-Devick (K-D) test captures impairment of eye movements and other correlates of suboptimal brain function. We investigated the K-D test as a sideline screening tool in a collegiate cohort to determine the effect of concussion on K-D test performance and to determine the effect of physical exercise on K-D scores in the absence of concussion.

Methods: In this study, 127 athletes (mean age 20 ± 1.2 years) from the Wheaton College football and men's and women's basketball teams underwent baseline K-D testing at pre-season physicals for the 2012-2013 season. K-D testing was administered immediately on the sidelines for football players with suspected head injury during the games and changes compared to baseline were determined. Post-season testing was also performed. Additionally, basketball players were tested immediately following an intense 2.5 hour workout to test the effects of physical exercise on K-D performance.

Results: Sideline K-D scores of concussed athletes ($n=11$) were significantly higher (worse) than baseline (36.5 ± 5.6 s vs. 31.3 ± 4.5 s, $p < 0.005$, Wilcoxon signed-rank test). While concussion resulted in worse K-D scores, there was no worsening after physical fatigue. In basketball players, K-D scores post-workout showed lower (improved) K-D scores (31.8 ± 4.9 vs. 34.5 ± 4.8 , $p < 0.05$, Wilcoxon signed-rank test). Additionally, post-season testing demonstrated improvement of scores likely consistent with learning effects. (35.1 ± 5.2 s vs. 34.4 ± 5.0 s, $p < 0.05$, Wilcoxon signed-rank test). Test-retest reliability was analyzed between baseline and post-season administrations of the K-D test resulting in high levels of test-retest reliability (intraclass correlation coefficient (ICC)=0.95 [95% Confidence Interval 0.85 - 1.05]).

Conclusions: The data show worsening of K-D scores after concussion however no worsening following physical fatigue. This study supports the King-Devick test as an accurate, reliable and rapid sideline tool to identify athletes with concussion.



National Athletic
Trainers' Association

Poster Presentation at the National Athletic Trainers' Association 2013 Annual Meeting

College and Elite Athletes Using the King-Devick Test iPad App

Hunsaker A, Hamson-Utley J, Mossbarger G
Weber State University

INTRODUCTION:

The cognitive impairments following a concussion most often affected are memory, attention, and information processing speed and efficiency (Livingston, 2011). Long-term symptoms associated with post-concussion syndrome include chronic headaches, fatigue, visual disturbances, sleep difficulties, personality changes, sensitivities to light and noise, dizziness when standing quickly, and deficits in short-term memory (Covassin et al., 2008; Daneshvar et al., 2011; Galetta et al., 2011a; Heitger et al., 2008). Oculomotor dysfunction has been shown to be one of the common symptoms of an athlete suffering from concussive symptoms (Heitger et al., 2009; Heitger, Jones, & Anderson, 2008). The King-Devick (K-D) sideline concussion test challenges athletes to process and recite numbers on three cards that become more difficult to read as the athlete progresses through the test. In previous research the K-D test has been an efficient way to detect athletes suffering from oculomotor dysfunction, delays in information processing, attention and language (Galetta et al., 2011; Galetta et al., 2011; King, Clark, & Gissane, 2012). The purpose of this study is to examine the differences in baseline test scores between genders and across collegiate and extreme sport professional athletes using the K-D sideline concussion test. Our first hypothesis was that athletes will have increases times compared to non-athletes. The second hypothesis was that there will be a difference between male and female test times.

METHODS:

Participants: 152 total participants (89 male, 58.6%; 64 female, 41.4%). 96 Collegiate Athletes (48 football, 26 women's soccer, 16 women's rugby, 6 men's hockey). 35 Elite extreme snow sport athletes. 21 University non-athletes.

Procedure: Each participant was tested on the K-D sideline concussion test, which tests the time it takes to perform rapid number naming. Tests were administered using the King-Devick Test app on the iPad. Participants were instructed to tap the screen of the iPad to start the test and then read the numbers out loud as fast as possible without making any errors and then tap the screen to stop the time. The test was given twice to each participant. The fastest time between two tests with no errors was recorded as the baseline score. Collegiate athletes were administered the test in the athletic training room or weight room. Elite athletes were tested in a hotel lobby during registration or in the medical trailer at the event. Non-athletes were tested in a classroom setting.

RESULTS:

There was a significant difference [$F_{(5, 146)} = 2.530, p = .031, \eta^2 = .080$] between sport types. Tukey HSD post-hoc expressed a significant pairwise comparison (P value range = 0.001- 0.015). Extreme-snow sports ($M = 47.69, SD = 7.58$) were significantly slower than university football ($M = 42.85, SD = 8.19$) and university men's hockey ($M = 36.43, SD = 8.06$). University women's soccer ($M = 46.45, SD = 7.48$) was significantly slower than university men's hockey ($M = 35.43, SD = 8.06$). There was no significant difference in test time-score between athletes and non-athletes [$F_{(1, 150)} = 0.092, p = 0.762, \eta^2 = 0.001$]. No significant difference was found between male and female [$F_{(1, 150)} = 1.10, p = 0.296, \eta^2 = 0.007$].

DISCUSSION & FUTURE DIRECTIONS:

Results of this study provide initial evidence of a deficit of visual tracking between different sports using the K-D test. Elite extreme-snow-sport athletes performed the K-D test at a slower time than university men's hockey and university football athletes. This may be due to the repeated, sub-concussive blows that occur from falls during practice and recreational snowboarding or skiing (Wright). Without looking at the number of concussions experienced in each sport, university women's soccer athletes performed slower on the K-D test than university men's hockey athletes. This could have been explained by the difference in gender, however the results of the study showed there were no difference in testing times on the K-D test between males and females. Our findings contradict a previous study that showed gender differences exist in outcomes of traumatic brain injuries and concussions (Dick, 2009). An assumption for each test was that the participant was reading the numbers as fast as they possibly could. In conclusion our results show there are differences in time to perform the K-D test between sports. This could be due to the number of repeated, sub-concussive blows that are experienced by athletes in different sports. Our findings showed no differences in time between gender or athletes and non-athletes. Further research should compare the number of concussions athletes have experienced to their baseline time to determine if there are deficits between athletes with more concussions as compared to athletes with no concussion history.



Poster Presentation at the European Neurological Society 2013 Annual Meeting

The King-Devick Test is Vastly Superior to the Symbol Digit Modalities Test as a Sideline Determinant of Concussion in Mixed Martial Arts Fighters

Daniel Kantor, MD *Neurologique, Ponte Vedra, FL USA*

OBJECTIVE: To compare the Symbol Digit Modalities Test (SDMT) to the King-Devick (K-D) test as a potential rapid sideline screening for concussion

BACKGROUND: Sports-related concussion is increasingly recognized as a major public health problem due to potential for neurologic sequelae. Despite recent research that has suggested the potential role of the K-D test as a sideline screening tool for concussion, there remains a need for a rapid sideline test that requires less examiner attention. The K-D test screens for combined impairments in eye movements, attention and language by measuring the speed of rapid number naming on 3 test cards. The written version of the SDMT is based on measurement of the speed of conversion of geometric designs into number responses, and captures impairments of attention, processing speed, eye movements, writing, and other correlates of cerebral dysfunction.

METHODS: The SDMT and K-D test were administered pre- and postfight by a single examiner to 16 mixed martial arts fighters. Changes in SDMT and K-D scores from pre- to postfight were compared for those with head trauma during the fight vs. those without.

RESULTS: There was a modest correlation between head trauma during the match and whether there was worsening (increase) in K-D scores ($r=0.54$, $p=0.015$), the actual change ($r=0.42$, $p=0.055$) and the percentage change in K-D scores from pre-to postfight ($r=0.50$, $p=0.025$). Only 1 fighter without head trauma had a worsening of K-D score by ≥ 5 seconds. There was only small to medium correlation between worsening of SDMT score (decrease) and K-D score. Surprisingly there was no correlation between SDMT scores and concussion during the match.

CONCLUSIONS: This study confirms that the K-D test, but not the SDMT, is reliable in rapidly identifying athletes with head trauma. This suggests that further validation of the K-D test, but not the SDMT, may be valuable in the early detection of concussion.



Poster Presentation at the Association for Research in Vision and Ophthalmology
2013 Annual Meeting

Concussion Screening in High School Football Using the King Devick Test

Vladimir Yevseyenkov, Kirk Kaupke, Shawn Lebsock, Matthew Kaminsky; *Vision Rehabilitation, Northwestern University, Glendale, AZ.*

PURPOSE: To evaluate the effectiveness of the King-Devick (KD) test, a screening which evaluates saccadic eye movements, to identify football players who may have sustained a concussion during play. Secondary outcomes include evaluating whether performance of KD testing increases awareness of concussion in high school football players.

METHODS: Forty seven high school football players ranging from freshmen to senior grade levels and all play levels were given a baseline KD test prior to beginning of the 2012 football season. Each student also filled out a survey gauging their level of awareness of concussion signs and symptoms. During the season, three varsity level players sustained concussions on-field. Each of these players had the KD test performed within thirty minutes of impact. The concussion diagnosis was confirmed by a neurologist within days of the on-field incident. At the end of the season, the KD test was again administered to all students. Students also took a post-season survey which was identical to the one they took prior to the start of the season to gauge their awareness of concussion.

RESULTS: There was very little variance in athletes who did not have concussion when comparing pre- and post-season testing with LOA of 95% and confidence intervals of 95%. Test-retest reliability was analyzed using intraclass correlation coefficients (ICC) between baseline and end of the season data, showing correlation of 0.873 with significance of $p < 0.05$. The three football players whose concussion diagnosis was confirmed by a neurologist did in fact demonstrate diminished KD test performance times within thirty minutes of the on-field injury. Times were diminished by 41% in student 1, 100% in student 2, and 143% in student 3. Regarding the knowledge of concussions survey administered pre- and post-season, paired sample t-tests showed $p > 0.05$ significance for the question "I would say that my current knowledge level of concussions is very high." Therefore, it is evident that the football students' level of awareness of concussion significantly increased throughout the season.

CONCLUSIONS: This study showed that the King-Devick Test can potentially be used as a rapid sideline tool to identify athletes who have potential concussion in a time period of under one minute.