Journal of Science and Medicine in Sport xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

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

Original research

The King–Devick test is a valid and reliable tool for assessing sport-related concussion in Australian football: A prospective cohort study

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ARTICLE INFO

Article history:
Received 9 June 2017
Received in revised form 20 January 2018
Accepted 20 March 2018
Available online xxx

Keywords:
Diffuse axonal injury
Neuropsychological tests
Visual motor coordination
Brain injury

ABSTRACT

Objectives: Sport-related concussion (SRC) research has focused on impaired oculomotor function. The King–Devick (K–D) test measures oculomotor performance and is reported to identify suboptimal brain function. The use of the K–D test in Australian football (AF), a sport involving body contact and tackling, has not been documented. Therefore, the objective of this study was to determine the test–retest reliability and diagnostic accuracy of the K–D test on a sub-elite AF team.
Design: Prospective cohort study
Methods: In total, 22 male players (19.6 + 2.3 years) were tested and re-tested on the K–D test. Those suspected of having a SRC secondary to a significant head impact were tested. Randomly selected additional players without SRC were assessed for comparison.
Results: There were observable learning effects between the first and second baseline testing (48 vs. 46 s). The ICC for the first and second baseline tests was 0.91. Post-match test times were longer than the baseline times for players with SRC (n = 7) (−1.9 s; z = −5.08; p < 0.0001). Players tested with no signs of SRC (n = 13) had an improvement in time when compared with their baseline score (3.0 s; z = −4.38; $p < 0.0001$). The overall sensitivity was 0.98, specificity 0.96, and a kappa of $\kappa = 0.94$. The positive likelihood ratio was 11.6 and the positive predictive value was 89.0%.
Conclusions: This study supports the use of the K–D test due to its test–retest reliability, high sensitivity and specificity, and fast and simple use that is ideal for sports medicine professionals to make quick judgement on management and playability.

1. Introduction

For healthcare providers affliated with sport, the complexities associated with the recongnition and management of sport-related concussion (SRC) is challenging.[1] The 2017 consensus statement on concussion in sport stated that SRC is a traumatic brain injury and typically results in the rapid onset of short-lived impairment to neurological function.[2]

One area of SRC research has focused on impaired oculomotor function following trauma to the brain.[3] Visual processing utilizes a number of circuits throughout the brain, including visual-spatial integration, attention, motor planning, motivation and spatial organization.[4] Increased latency and decreased accuracy of saccades (fast eye movements) is accepted to follow acute head trauma.[5,6] Thus, eye function tests are a robust measure for the identification of mTBI and SRC.[4] Heitger et al.[3] demonstrated an increased number of saccades and poor motor movement timings with slower velocities of eye movements in subjects with post-concussion syndrome. As well as reflecting changes in a number of cortical areas and pathways, saccades can be used to assess

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https://doi.org/10.1016/j.jsams.2018.03.011
1440-2440/

cognitive performance changes following brain trauma including attention, spatial and temporal orientation and working memory.[7]

The King–Devick (K–D) test was originally developed as a reading tool to assess the relationship between poor oculomotor functions and learning disabilities.[8] The K–D test utilizes a series of charts of numbers that progressively become more difficult to read in a flowing manner.[7] The K–D test is reported to identify suboptimal brain function in a range of conditions and diseases including hypoxia,[9] and sleep deprivation.[10] Furthermore, the K–D test can be used as a rapid assessment tool for the identification of SRC with the benefit of not requiring a medically trained person for administration.[11] King et al.[12] utilized the K–D test to assess club-level rugby union players who had not shown, or reported, any signs or symptoms of SRC but had a suspected head injury. In their 2013 study, King et al.[12] diagnosed 22 concussive incidents and interestingly the causative head impacts were not directly witnessed in 17/22 of these cases. However, SRC was successfully detected using the K–D test. A recent study by King et al.[13] investigated the ability of the K–D test to aid in identifying witnessed and unwitnessed episodes of SRC over subsequent seasons in a junior rugby league.

The use of the K–D test in rugby[12,13] is warranted as the sport is non-helmeted and associated with high levels of head impacts and head impact acceleration.[14] However, the use of the K–D test in Australian football (AF), which reports fewer head impacts and less impact acceleration,[15] has not been documented. This is important as AF players may be in danger of underreporting of SRC. Therefore, the primary aims of this study were to: (1) identify the test–retest reliability of the K–D test in semi-elite AF players, and (2) determine the diagnostic accuracy of the K–D test in identifying SRC that occurred from game participation. These are vital as oculomotor and saccadic disruption may indicate suspected concussion, therefore support the use of the K–D test as one of the tools in a multi-faceted approach to sideline evaluation.

2. Method

A prospective observational cohort study was conducted on a sub-elite West Australian Football League (WAFL) reserves team competing in the 2016 WAFL season. All members of the team were invited to participate in the study. Twenty-two male players (19.6 + 2.3 years; 184.2 + 6.9 cm and 79.4 + 7.2 kg) agreed to participate and were enrolled in the study. Consent was obtained from the players before enrolling in the study. The researchers' University ethics committee approved all procedures (MUHREC 2016/012). Consent was provided by the participating team and players prior to commencing the study.

All participants completed a baseline pre-game K–D assessment. The K–D test required the player to read single digit numbers aloud from left to right, from top to bottom taking approximately two minutes to complete. The reliability of the K–D test has reported to have an inter-class correlation for test–retest reliability of 0.97 (95% CI: 0.9–1.0).[16] A recent systematic review of the K–D test reports high sensitivity in identifying SRC (96/112 concussed athletes showed worsening; 95% CI: 78–92%), and high specificity (181/202 controls no worsening; 95% CI: 85–93%).[17]

Employing the version designed for tablet device (v2.2.0), players were instructed to complete two trials within a few minutes of each other to establish their initial baseline as per K–D test recommendations. Both errors in reading and speed of reading were included in deriving a K–D test time. The faster time from two error-free trials became the established baseline K–D test time and any subsequent faster time established a new baseline.[16]

Players who were suspected of having SRC secondary to a significant head impact (n = 7) (as observed from the sidelines or reported to the head physiotherapist) were assessed by the club's head physiotherapist (MM) who has post-graduate qualifications in sports physiotherapy and over 5 years' experience in AF. Players were assessed in a quiet medical room approximately 10 min following ceasing participation and the diagnosis of SRC was made using a comprehensive history and detailed neurological examination using the Sports Concussion Assessment Tool V.3 (SCAT3) as per the recommendations of the 2012 Consensus Statement on Concussion in Sport.[18] Those players diagnosed with SRC and randomly selected additional players without SRC were assessed with the K–D in a quiet medical room approximately 15 min post game (10–20 min window).

The same person who conducted the baseline assessments and utilising the same instructions given at baseline testing, administered all of the post-game tests. The post game tests were performed at random intervals following the baseline test with all post game tests being completed within a range of 1–12 weeks post baseline test. The post-game test time was compared with the participant's baseline to calculate reliability. Although there were 22 players, the 110 observations came from players having more than one post-game test during the season, for example a player may have completed two follow up tests at 4 weeks and 11 weeks from baseline. All collected K–D data were entered into a Microsoft Excel spreadsheet and analyzed using SPSS V24.0.0 (SPSS Inc., USA).

Data were presented as median [25th–75th inter-quartile range] for K–D test times. Differences in K–D test times from pre-competition (baseline establishment) were calculated, baseline and post-match K–D test times were compared using the Wilcoxon signed-rank test. Sensitivity, specificity, positive predictive value and likelihood ratios for the K–D test were calculated using a 2-by-2 contingency table with 95% CI. Cohen kappa (κ) with 95% CI were utilized to assess for intra-rater concordance.[19] Test–retest reliability was also estimated utilising the intra-class correlation coefficient (ICC), with 95% CI, to examine agreement between first and second baseline test scores and the post-match scores. Statistical significance was set at $p = 0.05$.

Table 1
King–Devick test times in seconds by median [25th–75th inter-quartile range] for all participants (n = 22) at baseline assessment (test 1 and 2), baseline established time and post season with differences, intra-class correlation coefficient, specificity and sensitivity.

K–D baseline 1, s, median [IQR]	48.3 [44.0–56.9]
Errors, average (SD)	0.1 (±0.4)
K–D baseline 2, s, median [IQR]	45.9 [42.2–56.1]
Errors, average (±SD)	0.0
Difference, s, median [IQR]	−3.4 [−0.8 to −7.8][b]
K–D baseline, s, median [IQR]	45.7 [42.2–52.2][b]
ICC (95% CI) K–D baseline 1 vs. baseline 2	0.91 [0.80–0.96]
K–D post-season, s, median [IQR]	42.7 [39.0–49.0][a]
Difference, s, median [IQR]	−0.9 [−2.9 to 1.9][a]
ICC (95% CI) K–D baseline vs. post-match total	0.92 [0.87–0.95]
Sensitivity K–D test (95% CI)	0.98 (0.87–1.00)
Specificity K–D test (95% CI)	0.96 (0.80–1.00)

IQR = inter-quartile range; s = seconds; SD = standard deviation; CI = confidence interval; ICC = intra-class correlation coefficient.
[a] Significant difference ($p < 0.05$) than baseline.
[b] Significant difference ($p < 0.05$) than post-season.

3. Results

There were observable learning effects between the first and second K–D test baseline trials (48 vs. 46 s; $z = -1.05$; $p = 0.2937$) (see Table 1). Over the duration of the study the K–D test demonstrated a sensitivity of 0.98 (0.87–1.00) a specificity of 0.96 (0.80–1.00), and a kappa of $\kappa = 0.94$ (0.85–1.00). The positive likelihood ratio was 11.6 (1.7–77.0) and the positive predictive value was 89.0% (54.5–98.2%). The ICC between the baseline trials was 0.91 [0.80–0.96]. Post-game K–D test times were increased, or worse,

Please cite this article in press as: Hecimovich M, et al. The King–Devick test is a valid and reliable tool for assessing sport-related concussion in Australian football: A prospective cohort study. *J Sci Med Sport* (2018), https://doi.org/10.1016/j.jsams.2018.03.011