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The utility of the King-Devick test as a sideline assessment tool for sport-related concussions: a narrative review

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Objective: *The objective of this paper is to review existing literature surrounding the utility of the King-Devick test which is a commonly used sideline assessment tool for sport-related concussions.*

Methods: *A review of the literature was performed using MEDLINE, CINHAL, and SportDiscus databases. The search was performed from the beginning of the record through November 16th, 2015.*

Results: *This search strategy yielded 27 articles from aforementioned databases. Further searching in The Cochrane Library with King-Devick AND Concuss* search terms yielded one additional article, summing a total of 28 articles. After removal of duplicates and implementation of the inclusion/exclusion criteria, 8 articles for extensively reviewed.*

Objectif : *L'objectif de cet article est de passer en revue la documentation scientifique existante concernant l'utilité du test King-Devick qui est un outil auxiliaire couramment utilisé pour évaluer les commotions cérébrales liées au sport.*

Méthodologie : *Une analyse des documents scientifiques a été réalisée en recherchant dans les bases de données MEDLINE, CINAHL et SportDiscus. La recherche a été effectuée du début des registres jusqu'au 16 novembre 2015.*

Résultats : *Cette stratégie de recherche a donné 27 articles des bases de données précitées. Une recherche plus poussée dans la bibliothèque Cochrane avec les termes de recherche King-Devick ET Concuss* a révélé un autre article, pour un total de 28 articles. Après l'élimination des doublons et la mise en œuvre des critères d'inclusion et d'exclusion, 8 articles ont fait l'objet d'un examen approfondi.*

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Conclusion: *This narrative review suggests that the King-Devick test is an efficient sideline assessment tool for sport-related concussions. However, we recommend that the King-Devick should be used as a sideline screening tool, not a concussion diagnosis tool at this time. A proper baseline time including multiple tests may be recommended to negate the learning affect and to have a reliable baseline in which to measure from for future reference. A three second difference appears appropriate to identify the possibility of concussion and to remove an athlete from play. At this time, the athlete should be monitored and further evaluated as symptoms are sometimes delayed. We suggest that further research may be useful to better determine the efficacy of the K-D test in detecting concussions across a broader range of athletes and sports. We also suggest further research may investigate the K-D test a potential return-to-play tool for clinicians and medical personnel.*

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KEY WORDS: chiropractic, concussion, King-Devick test, assessment, sideline, screening

Conclusion : *Cet examen narratif suggère que le test King-Devick est un outil d'évaluation auxiliaire efficace pour les commotions cérébrales liées au sport. Cependant, nous recommandons qu'à l'heure actuelle King-Devick soit utilisé comme un outil auxiliaire de dépistage, et non comme un outil de diagnostic de commotion cérébrale. Une période de référence appropriée comprenant des tests multiples peut être recommandée pour annuler l'effet d'apprentissage et avoir une référence fiable à partir de laquelle il soit possible de mesurer pour des références futures. Une différence de trois secondes semble appropriée pour reconnaître la possibilité d'une commotion cérébrale et pour retirer un athlète du jeu. À ce moment-là, l'athlète doit être surveillé et évalué de plus près, car les symptômes apparaissent parfois tardivement. Selon nous, d'autres recherches pourraient être utiles pour mieux déterminer l'efficacité du test K-D dans la détection des commotions cérébrales chez une plus grande variété d'athlètes dans diverses autres disciplines sportives. En outre, il nous semble que d'autres recherches pourraient étudier le test K-D comme un outil potentiel pour évaluer le retour au jeu par les cliniciens et le personnel médical.*

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MOTS CLÉS : chiropratique, commotion cérébrale, test King-Devick, évaluation, auxiliaire, dépistage

Introduction

A concussion is a brain injury caused by an impulsive force transmitted to the head resulting in a complex pathological process manifesting in the rapid onset of short-lived impairment of neurological function.[1,2] Traumatic force to the head during a sports-related concussion results in shear and pressure forces to the brain as a direct result of rapid acceleratory displacement of the brain relative to the skull.[3] Shear-induced tissue damage may produce diffuse axonal stretching resulting in changes of neurological function.[3]

Current estimates state that 465 people daily suffer a brain injury in Canada, with a concussion sustained in 1 in 5 injuries in sport.[4] Reports show that individuals who have suffered one concussion have three times greater chance of having a second concussion; making them more susceptible to a rare but serious condition known as second impact syndrome, increasing their risk of long term consequences such as neurodegenerative disease.[5] In Canada from 2001 to 2005, an estimated 502 000 emergency department (ED) visits for concussion occurred in children from the ages of 8 to 19 years.[6] These estimates are alarming when combined with the notion that there are knowledge transfer gaps and different management strategies being utilized by emergency physicians.[7]

Sustaining a concussion can have a multitude of clinical symptoms for the individual involved. Headache, irritability, balance and memory dysfunction, impaired eye

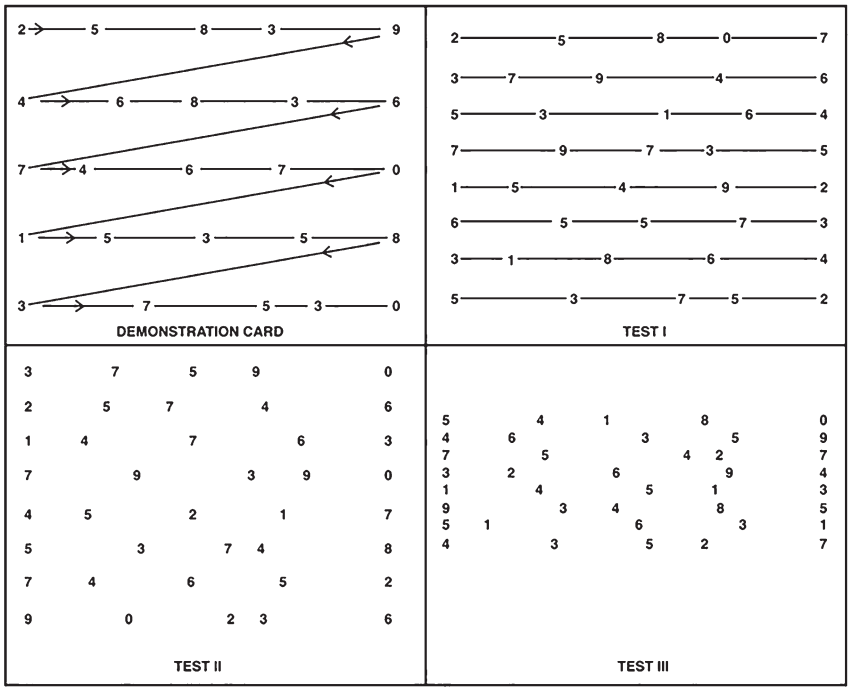

Figure 1.
Sample King-Devick test card.[18]

movement function, confusion, amnesia, nausea, slurred speech, fatigue, sensitivity to light, and sleep disturbances are within the spectrum of resultant signs and symptoms.[1-3, 8-10] Enhancing the ways in which we screen for concussions is pivotal, specifically in susceptible populations such as athletes where objective findings can be subtle and vastly underreported.[11] Closer screening is also important since detecting early signs of a concussion can improve outcomes.[12-14] This suggests that there is a clear need for a rapid screening test to efficiently assess high risk individuals such as athletes who may have sustained a concussion. Currently it is common practice for amateur sporting teams to utilize volunteer health care practitioners and student therapists to assist in their sideline medical coverage. Providing a modicum of reassurance are the recent studies by Bogglid and Kazemi which demonstrate that while there are gaps in knowledge, that medical students / residents and chiropractic interns / residents possess diagnostic and management skills to deal with concussions.[15,16] While a proportion of these therapists may have advanced first responder credentials, it is our contention that additional assessment tools with respect to concussion would be most useful particularly at the field of play.

The King-Devick (K-D) test is a test of the visual system and is based on measurement of the speed of rapid number naming.[17] The K-D test, takes two minutes to complete, is practical for sideline use and is quicker than the other standard tests of cognition such as Immediate Post-Concussion and Cognitive Testing (ImPACT)[18], the sport concussion assessment tool (SCAT 3) and the Military Acute Concussion Evaluation (MACE)[19]. The K-D test measures rapid number naming on three test cards; the score for the test is the sum of the three times, in seconds, needed to read the cards.[17-23] The test requires rapid eye movements, language function, and attention. These functions may be deficient and reflect suboptimal brain function in concussed athletes, individuals with Parkinson's, multiple sclerosis, extreme sleep deprivation, and hypoxia.[24,25] The objective of this paper is to present a review of the existing literature with respect to the efficacy of the King-Devick test as a sideline assessment tool for sport-related concussions.

Methods

A search of the literature was performed using MEDLINE, CINHAL, and SportDiscus databases. The electronic search strategy employed was designed as follows: (rapid visual screening tool* OR k-d test* OR king-devick*) AND (test-retest* OR sideline screen* OR accura* OR reliab* OR valid* OR predict* OR reproducibility OR specificity OR sensitiv* OR [MH "Predictive Value of Tests"] OR [MH "Reproducibility of Results"] OR [MH "Sensitivity and Specificity"]) AND (brain injur* OR [MH "Brain Injuries"] OR [MH "Brain Concussion"] OR concuss*). Search strategies for all databases were filtered for English Language. The search was performed from the beginning of the record through November 16th, 2015. This search strategy yielded 27 articles from aforementioned databases. Further searching in The Cochrane Library with King-Devick AND Concuss* search terms yielded another article, summing a total of 28 articles. After removal of 8 exact duplicates, 20 articles were admitted for evaluation.

For the purpose of this narrative review, our inclusion/exclusion criteria required the following: 1) The King-Devick be used in side-line assessment of concussion of athletes; 2) The athletes were adults (≥ 13 years of age) as defined by the SCAT 3; 3) The King-Devick used in a clinical trial and not referenced in a review or commentary. Implementation of these criteria resulted in 8 articles for the purpose of our review.

Results

In 2011 the *Journal of the Neurological Sciences* published the paper that provided initial evidence to support the use of the King-Devick test as a rapid sideline visual screening tool for concussions.[17] This ongoing longitudinal study involved 219 collegiate athletes from a varsity men's football team and both women's and men's soccer and basketball teams.[17] Each athlete completed a pre-season baseline King-Devick test, while the women's basketball team also underwent a pre-season Military Acute Concussion Evaluation (MACE) to assess for correlation between the King-Devick test and MACE scores. Athletes who sustained concussions in games or practices during the playing season were given an immediate sideline King-Devick test. The results showed that for the 10 athletes who sustained a concussion, as diagnosed by MACE scores and general practitioner, King-Devick scores were significantly more diagnostic (median 46.9 s post-concussion vs. 37.0 s baseline, $P < 0.009$, Wilcoxon signed-rank test).[17]

Galetta *et al*.[18] published an additional study in 2011 that evaluated the King-Devick test as a potential rapid sideline screening tool for concussion in boxers and mixed martial arts fighters. Thirty-nine fighters were tested twice at ringside immediately before and once after each round in a 3-round sparring session. Fighters who sustained head trauma during the fight were also given the MACE test immediately following the sparring session. Post-fight King-Devick scores were significantly worse for those with significant head trauma during the match (59.1±7.4 s post-fight vs 41.0±6.7 s baseline, $p < 0.0001$, Wilcoxon rank sum test). Those who lost consciousness showed an even greater worsening in pre-fight to post-fight King-Devick scores (65.5±2.9 s post-fight vs 52.7±2.9 s baseline, $p < 0.0001$, Wilcoxon rank sum test). Worsening of King-Devick scores by 5 seconds was a distinguishing characteristic noted only among participants with head trauma.[18]

Subsequently, the 2012 pilot study by King *et al*.[20] demonstrated the efficacy of the King-Devick test as a screening tool to identify neurological changes in players with both witnessed and un-witnessed head traumas. A cohort of 2 amateur rugby league teams (total of 50 players) was followed over an 8-week season and completed two trials of the King-Devick test a week before participation in any match. Players who reported any signs of a concussion, or who were suspected to have incurred a concussion as a result of match participation were removed from the match and assessed immediately with the K-D test and the SCAT2 within 30 min of the injury occurring. All players who participated in a match completed a post-game King-Devick Test regardless of concussion suspicion. A total of five athletes were diagnosed with concussion over the season.[20] Three of the five were identified by the King-Devick test after confirmed head trauma and later confirmed by the SCAT2 and physician.[20] When tested post-incident the K-D test times were longer than baseline (5.0 s–7.1 s, $p < 0.025$, Wilcoxon signed-rank test). Two of the athletes, with no witnessed head trauma were identified during post-game King-Devick testing and later confirmed by the SCAT-2 and physician.[20] These two recorded longer times on the post-match King-Devick test (8.9 s–9.1 s, $p < 0.219$, Wilcoxon signed-rank test), which

was not significant. When tested on the PCSS of the SCAT3, they recorded statistically significant difference's (14–15; $p < 0.0003$) from their baseline.

Recently two additional studies in the *Journal of the Neurological Sciences* showed that the King-Devick test was helpful in identifying cognitive impairments in both confirmed and un-witnessed head traumas.[26,27] The first study took a cohort of nineteen players of a junior level rugby team through two pre-competition baseline trials of the King-Devick Test.[26] During the competition season; any player that was removed from play or complained of concussion-like signs or symptoms was assessed on the sidelines using the King-Devick test. The players also completed a post-game King-Devick test. Any player that had a pre-to-post match King-Devick test difference greater than three seconds were referred for physician evaluation. A total of seven concussions were formally identified in six players that recorded post-match King-Devick test scores greater than three seconds from their baseline with a mean change of 7.4 s (±7.0 s, $p < 0.018$, Wilcoxon signed-rank test).[26] One player recorded 2 post-match times greater than three seconds from baseline and was identified to have incurred concussions on both occasions by his health practitioner.[26]

A second study published in 2015 by King *et al*.[27] followed 104 male, senior-level rugby union and rugby league players over three years. All 104 players completed two King-Devick trials, 10 minutes apart at the beginning of their competition season. All witnessed concussions were assessed with the King-Devick test and SCAT3 and were referred for further medical evaluation. All concussions (witnessed or un-witnessed) were only recorded if they were formally diagnosed by a healthcare practitioner. During the study, 52 concussive events were identified (8 witnessed and 44 un-witnessed).[27] Post-match King-Devick test scores were longer than the baseline score (4.6 s ±6.40; $p < 0.001$, Wilcoxon signed-rank test) for all concussive injuries identified. All 52 concussive events were detected by a three second decrease in King-Devick time and later confirmed by physician.[27] All reductions in King-Devick scores correlated with lower SCAT3 scores.[27] For every 1 point reduction in each of the post-injury SAC components of the SCAT3, there was a corresponding increase of King-Devick test times post-match for changes in orientation (2.9 [95% CI: 2.7 to 3.2]; $R^2 = 0.85$; $p < 0.001$), immediate memory (1.8 s [1.7 to 2.0]; $R^2 = 0.94$; $p < 0.001$) concentration (2.8 s [2.6 to 3.0]; $R^2 = 0.87$; $p < 0.001$), delayed recall (2.0 s [1.8 to 2.2]; $R^2 = 0.93$; $p < 0.001$) and SAC total score (1.7 s [1.6 to 1.8]; $R^2 = 0.95$; $p < 0.001$).[27]

Interestingly, Leong *et al*.[22] published an article that reported the King-Devick test (as a sideline screening tool) can be successfully administered by non-medically trained parents. Baseline King-Devick test times for 34 boxers were established before the competition by layperson testers, with no previous experience with the King-Devick test. After the sparring matches, boxers who sustained overt head trauma or who were suspected to have sustained head trauma, as assessed by a non-masked ringside physician, were given the MACE test immediately after the fight. All fighters completed King-Devick testing with a layperson following their match or following required MACE testing. Of the 34 boxers, one sustained a concussion confirmed by the ringside physician. This fighter was also accurately identified by the layperson tester due to the worsening in King-Devick test scores from the prefight baseline (48.3 s post-fight vs 45.1 s baseline).[22]

Leong *et al*.[28] further validated the King-Devick test as an accurate, reliable and rapid sideline tool to help objectively identify athletes with concussion and assist with removing from play decisions in 2015. The 127 collegiate athletes (football and men's and women's basketball) participating in the study underwent pre-season baseline testing with the King-Devick test. During the season, the King-Devick test and SCAT2 were both utilized in the sideline assessment of athletes suspected of head trauma. Post-season testing was also performed to compare non-concussed athletes' test performance. Results showed that concussed athletes consistently displayed sideline King-Devick test scores that were significantly worse than baseline test scores (36.5 ± 5.6 s sideline vs. 31.3 ± 4.5 s baseline, $p < 0.005$, Wilcoxon signed-rank test).[28]

Furthermore the recent work by Seidman *et al*.[29] demonstrated that the King-Devick test is an accurate and easily administered sideline screening tool for concussion in adolescent football players. A cohort of 343 high school athletes was given baseline King-Devick testing prior to competition. The test was re-administered to the concussed athlete for comparison to baseline immediately after a concussion diagnosis by a medical professional. Of the 343 athletes, nine were diagnosed with concussions

and all concussed players that were examined had scores for the King-Devick test were significantly worse then pre-season baseline scores (median 66.2 s sideline vs. 47.2 s baseline, $p < 0.001$, Wilcoxon signed-rank test).[29] A two tailed p-value of 0.05 or less was considered to indicate statistical significance.

Discussion

This review identified several citations in the literature useful in exploring the efficacy of the K-D test as a sideline screening tool in the evaluation of sports-related concussions. With the increasing interest and evolving knowledge pertaining to the subject of sport-related concussions over the last decade, information pertaining to screening tools and return-to-play guidelines has risen to the forefront of discussion within the athletic community. In accordance, a substantial increase in research on screening tools such as the King-Devick test have been proposed, evaluated and published.

The King *et al*.[20] research which utilized the K-D test as a sideline screen for concussions in rugby league players showed that the K-D was able to assist medical personnel in identifying cognitive impairments in players without any clinically observable symptoms. The K-D test was able to correctly identify concussions in players with both confirmed and unconfirmed head traumas that were later verified by the SCAT 2 or SCAT 3 and a medical doctor.[20,26,27] Similar results were also found in cohorts of amateur boxers, mixed martial arts (MMA) fighters, and high school and collegiate football players. All studies included in the results section consistently showed that in comparison to pre-season or pre-fight baseline, athletes suspected of having a concussion showed a significant increase in their K-D test time. The studies we examined consistently noted increases in K-D test scores ranged from 3 seconds to 7 seconds compared to baseline when athletes sustained a suspected concussion.[19,20,22,26-30] Future studies may investigate any possible correlation between the amount of time increased from baseline to perform the task and the severity of concussion injury.

The results of various studies reviewed also showed that a worsening of K-D scores correlated well with worsening MACE scores and worsening SCAT 2 or 3 scores in concussed athletes.[19, 22] These correlative associations suggest that using the K-D in conjunction with other concussion screening tools may enhance a health care practitioner's ability to more confidently identify sub-clinical cognitive manifestations of a sports-related concussion.

In general the studies reviewed also showed that the K-D test has high baseline test-retest reliability, making it an excellent tool for sideline medical personnel to use.[27,28] Interestingly, results of Leong *et al's*.[22] study showed boxers that sustained a concussion and were diagnosed by a ring-side physician could accurately be identified by a layperson trained to administer and interpret the K-D test, with no prior knowledge of the incident. Given that a layperson demonstrated the ability to adequately administer a K-D test to the athletic population, student therapists and health care students working as sideline personnel could feel confident in their ability to similarly administer the test appropriately.

Another interesting finding from our review of the literature was that there was no worsening in K-D scores associated with fatigue. In fact, in some documented cases, intense exercise improved time scores in athletes.[17,28] Post-season K-D testing in the rugby league studies also showed that players demonstrated improvement in their time scores.[20,26,27] This improvement is consistent with the supposed learning effects found in the other studies reviewed in this paper.[19, 20, 22, 28, 29]

Furthermore, with respect to predictive factors in sustaining a concussion, Seidman *et al.'s*[29] study with high school football players used univariate analysis to confirm the common notion that a history of a previous concussion is the most predictive for the incidence of future concussions.

With the increase in sports-related concussion in all levels of sport, it is important to identify the need for a quick and reliable sideline screening tool to help team personnel accurately detect a concussion. The results of our review further support the K-D test as an effective, reliable and rapid sideline screening tool with an ability to help identify a concussive event in a variety of sports.

Limitations

The overall number of publications is limited with research on the K-D test and its effectiveness as a sideline screening tool for sports-related concussions still in its infancy. We are also cognizant that our search methods may have unintentionally missed other published research studies pertaining to some aspect of the K-D test.

Conclusion

Taking into account the available studies as defined by our search criteria, this review supports the use of the King-Devick test as an efficient sideline assessment tool for sport-related concussions. Successful identification of concussions and appropriate subsequent management will lead to a reduced risk of a secondary concussion and long-term neurological complications.[5] Therefore it is our contention that all health care professionals dealing with an athletic population stay abreast of the evolving science and familiarize themselves with additional tools such as the King-Devick test.

We recommend further research to investigate the efficacy of the K-D test in detecting concussions across a broader range of individuals and age groups. In addition, a variety of contact sports still need to be assessed and critically evaluated using screening tools such as the K-D test. We also suggest that further research investigate the K-D test as a potential return-to-play marker for concussion clinicians and medical personnel.

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