TITLE
The King–Devick (K–D) test and concussion diagnosis in semi-professional rugby union players

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ABSTRACT

Aim: To determine the utility of the King-Devick (K-D) test in identifying sports-related concussion in semi-professional rugby players.

Methods: 176 male players were recruited from a semi-professional rugby union competition in New Zealand (NZ). Baseline K-D scores were obtained in the pre-season. Post-match K-D and Pitch Side Concussion Assessment Version 2 (PSCA2) scores were obtained in those with suspected concussion. Post-match K-D scores were also administered to selected control players.

Results: 19 concussions in 18 players were analysed. In addition, 33 controls were used for analysis. A positive K-D test was identified in 53% of players with concussion post-match. Conversely, a positive test was identified in 33% of controls. The sensitivity and specificity of the K-D test was calculated as 53% and 69% respectively. The positive predictive value and negative predictive value was 48% and 73% respectively. The PSCA2 correctly identified 74% of concussions. The K-D test identified 3 cases not identified by the PSCA2. When the PSCA2 and K-D were combined, 89% of concussions were correctly identified.

Conclusions: The K-D test does not appear to be effective if used as a stand-alone test for the diagnosis of concussion. However, if used alongside current side-line cognitive and balance tests, it may assist in more accurately diagnosing sports-related concussion. Further research should look to utilise the K-D test in in-match protocols to establish if this improves the diagnostic accuracy of in-match protocols for sports-related concussion.

Key words: King Devick test, concussion, sport concussion assessment tool, vision testing, rugby union

INTRODUCTION

Concussion is a clinical diagnosis based largely on the observed mechanism and signs and symptoms, along with a high index of suspicion (1). However as physical examination, central nervous system imaging, and other neuropsychological tests cannot always diagnose concussion accurately, clinicians must rely upon the subjective self-report of symptoms (1). This can be problematic as concussed athletes may underreport their symptoms. Some do not realise the significance of their symptoms while others admit to not reporting concussion symptoms so they can continue playing (2). Currently there is demand for a side-line test that assesses concussion quickly and accurately. The Sport Concussion Assessment Tool – 3rd Edition (SCAT3) is the most recognised side-line assessment tool that is sensitive and specific to domains affected by concussion (symptoms, balance, and cognitive function) (3). The use of objective aids may also be helpful when subjective self-report of symptoms are negative despite a high index of suspicion.

The King-Devick (K-D) test has been proposed as an objective, rapid (< 2 minutes) side-line screening test for concussion (4). The K-D test measures saccadic (i.e. rapid) eye movement and more specifically demonstrates how well a patient is able to perform anticipatory saccades (5). Since

approximately 50% of the brain's circuits are related to vision, performance measures involving visual function have been postulated as a promising addition to side-line cognitive and balance tests (5, 6). Other potential advantages are that the K-D test is cheap and requires minimal expertise with a recent study confirming it can be effectively administered by non-medically trained persons (7).

In recent years, the K-D test has been used to identify concussion in concussed boxers/ mixed martial arts fighters (8), collegiate athletes (4), university athletes (6), professional ice hockey players (9), and amateur rugby league (10) and rugby union players (11). Only Galetta et al (n=219) (4) and Marinides et al (n=217) (6) have had large sample sizes with the next largest sample size being that by King et al on amateur rugby league players (n=50) (10). Actual cases of concussion have also been small ranging between two and 35. None of these studies have used control athletes during actual game time for comparison.

As it currently stands, the K-D test is yet to be adequately validated. The K-D test needs to be validated in a variety of sports (either as a standalone measure and/or as part of a composite of measures), to determine its clinical utility in aiding sports concussion diagnosis. The aim of this study was to determine the utility of the K-D test in identifying sports-related concussion in semi-professional rugby players.

METHODS

Study participants

Participants were recruited from a New Zealand (NZ) male semi-professional rugby union competition during the 2014 season. All 14 teams were invited to participate in the study. Following consultation with the NZ Health and Disability Ethics Committee (HDEC), a formal approval was not required as this study was deemed to be a 'minimal risk observation study' and informed consent was obtained from all participants.

K-D test

The K-D test (Figure 1) requires participants to read aloud a series of single digit numbers on test cards as quickly as possible. The test includes one practise (demonstration) card and three test cards which progressively increase in difficulty (12). The sum of the time for the three test cards to the nearest tenth of a second is recorded as the "K-D score". The time was measured with a stop watch for the hard copy and recorded automatically with the iPad application. Testing followed the King-Devick Test©® protocol as described by the company. The test is repeated at least twice at baseline with the quickest time becoming the athlete's baseline score. No errors were allowed in establishing a baseline. No limits were set for the amount of attempts required to be error free.

For post injury assessment the test was repeated once and the number of errors recorded. A player was deemed to have "failed" a K-D test if they were slower than baseline or if there were any errors. A "failed" test is considered to be a "significant change" and consistent with the diagnosis of concussion (4, 8, 10, 11). The K-D test has previously been demonstrated to have a high test-retest reliability with intraclass correlations of 0.97 (95% CI, 0.90 to 1.0) (8) and 0.96 (95% CI, 0.93 to 0.99) (7). In the

current study, version 1 of the K-D test was used. Teams had the option of using either the hard copy or iPad version of the K-D test.

Pitch-Side Concussion Assessment Version 2 (PSCA2)

The PSCA2 has been endorsed by World Rugby as part of their concussion assessment protocol (13). The PSCA2 is based on the SCAT3 (1) and includes the symptom evaluation scale, Standardised Assessment of Concussion (SAC), upper limb coordination examination, and the modified Balance Error Scoring System (BESS). The PSCA2 is scored in identical fashion as the SCAT3 (1). It has been previously suggested that a 3-5 x increase in baseline total number of symptoms and a 6-8 point increase in symptom severity were reliable measures of change from baseline (3). The lower limits of this range (3x and 6 points) were used in this analysis. Normative post injury data on a population of rugby players with concussion provided by World Rugby included total SAC ≤ 24, concentration ≤ 2, delayed recall ≤ 3, and ≥ 3 errors on the tandem stance or ≥ 4 errors on the single leg stance components of the modified BESS. This normative data was used in the current study. In this study, any positive result for symptom evaluation, SAC, or BESS constituted a positive PSCA2.

Testing procedures

The study was conducted during the 2014 competitive season. All tests were administered by the team's usual lead medical personnel (team doctor or physiotherapist). Self-reported concussion history and baseline symptom evaluation was obtained from baseline CogSport computerised neurocognitive screening tests.

Baseline K-D testing was conducted in the pre-season. Players with suspected concussion were identified by experienced team medical personnel according to standardised concussion injury definitions (1). The diagnosis of concussion was based on the clinical assessment of the team doctor utilising standard post injury assessment protocols (including PSCA2 and CogSport). This was deemed the 'gold standard' for the purposes of this study.

Post injury testing with the K-D test and PSCA2 was conducted as soon as practical after each game. Control players were randomly selected each round from the starting 15 (via a random number generator at www.random.org) and tested as soon as practical after the game.

Statistical analysis

Using figures from Galetta et al (4), at a power of 80% and p value of 0.05, it was calculated that there would need to be n=15 per group to detect a clinically significant difference of 3 seconds between groups on the K-D test.

To analyse the data, a two way ANOVA was used to determine differences on continuous variables. Proportion tests were used to determine differences between proportions. Incidence rates and their 95% confidence intervals were calculated for concussion rates. When two rates were examined for differences a rate difference test was used along, with a risk ratio. The data was analysed using SPSSv21, CIA and VRP software.

RESULTS

Eleven teams initially agreed to participate of which seven teams completed the study. Two teams withdrew due to time constraints, one team was lost to follow up, and one team was excluded as the K-D test was only performed once at baseline. Four teams used the K-D iPad application, 2 teams used the physical hard copy, and one team doctor used a combination of both for testing.

K-D test scores were collected on 176 players from seven teams (total of 76 games or 1516 exposure hours). The average age was 24.1 years (range 18-35 years). Over the duration of the study, there were 24 suspected concussions to 23 players. Two players had concussion excluded after post match PSCA2 testing, leaving 22 concussions to 21 players. The overall incidence of concussion was 12.5 per 1000 hours (95% CI, 6.9 to 18.2). Three of the concussed players had incomplete datasets and were excluded from the study. Overall, 19 concussions to 18 players were included in the analysis. Thirty three controls were recruited.

Baseline data for the concussion and control groups showed that whilst they were well matched in terms of age and baseline K-D, the concussion group did have a higher average number of self-reported previous concussions (p=0.04) (Table 1).

Table 1 – Baseline characteristics of concussion and control groups

	Concussion (n=19)	Control (n=33)
Age at baseline (years)	23.8 ± 2.9 (19-30)	23.4 ± 3.0 (19-32)
Self -reported concussion history (mean)	2.7 ± 2.2 (0-6)	1.5 ± 1.6 (0-5)
K-D baseline test (sec) & mean errors	41.8 ± 7.4 (32.3-65.3) 0 errors	41.7 ± 8.0 (29-64.4) 0 errors

Mean ± SD (range)

The outcome of K-D testing for concussed and control players is summarised in Table 2. The K-D test was able to successfully identify 10 out of 19 concussions (53%). Conversely, 11 out of 33 control players (33%) failed the K-D test due to either a slower time or increased number of errors from baseline. Overall, the sensitivity and specificity of the K-D test was calculated as 53% and 69% respectively. The positive predictive value was 48% and the negative predictive value was 73%.

Table 2 – Outcome of the post match K-D test in semi-professional rugby union players

	Concussion (n=19)	Control (n=33)	
Post match K-D test (sec)	41.8 ± 8.3 (31.1-66.4) 0.3 errors	39.8 ± 8.2 (26.5-63.7) 0.1 errors	
K-D test FAIL (i.e. slower than baseline or errors)	10[1]	11[2]	PPV = 48%
K-D test PASS (i.e. faster than baseline with no errors)	9	22	NPV = 73%
	Sensitivity = 53%	Specificity = 69%	

Mean ± SD (range), PPV = positive predictive value, NPV = negative predictive value

[1] 4 players failed the test due to errors although 2 were faster compared to baseline

[2] 2 players failed the test due to errors although they were faster compared to baseline

The results of individual concussion cases are shown in Table 3. The symptom evaluation, SAC, and BESS correctly identified 58%, 33%, and 29% of concussion cases respectively. Two concussions were not identified by the K-D test or PSCA2.

.**Table 3 – Outcome of K-D test and PSCA components in concussed semi-professional rugby union players**

Concussion Case	K-D Test	Symptom Evaluation	SAC	Modified BESS	Comments
1	+	-	+	+	
2	+	-	-	-	Missed by PSCA2
3	+	-	-	-	Missed by PSCA2
4	-	+	-	-	
5	-	-	-	-	Missed by K-D & PSCA2
6	+	+	+	-	
7	-	+	-	+	
8	-	+	+	+	Missed by K-D
9	-	+	-	-	
10	+	+	-	-	
11	+	+	+	-	
12	+	+	-	+	
13	+	-	NR	NR	
14	-	-	+	-	
15	-	+	-	NR	
16	+	+	-	-	
17	-	-	-	-	Missed by K-D & PSCA2
18	+	-	+	+	
19	-	+	-	-	
Total	10 positive 10/19=53%	11 positive 11/19=58%	6 positive 6/18=33%	5 positive 5/17=29%	

Positive = FAIL, negative = PASS, NR = not recorded.

DISCUSSION

This study assessed the clinical utility of the K-D test in the diagnosis of concussion in rugby union. The results demonstrated that the K-D test is not effective if used in isolation with a reported sensitivity and specificity of 53% and 69% respectively. The results highlight that currently there is no single screening test for the side-line assessment of concussion and reinforces the concept that individuals with suspected concussion should be assessed in multiple domains.

K-D implications

In the current study, nine players out of 19 with clinically diagnosed concussion (47%) passed the K-D test. As previous studies have mainly utilized amateur athletes, this high false negative rate may be attributable to semi-professional athletes having greater incentive and motivation to pass the test. This finding has implications for non-medically trained persons who use the K-D test as a stand-alone remove from play side-line concussion screening test.

Performance measures involving visual function have been postulated as a promising addition to side-line cognitive and balance tests. The PSCA2 which is based on the SCAT3 and scored in identical fashion correctly identified 74% (14/19) of concussion. The K-D test was able to identify three cases (16%) not identified by the PSCA2. When the PSCA2 and K-D were combined, 89% (17/19) of concussions were correctly identified. The K-D test was therefore able to identify 26%, 28%, and 35% of concussion not identified by the symptom evaluation, SAC, and BESS respectively. These results show that there may be value in adding the K-D test to complement other in-match assessment tools. Two concussion cases were not identified by the PSCA2 or K-D test. One of these cases failed post-match CogSport neurocognitive testing. The second case passed all post-match testing including CogSport but was still diagnosed as concussed as per the clinical assessment of the lead medical person.

Controls

This is the first study to utilise control athletes during actual game time rather than simulated game time or exercise. Previous studies have tested male collegiate athletes (n=18) following a two hour basketball scrimmage (4) and amateur rugby union players following a repeat high intensity endurance test (median time=105.9 sec) (11). The results from the current study suggest that game related factors such as fatigue do not appear to have a negative effect on performance on the K-D test. A significant finding in this study was that 33% (11/32) of controls failed the post-match K-D test despite no signs or symptoms of concussion. This suggests either a high false positive rate, or the possibility of unrecognised concussions as reported in a previous study (11). Using the K-D test, King et al identified 17 unrecognised concussions in asymptomatic amateur rugby union players (11). No controls that had positive K-D tests were identified as concussed when followed up by the lead medical personnel in the ensuing week. However, the possibility of under reporting or unrecognised concussion (by both the patient and treating clinician) cannot be excluded.

Limitations

This study did not do a PSCA2 on controls post-match. The diagnosis of no concussion was therefore based on clinical judgement aided by prior observation of the game and clinician familiarisation of the athlete. Another limitation of this study was the absence of baseline SAC and BESS outcomes for analysis. As a result, this study was only able to compare the K-D test with normative post injury data rather than reliable change indices for SAC and BESS as was performed in a recent study (6).

In the current study, the K-D test was performed on the same day as soon as practical after the game, but not during, due to already established in-match testing protocols. This is relevant as the K-D test is largely recommended as a side-line assessment tool. Previous studies have conducted testing soon after the injury and are therefore more likely to capture a brief deficit in attention or visual function. Thirty seven percent of concussions in this study were reported post match and 63% were witnessed during the match. These players were immediately removed from play and monitored, with delayed K-D testing. As concussion is an evolving injury, when testing should take place is controversial. Current evidence recommends a minimum of 15 min rest before symptom, neurocognitive, and balance

assessment takes place in order to avoid the influence of exertion or fatigue on the athlete's performance (1).

Future research

Further research should look to utilise the K-D test in an in-match protocol to establish if this improves the diagnostic accuracy of in-match protocols for sports-related concussion.

CONCLUSION

The K-D test was shown to have a low sensitivity and specificity for the diagnosis of concussion in a cohort of semi-professional rugby union players. The results suggest that the K-D test is not effective if used as a stand-alone screening test for concussion. However, it may provide another important element in the assessment of a player with a possible sport-related concussion if used alongside other established concussion assessment tests.

What are the new findings?

- The K-D test is not effective when used as a stand-alone test in a cohort of semi-professional rugby union players
- When a post-match K-D test is added to other established assessment tools (SCAT3), 89% of concussions were correctly identified
- The K-D test may be used as a tool to complement other concussion assessment tools

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Disclosures

J.H. Molloy – was a lead medical personnel for one of the participating teams

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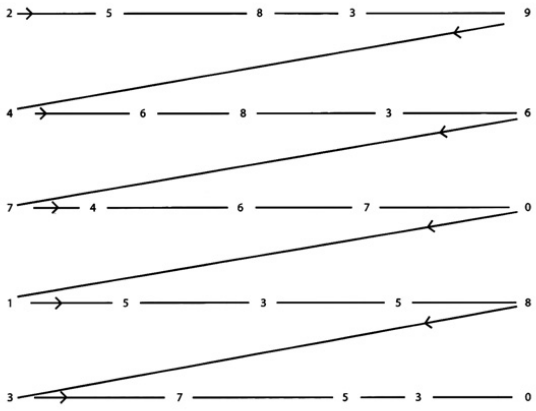
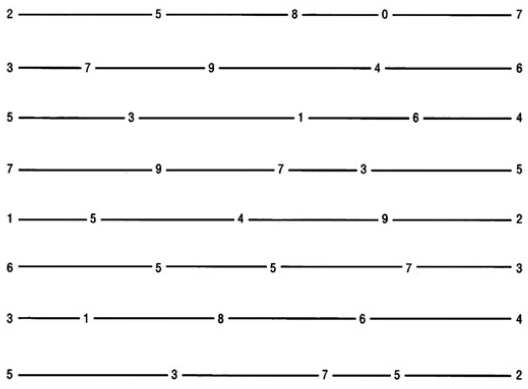
Figure 1 – King-Devick (K-D) test



DEMONSTRATION CARD



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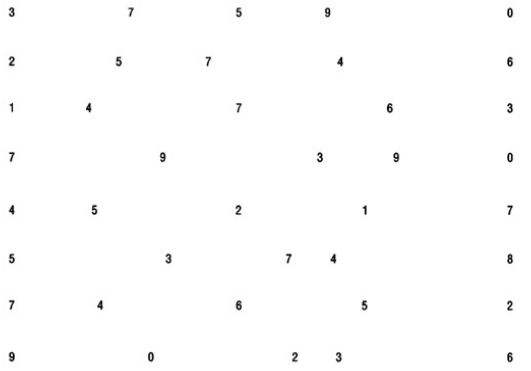

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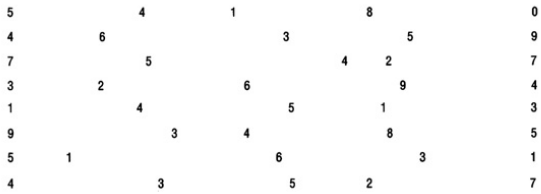

TEST III