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

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ABSTRACT

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 (7 s; 5.0–7.1; $p = 0.025$) and for those identified incidentally (>5 s; 8.9–9.1 s). 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.

1. Introduction

The identification and management of sports-related concussion is now an issue that is being faced by all sports. The risk of an acute catastrophic head injury [1] and long-term neurological sequelae as a result of repeated sports-related concussions [2] has been reported. The identification of concussion is a diagnostic challenge even for the sports medicine professional [3]. This is, in part, due to the fact that every sports-related concussion is unique and no two concussions present identically [3]. To complicate things further, the signs and symptoms of a sports-related concussion may not present immediately but may evolve over several hours to days after the event has occurred [3]. This challenge is even greater for the amateur sports volunteer who acts as the sideline medic or first aider.

Following the 2004 Second International Concussion In Sport (CIS) conference, the Sports Concussion Assessment Tool (SCAT) was published as part of the summary and agreement statement of those attending [4]. The third international conference on CIS in Zurich [5] resulted in the SCAT being amended and the SCAT2 was produced representing the only new sideline assessment tool published since 2009. The SCAT2 is a longer sideline concussion tool and, although is an improvement over the original SCAT, will require additional time of approximately 20 min to complete on the sideline making this more of a training room assessment tool as opposed to a readily available sideline assessment tool [3].

Originally developed as a reading tool to assess for the relationship between poor oculomotor functions and learning disabilities, the King–Devick (K-D) test uses a series of charts of numbers that progressively become more difficult to read in a flowing manner [6]. Poor oculomotor function has also been reported as one of the most robust discriminators for the identification of a mild Traumatic Brain Injury [7]. The K-D test has been reported to be a useful rapid screening test to assess sports participants with a suspected concussion on the sideline [8]. Requiring less than 2 min to administer, the K-D test is a practical sideline screening tool that is reportedly quicker than other concussion screening tools such as the Immediate Post-Concussion and Cognitive Testing (ImPACT), Cognitive Status Sport (Cog Sport) [9], the Standardized Assessment of Concussion (SAC) [10] and the Sports Concussion Assessment Tool 2 (SCAT2) [5]. Although these screening tools are useful in assessing for suspected concussion they do not assess eye movements or brain stem function well [11]. The K-D test does however test for impairment of eye movement, attention, language and other areas that correlate with sub-optimal brain function that may occur following a concussive episode [11]. The King–Devick [6,8] is reportedly able to be completed on the sideline in less than a minute and has been moderately

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correlated ($r_s = -0.54$; $p = 0.07$) with the Military Acute Concussion Evaluation (MACE) [12]. With this in mind 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.

2. Methods

A prospective cohort study was conducted on two teams participating in the amateur representative rugby league regional competition season (seven teams from around New Zealand playing in a home and away competition format over eight weeks from August to October 2011). Over the duration of the study 50 players (mean (±SD) age; 22.4±4.1 yr.; stature: 1.81±0.06 m; mass: 96.0±13.7 kg) were enrolled in the study. All players were considered amateur as they received no remuneration for participating in rugby league activities and derived their main source of income from other employment activities. The matches were played under the rules and regulations of the New Zealand Rugby League which includes the mandatory requirement for the wearing of mouthguards during match play. All participants were invited to participate in the study and received a clear explanation of the study, including the risks and benefits of participation. All procedures were approved by the Central Region Ethics Committee of the Health and Disability Ethics Committee (CEN/11/EXP/039).

2.1. Previous concussion history

All players were asked about their concussion history. This included history of concussions in the current and previous playing seasons, number of concussions, residual symptoms from any concussions reported and medical clearance to return-to-play.

2.2. King–Devick (K-D) Test

The King–Devick (K-D) test is a saccadic test measuring the speed of rapid-number naming [6]. The K-D utilises three test cards with a series of single-digit numbers that are read aloud from left to right. The test includes one practice (demonstration) card and three test cards that vary in appearance. Players were asked to read the numbers on each card aloud from left to right as quickly as possible without making any mistakes. The time taken for each card was recorded as was the number of reading errors made and this was combined to provide a summary score for the entire test, the K-D score. The entire test required less than 2 min to administer per player. The K-D test has been reported to have an inter-class correlation for test–retest reliability of 0.97 (95% CI: 0.90 to 1.0) [8]. The K-D tests utilised varied between v1.1.0 (http://www.kingdevicktest.com) on an IPad2 and hard copy (v2.0.0).

2.3. Post-Concussion Symptom Scale (PCSS)

The PCSS is a 22-item neuropsychological assessment scale that is a part of the larger Sport Concussion Assessment Tool (SCAT). Developed in the late 1980s [13], the PCSS was designed to measure the severity of symptoms in the acute phase of recovery from a concussion. Using a 7-point Likert-type scale anchored at 0 (complete absence) to 6 (most severe) players rank each symptom according to the severity that they have experienced. The symptoms are not specific to concussion and even non-injured participants have recorded symptoms on the PCSS [13]. A threshold symptom score of 7 was set for the duration of the study [14]. Any player reporting more than 7 symptoms on any assessment were referred for further medical evaluation. This threshold was adopted as an indicator of a head injury having occurred based on prior studies [14]. The internal consistency reliability (Cronbach's α) for the PCSS has been reported to range from 0.88 to 0.94 [13].

2.4. Sport Concussion Assessment Tool (SCAT)

The SCAT2 [5] is a tool developed by combining existing concussion assessment tools [4]. Established as having face validity, the SCAT2 reliability and change scores have not been reported to date [15]. The SCAT2 consists of both subjective and evaluative components consisting of the PCSS, modified Maddock's questions, cognitive assessment and neurological screening. The cognitive assessment consists of a five word immediate (upon hearing the words) and delayed (following concentration tasks) recall assessment, reciting the months of the year in reverse order and repeating single digits in reverse order. The SCAT2 (v1.1; http://www.scat2.org/) assessments were completed on an IPad2 or IPod-Touch.

2.5. Match exposure and concussion definition

Injury rates expressed as the number of injuries sustained per 1000 playing hours were determined using previously described methods [16]. Over the duration of the competition, all match and training injuries were recorded by the team sports medic who was a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment, and management. All injuries were recorded on a standardized injury reporting form regardless of severity [17]. The definition of a concussion utilised for this study was "any disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms and often does not involve loss of consciousness. Concussion should be suspected in the presence of any one or more of the following: (a) Symptoms (such as headache), or (b) Physical signs (such as unsteadiness), or (c) Impaired brain function (e.g. confusion) or (d) Abnormal behaviour" [5].

2.6. Testing procedure

Every player named in the representative squad's completed a pre-competition questionnaire on concussion history, a baseline PCSS and 2 trials of the K-D test a week before they participated in any match activities. The fastest time of the K-D test with no errors was recorded as the baseline score. During matches, any player observed to have received a direct blow to the head, was slow to rise from a tackle or collision or appeared unsteady on their feet following a collision were assessed on-field. Any signs of delayed answering, incorrect answers to questions or if the player appeared to be impaired in any way they were removed from the match activity and rested on the sideline. Player's with a loss of consciousness were treated for a cervical spine injury.

Players who reported any sign(s) 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 with the K-D test and the SCAT2 within 30 min of the injury occurring. The judgement of whether a player had incurred a suspected concussion was left to the team medic. No player with a suspected concussion was allowed to return to training or match activities without:

a. Having an initial medical assessment;
b. Having undertaken a graduated return-to-play protocol;
c. Had remained symptom free; and
d. Have received a full medical clearance to return to full match participation.

The management team established guidelines for the use of the K-D test in assessing players for suspected concussion based on previous studies [8,18]. These were:

(1) Any player who had a difference of up to 3 s from the baseline combined with a symptom score lower than seven on the PCSS was to undergo a further K-D test and PCSS assessment at the

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recovery session the next day. If the score did not lower to their baseline or they had a symptom score of seven or more the player was referred for medical assessment.
(2) Any player who had a difference of up to 3 s from the baseline combined with a symptom score higher than seven on the PCSS underwent the full SCAT2 and was to have a full medical evaluation for concussion.
(3) Any player with a post-match difference of more than 5 s [8,18] irrespective of their symptom score was automatically ineligible for selection for further matches, was sent for medical evaluation and underwent the return-to-play process for a suspected concussion as required by the national body (http://www.nzrl.co.nz/media/22461/concussionpolicysept2010.pdf).

Players returning to training following a concussive incident:

(1) Need to be symptom free, have been medically assessed and undertake a graduated return-to-play protocol.
(2) Need to have had a period of cognitive rest (2 training sessions missed).
(3) Assessed on the K-D test pre-training until medically cleared and:
   a. A difference of longer than 5 s from baseline — no training activities; and
   b. A difference of less than 5 s from baseline — in training activities but to wear an identifiable top.

2.7. Statistical analysis

All the data collected were entered into a Microsoft Excel spread sheet and analysed with MedCalc for Windows version 12.0.0 (MedCalc Software, Mariakerke, Belgium http://www.medcalc.be). Differences in the K-D time scores from pre-competition (baseline establishment) were calculated, baseline and post-match K-D time scores were compared using the Wilcoxon signed-rank test. The relationships of pre-competition K-D scores to the PCSS scores were determined using Spearman rank-correlations. Internal consistency reliability for the three test cards vs. total time scores at baseline were measured using Cronbach's alpha (α). Statistical significance was set at $p<0.05$.

3. Results

Over the duration of the study there were six round (12 games) resulting in 414.5 match exposure hours. Three concussions were identified by the team medic following witnessed events and two were found on routine post-match K-D testing, resulting in a concussion injury incidence of 12.1 (95% CI:1.5 to 22.6) per 1000 match hours. The K-D test was slightly correlated with the PCSS ($r_s=0.206$; $p=0.065$) but this was not significant. The internal consistency reliability of the PCSS was excellent ($\alpha=0.98$). The internal consistency reliability of the three K-D test cards was acceptable ($\alpha=0.72$ (test card 1); $\alpha=0.78$ (test card 2); $\alpha=0.76$ (test card 3)) between test card scores and total time score at baseline.

Over sixty percent (62%; n = 31) of players recorded previous concussions (see Table 1). Nearly a third of players (30.0%; n = 15) reported having incurred a concussion in the current playing season. A quarter of players reporting a previous concussion (25.8%) were removed from the match with five (16.1%) players receiving a subsequent medical clearance for return-to-play. The median (range) number of days that players were removed from match activities was 17.5 (2 to 21) days.

There were observable learning effects between the first and second testing (53.0 s vs. 48.2 s; $p<0.0004$) of the K-D to establish a baseline and this was significant. There were differences recorded between premier players reporting a previous concussion and no previous concussion when completing the baseline assessment at test 1 (48.0 s vs. 53.7 s; $p=0.031$) and test 2 (44.9 s vs. 48.4 s; $p=0.015$) and these were significant (see Fig. 1). There was an observable difference that the under 17 recorded a faster time than the baseline for games 3 (52.0 s vs. 42.8 s; $p<0.0001$); 5 (40.6 s; $p=0.007$) and 6 (43.6 s; $p<0.0001$) and these were significant (see Fig. 2).

Three players were identified with a suspected concussion on-field (see Table 2). When tested post-incident the K-D test times were longer than baseline (5.0 s–7.1 s; $p=0.025$), and they reported more symptoms on the PCSS (11–15; $p<0.0001$) and these were significant. Two players recorded longer times on the post-match K-D test (>5 s) (8.9 s–9.1 s; $p=0.219$) but this was not significant. When tested on the PCSS they recorded difference's (14–15; $p<0.0003$) from their baseline and this was significant. Following two reported epileptic seizures (known epileptic) the player recorded a longer time (5.8 s–6.3 s; $p=0.061$) and increased PCSS symptoms (15–19; $p<0.001$) and this were significant.

4. Discussion

The King–Devick (K-D) test is reported to be a strong candidate for rapid sideline screening test for concussion [8]. This study was conducted to assess the K-D test in an amateur rugby league environment for sideline screening for concussion. The findings of this study provides further evidence in support of previous studies

Table 1
Age, reported concussion history, King–Devick test scores and Post-Concussion Symptom Scores with percentages, median scores and ranges for amateur rugby league players competing in a regional representative competition in New Zealand.

Age at baseline, yrs. ± SD	U17 (n = 25)	Premiers (n = 25)	All players (n = 50)
	16.4 ± 0.7	22.1 ± 3.5	19.3 ± 4.0
Self-reported concussion history			
Previous concussions (%)	12 (48.0)	19 (76.0)	31 (62.0)
Number of concussions, mean (range)	1.5 (1 to 5)	2.0 (1 to 6)	2.0 (1 to 6)
Stand down period completed (%)	1 (8.3)	7 (36.8)	8 (25.8)
Stand down period, median (range) days	21	14 (2 to 21)	17.5 (2 to 21)
Medical clearances to RTP (%)	1 (8.3)	4 (21.1)	5 (16.1)
King–Devick testing			
Pre-competition test 1, s, median (range)	53.8 (38.1 to 61.6)	49.7 (36.5 to 72.6)	53.0 (36.5 to 72.6)
Pre-competition test 2, s, median (range)	52.0 (34.6 to 59.1)	48.0 (35.0 to 62.0)	48.2[a] (34.6 to 62.0)
difference, s median (range)	−2.5 (−0.3 to −8.9)	−3.0 (−0.2 to −20.9)	−3.1 (−0.3 to −20.9)
Baseline Post-Concussion Symptom Scale			
Physical, median (range)	0 (0 to 6)	0 (0 to 6)	0 (0 to 6)
Cognitive, median (range)	0 (0 to 5)	0 (0 to 6)	0 (0 to 6)
Sleep, median (range)	0 (0 to 2)	0 (0 to 2)	0 (0 to 2)
Emotional, median (range)	0 (0 to 2)	0 (0 to 5)	0 (0 to 5)

RTP = return to play; s = seconds; Significant difference ($p<0.05$) than (a) = Precompetition test 1.

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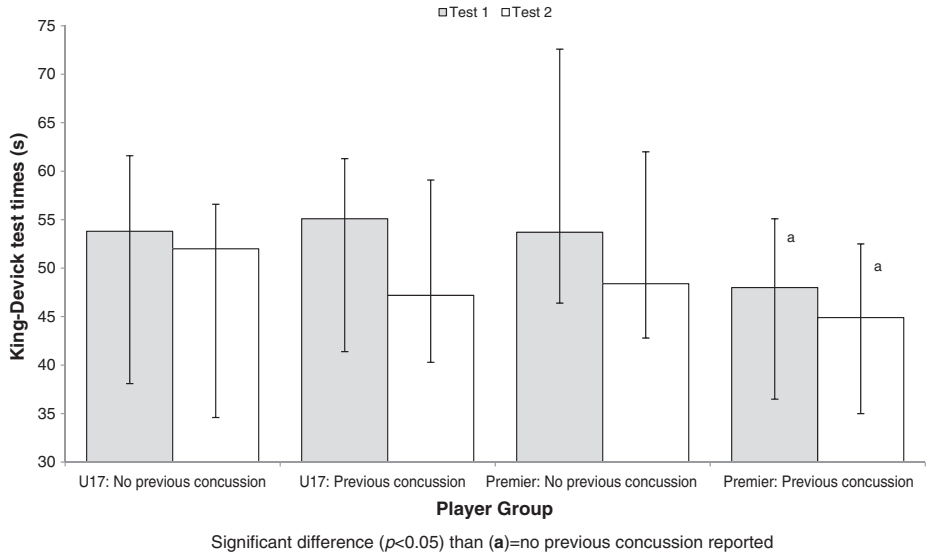

Fig. 1. King–Devick test scores for players with no reported previous and previous concussions reported with median scores and ranges for amateur rugby league players competing in a regional representative competition in New Zealand.

[8,18] reporting on the use of the K-D test as a sideline tool designed to complement other diagnostic sport-related concussion assessment tools. The K-D test was useful in rapidly identifying players that had a suspected concussion by being able to provide instant feedback to players. An unexpected finding was the identification of players who had not shown, or reported, any signs or symptoms of a concussion but who had meaningful head injury. Similar to other studies [8,18] reporting on the use of the K-D test this study found that players with a clinical diagnosis of concussion had a median increase of greater than 5 s (6.8 s). As well, a player with known epilepsy had a median longer time from baseline of 9.3 s following the epileptic seizures away from the sporting environment. This data supports previous statements [8,18] that the K-D test is sensitive to neurological changes such as those seen with sports-related concussion and epilepsy.

The K-D tests were available to the researchers as a spiral-bound moisture-proof 15 cm by 20 cm test cards, IPad2 and IPod-Touch applications making this a very portable and adaptable test on and away from the sideline [18]. The variety of the platforms available ensured ease of availability and variability for the testing of the players. In using the test-cards the players were able to read the numbers and when they read out the bottom right hand number then tester stopped the timing. But when the IPad2 application was used it was observed that some player's baseline scores were longer than those undertaken on the test-cards despite no match activities being undertaken. When re-testing the players with baseline scores of nearly a minute it was observed that some players would read the last number of the test card and wait to tap the screen to stop the timer. As a result of this the tester would stand beside the player undertaking the K-D test on the IPad2 and tap the screen when the player had read the bottom right hand number aloud to ensure that the correct time was recorded. The use of the spiral-bound test cards eliminated this problem as the tester would stop the timer when the last number of each page was read.

In addition to the recording of the time taken to complete K-D test, there is also the capacity to record the number of errors made during the rapid number naming task [18]. Although the number of players who made errors was minimal, this did occur. The errors recorded may be as a result of either the changes that occur with suboptimal brain function or the player trying to ensure that they meet their baseline time [8,12]. Only the number of errors and the time taken to complete the test was recorded in the current study but a possible change to future studies would be to add between 0.35 s to 0.5 s to

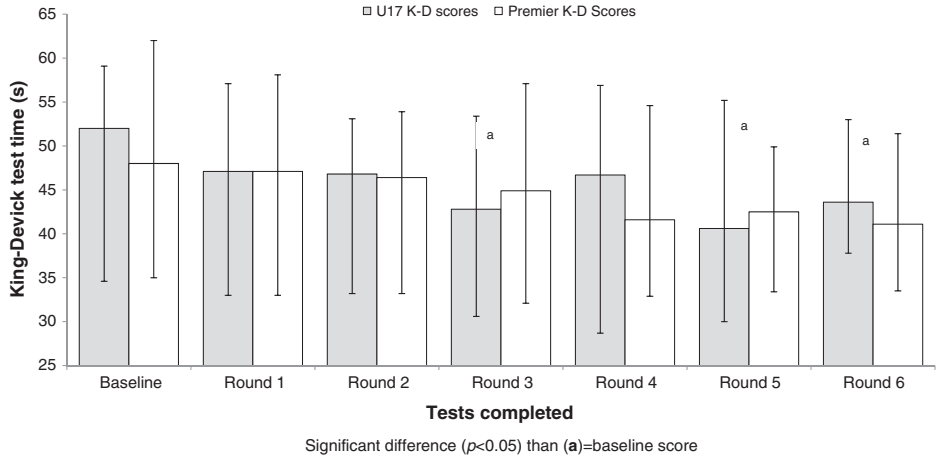

Fig. 2. Baseline and post-match assessments, differences from baseline and ranges of the King–Devick rapid concussion test from baseline with median scores and ranges for amateur rugby league players competing in a regional representative competition in New Zealand.

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Table 2
Reported, witnessed and incidental finding of concussion and other neurological condition for amateur rugby league players competing in a regional representative rugby league competition by baseline and post-match King–Devick scores and Post-Concussion Symptom scores.

Position	Age	Condition	How identified	King–Devick score		PCSS score	
				Baseline	Post-match	Baseline	Post-match
Wing	20	Concussion	Reported	38.2 s	45.2 s[a]	0	12[a]
2nd row forward	17	Concussion	Witnessed	41.2 s	46.2 s[a]	0	11[a]
Fullback	24	Concussion	Witnessed	43.1 s	50.2 s[a]	7	15[a]
Centre	16	Concussion	Incidental	38.2s	47.3 s	0	14[a]
Wing	17	Concussion	Incidental	47.4 s	56.3 s	1	15[a]
Hooker*	24	Seizure	Reported	51.3 s	57.1 s	7	15[a]
Hooker*	24	Seizure	Reported	51.3 s	58.1 s	7	19[a]

* = player with known epilepsy; s = seconds; significant difference ($p<0.05$) than (a) baseline score.

the total time score for each error made to account for accuracy trade off [18].

The finding that players who reported a previous concussion recorded faster times for the first and second baseline testing was unexpected. This may be a result of previous exposure to post-concussion assessments, and there may be some learning effects being seen [8,18]. This was observed when players completed the second baseline assessment with the majority recording a faster time on the second compared with the first trial. A similar finding was observed by decreasing test times over the duration of this study. There was a concern that some players may be able to remember the sequence of numbers on the test cards. To eliminate this, two versions of the K-D tests were available and these were interchanged randomly, along with the different test platforms.

There were three suspected concussions observed on-field during match activities. In all cases players were assessed for other injuries and then removed from the field of play when safe. Although one player was observed on-field to have had a period of non-responsiveness, and he admitted he was unable to recall the event, the sideline K-D test score was shorter (36.1 s) than baseline (45.5 s). It was identified that the test was done on the sideline less than 10 min from when the injury occurred. It has been reported that in the first 10 min from a concussive injury a complex cascade of ionic, neurometabolic, neurochemical and physiologic events occurs [19,20]. Following this cascade, a period of neuronal depression occurs in which cognitive dysfunction can be manifested [19,20]. When the player was reassessed after 15 min on the sideline his K-D test times were longer (36.1 s vs. 58 s). A result of this finding was that players suspected of concussion were not assessed with the K-D test until after 15 min on the sideline.

Two more suspected concussions were identified through the use of the K-D testing post-match and this finding was an unexpected result. At no stage through the matches were these players observed to be showing any signs of concussion or observed alteration in their playing roles. By getting the players to complete the K-D test after each match it was quickly identified that they had a difference from their baseline of longer than 5 s. In both cases the players identified underwent SCAT2 assessments. One player admitted to having no recall of the match while the other player admitted to receiving a knock in the match but unable to recall anything following this. Both players were unaware that what they reported were signs of concussion. The use of the K-D test in conjunction with the SCAT2 ensured that players assessed by the K-D test as a suspected concussion were not eliminated from future participation by error. Initial arguments that a longer K-D test score of greater than 5 s was a direct result of fatigue from participating in rugby league activities was able to be addressed with the use of the SCAT2.

The results of the current study should be interpreted with caution as this was study undertaken over a limited time-frame, with a limited number of participant's and match exposures. Additionally the protocols identified in this study were developed as the study progressed and not all participants underwent the full study protocols in the early stages. Further research is warranted in a wider range of contact sports such as rugby union and rugby league to fully assess the K-D test. These studies should incorporate existing protocols yet evaluate athletes over a longer duration while sampling a more diverse group of participants.

5. Conclusion

The K-D test was able to identify players with a suspected concussion, players with a concussion that was not reported or witnessed, assist in monitoring concussed players return to play process and manage the return of a player with epilepsy. 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. Further research is warranted in a wider range of contact sports to fully assess the K-D test.

Conflict of interest

The authors declare that there are no competing interests associated with the research contained within this manuscript.

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