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Use of the King-Devick test for the identification of concussion in an amateur domestic women's rugby union team over two competition seasons in New Zealand

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Abstract:	Objective: To investigate the use of the King-Devick (K-D) test for sideline assessment of concussive injuries in a New Zealand amateur women's rugby union team. Design: Prospective cohort observational. Methods: All players were K-D tested during pre-season using a tablet (iPad; Apple Inc., Cupertino, CA). Differences in K-D scores and test-retest reliability were calculated for baseline test scores, baseline, and post-injury (concussion) sideline assessment and baseline and post-season testing scores for tests by year and as a combined score. Results: One training-related (0.3 per 1,000 training-hrs) and nine match-related (16.1 per 1,000 match-hrs) concussions were recorded. The K-D post-injury (concussion) sideline test scores were significantly slower than established baseline (-4.4 [-5.8 to -3.4] s; $\chi2(1)=42.2$; $p<0.0001$; $t(9)=-4.0$; $p=0.0029$; $d=-0.8$). There was good-to-excellent reliability of the K-D test for baseline (ICC: 0.84 to 0.89), post-injury (concussion) sideline assessment (ICC: 0.82 to 0.97) and post-season evaluation (ICC: 0.79 to 0.83). Discussion: By utilising the baseline to post-injury (concussion) assessment comparisons, any player with a post-injury (concussion) assessment slowing of their K-D test time, regardless of whether the player has, or has not had a witnessed insult, should be withheld from any further participation until they are evaluated by a medical professional trained in the management of concussion. Conclusion: This study has provided additional evidence to support the use of the K-D test as a frontline method of assessing concussion given the good to excellent reliability of the test for baseline, side-line assessment and post-season evaluation.
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We hereby submit the article titled

Use of the King-Devick test for the identification of concussion in an amateur domestic women's rugby union team over two competition seasons in New Zealand

and certify that the authors have sufficiently contributed in the revision process to publicly acknowledge their responsibility for its content. This manuscript is an original work that that is not part of a bigger study and has not been published elsewhere. This manuscript has not, and will not, been submitted for publication elsewhere until a decision is made regarding its acceptability for publication in Journal of Neurological Sciences.

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Abstract

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Methods: All players were K-D tested during pre-season using a tablet (iPad; Apple Inc., Cupertino, CA). Differences in K-D scores and test-retest reliability were calculated for baseline test scores, baseline, and post-injury (concussion) sideline assessment and baseline and post-season testing scores for tests by year and as a combined score.

Results: One training-related (0.3 per 1,000 training-hrs) and nine match-related (16.1 per 1,000 match-hrs) concussions were recorded. The K-D post-injury (concussion) sideline test scores were significantly slower than established baseline (-4.4 [-5.8 to -3.4] s; $\chi^2_{(1)}$=42.2; p<0.0001; $t_{(9)}$=-4.0; p=0.0029; d=-0.8). There was good-to-excellent reliability of the K-D test for baseline (ICC: 0.84 to 0.89), post-injury (concussion) sideline assessment (ICC: 0.82 to 0.97) and post-season evaluation (ICC: 0.79 to 0.83).

Discussion: By utilising the baseline to post-injury (concussion) assessment comparisons, any player with a post-injury (concussion) assessment slowing of their K-D test time, regardless of whether the player has, or has not had a witnessed insult, should be withheld from any further participation until they are evaluated by a medical professional trained in the management of concussion.

Conclusion: This study has provided additional evidence to support the use of the K-D test as a frontline method of assessing concussion given the good to excellent reliability of the test for baseline, side-line assessment and post-season evaluation.

1. Introduction

Reportedly one of the most popular contact team sport played in more than 200 countries, [1-3] rugby union is a field-based sport that is contested between two opposing teams of 15 players comprised of eight forward-playing positions and seven back-playing positions [4]. The game of rugby is played at the professional, amateur and junior levels of participation by males and females. The game is played on a field measuring a maximum of 100 m by 70 m with two in-goal areas, typically of 10 m depth (end-zones). The objective of rugby union is to score as many points as possible by attacking the opposition team's defensive line with the ball, forcefully running towards, and into, the defensive line. The ball can only be passed backwards between players and only the player with the ball can be tackled by the defending team. There is an abundance of tactical kicking and chasing the ball and attempting to run through gaps in the opposition's defence [4]. The team without the ball can use physical contact to tackle the opposition player with the ball to limit advancement of the ball towards their try line and force errors to regain possession of the ball [4]. As a result, the team assumes both defensive and attacking roles multiple times within the same match. The game involves multiple aggressive contact situations (rucks and mauls) where attacking players control the ball and defending players must stop the advancement of the ball. Given rugby is physically demanding, involving both high-intensity (sprinting, tackling, rucking, mauling) and low-intensity (jogging and walking) activities, the risk of an injury is ever-present [5].

One injury that has received attention in rugby union is concussion or mild traumatic brain injury. Studies reporting on concussion injuries in rugby union have identified that the incidence was relatively low with reports varying from 0.2 [6] to 4.3 [2] per 1,000 playing hours, and 3.8 [7] to 5.7 [8] per 1,000 athlete exposures. However more recently it has been reported to be the most commonly reported injury in professional rugby union in England [9]. Moreover, the effects of repetitive concussions have been associated with poorer cognitive function in young adult males at least three months after their last concussion as well as depression, mild cognitive impairment, poorer memory and verbal fluency, and electrophysiological abnormalities diagnosed later in life [10-14]. The problem with concussion is that it is a unique and individualized injury that can present with a myriad of physical, emotional, somatic, cognitive and sleep-related symptoms and impairments [15]. In addition to this, symptoms may not manifest for several hours post event, so many participants may not produce symptoms that meet the clinical criteria for concussion [16].

Following any brain trauma, eye function movements may become impaired [17, 18]. It has been reported that latency and inaccuracy of saccades can occur following an acute traumatic brain injury [19]. These can remain in people with post-concussion syndrome, where there are a higher number of saccades and poor motor movement timings with longer durations and slower velocities of movement [20]. Poor oculomotor function is one of the most robust discriminators for the identification of [20], and one of the most widely reported visual problems in [17, 18], a mild-traumatic brain injury. The Sport Concussion Assessment Tool, version 5 (SCAT5) is one tool designed for the assessment of concussion [21]. Although the SCAT5 combines both cognitive and balance testing, including the Standardized Assessment of Concussion (SAC) and the Balance Error Scoring System (BESS) or timed tandem gait test, this composite of tests lack a vision-based performance measure [22].

Because approximately half of the brain's circuits are dedicated to vision, the ability to test these pathways has been suggested to increase our ability to detect concussion after any injury [23, 24]. One platform that has received numerous studies for the assessment of concussion in the King-Devick (K-D) test. The K-D test requires intact saccades and other eye movements to perform quickly, is reportedly relatively simple (timed rapid number naming), has a rapid administration (typically less than one-minute), a high test-retest reliability (ICC: 0.96 to 0.97) and reportedly can be utilised by non-medical personnel, including parents [25-27]. Recently it has been reported that the K-D test has high sensitivity and specificity for the detecting of concussion on the sideline [28]. When compared with other sideline screening tools that do not include vision testing, the K-D test has a reported greater accuracy [28].

Despite the growing evidence for the use of the K-D test for concussion assessment, much of this evidence is carried out with men and women are poorly represented. Although women's participation in sports is increasing in popularity, there is a dearth of published studies specifically reporting on them. In order to address this, there has been a call for researchers to direct their efforts towards the development of an evidenced based framework enabling an understanding of women's physiological, training, injury and illness surveillance data to be developed [29, 30]. This is important as much of the research used for exercise testing and prescription, injury prevention, as well as in the medical field have been completed on male participants [29]. In order to address this ‘call to action’ this study was undertaken to investigate the use of the K-D test for the sideline assessment of concussive injuries in an amateur women’s rugby union team in New Zealand over two consecutive competition seasons.

2. Methods

A prospective observational study was undertaken on a single amateur women’s domestic rugby union club-based team (n=69; 26.5 ±7.4 yr.; 1.65 ±0.7 m; 86.6 ±15.9 kg) over two years (2018-2019) in a women’s rugby union domestic competition (nine teams playing in a home and away format from April to July) (see Table 1). All players were amateur and did not receive match payments. Prior to the competition season commencing all players provided written consent to participate in the research and all procedures were approved by the institutional ethics committee.

Developed in the 1970’s by Alan King and Steven Devick to evaluate children suspected of dyslexia or impaired saccadic eye movements [31], the King-Devick (K-D) Test in association with Mayo Clinic is a rapid number naming task that takes < 2 min to administer [32]. The participant reads aloud a sequence of single digit numbers from the left to the right of the screen that includes one demonstration card and three visually distinct test cards that increase in difficulty [25]. Utilised in the assessment of collegiate football, soccer and basketball players [25], amateur rugby union and rugby league players [33], professional ice hockey players [26], boxers and mixed martial arts players [34], the K-D has been reported to have a high sensitivity (0.86; 95% CI: 0.79 to 0.92), specificity (0.90; 95% CI: 0.85 to 0.93) and an Inter Class Correlation (ICC) of 0.91 (95% CI: 0.85 to 0.97) [35, 36]. In addition, the K-D test has been reported to have significant correlations (p<0.0001) with the visual motor speed (VMS), reaction time (RT), verbal memory (VEM) and visual memory (VIS) of the Immediate Post-concussion Assessment Cognitive Test (ImPACT®) [37] computerised concussion evaluation system. The K-D test relies upon comparing the differences between baseline and post-injury results to provide an insight into a potential concussive injury [38] and has been utilised by parents and non-health care professionals [27]. The K-D test has not been recommended for use as a standalone diagnostic tool [35, 39], rather the K-D should be utilised in conjunction with other concussion assessment tools as a sideline screening tool [39, 40].

All players were tested during pre-season with a tablet (iPad; Apple Inc., Cupertino, CA) according to the developer's recommendations (v4.2.2; King-Devick technologies Inc.). All baseline testing was completed at training to mimic the sideline playing field environments. Players were asked to read card numbers from left to right as quickly as they could without making any errors using standardized instructions. Time was kept for each test card, and the entire test K-D summary score was based on the cumulative time taken to read all three test cards [41]. The number of errors made in reading test cards was recorded. The best time (fastest) of two trials 5-minutes apart without errors became the established baseline K-D test time [34].

During matches, the team medic (and lead researcher), observed players for any signs of direct contact to the head, or being slow to rise from a tackle or collision, or being unsteady on their feet following a collision. If this occurred, players were assessed on-field. If any signs of delayed answering, incorrect answers to questions, or if the player appeared to be impaired in any way, the player was removed from match activity and rested on the sideline. Players who reported any sign(s) of a concussion, who were suspected to have received a concussion, or who were removed from match participation were initially assessed with the sideline K-D test after a 15-minute rest period; not allowed to return to play on the same day; and, referred for further medical assessment. The test was administered once using the same instructions, and time and errors were recorded and compared to the participant's baseline. Worsening time and/or errors identified on the sideline or post-match K-D have been associated with concussive injury [25, 26, 34]. The K-D test performance has been shown to be unaffected in various noise levels and testing environments [42].

No player who had been identified with delayed (worsening) post-match K-D times were allowed to return to training or match activities without a full medical clearance. Players with a loss of consciousness were treated for a cervical spine injury and managed accordingly. All suspected concussive injuries were evaluated by the player's own health professional. All players that were identified with a delay (worsening) of the K-D test from their baseline were assessed by their health professional for a formal assessment. No player was allowed to return to full match activities until they were medically cleared and, had returned to their baseline K-D score.

Concussions were classified as witnessed (a concussive injury that met the definition of a concussion, [21] that was identified during match activities resulting in removal from match activities and had >3 s for pre to post-match K-D, and later confirmed by a physician's clinical assessment) or unwitnessed (changes >3 s for pre to post-match K-D with associated changes, and later confirmed by a physician's clinical assessment). The 3 s threshold for changes in post-match K-D is identical to studies reporting K-D test use [1, 43]. 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*" [21]. An 'unwitnessed' concussion was defined for the purpose of this study as "*any disturbance in brain function caused by a direct, or indirect force, to the head that does not result in any immediate observable symptoms, physical signs, impaired brain function or abnormal behaviour but had a delay in the post-match K-D score of >3 s and associated changes in the post-match SCAT5*" [33].

Statistical analyses were conducted once all data collected were entered into a Microsoft Excel spread sheet and analysed with SPSS v22.0.0. Data were screened for normal distribution using the Shapiro-Wilk test and found to be normally distributed ($W_{(53)}$=963; p=0.0995). Independent *t*-tests were used to assess differences in baseline data. Concussion missed-match duration were recorded as the total day's players missed participating in rugby matches.

Test-retest reliability were calculated using intra-class correlation coefficient (ICC), with 95% CI, to examine agreement between pre-competition first and second (T1 and T2) baseline test scores, established baseline and post-injury (concussion) sideline assessment and established baseline and post-season K-D testing scores for tests by year and as a combined score. The ICC was interpreted as poor (<0.50), moderate (0.51 to 0.75), good (0.76 to 0.90) and excellent (>0.91) reliability [44].

Differences in K-D scores from pre-competition first and second (T1 and T2) baseline test scores, established baseline and post-injury (concussion) sideline assessment and established baseline and post-season K-D scores were compared using a Generalised Linear Model by the reporting year and as a combined composite score. If differences were detected, a post-hoc two-tailed *t*-test was utilised to determine if any significant differences existed. A Bonferroni-type adjustment was applied to maintain the type-1 error probability at the 0.05 alpha level. Cohen's *d* effect sizes [45] were also computed to complement interpretation of results, with effect sizes being interpreted as negligible/very small (d<0.20), small (d=0.20 to 0.49), medium (d=0.50 to 0.79), or large (d >0.80). Data are presented as mean (±SD) for player data, concussive injury per 1,000 match hours with 95% confidence interval (95% CI), ICC as mean and 95% CI, and median [25th to 75th inter-quartile range] for K-D scores.

3. Results

Over the study, forwards were older (28.6 ±8.1 yr. vs. 23.4 ±4.9 yr.; $t_{(27)}$=4.4; p=0.0001) and had a higher body mass (92.5 ±15.2 kg vs. 78.0 ±10.8 kg; $t_{(27)}$=4.1; p=0.0003) than backs (see Table 1). Players were significantly older in 2019 than in 2018 (28.9 ±8.0 yr. vs. 24.2 ±6.0; $t_{(17)}$=-2.4; p=0.0289).

Players undertook 114 training sessions for an exposure of 3,339.5 training hrs and 29 match activities for an exposure of 558.6 match hrs. One training related and nine match related concussions were recorded over the study resulting in a concussion injury rate of 0.3 (95% CI: 0.0 to 2.1) per 1,000 training hrs and 16.1 (95% CI: 8.4 to 31.0) per 1,000 match hrs (see Table 2). Although there were more match related concussions in 2018 (18.8 [95% CI: 8.4 to 41.8] per 1,000 match-hrs.) when compared with 2019 (RR: 1.5 [95% CI: 0.4 to 5.9]; p=0.5637), this was not significant.

There was a significant difference in the K-D test baseline establishment in 2018 between the scores for baseline test 1 and test 2 ($\chi^2_{(1)}$=52.0; p<0.0001; $t_{(30)}$=6.0; p<0.0001; d=0.70) (see Table 3). There was good reliability between the tests for K-D test baseline establishment in 2018 (ICC: 0.88 [95% CI: 0.75 to 0.94]; $F_{(30,30)}$=8.4; p<0.0001). This was similar in 2019 for K-D baseline test 1 and test 2 ($\chi^2_{(1)}$=30.2; p<0.0001; $t_{(21)}$=4.0; p=0.0006; d=0.63). There was good reliability between the tests for K-D test baseline establishment in 2019 (ICC: 0.84 [95% CI: 0.62 to 0.94]; $F_{(21,21)}$=6.4; p<0.0001).

Although the K-D test baseline established in 2019 (44.0 [38.3 to 47.8] s) was faster than 2018 (49.1 [44.8 to 55.9 s; $\chi^2_{(1)}$=0.4; p=0.5207; $t_{(21)}$=3.9; p=0.0009; d=1.03) this difference was not significant.

Post season analysis of the test scores for the K-D test showed significant mean improvements of 9.8 [5.6 to 15.2] s ($\chi^2_{(1)}$=62.7; p<0.0001; $t_{(21)}$=8.7; p<0.0001; d=2.17) in 2018 and 8.8 [5.5 to 14.9] s ($\chi^2_{(1)}$=8.1; p=0.0045; $t_{(35)}$=10.9; p<0.0001; d=1.41) in 2019 (see Table 3). There was good reliability between the baseline and post-season K-D test scores (ICC: 0.82 [95% CI: 0.65 to 0.91]; $F_{(35,35)}$=5.6; p<0.0001) in 2019. When combined, the K-D test post-season scores were significantly faster (9.6 [5.5 to 15.2]; $\chi^2_{(1)}$=35.8; p<0.0001; $t_{(57)}$=14.5; p<0.0001; d=1.44) than the K-D test baseline scores. There was good reliability between the combined K-D test baseline and post-season K-D test scores (ICC: 0.83 [95% CI: 0.71 to 0.90]; $F_{(57,57)}$=5.8; p<0.0001).

The K-D post-injury (concussion) sideline test scores were significantly slower than the K-D baseline test scores (-4.6 [-6.6 to -3.5] s; range -19.1 to -3.4 s; $\chi^2_{(1)}$=15.4; p=0.0001; $t_{(9)}$=-4.0; p=0.0029; d=-0.86) (see Figure 1). There was good reliability between the combined concussion K-D sideline assessment (ICC: 0.83 [95% CI: 0.71 to 0.96]; $F_{(9,9)}$=5.5; p=0.0093).

4. Discussion

This prospective study undertook to document the changes in the K-D test from baseline, sideline assessment and post-season over two consecutive competition seasons of an women's rugby union team in New Zealand. The principal findings of this study were: (1) There was a higher incidence of concussion in this cohort of amateur women's rugby union matches than previously reported; (2) The mean days-lost from match participation was 27.3 ±6.2 days; and (3) there was good to excellent reliability of the K-D test for baseline (ICC: 0.84 to 0.89), post-injury (concussion) sideline assessment (ICC: 0.82 to 0.97) and post-season evaluation (ICC: 0.79 to 0.83).

The use of the K-D test for the assessment of a concussive injury was undertaken at the sideline as a screening tool only, does not preclude a comprehensive concussion evaluation and was not utilised to diagnose concussion [38]. By utilising the baseline to post-injury (concussion) assessment comparisons, any player with a post-injury (concussion) assessment slowing of their K-D test time, regardless of whether the player has, or has not had a witnessed insult, should be withheld from any further participation until they are evaluated by a medical professional trained in the management of concussion [46]. Although it has been previously reported that intense exercise has not resulted in worsening of the K-D test scores [1, 25], it has been recently reported [47, 48] that there have been false positives recorded, further supporting the use of the K-D test as a screening tool only and as part of a battery of tests for the assessment of concussion. In the management of these injuries for this study, further evaluations were required by a health professional to confirm the diagnosis of concussion. When this was confirmed the player commenced a graduated return to activity programme. Players with a medically diagnosed concussion were required to complete the K-D test again before returning to full training activities and then before they commenced full match activities.

The incidence of concussion for match participation (16.1 per 1,000 match-hrs.) over the study was higher than previous women's rugby union studies (0.55 per 1,000 playing hours) [49]. The mean missed-match duration for concussions were 28.9 ±3.7 days which was similar to a previous study [50] where the majority of concussions took 28 days to recover. This finding is in conflict with the Concussion in Sport Consensus (CISC) where it identified that 80% to 90% of all concussions recover in seven to 10 days [15, 21]. The New Zealand Rugby concussion guidelines (https://www.rugbysmart.co.nz/assets/Resources/2d581e65f7/Concussion-return-guidelines.pdf) are based on the CISC guidelines and outline that players can return to match activities on the 21st day post-injury with medical clearance. No players in this study with an identified concussion were allowed to commence contact training in preparation for match participation until they had equalled or surpassed (faster) their baseline K-D test despite the presentation of a medical clearance by their own health practitioner. No player with an identified concussion returned to their baseline K-D test before 21 days post-injury. As a result, no player was allowed to return to full match participation until they had completed two contact training sessions, were symptom free and, there were no worsening (slower) time of their K-D test from their baseline.

Only one concussion throughout the study was an unwitnessed concussion. The participant had been in a tackling drill and when attempting to tackle the other player her head connected with the other player's knee. The player continued on with tackling other players as part of the drill until another player reported her to the coaching staff. This player was taken away from the training activity and tested after five minutes rest where her post- 'event' K-D test score had worsened when compared with her baseline (33.3 s vs. 52.4 s). This is consistent with previous studies [25, 33, 34, 43, 51] where participants tested at the side of the match venue immediately following an injury have demonstrated substantial worsening of the K-D test times when compared with their baseline scores.

The range of scores for the K-D test of this cohort at baseline (2018: range 37.6 to 65.6 s: median 49.0; 2019 range 35.6 to 55.4 s: median 44.0) were broad and this is consistent with previously published studies reporting on professional ice hockey (range 29.4 to 58.3 s; median 40.3), amateur rugby league (range 34.6 to 59.1 s; median 52.0), amateur male rugby union (25.6 to 56.8 s; median 37.3) and collegiate contact sports participants (range 23.4 to 52.1 s; median 36.1) [1, 25, 26, 34, 43].

Rugby is a popular contact team sport played in more than 200 countries around the world by both male and female players. Because of the physicality involved it is also associated with an increased incidence of injury, and concussion is one of the consequences reported to be increasing in women players. The measures highlighted thus far have been encouraging and further support is warranted to match the participation rates of the sport's popularity.

5. Conclusion

This study has provided additional evidence to support the use of the K-D test as a frontline method of assessing concussion in female rugby players given the good to excellent reliability of the test for baseline, side-line assessment and post-season evaluation.

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Table 1: Player age, height, weight and playing experience for forwards, backs and total players over the 2018 and 2019 women's rugby union training and competitions in New Zealand. Data reported by number of players and mean with standard deviation.

	2018		2019		Total	
	n=	**Mean ±SD**	**n=**	**Mean ±SD**	**n=**	**Mean ±SD**
Age (years)						
Forwards	18	25.6 ±6.9[d]	23	31.0 ±8.3[c]	41	28.6 ±8.1[b]
Backs	17	22.8 ±4.7	11	24.4 ±5.5	28	23.4 ±4.9[a]
Total	35	24.2 ±6.0[d]	34	28.9 ±8.0[c]	69	26.5 ±7.4
Height (meters)						
Forwards	18	1.69 ±0.79	23	1.64 ±0.57	41	1.66 ±0.71
Backs	17	1.64 ±0.81	11	1.64 ±0.66	28	1.64 ±0.74
Total	35	1.67 ±0.82	34	1.64 ±0.59	69	1.65 ±0.72
Weight (kg)						
Forwards	18	95.3 ±20.7[b]	23	90.3 ±11.5[b]	41	92.5 ±15.2[b]
Backs	17	78.3 ±12.0[a]	11	77.6 ±9.2[a]	28	78.0 ±10.8[a]
Total	35	87.1 ±18.9	34	86.2 ±12.3	69	86.6 ±15.9
Playing Experience (years)						
Forwards	18	4.4 ±4.2	23	4.3 ±4.3	41	4.3 ±4.2
Backs	17	3.0 ±2.4	11	6.2 ±5.8	28	4.3 ±4.3
Total	35	3.9 ±3.4	34	4.9 ±4.8	69	4.3 ±4.2

SD = Standard Deviation; Significant difference (p<0.05) than (a) = Forwards; (b) = Backs; (c) = 2018; (d) = 2019.

Table 2: Number of training and match activities, exposure hrs, concussion incidence rate and mean days lost over the 2018 and 2019 women's rugby union training and competitions in New Zealand.

	2018						2019					
	Exposure		**Concussion incidence**		**Days lost**		**Exposure**		**Concussion incidence**		**Days lost**	
	n=	**Hrs**	**n=**	**rate (95% CI)**	**Total**	**mean ±SD**	**n=**	**Hrs**	**n=**	**rate (95% CI)**	**Total**	**mean ±SD**
Training	60	1,709.40	0	0.0 -	0	0.0 -	16	319.2	6	18.8 (8.4-41.8)	174[b]	29.0 ±4.6
Match	54	1,630.10	1	0.6 (0.1-4.4)	30	30 -	12	239.4	3	12.5 (4.0-38.9)	86[a]	28.7 ±1.2
Total	**114**	**3,339.50**	**1**	**0.3 (0.0-2.1)**	**30**	**30 -**	**28**	**558.6**	**9**	**16.1 (8.4-31.0)**	**260**	**28.9 ±3.7**

CI: Confidence Interval; SD = Standard deviation; Significant difference than (a) = 2018; (b) = 2019.

Table 3: King-Devick Test scores and range of scores for pre-season test 1 and test 2, baseline (fastest time of test 1 and test 2) establishment and post season compared to baseline scores over the 2018 and 2019 women's rugby union training and competitions in New Zealand.

	2018			2019			Combined		
	n=	Median [IQR]	Range	n=	Median [IQR]	Range	n=	Median [IQR]	Range
Baseline Establishment									
Test 1	35	57.3 [50.1 to 64.8][b]	41.7 to 71.2	34	46.6 [42.2 to 53.5][b]	36.4 to 61.3	69	53.1 [45.4 to 59.1]	36.4 to 71.2
Test 2	35	49.0 [45.9 to 57.0][a]	37.6 to 65.6	34	44.6 [39.4 to 48.0][a]	35.6 to 55.4	69	47.3 [42.9 to 51.0]	35.6 to 65.6
Baseline	**35**	**49.0 [45.9 to 56.8]**	**37.6 to 65.6**	**34**	**44.0 [38.3 to 47.8]**	**35.6 to 55.4**	**69**	**47.3 [42.9 to 51.0]**	**35.6 to 65.6**
Difference		6.0 [3.1 to 8.6]	-1.2* to 21.4		3.9 [2.2 to 5.2]	-8.2* to 14.0		4.1 [1.9 to 7.2]	-8.2* to 21.4
ICC** / ES		0.88 [0.75 to 0.94]	0.70		0.84 [0.62 to 0.94]	0.63		0.89 [0.82 to 0.94]	0.61
Post Season									
Baseline	35	49.0 [45.9 to 56.8][c]	35.6 to 55.4	34	44.0 [38.3 to 47.8][d]	35.3 to 65.6	69	47.0 [42.0 to 50.9]	35.3 to 65.6
Post Season	35	33.6 [31.4 to 35.4][d]	29.0 to 38.2	34	38.5 [34.9 to 43.0][c]	29.9 to 60.1	69	36.7 [33.1 to 39.1]	29.0 to 60.1
Difference		**9.8 [5.6 to 15.2]**	**2.1 to 17.6**		**8.8 [5.5 to 14.9]**	**1.4 to 19.8**		**9.6 [5.5 to 15.2]**	**1.4 to 19.8**
ICC** / ES		0.79 [0.59 to 0.89]	2.17		0.82 [0.65 to 0.91]	1.41		0.83 [0.71 to 0.90]	1.44

* = Negative scores indicate a worsening (slower) time; IQR = Interquartile Range; ICC = Interclass Correlation Coefficient; ** = data reported as mean (95% Confidence Interval); ES = Effect size; # = includes training and match concussions; Significant difference (p<0.05) than (a) = Baseline Test 1; (b) = Baseline Test 2; (c) = Pre-season Baseline; (d) = Post-Season.

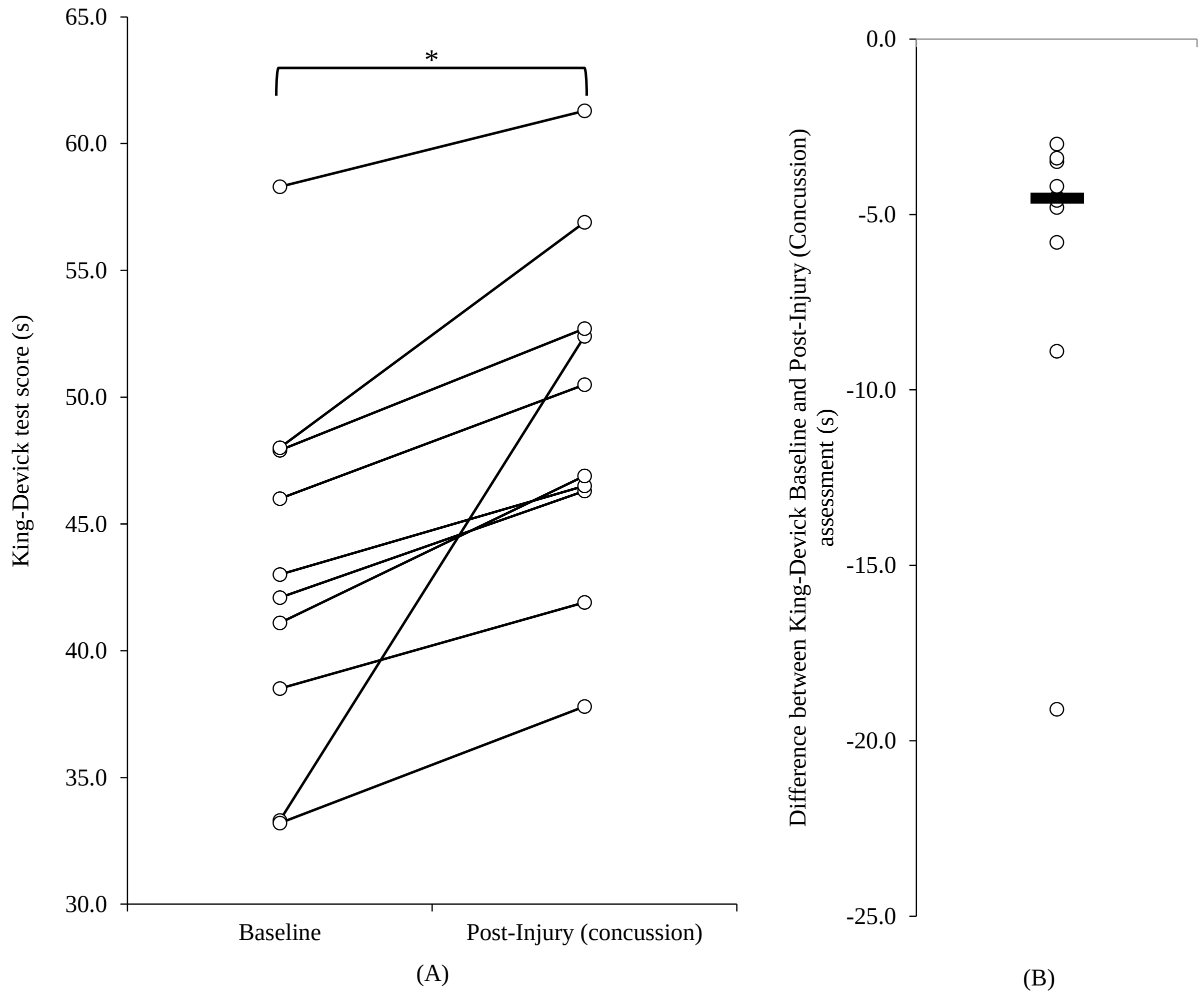

Figure 1: Scatterplot of (A) King-Devick test baseline score and post-injury (concussion) sideline scores in seconds and (B) differences in the scores in seconds. The black line is the median score for amateur women rugby union players in New Zealand. * = significant difference ($\chi^2_{(1)}$=15.4; p=0.0001; $t_{(9)}$=-4.0; p=0.0029; d=0.86); s = seconds.