

Use of the concussion check protocol for concussion assessment in a female soccer team over two consecutive seasons in New Zealand

Doug King^{a,b,c,d,e,*}, Patria Hume^{a,b,e,f}, Trevor Clark^g, Jennifer Wethe^h

^a Auckland Bioengineering Institute, The University of Auckland, Auckland, New Zealand

^b Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

^c School of Science and Technology, University of New England, Armidale, NSW, Australia

^d Wolfson Research Institute for Health and Wellbeing, Department of Sport and Exercise Sciences, Durham University, Durham, UK

^e Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand

^f Technology and Policy Lab - Law School, The University of Western Australia, Perth, Australia

^g International College of Management Sydney, Manly, New South Wales, Australia

^h Mayo Clinic School of Medicine, Scottsdale, AZ, USA

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ABSTRACT

Aim: Address deficiencies in access to sports sideline medical care by using a Concussion Check Protocol (CCP) for non-medically-trained people.

Method: A prospective observational cohort study was undertaken on a single amateur female club-based soccer team over two consecutive years in New Zealand utilising a non-medically trained support person termed a Safety officer. CCP is an extension of the King-Devick test with features such as warning signs and symptoms of concussion built into the application. All players suspected of having a potential concussive injury were tested on the match sideline.

Results: The study overall incidence of match-related concussions was 20.8 (95% CI: 11.8 to 36.6) per 1000 match-hrs, with mean missed-match duration of 31 (95% CI: 27.9 to 34.1) days. Twelve players over the study had a significantly slower post-injury K-D (49.9 [44.3 to 64.1]s; $\chi^2_{(1)} = 11.0$; $p = 0.0009$; $z = -2.9$; $p = 0.0033$; $d = 0.30$) and/or reported symptoms, compared with their own baseline (47.2 [44.3 to 64.1]s). CCP had an overall sensitivity of 100% (95% CI: 73.5% to 100.0%), specificity of 100% (95% CI: 69.2% to 100.0%) and positive predictive value (PPV) of 100% (84.6% to 100.0%).

Conclusion: Sideline use of CCP was undertaken successfully by non-medically trained people and provided a reliable platform for concussion identification.

1. Introduction

Participation in football (hereinafter termed soccer) has been reported [1] to induce considerable health benefits in terms of cardiovascular and neuromuscular fitness across the age spectrum. Although soccer has potential to support a healthy lifestyle, it is deemed a high-intensity sport with frequent changes of direction and movement velocity combined with direct physical contact including high impacts that all pose injury risk [2]. As such, soccer is considered one of the top five sports where participants are most at risk of sustaining an injury [3,4]. Although males are at a higher risk of injury during soccer compared with females, [5,6] due to the increased game speed, females are more likely to suffer severe injuries compared with males [6]. The skill level of

females compared with male participants alongside the decreased medical support for female teams have been suggested as potential confounding injury risk factors [6]. One injury that can occur from match participation in soccer is concussion.

Also termed a mild traumatic brain injury (mTBI), concussion can occur from an impulsive blow to the head or body that results in transient neurologic signs or symptoms [7]. Identified as “the most complicated disease of the most complex organ of the body” [8], concussions are becoming a global concern for participants in all sports due to increasing possibility of long-term consequences on brain function [9]. Children and adolescents are more vulnerable to effects of concussion and have a reported increased risk for longer-term sequelae [10,11]. Studies have shown sex-based differences in concussion incidence in sex-comparable

* Corresponding author at: Emergency Department, Hutt Valley District Health Board, Private Bag 31-907, Lower Hutt, New Zealand.

E-mail address: douglas.king@huttvalleydhb.org.nz (D. King).

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sports [12], with one large meta-analysis [13] reporting that concussion rates were notably higher in females compared to males in soccer and basketball. At the professional level of participation, females' face greater concussion risk and experience more post-concussion symptoms compared to males. Even at high school participation level, it has been reported [14] that female soccer has the highest incidence of concussion compared with all other sports. Athletes at high school and collegiate levels of participation often underreport the symptoms of concussion, thus placing themselves at risk of a repeated injury [15,16]. This underscores the need for quick, objective tools on sport sidelines to identify when an important head injury has occurred and aid in timely removal from play. This is of particular importance in youth athletes who may be more susceptible to injury and prolonged recovery [17,18].

Assessing for concussion on the sideline of a sporting activity is particularly challenging [19]. Symptoms of concussion can vary in nature and depend upon the self-reporting of the athlete [20]. As well, the physical symptoms that can manifest may not be the same for every participant [21]. Add in the lack of access to qualified health professionals at amateur sporting activities and the paucity of available sideline assessment tools for the non-medically trained volunteers, and players may engage in 'team-doctoring' [22]. Team doctoring is where players seek medical advice from their teammates and coaches, many of whom may not be appropriately trained in concussion identification and assessment. As a result, many concussions go undetected. Returning the player to the sports environment with a concussion can have long-term or even catastrophic outcomes.

1.1. Aim

The aim of our investigation was to explore the use of a sideline concussion protocol for non-health professionals to assist with the identification of players at risk of having incurred a concussive type of injury.

2. Methods

A prospective observational cohort study was undertaken on a single amateur female club-based soccer team ($n = 49$; 23.0 ± 9.8 yr.) over two consecutive years (2022–2023). The team participated in a female's premier competition comprising of eight teams playing in a home and away format from March to August. 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 (AUTEC #19/98).

2.1. Concussion check protocol

The Concussion Check Protocol (CCP) is a three-step protocol to identify potential concussions and refer individuals to medical-health care personnel. The guidelines utilised for the CCP were designed to help both lay people and healthcare professionals identify symptoms of a potential concussion. If a potential concussion is identified, the protocol instructs that the athlete should be removed from play and referred to appropriate medical-health care personnel for further evaluation and treatment. This is useful in settings like sports, where concussions occur frequently, and early identification is crucial.

Concussion Check comprises instructional videos, interactive learning modules, and the CCP App, an extension of the King-Devick test (K–D) with features such as warning signs and symptoms of concussion. The CCP App supports individuals in performing the CCP. The CCP includes systematic identification of signs and symptoms of concussion, [23] situational awareness questions (see Supplemental Table), and the King-Devick Test, an objective rapid-number naming test that screens for oculomotor dysfunction and is sensitive to acute concussion [24]. Concussion Check was used to train parents and team management to be

involved in the sporting environment as Safety Officers, lay persons trained to recognise and test for the possibility of concussion during sporting events and training sessions.

In this study, prior to any competition, the team Safety Officer used the CCP App to establish a pre-season baseline which included the K–D [25]. Players read aloud a sequence of single digit numbers in rapid succession from left to right on an iPad (iPad; Apple Inc., Cupertino, CA) according to the developer's recommendations (v1.0.51; King-Devick technologies Inc.). The K–D has 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) [26,27]. All baseline testing was completed by the team Safety Officer at training to mimic the sideline playing field environments. Time was kept for each test screen, and the entire test K–D summary score was based on the cumulative time taken to read all three test screens [28]. The number of errors made in reading test cards was recorded. The best time (fastest) of two trials without errors became the established baseline K–D test time [24]. At the end of the K–D test, players were asked if they had any of 12 symptoms listed. This then formed the baseline for the individual player.

The K–D test enabled comparison of the individual players baseline score with their post-injury results to provide an insight into a potential concussive injury [29]. The K–D test assessed oculomotor function and required integration of multiple motor efforts, sensory inputs [30] and cognitive processes such as sustenance of attention, spatio-temporal memory, target selection, and expectation [31]. Poor oculomotor function has been determined as one of the most robust discriminators for identification of a concussive injury [32]. The K–D is not recommended as a standalone diagnostic tool [26,33] and should be utilised in conjunction with other concussion assessment tools as a sideline screening tool [33,34]. It has been recommended that any slowing (worsening) of >1 s from the individual's baseline is a "fail" and the individual should be referred for further assessment. With addition of the CCP, the player was monitored for signs of serious injury and other signs and symptoms of a concussive injury. Upon completing the CCP with the K–D on the iPad, the results were instantly displayed.

2.2. Match-day protocol

For the study, a member of the team management (assistant medic) was termed the Safety Officer and undertook to complete the CCP. The Safety Officer was a sports therapist but had no formal medical training in concussion assessment and identification. The team medic was a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment, and management and provided support to the Safety Officer following any assessment of potential concussion by the CCP. During matches, the Safety Officer observed players for any signs of direct contact to the head, being slow to rise from a collision, being unsteady on their feet following a collision or contact with the ball or if they appeared confused. If there were any concerns the player was removed from match participation and screened with the sideline CCP by the Safety Officer after 10-min of rest. Another player was selected that was similar to the identified player in age, height and player position to act as a control participant. The Safety Officer utilised the CCP App to screen for red flags, document observable behaviours and signs of concussion, assess situational awareness, administer a single trial of the K–D test, and ask the player if they had any of 12 concussion symptoms [23] (See Supplemental Table). Via the CCP App, the resulting K–D time, errors and any reported symptoms were compared with the individual's baseline and, if this was a failure due to symptoms and/or signs and/or slowing (worsening) of time, the player was deemed to have had a potential concussive injury and referred for further medical evaluation. No player who had been identified with delayed (worsening) post-injury K–D times or signs or symptoms of concussion was allowed to return to training or match activities. All potential concussive injuries were evaluated by the player's own health professional or the Emergency

Department on the same day. No player was allowed to return to full match activities until they were medically cleared and, had returned to their baseline K—D score.

2.3. Concussion definition

The definition of 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.” [35]. 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 symptoms, physical signs, or abnormal behaviour but had a delay in the post-match K-D score of >1s and/or associated changes and reported symptoms in the post-match CCP.” [36].

2.4. Statistical analyses

Statistical analyses were conducted once all data collected were entered into a Microsoft Excel spread sheet and analysed with SPSS v29.0.0. (SPSS Inc., Chicago, IL). Data were checked for normality and homogeneity of variance using a Shapiro-Wilk’s test of normality ($W_{(60)} = 0.945; p = 0.0088$). Data were identified to be not normally distributed, therefore the equivalent non-parametric tests were utilised.

Injury incidence rates (IIR) for match related female’s soccer concussions were calculated utilising established formula for rates per 1000 match-hrs: [37].

$$IIR = \left(\frac{\sum \text{injuries}}{\sum \text{exposure}} \right) \times 1,000$$

Post hoc probabilities of a female’s soccer match-related-concussion injury occurring over a competition season were also determined utilising a Poisson distribution: [38].

$$P(\kappa) = \frac{(\lambda t)^\kappa e^{-\lambda t}}{\kappa!}, \text{ for } \kappa = 1, 2, 3, \dots$$

where κ is total number of injuries occurring in a squad of players and total time of match play exposure over a single season, t is time-interval in hours, e is base of the natural logarithm ($e = 2.71828\dots$), $\kappa!$ is factorial of ‘ κ ’ and λt is injury incidence multiplied by length of exposure.

Previously utilised in studies reporting on rugby union [38] and soccer, [39] the Poisson distribution for injury probability helps describe frequency of injuries occurring based on the presumption that these occur independently and take place over time or space [40]. To calculate injury probability incidence rate, the duration, and number, of matches played in a single season are required. Therefore, to utilise the Poisson distribution for injury probability, it must be presumed that each player within the squad would have a similar risk of sustaining an injury [38]. As such, probability calculations were undertaken based on match duration of 90 mins and the concussion injuries being independent events.

Differences in K—D scores from pre-competition first and second (B1 and B2) baseline test scores, established baseline and post-injury (concussion) sideline screening were compared using a Friedman repeated measures ANOVA on ranks. If notable differences were observed, a Wilcoxon signed-rank post-hoc test was conducted with a Bonferroni correction applied.

Players ages were compared between 2022 and 2023 with a t -test and the number of concussions recorded per year were compared with a one-sample chi-squared (χ^2) test was utilised. Test-retest reliability was calculated using ICC, with 95% CI, to examine agreement between pre-competition first and second (B1 and B2) baseline test scores,

established baseline and post-injury (concussion) sideline screening. This was undertaken utilising a two-way mixed model with Yates corrected Chi-square for absolute agreement of a single rater/measurement. This was chosen as: (a) the model refers to the repeatability between consecutive sessions taken by the same instrument under the same conditions; (b) the use of a two-way mixed-effects model is recommended as appropriate for analysing multiple scores from the same rater because the repeated measurements are not regarded as randomised samples and generalising one rater’s scores to a larger population is not a concern; [41] and (c) absolute agreement should always be chosen for test-retest reliability [42]. 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 [42]. Cohen’s d effect sizes were 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 ($d > 0.80$) [43].

Sensitivity, specificity and positive predictive value (PPV) of the full CCP and its individual components were computed utilising a 2×2 contingency table with Clopper-Pearson confidence intervals reported using a Yates correction with a one-sample chi-squared (χ^2) test for all players screened on the sideline [44]. The level of significance was set at $p < 0.05$ and data are presented as mean (\pm SD) for concussive injury per 1000 match hours with 95% confidence interval (95% CI), ICC as mean and 95% CI, percentage (%) and 95% CI for CCP sensitivity, specificity and PPV, and median [25th to 75th inter-quartile range] for K—D scores.

3. Results

There were 49 players enrolled in the study over the two years. Only 11 players were the same in both seasons. The playing group was older in 2023 (25.1 ± 10.8 yr.) compared with 2022 (20.4 ± 7.2 yr.; $t_{(28)} = -1.7; p = 0.0488$) (see Table 1). Overall incidence of match-related concussions for the study was 20.8 (95% CI: 11.8 to 36.6) per 1000 match-hrs. The number of concussions recorded in the 2022 season ($n = 7; 23.6$ (95% CI: 11.2 to 49.4) per 1000 match-hrs) compared with 2023 ($n = 5; \chi^2_{(1)} = 0.2; p = 0.6322$) was not significantly different. There was a 22% probability of a player incurring a concussive injury over the duration of the study.

While there were noticeable differences in the K—D test baseline establishment in 2022 between the scores for baseline test 1 and test 2 ($\chi^2_{(1)} = 23.5; p < 0.0001; z = -4.47; p < 0.0001; d = 0.36$) (see Table 2), statistically there was excellent reliability between tests for K—D test

Table 1

Concussions observed, expected, match hrs, concussion incidence rate, days lost, injury burden, hours per injury, injuries per game, probability occurring and mechanism of injury of a concussion for an amateur female’s soccer team in New Zealand.

	2022	2023	Total
Number of players, n	29	31 ^a	49 ^b
Player age, yr. mean \pm SD	20.4 ^d \pm 7.2	25.1 ^c \pm 10.8	23.0 \pm 9.8
Exposure hrs	297.0	280.5	577.5
Concussions observed, n=	7	5	12
Concussions Expected, n=	6.2	5.8	12
No games played, n=	18	17	35
Concussion incidence rate* (95% CI)	23.6 (11.2 to 49.4)	17.8 (7.4 to 42.8)	20.8 (11.8 to 36.6)
Days lost, total (mean \pm SD)	216 (30.9 \pm 5.1)	156 (31.2 \pm 5.2)	372 (31.0 \pm 4.9)
Hrs per concussion (95% CI)	42.4 (31.4–57.3)	56.1 (43.2–72.9)	48.1 (36.3–63.8)
Total no. concussion per game (95% CI)	0.4 (0.0–9.0)	0.3 (0.0–10.9)	0.3 (0.0–9.7)
Concussion probability (%)	15.2	8.5	22.1

a = includes 11 players who were enrolled in 2022; b = total players enrolled over 2 yrs.; * = Rate per 1000 match-hrs; CI = Confidence Interval; Significant difference ($p < 0.05$) than (c) 2022; (d) 2023.

Table 2

King-Devick test scores for baseline test 1 and test 2, established baseline, differences between scores, Inter-Class Correlation, Effect Size, post-injury and post-injury differences for total, non-concussed and concussed amateur female soccer (soccer) players in New Zealand over two consecutive years.

	2022			2023			Combined		
	n=	Median [IQR]	Range	n=	IQR [25–75]	Range	n=	IQR [25–75]	Range
Total Players									
Test 1	31	50.5 ^b [43.8–58.0]	37.5 to 86.3	29	50.9 ^b [45.9 to 54.1]	35.6 to 72.3	60	50.7 ^b [44.0 to 55.9]	35.6 to 86.3
Test 2	31	47.5 ^a [38.8 to 54.7]	30.3 to 74.6	29	47.1 ^a [41.4 to 52.5]	31.9 to 55.9	60	47.2 ^a [39.2 to 52.6]	30.3 to 74.6
Baseline	31	45.0 [38.7 to 54.7]	30.3 to 74.6	29	47.1 [41.4 to 51.0]	31.9 to 55.9	60	46.6 [38.8 to 52.1]	30.3 to 74.6
Difference		3.5 [1.9 to 6.9]	–3.5 to 11.9		2.0 [0.1 to 5.1]	–5.9 to 33.5		2.8 [0.5 to 6.6]	–5.9 to 33.5
ICC**/ES		0.97 (0.95 to 0.99)	0.36		0.69 (0.35 to 0.86)	0.48		0.91 (0.85 to 0.95)	0.39
Post-Injury	11	54.4 [39.6 to 64.1]	38.1 to 87.6	11	46.4 [41.2 to 49.9]	33.0 to 55.8	22	46.4 [40.0 to 52.7]	33.0 to 87.6
Difference		–0.3 [–2.5 to 2.7]	–13.2 to 6.1		0.1 [–5.5 to 2.8]	–6.8 to 7.1		0.2 [–2.3 to 2.7]	–14.6 to 12.4
Non-concussed									
Test 1	24	48.9 ^b [42.4 to 55.8]	37.5 to 70.1	24	51.2 ^b [45.8 to 54.2]	35.6 to 59.5	48	50.9 ^b [43.4 to 55.7]	35.6 to 70.1
Test 2	24	44.9 ^a [38.8 to 51.5]	30.3 to 66.2	24	47.6 ^a [41.8 to 52.9]	35.0 to 55.9	48	46.0 ^a [39.6 to 52.7]	30.3 to 66.2
Baseline	24	44.9 [38.6 to 51.5]	30.3 to 60.2	24	47.5 [41.8 to 52.1]	35.5 to 55.9	48	46.0 [38.9 to 52.3]	30.3 to 66.2
Difference		3.5 [2.3 to 6.8]	–0.7 to 11.9		2.0 [0.2 to 4.4]	–5.9 to 11.1		2.7 [0.6 to 5.5]	–5.9 to 11.9
ICC**/ES		0.97(0.93 to 0.99)	0.45		0.89 (0.75 to 0.95)	0.38		0.95 (0.90 to 0.97)	0.40
Baseline	4	44.9 [37.7 to 49.2]	36.3 to 49.5	6	51.9 ^d [40.1 to 54.9]	35.8 to 55.9	10	48.8 [40.2 to 53.7]	35.8 to 55.9
Post-Injury	4	41.5 [36.8 to 44.9]	39.6 to 45.4	6	47.3 ^c [39.2 to 50.9]	33.0 to 55.8	10	45.4 [38.7 to 48.5]	33.0 to 55.8
Difference		3.0 [2.3 to 5.4]	2.1 to 6.1		2.5 [0.3 to 5.7]	0.1 to 7.1		2.7 [0.4 to 5.2]	0.1 to 7.1
Concussed									
Test 1	7	52.8 [44.0 to 82.0]	43.8 to 86.3	5	48.7 [54.4 to 62.7]	35.6 to 72.3	12	50.5 [44.0 to 72.3]	35.6 to 86.3
Test 2	7	50.2 [47.5 to 74.4]	37.2 to 74.6	5	41.2 [35.4 to 49.7]	31.9 to 52.1	12	47.5 [38.8 to 57.3]	31.9 to 74.6
Baseline	7	50.2 [44.0 to 74.4]	37.2 to 74.6	5	41.2 [35.4 to 48.0]	31.9 to 48.7	12	47.2 ^d [38.8 to 57.3]	31.9 to 74.6
Difference		4.1 [0.3 to 7.6]	–3.5 to 11.7		3.7 [–1.7 to 22.7]	–3.4 to 33.5		3.7 [0.0 to 11.7]	–3.5 to 33.5
ICC**/ES		0.97 (0.84 to 0.99)	0.25		0.66 (0.25 to 0.96)	0.84		0.87 (0.54 to 0.96)	0.41
Post-Injury	7	52.7 [44.3 to 75.3]	38.1 to 87.6	5	46.4 ^c [41.8 to 51.3]	38.7 to 52.7	12	49.9 ^c [44.3 to 64.1]	38.1 to 87.6
Difference		–0.9* [–6.8 to –0.3]	–13.2 to 3.2		–5.5* [–6.5 to –3.2]	–6.8 to –1.2		–5.2* [–6.8 to –0.9]	–13.2 to –0.3

* = Negative scores indicate a worsening (slower) time; IQR = Interquartile Range; ICC = Intra-class Correlation Coefficient; ** = data reported as mean (95% Confidence Interval); ES = Effect size; Significant difference ($p < 0.05$) than (a) = Baseline Test 1; (b) = Baseline Test 2; (c) = Baseline score; (d) = Post-injury score.

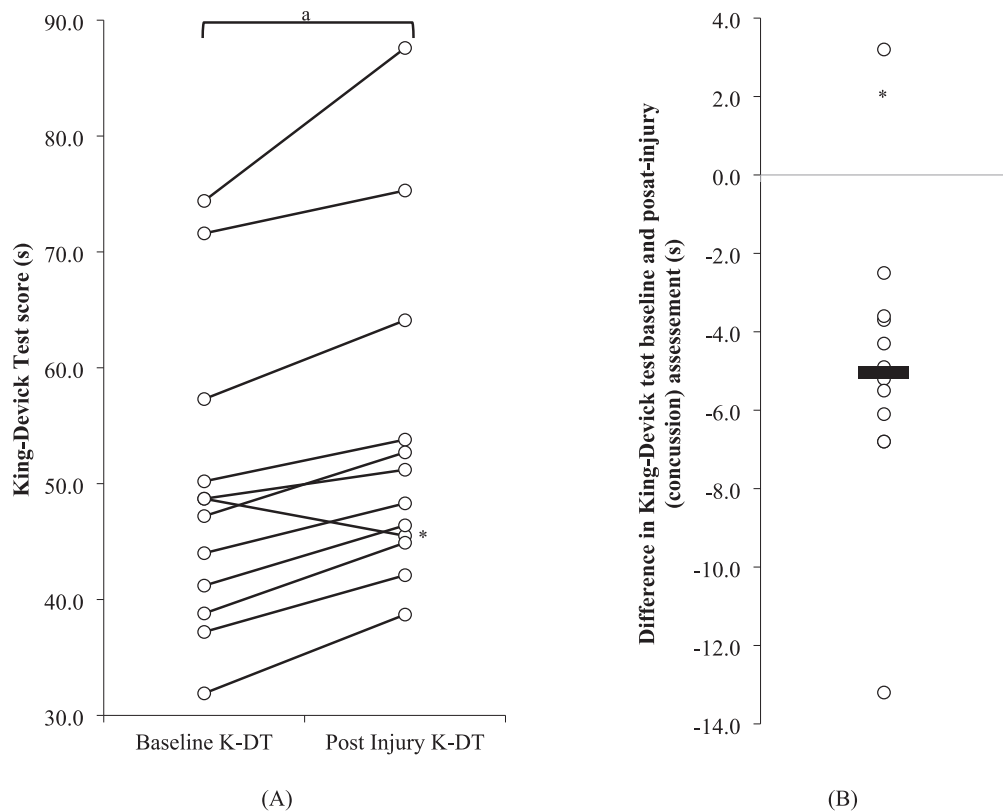


Fig. 1. Scatterplot of (A) King-Devick test baseline scores and post-injury (concussion) sideline scores in seconds and (B) differences in the score in seconds. The black line is the median score for amateur female soccer players in New Zealand. * = Player with witnessed head clash had faster post-injury King-Devick test score but reported five symptoms (later medically reviewed as concussed). a = Significant difference ($p < 0.05$) post-injury compared with baseline test; s = seconds,

baseline establishment in 2022 (ICC: 0.97 [95% CI: 0.95 to 0.99]). This was similar for 2023 for K–D baseline test 1 and test 2 ($\chi^2_{(1)} = 9.1$; $p = 0.0025$; $z = -3.0$; $p = 0.0032$; $d = 0.48$). There was moderate reliability between tests for K–D test baseline establishment undertaken in 2023 (ICC: 0.69 [95% CI: 0.35 to 0.86]). The K–D test baseline established in 2022 (45.0 [38.7 to 54.7] s) was not significantly faster than 2023 (47.1 [41.4 to 51.0] s; $\chi^2_{(1)} = 0.31$; $p = 0.5775$; $z = -0.4$; $p = 0.6891$; $d = 0.24$).

Seven players assessed sideline in 2023 for a potential concussion who reported no symptoms had a significantly faster post-match K–D (47.3 [39.2 to 50.9] s; $\chi^2_{(1)} = 6.0$; $p = 0.0143$; $z = -2.2$; $p = 0.0277$; $d = 0.37$) compared to their own baseline (51.9 [40.1 to 54.9]s) (see Table 2). No concussion was diagnosed in these players. Over the study, 11 players had a significantly slower post-injury K–D (49.9 [44.3 to 64.1]s; $\chi^2_{(1)} = 11.0$; $p = 0.0009$; $z = -2.9$; $p = 0.0033$; $d = 0.30$), compared with their own baseline (47.2 [38.8 to 57.3]s) with a median worsening of the K–D test score by -5.2 s, and these were subsequently diagnosed with a concussion by their health practitioner (see Fig. 1). One additional player assessed for potential concussion produced a post-injury K–D test time faster than her baseline but reported 5 symptoms and thus failed the CCP. This player was subsequently diagnosed with a concussion.

The main concussion symptoms for the 12 amateur female soccer players recorded via the CCP (see Fig. 2) were headache ($n = 8$; 66.7%), feeling slowed down ($n = 5$; 41.7%), drowsiness ($n = 5$; 41.7%) and fatigue ($n = 5$; 41.7%). There were on average 4 ± 2 symptoms reported per player post-injury over the study. There was on average 31 (95% CI: 27.8 to 34.1) days lost from match participation for concussions over the study (see Fig. 3).

The CCP had an overall sensitivity of 100% (95% CI: 73.5% to 100.0%), specificity of 100% (95% CI: 69.2% to 100.0%) and PPV of 100% (84.6% to 100.0%) (see Table 3). This was similar for players with ≥ 2 symptoms of concussion with a sensitivity of 100% (95% CI: 73.5% to 100.0%), specificity of 100% (95% CI: 69.2% to 100.0%) and PPV of 100% (73.5% to 100.0%).

4. Discussion

This study undertook to document for the first time the efficacy of the CCP for baseline and sideline assessment over two consecutive competition seasons of a single amateur female’s club-based soccer team in New Zealand. The principal findings of this study were: (1) the CCP protocol as administered by a team Safety Officer displayed excellent

sensitivity and specificity to medically diagnose concussion; (2) The incidence of concussion was 20.8 per 1000 match-hrs; (3) The mean days-lost from match participation was 31.0 (95% CI: 27.9 to 34.1) days; and (4) The average number of symptoms reported by players with a concussive injury was 4 ± 2 .

The Safety Officer does not have to be someone with a medical background, but could be the Coach, Manager, or another member of team management / volunteer. The term ‘Safety Officer’ was provided to preclude traditional roles already undertaken in sport. Over the study it was observed that no other team in the same competition had any form of medical support for injured players, and in some cases, the team medic aided with injuries that occurred to both participating teams. The observation of no other team having medical support highlights the usefulness of an assessment tool such as the CCP for concussion assessment by a non-medically trained team member.

Use of the CCP for assessment of a concussive injury was undertaken at the sideline as a screening tool only. It did not preclude a comprehensive concussion evaluation and was not utilised to diagnose concussion [29]. By utilising baseline to post-injury (concussion) comparisons, any player with a post-injury (concussion) slowing of their K–D test time and/or any self-reported symptoms, 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 [45]. In accordance with the developer’s recommendation, [29] any slowing (worsening) of the K–D test score of >1 s was a fail and concerning for a concussive injury, especially following a traumatic force to the head and brain [46]. Players tested post-injury (concussion) recorded a mean slowing (worsening) of -5.2 s (range: -6.8 s to -0.9 s).

Twenty-two players were identified as either having a possible concussion, or as a suitable control person, through direct observation by the management team or the players family members present at games. Players that had received a ball to the head or had body contact with another player or the ground and had changes in any of the clinical domains [7] were identified as having a potential concussive event. All players identified with a potential concussive event were removed from the field of participation and tested with the CCP on the sideline by the Safety Officer. As a result, 11 players failed the K–D test and reported symptoms of concussion. One player recorded a pass on the K–D test with a faster time post-injury (45.5 vs 48.7 s) compared to the established baseline but reported five symptoms on the sideline. This player was medically evaluated four hours later in the Emergency Department

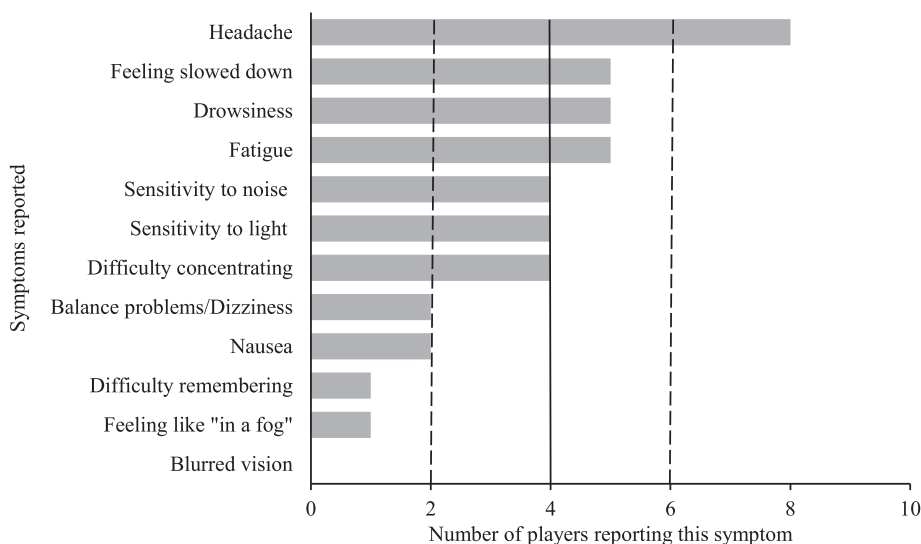


Fig. 2. Number of concussion symptoms reported at time of assessment post-injury with the mean (solid line) and standard deviation (broken line) of the number of symptoms on the Concussion Check protocol reported for amateur female soccer (soccer) players in New Zealand.

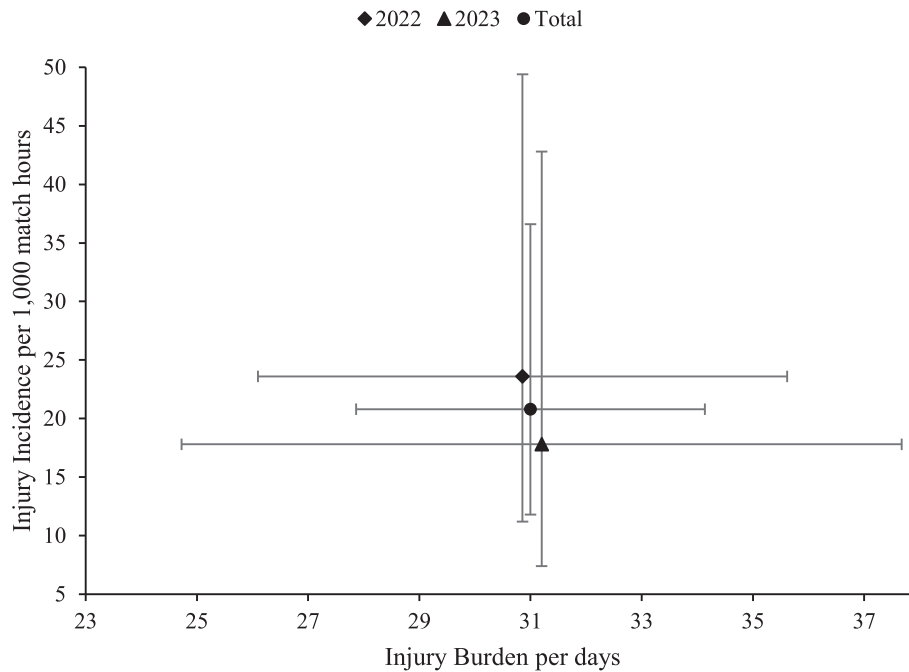


Fig. 3. Incidence of injury and injury burden of concussions by competition season and total concussions with 95% Confidence Interval for amateur female soccer players in New Zealand.

Table 3

Sensitivity, specificity, and positive predictive value (PPV) of the Concussion Check protocol (CCP) used to detect concussions in amateur female soccer (soccer) players in New Zealand over two consecutive years.

	Sensitivity	Specificity	PPV	Chi-square test	
	% (95% CI)	% (95% CI)	% (95% CI)	$\chi^2_{(1)}=$	p-value
Concussion protocol	100.0 (73.5–100.0)	100.0 (69.2–100.0)	100.0 (84.6–100.0)	22.0	<0.0001
Red Flags	0.0 -	100.0 (69.2–100.0)	N/A	-	-
Observable Signs	83.3 (51.6–97.9)	100.0 (69.2–100.0)	100.0 (69.2–100.0)	15.3	<0.0001
1 Sideline symptom	100.0 (73.5–100.0)	100.0 (69.2–100.0)	100.0 (73.5–100.0)	22.0	<0.0001
≥2 sideline symptoms	100.0 (73.5–100.0)	100.0 (69.2–100.0)	100.0 (73.5–100.0)	22.0	<0.0001
Awareness	33.3 (9.9–65.1)	100.0 (69.2–100.0)	100.0 (39.8–100.0)	4.1	0.0435
K-D Test pass/fail	66.7 (34.9–65.1)	100.0 (69.2–100.0)	100.0 (63.1–100.0)	10.5	0.0012

and was medically assessed to have had a concussive injury.

No player that failed the CCP that was medically assessed post injury was cleared from a concussion on the same day. All 12 players who failed the CCP via sideline assessment were ultimately diagnosed with a concussion following medical evaluation. Interestingly no player demonstrated any red flags indicating emergent transportation to a health care facility for emergency medical evaluation. The inclusion of observable signs in the CCP provided further support that some form of injury had occurred with balance difficulties, slow to get up and the holding or the shaking of the head being the most frequent observable symptoms identified. The self-reporting concussion symptoms added further support to the assessment for concussion. Recently updated diagnostic criteria [47] require that in the absence of acute signs, the diagnosis of concussion requires 2 or more symptoms to be reported. The average number of symptoms reported in this cohort of players was 4 ± 2 symptoms, with all concussed players reporting two or more symptoms. All players medically assessed as being concussed underwent a supervised return-to-play process and were medically cleared before any return to match or training activities.

Concussion knowledge is required to enable optimal clinical care for players [48,49]. Suboptimal recognition of concussion signs and symptoms may lead to an athlete with an unrecognised concussion being returned to the match or training environment [48,49]. This can lead to prolonged recovery times, [50] secondary injury and a risk of more

serious subsequent injuries to the brain [51]. Even trained athletic therapists can mistake signs and symptoms of concussion. For example, between 22% [49] to 27% [48] of athletic therapists were not able to identify concussion signs and up to 58% [48] would reportedly allow a return to activity for a player reporting a descriptor of a transient moment of deficits in cognitive or motor function as a result of a concussive-type impact [52]. Therefore, non-medically trained people who volunteer on the sidelines of sporting activities would also likely miss these signs and symptoms. This highlights the need to have a clear, objective protocol and application that clearly identifies when an athlete should be removed from play.

The first step in providing care of the player with a concussion is recognizing it has occurred [53]. Identification of a concussion on the sideline is a challenging endeavour for sports medicine practitioners [19] making this injury more difficult for non-medically trained sideline volunteers in amateur sports [54]. Although there are tools available for concussion assessment, these are primarily aimed at the medically trained professional. As a result, there is a paucity of objective tools available for concussion assessment for non-medically trained volunteers at the sideline. A multi-modal approach to concussion evaluation is widely recommended but the exact format with how this is undertaken varies by different studies [19,34]. Sideline evaluation often requires the person doing the assessment to have appropriate skills and training, and there is minimal time during the match activity to ensure that subtle

concussions are not missed. The CCP incorporates a multi-modal approach that consists of identification of “Red Flags” [55] observable behaviours and signs of potential of concussion, [56] situational awareness questions, [55] a symptom checklist, [23] and the K–D test.

The incorporation of “Red Flags” [55] prompts the Safety Officer to ensure that the player should be assessed for any signs and symptoms (see Supplemental Table 1) that mandate referral to a medical facility for further evaluation post injury. Next is the list of observable behaviours and signs of potential concussion. This list can assist to raise the index of suspicion for a concussion having occurred as these can be highly predictive of a concussion diagnosis upon medical assessment [57]. As reported, players medically diagnosed with a concussion had an average of 3 ± 1 observable behaviours and signs of a potential concussion when viewed from the sideline by the Safety Officer.

The situational awareness questions enable capture of any player with any incorrect answer and warrants a more comprehensive off-field evaluation for possible concussion [55]. Similar to the Maddocks’ questions, the situational awareness questions are designed to assess the individual player for recently acquired information about the current situation of match or training participation [58]. Use of these situational awareness questions as a stand-alone assessment of concussion has been reported to be unsafe as these questions may potentially miss 9 out of 10 concussions and this should not be the only sideline assessment for a potential concussion. This can be seen in the current study as 75% of players identified as having a concussion passed these questions and may have potentially been returned to play with possible long-term consequences.

In the current study there was an average 4 ± 2 symptoms self-reported by the players. In a recent study it was reported that symptoms that occur after a potential concussion was the most accurate way to diagnose a concussion [59]. However, this is problematic as players may not be aware of, or report their symptoms as they may be delayed, or may deliberately not disclose them to avoid removal from participation [59]. Similar to the use of the situational awareness questions, the use of just the reporting of symptoms as a concussion screening tool is not always reliable [57]. The use of an objective test such as the K–D test has been reported [59] to have an excellent sensitivity (85%), specificity (76%) and reliability (0.71) and may be the most accurate objective assessment for the diagnosis for concussion. In addition, the K–D test has an acceptable diagnostic accuracy at the 0 to 6 h and 24 to 48 h post concussive injury time frames [60] Although individually these components of the CCP do have limitations, when combined in a single app, they enable the Safety Officer to conduct a multi-modal sideline assessment with excellent sensitivity. Being able to screen the player on the sideline with the CCP ensures all aspects of the sideline assessment are undertaken and are reported. Even if the players oculomotor function is not immediately affected, the signs and symptoms can be recorded. The ability to have an instant result on the sideline post-assessment ensures that players at risk are removed from the area of participation. The CCP is only a screening tool, not a final comprehensive medical diagnosis. When utilised to assess for potential concussion, the CCP recommends that individuals who pass the CCP be evaluated again after the match or practice as concussion symptoms may evolve over time.

The incidence of concussion for match participation (20.8 per 1000 match-hrs.) over the study was higher than previous female soccer studies (0.1 [39] to 0.2 [61] per 1000 match-hrs). The mean missed-match duration for concussions in the current study was 31 days which was similar to previous studies [36,62] reporting on female concussion recovery. This finding conflicts with the Concussion in Sport Consensus (CISC) where it identified that 80% to 90% of all concussions recover in 19 days [55]. No players in this study with an identified concussion were allowed to commence training in preparation for match participation until they had surpassed their baseline CCP test despite the presentation of a medical clearance by their own health practitioner. No player with an identified concussion returned to their baseline CCP 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 of their CCP test from their own established baseline.

Studies [13,63,64] have suggested that female sports participants have an increased risk of them sustaining a concussive injury when compared with male sports participants. The reasons for this may include, but not be limited to, biological sex differences (e.g. neck musculature being smaller relative to head size, hormonal influences), gendered behavioural differences (e.g. earlier access to medical care; symptom reporting when compared to males) or sociocultural aspects [65–67]. In a recent study [68], it was highlighted that female athletes reported more symptoms, exhibited worse Immediate Post-concussion Assessment and Cognitive Testing (ImPACT) Visual memory, Clinical Reaction Time and K–D Test total time scores post-concussion than male athletes yet there were no differences in the recovery trajectories at six-months post-concussion.

However, more recent research [65,68–70] suggests that when provided with similar access to the same medical care as male sports participants, females are not at an increased risk for sustaining a concussive injury, nor do they not take longer to recover from a concussive injury. As previously reported, the team under study were the only team in this competition with any visible medical support. This lack of medical support for these participants places them at a higher risk of incurring an unrecognised concussive injury, staying on playing and returning to participation while still symptomatic with potential long-term complications. The use of the CCP can assist with the identification of participants at risk enabling participants to be removed from further risk of injury.

4.1. Limitations

The study was conducted on a single female amateur club-based soccer team over two consecutive competition seasons and there were a limited number of concussions. To date there are no studies reporting specifically on female soccer player concussions in New Zealand. The incidence of concussions in this study may not be reflective of all female amateur soccer teams given this was a sample of a single female soccer club-based team in New Zealand. Consequently, the results should be interpreted with caution and may not be transferable to other levels of soccer participation. The CCP utilised in this study did not include a balance component in the assessment for concussion on the sideline. Balance has been associated with cervicovestibular changes post injury [55] and reduces the error of missing a concussed player and prevents erroneously returning them to match actives [71]. Further studies utilising the CCP should include a balance component such as the K–D Balance app [72].

5. Conclusions

This study reported for the first time the use of the proposed Concussion Check protocol (CCP) with a female amateur club-based soccer team in New Zealand. The CCP identified 11 players that failed the K–D Test and symptom check, and one player who passed the K–D Test but failed the symptom check. As a result, these players had an average of four symptoms and a median worsening of the K–D test score by -5.2 s and were all medically diagnosed with concussion. The CCP had an excellent sensitivity, specificity and PPV for identification of concussion. Use of the CCP was undertaken by non-medically trained people on the sideline and provided a reliable multi-modal platform for identification of concussion and referral to medical-health care professionals.

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CRedit authorship contribution statement

Doug King: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Patria Hume:** Methodology, Project administration, Writing – original draft, Writing – review & editing. **Trevor Clark:** Methodology, Writing – original draft, Writing – review & editing. **Jennifer Wethe:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

DK, PH and TC declare no conflicts of interest. JW is an employee of Mayo Clinic, which had a prior financial interest in the King-Devick sideline test.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jns.2024.123011>.

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