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Baseline concussion assessment performance of community-based senior rugby players: a cross-sectional study

Danielle M. Salmon[a], Jason Chua[a], S. John Sullivan[a], Chris Whatman[b], James Brown[c], Johna Register-Mihalik[d,e,f], Ian Murphy[a], Simon Walters[b], Amanda Clacy[g], Gisela Sole[h], Zachary Y. Kerr[d,e,f], Karen Rasmussen[a] and Mike England[a]

[a]Injury Prevention and Welfare, New Zealand Rugby, Wellington, New Zealand; [b]School of Sport and Recreation, Sports Performance Research Institute New Zealand, Auckland University of Technology, Auckland, New Zealand; [c]The Institute of Sport and Exercise Medicine, Stellenbosch University, Cape Town, South Africa; [d]Matthew Gfeller Sport-Related Traumatic Brain Injury Research Center, Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; [e]Injury Prevention Research Center and Rehab University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; [f]Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina U.S.A; [g]Vitality Village, Wearebe, Kensington, Queensland, Australia; [h]Centre of Health, Activity, Rehabilitation Research, School of Physiotherapy, University of Otago, Dunedin, New Zealand

ABSTRACT

Objective: To report pre-season baseline concussion assessment performance among senior rugby players and explore associations between assessment performance and player demographics.

Design: A cross-sectional study using the New Zealand Rugby Concussion Assessments (NZRCA), comprising symptom, cognitive and dynamic coordination assessments was conducted in the 2018–2019 season.

Methods: Players' baseline assessments were characterised using descriptive statistics; effect sizes (ES) and t-tests were used to explore associations between player demographic characteristics and NZRCA performance.

Results: A total of 733 players (11.4% female) aged between 16 and 52 years completed the NZRCA. The median (range) value for symptom severity, endorsed symptoms and "percentage normal" was respectively, 5 (0–40), 5 (0–21) and 90% (30–100%). A perfect standardised assessment of concussion score was achieved by one participant; seven achieved ≥27/30 for immediate recall, and 22 achieved a perfect delayed recall score. Most participants (n = 674, 92%) passed the tandem gait test. Associations between NZRCA performance and gender, concussion history, and Pasifika ethnicity were observed with effect sizes ranging from small (0.18) to large (0.70). Six hundred and twenty-three (85%) participants reported at least one symptom.

Conclusions: The results from this study could help support decision-making by clinicians, improving the management of concussions in the community setting.

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Introduction

Among full-contact sports, rugby union (rugby) has taken a proactive role to improve player welfare following a concussion (1–4). In New Zealand (NZ), estimates suggest 10 per 1000 players per year make an injury claim for concussion; that rate doubles for players aged between 18 and 20 years (5), with peaks in sub-elite competition (6). However, the true incidence of concussion is likely to be underreported due to low levels of concussion literacy and reporting behaviors in players (7) and inconsistent quality of care (8–11).

Early identification of suspected concussions, removal from sports, and referral to healthcare professional are the key components of quality concussion care (2–4,12). Delays in diagnosis and recovery ultimately compromise player welfare (13,14), leaving players more susceptible to prolonged recovery (15) and other musculoskeletal injuries (16). Subsequently, the timely and appropriate management of concussion in the community is a priority area for World Rugby (2) and NZ Rugby (NZR) (3,7).

Various tools for concussion assessment have been developed to assist with evaluating sports-related concussion (17). Testing with the widely adopted Sports Concussion Assessment Tool (SCAT) provides a score of an individual's neurocognitive function across different dimensions such as cognitive status, gross neurological function and symptomology (12). However, uptake and implementation of this tool, particularly in primary care setting, is limited, partly due to total time required to complete the SCAT assessment (18–22). In NZ, General Practitioners (GPs) are publicly funded for 15-minute clinical appointments; however, a SCAT5 assessment takes approximately 10 minutes to complete if an individual is familiar with the assessment (12), highlighting the challenges with respect to its utility in this environment.

In 2017 NZR worked with local GPs in four provincial unions in NZ to explore the use of current best practice concussion guidelines, which included the use of the SCAT5 (12). Post-season, GPs reported significant challenges diagnosing and managing concussions due to: a lack of

CONTACT Danielle M. Salmon danielle.salmon@nzrugby.co.nz New Zealand Rugby, PO Box 2172, Wellington, 6140, New Zealand

familiarity with current best practice and return to play guidelines, in experience with the use of standardized tools (e.g., SCAT5), insufficient time to properly examine or medically clear players and relatively minimal regular exposure to concussive injuries (4). Similar strategies have been taken to use evidence-based approaches in other countries (e.g., Canada (23), USA (24)), to enhance the uptake of the SCAT. To address these challenges NZR developed the NZR Sport Concussion Assessment Pathway (NZRCAP), a protocol designed to minimize the time burden and difficulty of utilizing the SCAT5 and to ensure appropriate literacy levels of components such as the symptoms measure descriptors (4). This resulted in a subset of components from the SCAT5 (25), Child SCAT5 (26) and SCAT3 (27) being selected. Each of the selected components from the SCAT assessments has been independently validated (28–31) and is often used independently. The selected sub-components are collectively referred to as the NZR Concussion Assessment (NZRCA) (4).

In the absence of gold-standard diagnostic criteria for concussion, the clinical utility of assessment measures can be enhanced if an individual's score on the measured dimensions (following a suspected concussive event) are compared against pre-injury scores (2,32,33). Similarly, knowledge of specific population-level baseline norms could support the interpretation of individual scores where baseline assessment data are not available (32,33), assisting clinical decisions about a player's concussion status (33,34). Normative data for concussion assessment has been collected to establish reference values among professional ice hockey (35) and rugby players (33,34), high school rugby players (36) and collegiate-level athletes (37). As baseline performance may vary by sport, level of competition and population characteristics, it is important to develop population-specific norms (38). Therefore, in the absence of individual baseline assessment and NZ-specific population data for the NZRCA, the purpose of this study was to (i) report reference population performance data for community-based adult rugby players in NZ, and (ii) explore the impact that player demographic factors have on NZRCA subcomponent scores.

Method

Design

This prospective cross-sectional study of community rugby players' baseline NZRCA performance sits within a larger programme in NZR that targets positive concussion attitudes, behavior changes, and reporting in the community setting (3). Ethics approval was obtained from the University of Otago Ethics Review Board (approval 18/087) to conduct this project.

Participants

All premier players (highest level of amateur community club rugby in NZ) registered with the involved rugby teams were eligible to participate. Players were excluded if they had sustained a concussion in the previous 3-months or sustained a lower limb injury that could have influenced their tandem gait performance. All players were informed of the goals of the study and provided written informed consent.

Recruitment and sampling

Recruitment of community rugby players was undertaken through three provincial rugby unions (PUs) over the 2019 and 2020 seasons. By design the three PUs covered a range of geographical locations, ethnicities, and socioeconomic backgrounds. PUs provided locality consent for their clubs' participation. A research team member (DS) contacted clubs and their respective premier-level team managers to participate in the study. After receiving approval from a relevant club/team-level representative (e.g., club president, coach, or team manager), individual players were invited to participate.

Baseline assessment

The NZRCA (4) consists of independent components and subcomponents selected from the SCAT5, Child SCAT5, and SCAT3: (i) symptom assessment (Child SCAT5 symptom checklist (26)), symptom severity (rating 0–3; sum 0–63), endorsed symptoms (0–21), percentage feeling normal (rating 1–100%)); (ii) cognitive assessment (Standardized Assessment of Concussion 50 (SAC50; 0–50), sum of the immediate 10-word recall (0–30), delayed 10-word recall (0–10) and orientation (0–5, 12)); (iii) concentration assessment (total score (0–5) sum of digits backwards (0–4) and months in reverse (0–1)) (12) and (iv) dynamic coordination assessment (tandem gait (fastest tandem gait time in seconds and pass/fail rate) (39)). The NZRCA is part of the NZR concussion assessment pathway that was developed in collaboration with local GPs in NZ and is described in detail in Table 1.

Protocol

Baseline NZRCA data were collected during the pre-season /start of season by a trained research assistant, team manager or support staff using a bespoke NZRCA data collection mobile phone application (CSx, Auckland, NZ). To minimize participant burden, participants were typically assessed prior to a training session, in a quiet room at their club's training facilities.

Demographic details, including self-reported clinical diagnosis of concussion and brief medical history were collected using a paper-based questionnaire prior to the baseline assessment. The sample was stratified by age (≤22 years, ≥23 years), gender (males, females), ethnicity (NZ European, Māori and Pasifika) and history of concussion (yes, no). Pasifika is a broad and diverse term that encompasses individuals from or whose ethnic heritage links them to various Island nations and communities (e.g., Samoa, Tonga) in the South Pacific (40). The NZRCA components were recorded and instantaneously uploaded to a secure server using the specifically designed CSx mobile App (33,41). Participants' demographic characteristics were linked with NZRCA data exported from CSx using a unique identifier to ensure participant anonymity.

Table 1. Summary of items included in the New Zealand rugby concussion assessment

Items from the NZR concussion assessment	Reference	SCAT version	Data format
(1) **Demographic details**			
(1) **Red flags**	(52)	SCAT5	Yes, no
(1) **Concussion yellow flags**	(52)		
(a) **Concussion injury history**			
(i) Have you been diagnosed with a concussion before?		SCAT5	Yes, no
(i) How many concussions have you been diagnosed with?		SCAT5	Number
(i) How long was the return to play period of your last concussion?		SCAT5	Days
(i) When was your most recent concussion?		SCAT5	Date
(i) How many concussions have you had in the past 12 months?			Number
(a) **Other medical history**	(52)		
(i) Have you ever been diagnosed or treated for a learning disorder or dyslexia?		SCAT5	Yes, no
(i) Have you ever been diagnosed or treated for ADD or ADHD?		SCAT5	Yes, no
(i) Have you ever been diagnosed or treated for headaches/migraines?		SCAT5	Yes, no
(i) Have you ever been diagnosed with depression, anxiety, or other psychiatric disorder?		SCAT5	Yes, no
(i) Have you ever been hospitalized for a head injury?		SCAT5	Yes, no
(1) **Neurological exam**			
(1) **Head and cervical spine assessment**	(52)		
(i) Does the athlete report that their neck is pain free at rest?		SCAT5	Yes, no
(i) If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain-free movement?		SCAT5	Yes, no
(i) Is the limb strength and sensation normal?		SCAT5	Yes, no
(1) **Symptom checklist (Part of NZRCA)**	(26) (56)	Child SCAT5	0–3
Total number of symptoms (sum of endorsed symptoms)		Child SCAT5	0–21
Symptom severity score (sum of symptom severity ratings)		Child SCAT5	0–63
Percentage normal		Child SCAT5	0–100; (0) very bad, (100) very good
(1) **Cognitive assessment (Part of NZRCA)**	(29)		
(a) **Immediate memory**		SCAT5	0–30 (10-item list)
(a) **Delayed recall**		SCAT5	0–10 (10-item list)
(a) **Orientation (higher scores are better)**		SCAT5	0–5
(a) **Concentration assessment**			
Digits backwards (sum of 4 trials; 1 point per trial)		SCAT5	0–4
Months in reverse order		SCAT5	0–1
(1) **Dynamic coordination assessment (Part of NZRCA)**	(30, 31)		
Tandem Gait (best time of 4 trials; >14 seconds is a failed trial)		SCAT3	Duration (secs) & pass/fail

SCAT3: McCrory, P. (2013). "Consensus Statement on Concussion in Sport – The 4th International Conference on Concussion in Sport Held in Zurich, November 2012." Physical Medicine & Rehabilitation **5** (4): 255–279.
Child SCAT5©: Davis, G. A. (2017). "The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5): Background and rationale." British Journal of Sports Medicine **51** (11): 859–861.
SCAT5©: Echemendia, R. J. (2017). "The Sport Concussion Assessment Tool 5th Edition (SCAT5): Background and rationale." British Journal of Sports Medicine **51** (11): 848–850.
†21-item checklist adopted from the Child SCAT5 symptom scale[5]
††10-word list size adopted from the SCAT5[6]

Data analysis

The distribution of the NZRCA components and sub-components were summarized by their mean (SD [95% CI]), median [IQR], and minimum/maximum value. The SAC50 score was calculated as the sum of scores for orientation, 10-item immediate memory, and delayed recall and concentration (25). The tandem gait time was recorded in seconds and ranked as a pass/fail based on the players' ability to complete one of four trials within the 14-second time threshold (27).

The sample was stratified (Table 1) and summary variables and distributions were explored graphically for normality using histograms. Median and range scores were generated for the overall sample for each of the NZRCA components. Standardized effect sizes were calculated using Cohen's *d* where 0.2, 0.5, and 0.8 are considered thresholds for small, medium and large effect sizes (ES), respectively (42). The mean differences (MDs) between groups were assessed for statistical significance using the independent samples t-test. Where appropriate, the ANOVA family-wise error rate was controlled with a Games-Howell *post hoc* adjustment based on unequal variance between the groups. An alpha of <0.05 assessed statistical significance. Pearson's chi-squared test was used to assess differences between the pass/fail rates (%) for months in reverse and tandem gait. A sensitivity analysis using the Mann–Whitney U-test and Kruskal Wallis test (Bonferroni adjusted) was also used to assess the robustness of the significant parametric test results.

Normative ranges for the NZRCA components were calculated based on methods described elsewhere (33,43,44). Briefly, cutoffs were based on percentile ranges corresponding to performance intervals of broadly normal (0–75th percentile rank), above/below average (76th-90th percentile rank), unusually high/low (91st-98th percentile rank) and extremely low/high (>98th percentile rank) (43). Cutoffs were applied as close as possible to the defined performance intervals (43). Percentiles were calculated in the direction of decreasing performance for each NZRCA component. All analyses were completed using SPSS Statistics (Version 25, Armonk, NY, IBM Corporation).

Results

Over the 2019–2020 season 29 teams consented to participate with a total of 989 registered players. A total of 733 players (n = 649 males, n = 84 females; age mean

Table 2. Sociodemographic characteristics of premier rugby players (n = 733).

Demographic characteristics	n (%)
Age	
≤22	397 (54.8)
≥23	328 (45.2)
Ethnicity	
New Zealand European	386 (53.0)
Māori	140 (19.2)
Pacific	165 (22.7)
Other	37 (5.1)
Gender	
Male	649 (88.5)
Female	84 (11.5)
Self-reported history of concussion	
Yes	352 (51.1)
No	337 (48.9)
Self-reported medically diagnosed concussion number	
0	337 (48.9)
1	152 (20.7)
2	114 (15.6)
3	56 (7.6)
>3	30 (4.1)
Hospitalized for head injury	
Yes	117 (17.0)
No	570 (83.0)
History of migraines or headaches	
Yes	113 (16.5)
No	574 (83.6)
History of learning disability	
Yes	31 (4.5)
No	656 (95.5)
History of ADD or ADHD	
Yes	24 (3.5)
No	663 (96.5)
History of anxiety and depression, or other mental health fdisorder	
Yes	43 (6.3)
No	644 (93.7)

Note: ADD = attention deficit disorder; ADHD = Attention deficit hyperactivity disorder

±SD = 23.3 ± 4.3 years, range 16–42; n = 3 females and n = 1 male ≤18 years) consented to be involved and were baseline tested (Table 2). A total of 53% participants identified as NZ European, 23% as Pasifika, 19% as Māori, and 5% as 'other' ethnicity. Over half (54%) of the participants were ≤22 years of age (n = 397). A history of self-reported concussion was reported by 51% (n = 352) of respondents, of which 76% (n = 266) reported 1–2 concussions and 24% (n = 86) reported three of more diagnosed concussions. The majority of participants (83-97%) reported no history of any health condition.

At the time of assessment, 85% of the sample reported at least one symptom (Figure 1). The five most reported symptoms were 'forgetful' (n = 406, 55%), 'distracted easily' (n = 372, 51%), 'trouble remembering' (n = 362, 49%), 'often tired' (n = 335, 46%) and 'trouble paying attention' (n = 294, 40%).

Descriptive variables for the NZRCA components and subcomponents are presented in Table 3. The median symptom severity score was 5 (range: 0–40). The median number of endorsed symptoms was 5 (range: 0–21). Severity for symptoms was primarily rated as 'a little.' The median value for "what percent of normal do you feel" was 90% (range: 30–100%). A perfect score on the SAC50 was achieved by one participant; n = 7 achieved ≥27/30 for immediate recall; and n = 22 achieved a perfect 10/10 delayed recall score. Most participants (92%, n = 672) passed the tandem gait test with a median time of 12.3 seconds (range: 7.5–25 seconds). The distributions of the NZRCA components are reported in Table 3. Some components were not normally distributed, resulting in normative ranges selected as close as possible to the predefined percentile intervals (Table 4).

The NZRCA component scores stratified by age and gender are summarized in Table 5. When the study cohort was examined by age, including both male and female players, younger players (≤22 years) scored significantly higher by 1.2-points on the SAC50 (95% CI [0.3, 2.1], ES:0.22;), but performed 0.3 seconds slower on the dynamic coordination assessment (95% CI [0.1, 0.6], ES:0.21) and were more likely to fail (5% difference; p = .01).

Compared to females, males reported 1.9-points lower on the symptom severity (95% CI [−3.6, −0.3], ES:-0.26) and endorsed 1.2 fewer symptoms (95% CI [−2.1, −0.1], ES:-0.25). Males scored significantly lower than females on

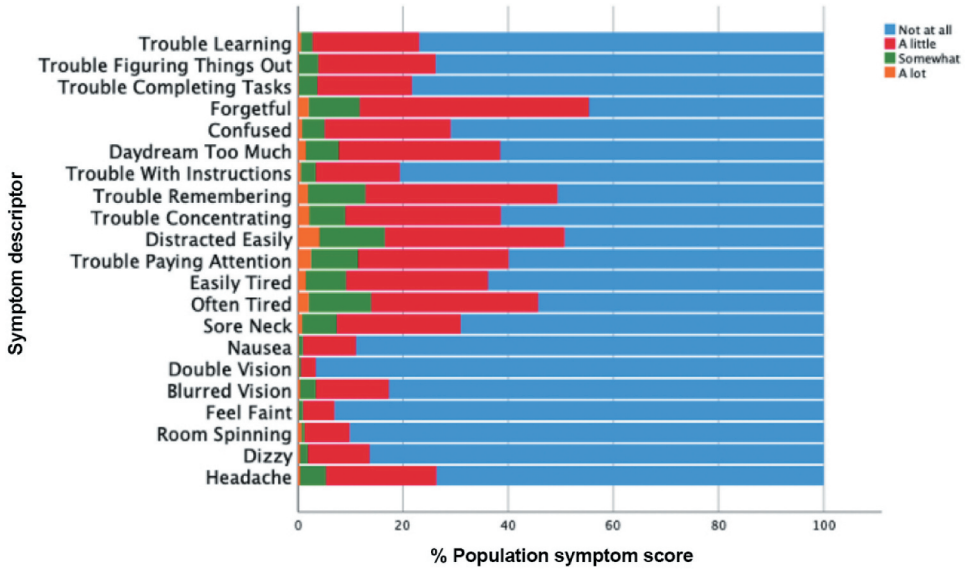

Figure 1. Total sample distribution (n = 733) of endorsed symptoms and symptom severity.

Table 3. The distribution or NZRCA component and sub-component scores for premier rugby players (n = 733).

NZRCA components	n	Mean (SD)	Median [IQR]	Range
Symptom assessment:				
Symptom severity	733	7.5 (7.3)	5 [2]	0–40
Endorsed symptoms	733	5.9 (4.9)	5 [2]	0–21
Percentage normal	722	84.7 (15.0)	90 [80]	30–100
Cognitive assessment:				
SAC50	707	33.3 (5.7)	33 [30]	15–50
Immediate	707	19.0 (3.7)	19 [17]	7–30
Delayed	707	6.1 (1.8)	6 [5]	1–10
Orientation	733	4.8 (0.4)	5 [5]	1–5
Concentration assessment:				
Digits backwards	733	2.7 (1.1)	3 [2]	0–4
Months in reverse	733	0.7 (0.5)	1 [0]	0–1
Total score	733	3.4 (1.3)	3 [3]	0–5
Dynamic coordination assessment:				
TG fastest time	733	12.3 (1.7)	12 [11.5]	7.5–25

the SAC50 by 3.9-points (95% CI [−5.2, −2.6], ES:-0.70), 0.2-points for orientation (95% CI [−0.2, −0.01], ES:-0.18) and were more likely to fail months in reverse (15% difference; p = .005). However, males' dynamic coordination assessment was better than females with 10% higher pass rate (p = .01) and 0.5 second faster tandem gait time (95% CI [−0.9, −0.1], ES:-0.31).

Stratifying NZRCA component scores by ethnicity (Table 6), Pasifika players achieved lower scores than NZ European and Māori across a range of components with small to moderate effect sizes of 0.3–0.6. Compared to Pasifika, NZ European players reported lower symptom severity by 2.5-points (95% CI [−4.5, −0.6], ES:-0.35), endorsed 1.5 fewer symptoms (95% CI [2.7, −0.2], ES:-0.30), 3.2-points higher on the SAC50 (95% CI [1.8, 4.7], ES:0.58), 2.3-points higher for immediate recall (95% CI [1.3, 3.2], ES:0.62) and 0.6-points higher for delayed recall (95% CI [0.1, 1.0], ES:0.33). Māori players also scored 2.0-points higher than Pasifika players on the SAC50 (95% CI [0.2, 3.8], ES:0.34) and 1.4-points higher on the immediate recall assessment (95% CI [0.3, 2.6], ES:0.37). Compared to NZ European and Māori, Pasifika players were more likely to fail the months in reverse (13% difference; p < .02). Compared to NZ European, Māori were more likely to fail the tandem gait test (6% difference; p = .02).

Players with a history of self-reported concussion performed significantly better on some of the NZRCA components (Table 7). Players with a history of concussion scored 1.0-points higher on the SAC50 (95% CI [0.1, 1.9], ES:0.17), 0.7-points higher on immediate recall (95% CI [0.1, 1.2], ES:0.18), 0.2-points higher on digits backwards (95% CI [0.1, 0.4], ES:0.20) and 0.2-points higher on total concentration score (95% CI [0.02, 0.4], ES:0.16). The sensitivity analysis did not produce strong evidence against the robustness of the parametric tests. Only the association between gender and endorsed symptom score was no longer significant following the Mann–Whitney U-test.

Discussion

This study examined the NZRCA in community rugby premier players to establish baseline performance reference values and to explore the association of these values with player demographic characteristics. The majority of players reported some level of symptoms, which aligns with previously published data in high school players using the full SCAT5 (36). Females reported higher symptom severity scores, endorsed more symptoms, achieved higher scores on SAC50, orientation and months in reverse, but recorded slower performances on the tandem gait assessment than males. Similar gender patterns have been observed in elite male and female rugby players (34). When the role of ethnicity was examined, players who identified as Pasifika endorsed more symptoms, were more symptomatic, achieved lower scores on the SAC50, immediate and delayed recall. These findings align with previous research, which has identified ethnic differences in the scores achieved on the SCAT5 assessment (37). Older players achieved lower scores on the SAC50 but achieved faster times on the dynamic coordination task. Players with a history of self-reported concussions were more likely to perform better on the SAC50 and concentration assessments, which may be explained by previous exposure to the SCAT. Similar cognitive performance results have been recently reported in a study examining the effect of concussion in professional players (46).

Table 4. Normative ranges for Premier players (N = 733).

NZRCA components (scale [worst-best])	Broadly normal Cutoff	%	Above/below average Cutoff	%	Unusually low/high Cutoff	%	Extremely low/high Cutoff	%
Symptom assessment:								
Symptom severity (63–0)	0–11	75.7	12–18	15.1	19–27	7.4	28–40	1.8
Endorsed symptoms (21–0)	0–9	75.2	10–13	15.1	14–17	7.4	18–21	1.9
Percentage normal (0–100)	100–80	75.7	70–60	19.1	50	2.8	40–30	1.4
Cognitive assessment:								
SAC (45–0)	50–30	75.4	29–26	15.6	25–21	7.2	20–15	1.8
Immediate	30–17	75.4	16–15	13.7	14–11	8.8	10–7	2.1
Delayed	10–5	80.6	4	12.2	3	4.2	2–1	3.0
Orientation (0–5)	5	85.2	NA	NA	4	13.4	3–1	1.4
Concentration assessment:								
Digits backwards (0–4)	4–2	88.0	NA	NA	1	10.6	0	1.4
Months in reverse (pass/fail)	Pass	68.8	Fail	31.2	NA	NA	NA	NA
Total score (0–5)	5–3	75.7	NA	NA	2	17.5	1–0	6.8
Dynamic coordination assessment:								
Tandem gait (pass/fail)	NA	NA	Pass	91.7	Fail	8.3	N/A	NA
TG fastest time (seconds)	7.5–13	81.5	13.1–13.7	8.5	13.8–15.6	8.2	16–25	1.9

Table 5. NZRCA components stratified by age and gender.

NZRCA components	Age (Mean (SD)) Age ≤22 (n = 397)	Age ≥23 (n = 328)	Mean Difference (95% CI), [Effect Size]	Gender (Mean (SD)) Males (n = 649)	Females (n = 84)	Mean Difference (95% CI), [Effect Size]
Symptom assessment:						
Symptom severity	7.4 (7.6)	7.7 (6.9)	−0.3 (−1.4, 0.8), [−0.04]	7.3 (7.1)	9.2 (8.1)	**−1.9*** (−3.6, −0.3), [−0.3]
Endorsed symptoms	5.7 (5.1)	6.1 (4.7)	−0.4 (−1.1, 0.3), [−0.1]	5.8 (4.8)	7.0 (5.4)	**−1.2***† (−2.3, −0.1), [−0.2]
Percentage normal	85.2 (14.4)	84.1 (15.0)	1.1 (−1.1, 3.2), [0.7]	84.9 (14.8)	84.0 (14.3)	0.9 (−2.4, 4.3), [0.6]
Cognitive assessment:						
SAC50	33.9 (5.5)	32.7 (6.0)	**1.2*** (0.3, 2.1), [0.2]	32.8 (5.7)	36.7 (5.0)	**−3.9*** (−5.2, −2.6), [−0.7]
Immediate	19.2 (3.6)	18.5 (4.0)	0.8 (0.3, 1.4), [0.2]	18.7 (3.7)	21.3 (3.3)	−2.6 (0.4, −3.5), [1.3]
Delayed	6.2 (1.8)	5.9 (1.8)	0.3 (0.1, 0.6), [0.2]	6.0 (1.8)	7.0 (1.7)	−1.0 (0.2, −1.4), [1.0]
Orientation	4.9 (0.4)	4.8 (0.4)	0.1 (0, 0.1), [0.1]	4.8 (0.4)	5.0 (0.3)	**−0.2***† (−0.2, −0.01), [−0.2]
Concentration assessment:						
Digits backwards	2.8 (1.1)	2.7 (1.0)	0.1 (−0.1, 0.3), [0.1]	2.7 (1.1)	2.8 (1.0)	−0.1 (−0.3, 0.2), [−0.1]
Months in reverse pass rate, n (%)^	263 (66.2)	235 (71.6)		435 (67.0)	84 (82.1)	**
Total score	3.4 (1.2)	3.4 (1.3)	0.04 (−0.1, 0.2), [0.03]	3.4 (1.3)	3.6 (1.2)	−0.2 (−0.5, 0.1), [−0.19]
Dynamic coordination assessment:						
Tandem gait pass rate, n (%)^	355 (89.4)	310 (94.5)	*	603 (92.9)	69 (82.1)	*
TG fastest time (seconds)	12.4 (1.9)	12.1 (1.5)	**0.3*** (0.1, 0.6), [0.21]	12.2 (1.7)	12.7 (1.8)	**−0.5**** (−0.9, −0.1), [−0.3]

*p < 0.05, **p < 0.01; ^χ^2 test for months in reverse and tandem gait pass rate; †No longer significant using the Mann–Whitney U test

Table 6. NZRCA components stratified by ethnicity.

NZRCA Components	Ethnicity, Mean (SD) NZE (n = 386)	Māori (n = 140)	Pasifika (n = 165)	Mean Difference (95% CI) [ES] NZE vs Māori	NZE vs Pasifika	Māori vs Pasifika
Symptom assessment:						
Symptom severity	6.7 (6.6)	7.7 (6.7)	9.2 (8.6)	−1.0 (−2.7, 0.7), [−0.2]	**−2.5**** (−4.5, −0.6), [−0.4]	−1.5 (−3.8, 0.7), [−0.2]
Endorsed symptom	5.4 (4.8)	6.3 (4.7)	6.9 (5.3)	−0.9 (−2.0, 0.4), [−0.2]	**−1.5*** (−2.7, −0.2), [−0.3]	−0.6 (−2.1, 0.8), [−0.1]
Percentage normal	85.1 (14.4)	83.0 (14.4)	85.2 (15.9)	2.1 (−1.6, 5.8), [0.2]	−0.1 (−3.9, 3.7), [−0.01]	−2.2 (−6.8, 2.4), [−0.1]
Cognitive assessment:						
SAC50	34.2 (5.2)	33.0 (5.6)	31.0 (6.3)	1.2 (−0.2, 2.7), [0.23]	**3.2***** (1.8, 4.7), [0.6]	**2.0**** (0.2, 3.8), [0.3]
Immediate †	19.6 (3.4)	18.8 (3.6)	17.4 (4.1)	0.8 (−1.7, 0.1), [0.2]	**2.3***** (1.3, 3.2), [0.6]	**1.4**** (0.3, 2.6), [0.4]
Delayed †	6.3 (1.7)	6.0 (2.0)	5.7 (2.0)	0.3 (−0.2, 0.8), [0.2]	**0.6**** (0.1, 1.0), [0.3]	0.3 (−0.3, 0.9), [0.1]
Orientation †	4.8 (0.4)	4.9 (0.3)	4.8 (0.5)	−0.04 (−0.1, 0.1), [−0.1]	0.07 (−0.1, 0.2), [0.2]	0.1 (0, 0.2), [0.2]
Concentration assessment:						
Digits backwards	2.8 (1.1)	2.6 (1.0)	2.6 (1.1)	0.2 (−0.1, 0.4), [0.1]	0.2 (−0.1, 0.5), [0.2]	0.1 (−0.3, 0.4), [0.1]
Months in reverse pass rate, n (%)^	274 (71.0)	99 (70.7)	95 (57.6)		**	*
Total score†	3.5 (1.2)	3.4 (1.2)	3.2 (1.3)	0.2 (−0.2, 0.5), [0.1]	**0.3*** (0, 0.7), [0.3]	0.2 (−0.2, 0.6), [0.2]
Dynamic coordination assessment:						
TG fastest time	12.2 (1.5)	12.29 (1.6)	12.5 (2.3)	−0.1 (−0.5, 0.3), [−0.1]	−0.2 (−0.8, 0.2), [−0.1]	−0.2 (−0.8, 0.4), [−0.1]

*p < 0.05; **p < 0.01, ***p < 0.001
NZE = New Zealand European; the †SAC50 score is the sum of scores on these items
^χ^2 test for months in reverse pass rate.

In the current study 85% of players endorsed at least one symptom on the Child SCAT5 symptom checklist, in contrast to results published among professional ice hockey players (52%) (35), professional rugby union players (27%) (33) and mixed sports college athletes (48%) (47). However, the Child SCAT5 symptom checklist (26) was used in the current study, making direct comparison of symptoms scores between studies difficult. The decision to use the Child SCAT5 symptom checklist was based on literacy challenges identified in the high school population. One possible explanation for the observed difference may be the level of comprehension of the symptom descriptors used in the SCAT5 and Child SCAT5 where Child SCAT5 symptom descriptors used in the current study may have resulted higher level of comprehension. Nevertheless, in the aforementioned studies, fatigue was consistently reported in the top three endorsed symptoms (33,35,47). The current study produced similar results, with 'often tired' ranking fourth after 'forgetful,' 'distracted easily' and 'trouble paying attention,' respectively. In contrast to the symptom endorsement level reported for professional players of only 0–1.75 symptoms (33,35), players in the current study endorsed a median of 5 symptoms (range 0–21). Similar results have been observed by Black et al. (36), who also recently published similar results in Canadian high school players (median = 6, range 0–22). Normative ranges thus may not be generalizable between professional and nonprofessional player cohorts, possibly explained by previous exposure to SCAT baseline testing (46) or motivational differences between the two groups with regards to the desire to continue playing. Higher reporting of baseline symptoms may also reflect different cultural beliefs, attitudes, and reporting behaviors for reporting concussion in NZ. It would be prudent to explore such cross-cultural differences in future research.

A key finding from the current study is that at baseline female players had higher symptom severity scores, endorsed more symptoms and performed worse on the

Table 7. NZRCA components stratified by history of concussion.

NZRCA components	History of concussion Mean (SD) Yes (n = 352)	No (n = 337)	Mean Difference (95% CI) [Effect Size]
Symptom assessment:			
Symptom severity	7.8 (7.5)	7.2 (7.2)	0.6 (−0.5, 1.7), [0.1]
Endorsed symptom	6.1 (5.0)	5.7 (4.9)	0.4 (−0.4, 1.1), [0.1]
Percentage normal	8.4 (1.5)	8.5 (1.4)	−0.1 (−0.3, 0.1), [−0.1
Cognitive assessment:			
SAC50	33.9 (5.5)	32.9 (5.9)	**1.0*** (0.1, 1.9), [0.2]
Immediate	19.3 (3.6)	18.7 (3.8)	**0.7*** (0.1, 1.2), [0.2]
Delayed	6.2 (1.8)	6.1 (1.8)	0.1 (−0.2, 0.4), [0.1]
Orientation	4.9 (0.4)	4.9 (0.5)	0.01 (−0.1, 0.1), [0.03]
Concentration assessment:			
Digits backwards	2.9 (1.0)	2.6 (1.1)	**0.2*** (0.1, 0.4), [0.2]
Months in reverse pass rate, n (%)^	240 (68.2)	232 (68.8)	
Total score	3.5 (1.2)	3.3 (1.3)	**0.2*** (0.02, 0.4), [0.2]
Dynamic coordination assessment:			
Tandem gait pass rate, n (%)^	326 (92.6)	306 (90.8)	
TG fastest time	12.3 (1.7)	12.3 (1.7)	0.01 (−0.3, 0.3), [0]

*$p < 0.05$
^χ^2 test for months in reverse and tandem gait pass rate

dynamic coordination assessment, but performed better on the SAC50 and orientation assessments when compared to males. The results mirror those of elite male and female rugby players (34). A recent study by Black et al. (36), found that in high school rugby players females experienced higher symptom severity and endorsed more symptoms when compared to males. However, this study showed no associations for orientation score or months in reverse (36). In contrast, a study of high school and collegiate athletes by Chin et al. (44) found similar results to the current study, where females endorsed more symptoms (ES: 0.25) and were more symptomatic (ES: 0.32). The current study observed similar magnitudes of effect for both symptom endorsement and symptom score, ES: 0.26 and ES: 0.25, respectively. Chin et al. (44) also found females scored significantly higher five-word composite SAC30 score, immediate, delayed recall and total concentration score. In the current study, females reported higher SAC50 scores and months in reverse, but no associations were detected for immediate, delayed recall or total concentration score – although the mean difference between groups tended to favor higher scores for females across these sub-components. In contrast, a study of collegiate athletes (47) detected no gender differences. As previously highlighted, the proportion of females included in the current cohort (48) reflects female participation rates at the senior club level in NZ. The sample size is small, so caution is needed when interpreting these data. Future research should look to increase the number of females recruited to ensure the validity of the reference population data as higher symptom severity scores reported by women may put them at a higher risk of adverse clinical outcomes post-concussion (49).

Several significant associations were detected between ethnicity and NZRCA performance. When compared to NZ European players, Pasifika players were more symptomatic, endorsed more symptoms, and achieved lower scores on the SAC50, months in reverse, total concentration score, immediate and delayed recall. The magnitude of effect was small to moderate across these associations. The largest effect was observed for immediate recall (NZ European vs Pasifika d= 2.3, Māori vs Pasifika d= 1.4. An interesting observation was that Pasifika achieved a lower score on immediate recall than Māori or NZ European. We interpret that low immediate recall performance drove lower Pasifika performance on the SAC50, which may be attributed to two possible explanations. Firstly, the words used for the immediate and delayed recall measures may influence sub-components response comprehension for Pasifika players where English literacy challenges exist as English may not be their first/home/preferred language (50). English language proficiency was not assessed, yet recent evidence suggests English as a second language may have a positive effect on delayed recall performance (37). Further investigation is required to confirm this assertion. Second, few studies have investigated if normative data differ by cultural or ethnic background. A study by Norheim et al. (37) suggested that race/ethnicity may influence assessment performance. In NZ, understanding the impact of ethnicity on NZRCA normative scores is important given that Māori and Pasifika ethnicity is associated with socioeconomic disadvantage (45,51). This disadvantage is generally associated with lower access to the social determinants of health. In this study Pasifika players tended to report a greater number of symptoms, greater symptom severity, and lower cognitive and concentration assessments. Specifically, the lower SAC50 (−3.2-points) and immediate 10-word recall assessment (−2.3-points) performance for Pasifika players when compared to NZ Europeans, with their moderate-large effect sizes (0.58 and 0.62, respectively) may be relevant for clinicians to understand population-specific differences in NZRCA baseline assessment.

Our immediate and delayed recall findings suggest the SCAT5 10-word list size addresses the ceiling effect which has previously been associated with the 5-word recall list size (52). Only one person achieved a perfect score for the

immediate recall; however, 22 people were able to achieve a perfect delayed recall score. These findings are comparable to previous studies that have shown medians of 15–21 (range 3–30) immediate recall words and 6–7 (range 1–10) (33,36,37).

Older players (≥23 years) achieved lower scores on the SAC50 and performed better dynamic coordination assessment. However, these differences were small in effect size (d< 0.22), suggesting that these differences may not be clinically meaningful. The literature on age differences in relation to SCAT performance is inconclusive (38). While some studies have previously failed to find any age-related differences in concussion presentation (35,53), other studies have identified that younger age (<20 years) was associated with significantly different performance on all components of the SCAT3, except for coordination (33). As there are persistent concerns that these identified differences may not be clinically meaningful, further research is required.

Regarding concussion history, players with a history of self-reported concussions achieved 1-point higher SAC50, 0.7 points higher immediate recall, 0.2-higher digits backwards and 0.2-higher concentration total score compared to players with no previous concussion history. Given the small effect sizes and mean differences (0.99–0.20) for these sub-components caution is needed with the interpretation of these results. These findings align with normative data published for collegiate athletes (47), collegiate rugby players (36), professional rugby (46) and ice hockey players (35) which also reported little, if any association between SAC performance and concussion history. The effect of concussion history on concussion assessment performance is still inconclusive in the literature (38).

In community rugby in NZ, sideline medical support is often limited and in best case scenarios access to GPs normally occurs 48 hours post-injury (41). Additionally, GPs will often only see a possible concussion case once a month which encompasses all etiologies of injury, and have a 15-minute session for the diagnosis and medical clearance of a player (4). Given this limited exposure to concussion management, unfamiliarity with current best practice and/or how to use the SCAT is not unexpected. The NZRCA was generated from a collaboration between NZR and local GPs as a tool that could be used in primary care, grounded in current best practice, and that would assist with clinical decision-making. The components from the SCAT family of assessments that comprise the NZRCA can be completed in a 5-minute time frame, allowing 10 minutes for patient history, the physical examine and patient education. The components included are relatively easy to comprehend and the only requirement is the 3 m space to conduct the tandem gait ensuring that the NZRCA is a pragmatic tool for use within most typical GP practice settings.

Neurocognitive assessments and symptom patterns fluctuate over time and are affected by many factors such as anxiety (54) or sleep deprivation (55). It is therefore unlikely that perfect and stable performance across the NZRCA sub-components is achievable. The normative data in the current study, however, provide score distribution patterns in adult community rugby players, which, may help inform GPs' clinical assessment of patients in NZ, along with other factors such as vision, exertion, vestibular function, and cervical spine assessment (12). While the NZRCAP was developed in response to challenges observed in primary care in NZ, these issues are not unique to NZ (19–22). These data may be used by GPs, for example, to identify players who appear to score outside of the broadly normal range, which may help with the clinical interpretation of a patient's score.

A strength of this study is the representative sample of community-based rugby players and the moderate sample sizes for the ethnic groups surveyed, which make these findings generalizable to other populations with similar social and cultural characteristics. The NZRCA was developed in response to challenges identified with the use of SCAT5 in primary care and its implementation with players in NZ (use of the Child SCAT5 symptom checklist). As part of a larger NZR Community Concussion Initiative, working closely with primary care, we ensured that the collected data are relevant to inform clinical care (4,41). As highlighted previously in this discussion the results observed in the current study align with patterns and trends, which have been observed previously with the full SCAT5 and SCAT3. Thus, while the results of this study represent population reference data of senior rugby players in NZ these findings and the development of the NZRCA may help inform other population reference values in other nations and sports and how best practice can be adapted to meet the constraints of primary care.

This study has several limitations. Firstly, the sample of female players was small. Second, multiple research assistants were used to collect data, which may have introduced variability into the data collected; however, the use of an application-based platform to conduct the NZRCA baseline assessment helped minimize this source of error. Future research should aim to establish the optimal frequency of baseline concussion assessment for concussion detection and increase the sample of females tested to ensure the validity of the normative values. We also used a simple bivariate analysis to explore associations between player demographic characteristics and NZRCAT performance. Therefore, the group differences presented in the current study may be inflated due to other confounding variables not included in our analysis. Players' may have also under-reported the true prevalence of their history of concussion which may have minimized the true effect of concussion history on baseline performance. Lastly, participants' primary and/or preferred language was not collected as part of this study, which may better explain the differences between ethnicities observed in this study, rather than ethnic differences per se.

Conclusion

This study provides population data from a neurocognitive assessment to help inform clinical interpretation and primary care management of concussion for nonprofessional adult rugby players. The generation of normative population ranges for the sub-components of the NZRCA provide GPs with some objective information to determine if a patients score post-injury or

during a medical clearance falls within a broadly normal category or if their score falls within the "unusually" or "extremely" low/high category, which may help inform their clinical decision. In the current cohort, 85% of players were considered symptomatic at baseline. Gender, ethnicity, age and concussion history influenced the scores on various NZRCA components and sub-components. The population data generated from this player cohort provides a NZ-specific reference for interpretation of baseline scores in a clinical setting and may inform GPs when using this tool for athletes as part of a concussion assessment.

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ORCID

Danielle M. Salmon http://orcid.org/0000-0003-1254-8308
Jason Chua http://orcid.org/0000-0002-0224-2818
S. John Sullivan http://orcid.org/0000-0001-9407-6484
Chris Whatman http://orcid.org/0000-0002-1468-3901
James Brown http://orcid.org/0000-0002-7778-7783
Johna Register-Mihalik http://orcid.org/0000-0002-4229-4743
Simon Walters http://orcid.org/0000-0002-6467-4982
Amanda Clacy http://orcid.org/0000-0003-3381-9154
Gisela Sole http://orcid.org/0000-0002-1632-0338
Zachary Y. Kerr http://orcid.org/0000-0003-1423-1259
Karen Rasmussen http://orcid.org/0000-0002-6354-2232
Mike England http://orcid.org/0000-0002-9004-0801

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