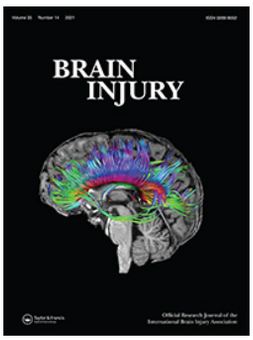

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Sport concussion assessment in New Zealand high school rugby players: a collaborative approach to the challenges faced in primary care

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ABSTRACT

Primary Objective: To describe the collaborative development of a New Zealand Rugby Concussion Assessment (NZRCA) for primary care and to provide normative baseline data from a representative group of high school rugby players.

Methods: This study, conducted over the 2018 and 2019 community rugby season where players were baseline tested during the pre- or start of season period.

Results: Data were collected from 1428 players (males n = 1121, females n = 307) with a mean age of 15.9 ± 1.4 years. The mean ± SD symptom severity score was 11.3 ± 8.6, the mean number of endorsed symptoms was 8.5 ± 5.3 and the percentage feeling "normal" was 80.2 ± 15.3%. Only 5.3% of players reported no symptoms at baseline. The most common reported were: 'distracted easily' (72.5%), 'forgetful' (68.5%), and 'often tired' (62.6%). None of the participants achieved a perfect score for the SAC50. The majority of participants (89.7%) passed the tandem gait test with a time of 12.2 ± 1.7 seconds. Age, gender, and ethnicity were associated with NZRCA performance; albeit weakly.

Conclusion: This study provides normative reference values for high-school rugby players. These data will aid healthcare providers in their identification of suspected concussion in the absence of individualized baselines.

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Rugby union; concussion; head injury; baseline; normative data

INTRODUCTION

In New Zealand (NZ), rugby union (rugby) is played by some 40,010 male and female high-school athletes aged 13–18 years (NZR National Rugby Database, 2020) and accounts for the greatest number and cost of sport-related injuries amongst participants aged 5–40 years (1). The collision-based nature of rugby brings a significant risk of concussion (2,3). NZ medical claims data from 2005 to 2017 show that 3.1% of all rugby injury claims were attributable to concussion (1). Yet, the true prevalence of concussions is likely to be much greater, given the reported rates of player non-disclosure in community rugby (4,5).

A number of prevention measures have been developed and implemented in an attempt to reduce concussions sustained in rugby (6–9), such as lowering the tackle height, coaching correct tackle technique, and providing concussion education and resources (https://playerwelfare.worldrugby.org/concussion). However, the inherent collision-based nature of rugby means that complete elimination of concussions from the game is probably unrealistic (1). Thus, alongside primary prevention, the aim of healthcare professionals and others involved in the sport is the minimization of harm through secondary measures such as early identification of suspected concussions, subsequent removal from play and preventing players from returning to play or training without medical clearance (10–12). To operationalize these aims NZ Rugby (NZR) developed a national community concussion initiative to target positive concussion attitudes and reporting behaviors (9). A major component of this initiative is the concussion management pathway which considers the various stakeholders involved in the recognition, removal, referral, and treatment of concussions (8). Within the NZR concussion management pathway, the General Practitioner (GP) is often responsible for the player's diagnosis assessment and the medical clearance, which enables the player to return to contact training (8,12).

Growing evidence suggest that individuals with suspected concussions are now entering the healthcare system via primary care (PC), in contrast to the more traditional hospital emergency department (13). In NZ, GPs have 15-min appointment 'windows,' this includes those for concussion diagnosis and medical clearance assessments (12). In 2017, NZR collaborated with GPs and learned that they faced significant challenges diagnosing and managing concussions due to: a lack of

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familiarity with current best practice and return to play guidelines, lack of use of standardized tools (e.g. SCAT5), insufficient time to properly examine or medically clear players and often only seeing 1–2 concussions each per month (12). While these challenges were identified in the context of PC working with community rugby players in NZ (12), similar challenges have been reported internationally (14–17). Although the SCAT5 is the current gold standard tool to assist with concussion assessment (18) and is recommended as an essential tool for the management of concussions (7) a major barrier to its uptake is the time required to complete the assessment (14–17). Due to the challenges faced by GPs in NZ, it was decided there was a need to help facilitate concussion management through the development of an NZR Concussion Assessment. (NZRCA) (12). This forms a central part of the previously described NZR Concussion Assessment Pathway (NZRCAP) (12).

In the absence of clear criteria for diagnosing concussion, a key consideration was how the NZRCAP would be used in clinical practice (19,20). In PC, GPs typically review players unfamiliar to them. In this scenario, the use of a clinical tool that would allow GPs to conduct a post-injury assessment that can be compared to either a pre-injury baseline specific to the patient or population normative data (19–21). While an individual baseline assessment may be useful (20), such information is often unavailable due to financial and personnel restrictions (19). An alternative is normative reference data that can be of value when interpreting the degree of variation of the post-injury score from the population norm (22). It also provides context for the test to be interpreted (22). These data could then be integrated into a concussion management pathway that could support GP's clinical decision-making around concussion diagnosis and medical clearance (21).

Research has reported that both socioeconomic status and ethnicity influence components of the SCAT5 (23) and memory performance on neurocognitive testing (24). In NZ, 50% of the high school playing population identifies as non-European (NZR National Rugby Database, 2020) and as a sport, rugby is played in schools across all levels of the socioeconomic spectrum. To inform the use of the new NZRCA in PC, the need for context-specific normative reference data is warranted. Thus, the purpose of this study was to describe the collaborative development of a New Zealand Rugby Concussion Assessment (NZRCA) for primary care and present normative reference values for the NZRCA for use with high school rugby players and in primary care.

METHODS

This prospective cross-sectional study involving NZ high school rugby players was conducted over two seasons (2018 and 2019) and is presented in two parts. In Part 1, the rationale and development of the NZRCA is described. In Part 2, the methods used to collect and generate normative data for the NZRCA are reported. This study is part of a larger body of work that is exploring the use of a social ecological framework to improve the management of concussion in community rugby. The development of a baseline assessment/normative data that can be completed pre-season on a mobile App and how this information is used to help inform the concussion diagnosis and medical clearance is outlined in Figure 1.

Part 1: development of the NZR concussion assessment

During the 2017 rugby season NZR piloted a concussion management pathway (21) in a selected group of diverse high schools from four Provincial Unions (PUs) (regional rugby governing organizations that operate under the oversight of NZR). The concussion management pathway involved; (i) gathering player baseline SCAT5 data conducted using a mobile phone App, (ii) upskilling GPs to adopt concussion best-practice guidelines (7,18), including the SCAT5 (18) and (iii) linking players' baseline data with GP consultations (9). A description of these processes is provided in Figure 2.

Barriers to implementing the concussion management pathway were encountered during the pilot. For example, the SCAT5 was reported by GP's to take between 20 and 30 minutes to complete (GPs have standard 15-min consultations) (12). In addition, during the baseline assessments, players reported having difficulty understanding the SCAT5 symptom checklist. For example, players were often unaware what was meant by the symptoms "Nausea," "Feeling like in a fog," "Irritability" and "Anxious." Across the seven senior high-school teams (n = 725) testing during the 2017 season 45% (n = 326) of players reported having issues comprehending one or more of the symptom descriptors used in the adult SCAT5 symptom checklist. To address this lack of understanding prior to the start of the 2018 season, we piloted the Child SCAT5 symptom list in rugby players from six socioeconomically and culturally diverse schools. We found improved comprehension, with no issues in comprehension reported. We therefore elected to use the Child SCAT5 symptom scale (25) for all ages. In addition, the Tandem Gait protocol from the SCAT3 (26) was also chosen to assess dynamic balance (27) following feedback from GPs who found the modified balance error scoring system (BESS) too complicated to implement (12).

Post-season we formed an "Expert Group" whose membership is presented in Figure 1. The purpose of this group was to develop a NZ-specific concussion pathway and tool to support GPs clinical management of concussions. The group examined the practicality of the pilot scheme given the constraints of PC and explored how to minimize barriers. Two key barriers were identified: (i) the length of time taken to administer the SCAT5 in PC and in high schools and (ii) the need for normative data or baseline scores to supplement post-injury assessment and inform clinical decisions (12).

On the basis of the identified barriers from the 2017 rugby season, current concussion best-practices and a review of literature covering current concussion assessment tools, the Expert Group reached consensus on a selection of items that

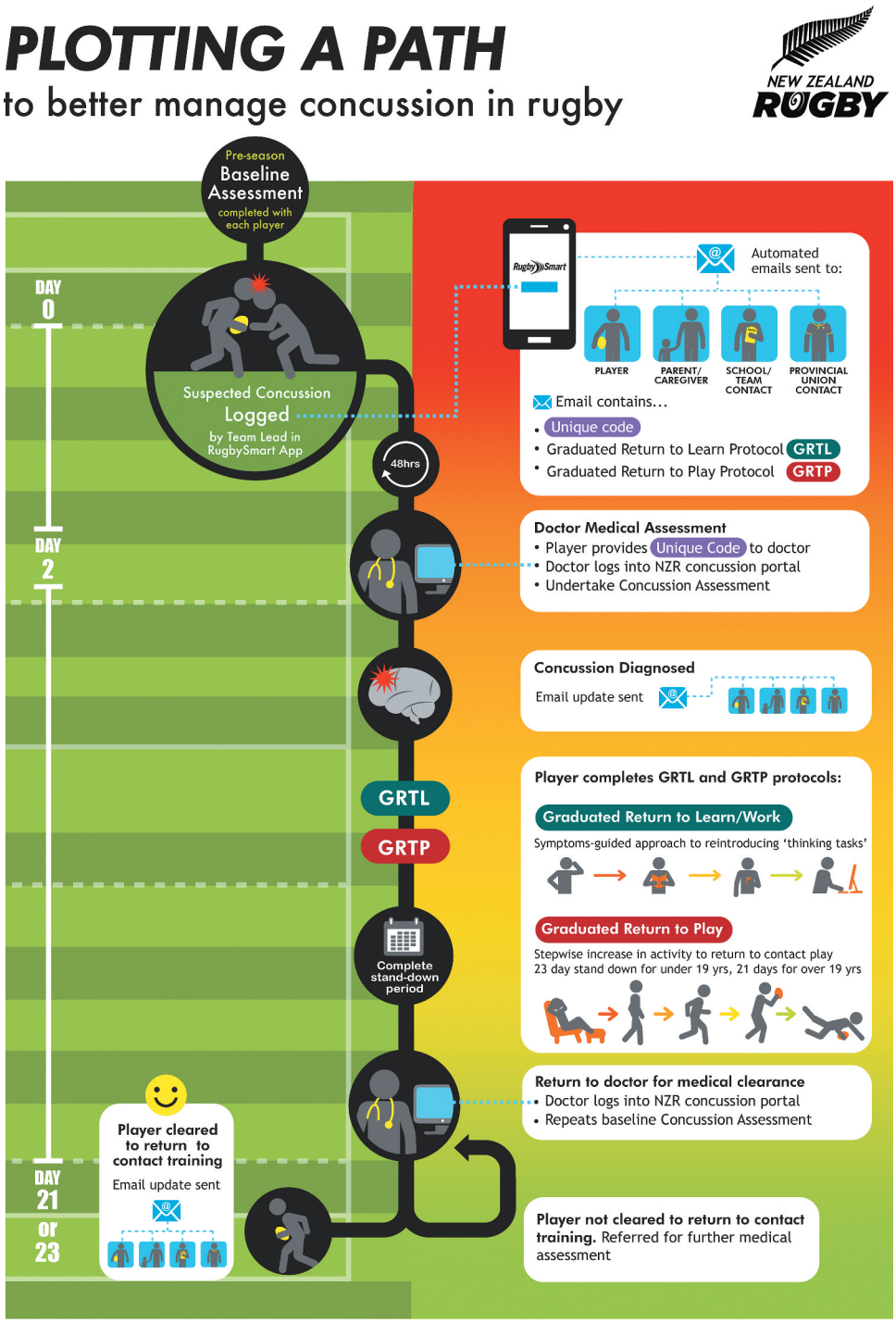

Figure 1. New Zealand Rugby community concussion management pathway.

met both GP clinical and data collection requirements. This resulted in: (i) the development of a NZ Rugby Concussion Assessment Pathway (NZRCAP) for PC and (ii) a subset of validated individual neurocognitive assessment components from the SCAT5, Child SCAT5 and SCAT3 for the development of the NZRCA (12). The specifications of the NZRCAP and NZRCA are summarized in Table 1. A concussion management software developer (CSx) was then engaged to develop an app for baseline testing using the NZRCA.

Part 2: Collection of high school player normative reference data

Participants

All rugby players registered with the selected high-school teams were eligible to participate. Players were excluded if they had sustained a concussion in the previous 3-months or had sustained a lower limb injury that could have influenced their tandem gait assessment. At the time of assessment all players were informed

Figure 2. New Zealand Rugby timeline for the collaborative development of the concussion assessment pathway encompassing the NZR concussion management protocol and NZR concussion assessment.

about the goals of the study. Participants provided informed written consent and for players aged 15 years or younger, written consent was also obtained from their parents/caregivers. Ethics approval was obtained from the University of Otago Human Ethics Committee (approval 18/087) to conduct this project.

Recruitment

In alignment with the GPs involved from the four PUs in the development of the NZRCAP, these same PUs were invited to participate as their player base covered a range of geographical locations, ethnicities, and socioeconomic backgrounds. PUs provided locality consent for their schools' participation. Schools within the PUs were then purposefully selected on the basis of maximizing the heterogeneity of the ethnicity and school decile ranking. At the high school level, 27% of male and 38% of female rugby players identified as being Māori (NZ's indigenous people) and 24% of male and 29% of female identified as being Pasifika (NZR National Rugby Database, 2020). 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 (28). The term school

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

Items from the NZR concussion assessment protocol	Reference	SCAT version	Data format
(1) Demographic details			
(2) Red flags		SCAT5	Yes, no
(3) Concussion yellow flags			
(a) Concussion injury history			
(i) Have you been diagnosed with a concussion before?		SCAT5	Yes, no
(ii) How many concussions have you been diagnosed with?		SCAT5	Number
(iii) How long was the return to play period of your last concussion?		SCAT5	Days
(iv) When was your most recent concussion?		SCAT5	Date
(v) How many concussions have you had in the past 12 months?			Number
(b) Other medical history			
(i) Have you ever been diagnosed or treated for a learning disorder or dyslexia?		SCAT5	Yes, no
(ii) Have you ever been diagnosed or treated for ADD or ADHD?		SCAT5	Yes, no
(iii) Have you ever been diagnosed or treated for headaches/migraines?		SCAT5	Yes, no
(iv) Have you ever been diagnosed with depression, anxiety or other psychiatric disorder?		SCAT5	Yes, no
(v) Have you ever been hospitalized for a head injury?		SCAT5	Yes, no
(4) Neurological exam			
(5) Head and cervical spine assessment			
(i) Does the athlete report that their neck is pain free at rest?		SCAT5	Yes, no
(ii) If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain-free movement?		SCAT5	Yes, no
(iii) Is the limb strength and sensation normal?		SCAT5	Yes, no
(6) Symptom checklist (Part of NZRCA)	†(29)+	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
(7) Cognitive assessment (Part of NZRCA): Standardized Assessment of Concussion 50 (SAC50)	††(44)++		
(a) Immediate memory		SCAT5	0–30 (10-item list)
(b) Delayed recall		SCAT5	0–10 (10-item list)
(c) Orientation (higher scores are better)		SCAT5	0–5
(d) Concentration assessment			
Digits backwards (sum of 4 trials; 1 point per trial)		SCAT5	0–4
Months in reverse order		SCAT5	0–1
(8) Dynamic coordination assessment (Part of NZRCA)	(29,30)		
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." Br J Sports Med 51(11): 848–850.
†21-item checklist adopted from the Child SCAT5 symptom scale[5]
††10-word list size adopted from the SCAT5[6]

decile in NZ refers to the socioeconomic status of the community where the school is located. Schools with a decile ranking of 1 represent the poorest 10% and schools with a decile ranking of 10 represent the wealthiest 10% of the population (www.education.govt.nz). Schools that consented to be involved were then asked to identify and invite suitable teams to take part in the study.

Protocol

For pragmatic reasons, the NZRCA data were collected following a scheduled NZR concussion education session conducted during the 2018 and 2019 pre-season/start of season (February–May) as part of NZR community concussion initiative (9). These sessions occurred during lunch breaks or prior to a scheduled training session. The NZRCA was administered in English and in a quiet distraction-free environment with the player in a resting state (20) and delivered by a trained research assistant, team medical or support staff. Participant demographic and concussion and medical history details were collected using a paper-based questionnaire see Table 1. The NZRCA components were recorded and instantaneously uploaded to a secure server using the CSx mobile App designed for baseline concussion assessment testing (21). Participants' demographic characteristics were linked with NZRCA data exported from CSx using a unique identifier to ensure participant anonymity.

Data analysis

The distribution of the NZRCA component and sub-component scores as outlined in Table 1 was described using the mean (SD [95% CI]), median [IQR], and minimum/maximum values. The Standardized Assessment of Concussion 50 (SAC50) score was calculated as the sum of scores for orientation, 10-item immediate memory and delayed recall and concentration (29). The Tandem Gait time was recorded in seconds and then ranked as a pass/fail based on the players' ability to complete one of four trials within the 14 second time threshold (30).

The sample was stratified as outlined in Table 2 and summary variables were explored graphically for normality using histogram and distributions were reviewed. Median and range scores were also generated for the overall sample NZRCA component and sub-component scores. Standardized effect

Table 2. Sociodemographic characteristics of high school rugby players (n = 1428).

Characteristics	n (%)
Age [a]	
≤ 15	502 (35.2)
≥ 16	926 (64.8)
School decile	
1–3	202 (14.1)
4–7	366 (25.6)
8–10	860 (60.2)
Ethnicity [b]	
New Zealand European	769 (54.1)
Māori	318 (22.4)
Pasifika	282 (19.8)
Other	52 (3.7)
Gender	
Male	1121 (78.5)
Female	307 (21.5)
Self-reported history of concussion [c]	
Yes	467 (34.9)
No	871 (65.1)
Number of self-reported medically diagnosed concussion	
0	871 (61.0)
1	293 (20.5)
2	117 (8.2)
3	33 (2.3)
>3	1114 (8.0)
Hospitalized for head injury [d]	
Yes	184 (13.8)
No	1147 (86.2)
History of migraines or headaches [e]	
Yes	296 (22.3)
No	1034 (77.7)
History of learning disability [f]	
Yes	79 (5.9)
No	1251 (94.1)
History of ADD or ADHD [g]	
Yes	34 (2.6)
No	1295 (97.4)
History of anxiety, depression, other mental health disorder [h]	
Yes	45 (3.4)
No	1285 (96.6)

Missing n: a = 18; b = 7; c = 90; d = 97; e = 98; f = 98; g = 99; h = 98; i = 90; ADD = attention deficit disorder; ADHD = attention deficit hyperactivity disorder.

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, respectively (31). The mean differences (MD) between groups for age, gender, ethnicity, and history of concussion 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. An alpha of <0.05 was considered statistically significant. We also performed a sensitivity analysis using the Mann-Whitney U-test and Kruskal Wallis test to assess the robustness of the significant parametric test results. Pass rate (%) change scores for the reverse months and tandem gait tests were evaluated using the Chi-squared test.

Normative ranges for the NZRCA components were calculated based on methods described elsewhere (19,20,32) for the overall sample. 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) (32). We defined cutoffs as close as possible to the defined performance intervals (32). 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

A total of 1428 players (males n = 1121, females n = 307) from 22 high schools with a mean age of 15.9 ± 1.4 years were baseline tested (Table 2). The overall response rate for baseline testing was 82.9% (n = 1428) out of the 1732 players that consented to participate. Participants were predominantly 16 years or older (n = 926, 64.8%) and were from decile 8 schools or higher (n = 860, 60.2%). Almost two-thirds (n = 871, 61.0%) of the sample had not sustained a medically diagnosed concussion. For those that had sustained a concussion, the majority of players (n = 293, 20.5%) reported only having sustained one concussion. A total of 1147 (86.2%) of players had never been hospitalized for a head injury and between 1034 and 1295 (77.7–97.4%) had no other history of health conditions surveyed. Missing demographic data were due to participants not providing the requested information.

The distribution of the NZRCA component and sub-component scores are provided in Table 3. The mean ± SD symptom severity score was 11.3 ± 8.6, mean number of endorsed symptoms 8.5 ± 5.3 and the percentage reporting feeling "normal" was 80.2 ± 15.3%. None of the participants achieved a perfect score for the SAC50. The majority of participants (89.7%) passed the tandem gait test with a time of 12.2 ± 1.7 seconds. The normative range cutoffs for the NZRCA components and sub-components are provided in Table 4 (20,32).

Only 75 (5.3%) players reported no symptoms at the time of assessment. The most common reported symptoms were: 'distracted easily' (n = 1035, 72.5%), 'forgetful' (n = 978, 68.5%), 'often tired' (n = 894, 62.6%), 'trouble remembering' (n = 874 61.2%), and 'trouble paying attention' (n = 814, 57.0%). The distribution of symptom severity for each symptom is reported in Figure 3.

The NZRCA components stratified by age and gender are summarized in Table 5. Compared to players aged ≥16 years, those aged ≤15 years had higher symptom severity scores, (MD = 1.4, 95% CI[0.4, 2.3]) and endorsed more symptoms

Table 3. Distribution of NZRCA components and sub-components.

NZRCA components	n	Mean (SD)	Median [IQR]	Range
Symptom assessment:				
Symptom severity	1428	11.3 (8.6)	9 [5–17]	0–47
Endorsed symptoms	1428	8.5 (5.3)	8 [4–13]	0–21
Percentage normal	1422	80.2 (15.3)	80 [70–100]	20–100
Cognitive assessment:				
SAC50	1353	32.8 (5.4)	33 [29–37]	14–47
Immediate recall	1353	18.7 (3.6)	19 [16–21]	7–29
Delayed recall	1353	6.2 (1.8)	6 [5–7]	0–10
Orientation	1428	4.8 (0.5)	5 [5–5]	0–5
Concentration assessment:				
Digits backwards	1428	2.5 (1.0)	2 [2–3]	0–4
Months in reverse	1428	0.6 (0.5)	1 [0–1]	0–1
Total score	1428	3.1 (1.2)	3 [2–4]	0–5
Dynamic coordination assessment:				
Tandem gait time	1428	12.2 (1.7)	12.2 [11.3–13]	7.2–22

SAC = Standardized assessment of concussion

Table 4. Normative ranges for NZRCA components and sub-components (n = 1428).

	Broadly normal		Above/below average		Unusually low/high		Extremely low/high	
NZRCA components (scale [worst-best])	Cutoff	%	Cutoff	%	Cutoff	%	Cutoff	%
Symptom assessment:								
Symptom severity (63–0)	0–16	74.6	17–23	15.4	24–32	7.8	33–47	2.2
Endorsed symptoms (21–0)	0–12	74.9	13–15	13.0	16–19	10.2	20–21	1.8
Percentage normal (0–100)	100–88	72.6	70	14.9	60–50	10.9	40–22	1.6
Cognitive assessment:								
SAC50 (50–0)	47–30	73.6	29–26	17.6	25–22	6.8	21–14	2
Immediate (0–30)	29–17	74.4	16–15	14.3	14–11	9.6	10–7	1.8
Delayed (0–10)	10–5	84.1	4	9.24	3	4.7	2–0	2
Orientation (0–5)	5	79.9	NA	NA	4	17.4	3–0	2.7
Concentration assessment:								
Digits backwards (0–4)	4–2	84.6	NA	NA	1	13.4	0	2.0
Months in reverse (fail/ pass)	Pass	57.7	Fail	42.3	NA	NA	NA	NA
Total score (0–5)	5–3	68.4	2	21.4	1	8.7	0	1.6
Dynamic coordination assessment:								
Tandem gait (fail/pass)	Pass		89.7		Fail		10.3	
Tandem gait time (seconds)	7.2–13	77.9	13.1–13.9	11.8	14–15.7	8.0	16–22	2.2

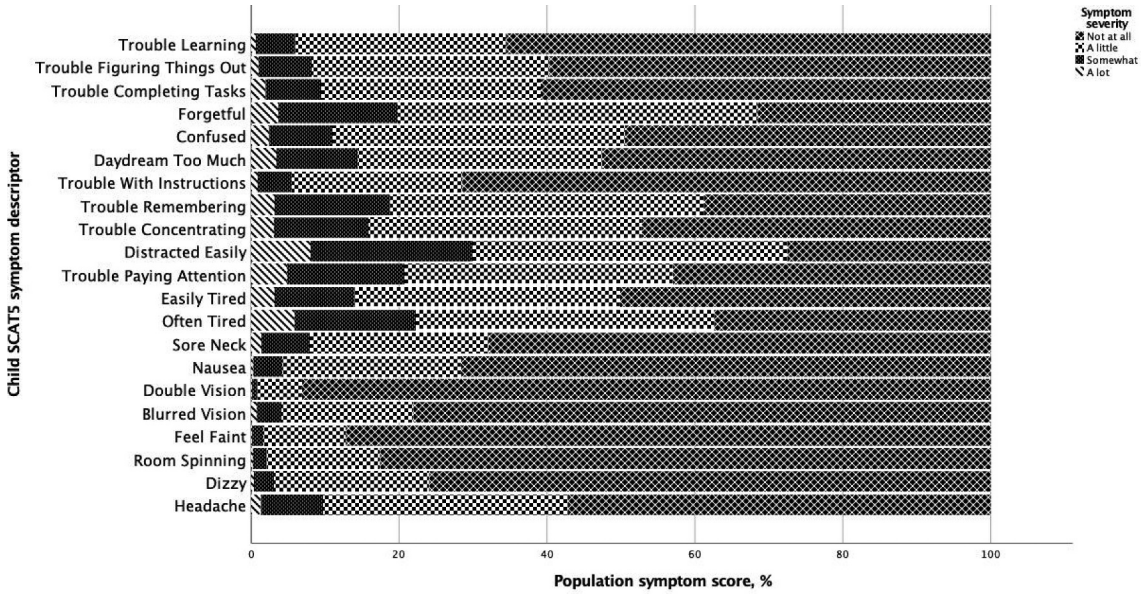

Figure 3. Total sample distribution (n = 1428) of endorsed symptoms and symptom severity.

(MD = 0.8, 95% CI [0.2, 1.4]); but reported feeling less normal (MD = −2, 95% CI[−4.0, −0.2]), achieved lower scores on the digits backwards (MD = −0.2, 95% CI [−0.3, −0.1]), months in reverse (11.2% change; p < .001) and total concentration assessment (MD = −0.3, 95% CI [−0.5, −0.2]). The effect sizes for these differences were small ($-0.1 \geq d \leq 0.2$).

Males endorsed more symptoms, MD = 1.2, 95% CI[0.5, 1.8]; reported feeling more normal MD = 0.2, 95% CI[0.1, 0.4]; performed better on digits backwards, MD = 0.02, 95% CI [0.04, 0.3]; and had faster tandem gates, MD = −0.6, 95% CI [−0.8, −0.4] and greater pass rates, 4.7% change; p = .02, when compared to their female counterparts. However, males achieved lower scores for: SAC50, MD = −1.7, 95% CI[−2.4, −1.0]; immediate, MD = −1.1, 95% CI [−1.6, −0.7] and delayed recall, MD = −0.6, 95% CI [−0.8, −0.4]; orientation, MD = −0.1, 95% CI[−0.2, −0.1]; and months in reverse (7.4% change; p < .05). The effect sizes for these differences were small ($-0.4 \geq d \leq 0.2$).

When the NZRCA component scores were stratified by ethnicity (Table 6), Pasifika players scored lower than NZE on the following: SAC50, MD = 1.7, 95% CI[0.7, 2.7]; immediate memory, MD = 1.4, 95% CI[0.7, 2.0], and delayed recall, MD = 0.4, 95% CI[0.1, 0.7]. When Pasifika players were compared to Māori they achieved lower scores on immediate recall, MD = 1.0, 95% CI[0.2, 1.7]. All comparisons were of small effect size ($0.2 \geq d \leq 0.4$). Compared to NZE, Māori also tended to fail the tandem gait test more often (5.7% change; p = .005).

A significant association was observed between gender and concussion history, $x^2(1, N = 1338) = 10.5$, $p \leq .01$, where 37.1% of male players reported having sustained a concussion compared to 26.8% of females players. Based on this gender difference concussion history was analyzed separately for males and females. Male players with a history of concussion performed better on the months in reverse, 8.6% change (p < .01); and achieved a better total score for the concentration assessment, MD = 0.2, 95% CI[0.0, 0.3] (Supplementary Table 7). All

Table 5. NZRCA components stratified by age and gender.

	≤ 15 years	≥ 16 years				
NZRCA components	Mean (SD) (n = 502)	Mean (SD) (n = 908)	Mean Difference (95% CI) [Effect size]	Male Mean (SD) (n = 1121)	Female Mean (SD) (n = 307)	Mean Difference (95% CI) [Effect size]
Symptom assessment:						
Symptom severity	12.2 (9.3)	10.8 (8.2)	1.4** (0.4, 2.3) [0.2]	11.4 (8.4)	10.7 (9.5)	0.7 (−0.4, 1.8) [0.1]
Endorsed symptoms	9.0 (5.4)	8.2 (5.2)	0.8** (0.2, 1.4) [0.2]	8.8 (5.2)	7.6 (5.2)	1.2*** (0.5, 1.8) [0.2]
Percentage normal	81.0 (15.8)	82.8 (14.9)	−2* (−4, −0.2) [−0.1]	82.6 (15.0)	80.6 (16.1)	0.2*† (0.1, 4.0) [0.1]
Cognitive assessment:						
SAC50	32.7 (5.3)	32.8 (5.4)	−0.1 (−0.7, 0.5) [−0.02]	32.5 (5.3)	34.2 (5.3)	−1.7*** (−2.4, −1.0) [−0.3]
Immediate′	18.7 (3.6)	18.7 (3.6)	−0.01 (−0.4, 0.4) [0.00]	18.5 (3.5)	19.6 (3.5)	−1.1*** (−1.6, −0.7) [−0.3]
Delayed	6.3 (1.7)	6.2(1.8)	0.2 (−0.04, 0.4) [0.09]	6.1 (1.8)	6.7 (1.8)	−0.6*** (−0.8, −0.4) [−0.3]
Orientation	4.8 (0.5)	4.8 (0.5)	0.01 (−0.05, 0.1) [0.01]	4.7 (0.5)	4.9 (0.5)	−0.1*** (−0.2, −0.1) [−0.3]
Concentration assessment:						
Digits backwards	2.4 (1.1)	2.6 (1.0)	−0.2*** (−0.3, −0.1) [−0.2]	2.6 (1.0)	2.4 (1.0)	0.02** (0.04, 0.3) [0.2]
Reverse months pass rate, n (%)^	254 (50.6)	561 (61.8)	11.2% change***; χ^2 (1, n = 1410) = 16.6, p = .00	629 (56.1)	195 (63.5)	7.4% change**; χ^2 (1, n = 1428) = 5.4, p = .02
Total score	2.9 (1.3)	3.2 (1.2)	−0.3* (−0.5, −0.2) [−0.3]	3.1 (1.2)	3.0 (1.2)	0.1 (−0.1, 0.3) [0.1]
Dynamic coordination assessment:						
TG pass rate, n (%)^	445 (88.6)	818 (90.1)	1.5% change; χ^2 (1, n = 1410) = 0.7, p = .40	1017 (90.7)	264 (86.0)	4.7% change*; χ^2(1, n = 1428) = 5.8, p = .02
TG fastest time	12.3 (1.8)	12.2 (1.7)	0.1 (−0.05, 0.3) [0.1]	12.1 (1.7)	12.7 (1.6)	−0.6*** (−0.8, −0.4) [−0.4]

*p < 0.05; **p < 0.01; ***p < 0.001; †Not significant using the Mann Whitney U test; SSS = symptom severity score; ESS = endorsed symptom score; ^χ^2 test for months in reverse and tandem gait pass rate

the mean differences were of small effect size ($-0.1 \leq d \leq 0.1$). While no significant differences for concussion history were observed for the female players (Supplementary Table 8).

The results of the sensitivity analysis did not produce results inconsistent with the overall findings of the primary analysis. Significant differences identified using the non-parametric tests were consistent across all comparisons except for the differences between age and gender on the outcome variable 'percentage normal,' and differences between history of concussion on the outcome variables percentage normal and fastest tandem gait time.

DISCUSSION

While the SCAT/Child SCAT family of tools are widely accepted and used in the sporting environment, there is no compelling evidence that these tools are being used by GPs in a primary care setting (12,33). Research examining the management of concussion in primary care has found that GPs are often uncomfortable with the diagnosis and management of concussions (14–17), thus the purpose of the NZRCA was to provide GPs with a tool and some key information that can assist their clinical decisions. The NZRCA is not diagnostic in and of itself. It provides a useful context-relevant tool to inform the diagnosis and management of concussions and that can be completed in a 5-min time frame, allowing a further 10 minutes for taking 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, thus ensuring that the NZRCA is a pragmatic tool for use within most typical GP practice settings. This study extends previous studies conducted in professional rugby (20,34) and ice hockey (32) producing population-specific normative outcome data. The normative data from the current study could assist GPs with their clinical assessments and interpretation of their patient's post-injury data in primary care.

The study was customized for use in the NZ community and PC setting in several ways to enhance data collection and promote obtaining quality data for the purposes of a baseline assessment. Following consultation with the community rugby players and local GPs, we introduced the Child SCAT5 symptom assessment (25) in an attempt to more accurately capture a better reflection of what the players wished to share with us around their symptomology. Based on our pilot work, it was considered that not all participants fully understood the symptom descriptors currently employed in SCAT5 (18); this prompted the use of the symptom checklist from the Child SCAT (25). Although this may limit comparison to other studies who have used similar demographics (35), we are confident that this provides an accurate representation of their symptomology. This raises the issue of whether some populations have previously responded in a less than valid manner due to literacy level and/or cultural competency of the measures. Another key item substitution was the tandem gait task (SCAT3) in lieu of the widely used modified BESS as described in the SCAT5. It was felt that the quantitative timed tandem gait protocol was a well-established measure of dynamic balance (27) and did not require the same degree of training to interpret the subjective observation and time to administer. Both our participants and our research assistants related well to the tandem gait task.

Table 6. NZRCA components and sub-components stratified by ethnicity.

	Ethnicity			Mean Difference (95% CI) [Effect Size] by Ethnicity		
NZRCA components	NZE Mean (SD) (n = 769)	Māori Mean (SD) (n = 318)	Pasifika Mean (SD) (n = 282)	NZE vs Māori	NZE vs Pasifika	Māori vs Pasifika
Symptom assessment:						
Symptom severity	9.6 (8.1)	10.6 (8.7)	10.9 (8.5)	−0.9 (−2.4, 0.6) [−0.1]	−0.8 (−2.4, 0.8) [−0.1]	0.1 (−1.7, 2.0) [0.01]
Endorsed symptoms	7.5 (5.3)	7.9 (5.3)	8.1 (5.3)	−0.2 (−1.2, 0.7) [−0.1]	−0.3 (−1.3, 0.6) [−0.1]	−0.05 (−1.2, 1.1) [−0.01]
Percentage normal	82.2 (14.6)	82.3 (15.4)	82.4 (16.8)	−0.15 (−2.8, 2.5) [−0.01]	−0.2 (−3.0, 2.6) [−0.02]	−0.1 (−3.4, 3.2) [0]
Cognitive assessment:						
SAC50	33.6 (5.2)	32.7 (5.5)	31.3 (5.9)	0.7 (−0.3, 1.7) [0.1]	1.8*** (0.8, 2.8) [0.3]	1.1 (−0.1, 2.3) [0.2]
Immediate	19.0 (3.4)	18.6 (3.7)	17.6 (3.7)	0.4 (−0.2, 1.0) [0.1]	1.4*** (0.7, 2.0) [0.4]	1.0** (0.2, 1.7) [0.3]
Delayed	6.3 (1.8)	6.2 (1.8)	5.9 (1.8)	0.1 (−0.2, 0.5) [0.1]	0.4** (0.1, 0.7) [0.2]	0.3 (−0.1, 0.7) [0.2]
Orientation	4.8 (0.5)	4.8 (0.5)	4.7 (0.6)	0.06 (−0.03, 0.2) [0.1]	0.1 (−0.02, 0.2) [0.1]	0.01 (−0.1, 0.1) [0.02]
Concentration assessment:						
Digits backwards	2.6 (1.04)	2.5 (1.0)	2.6 (1.1)	0.04 (−0.1, 0.2) [0.04]	−0.05 (−0.2, 0.1) [−0.05]	−0.1 (−0.3, 0.1) [−0.1]
Reverse months pass rate, n (%)^	460 (59.8)	172 (54.1)	160 (56.7)	5.7% change; χ^2 (1, n = 1087) = 3.0, p = .08	3.1% change; χ^2 (1, n = 1051) = 0.8, p = .37	2.6% change; χ^2 (1, n = 600) = 0.4, p = .52
Total score	3.2 (1.2)	3.1 (1.2)	3.1 (1.3)	0.1 (−0.1, 0.3) [0.1]	−0.02 (−0.2, 0.2) [−0.02]	−0.1 (−0.4, 0.1) [−0.1]
Dynamic coordination assessment:						
TG pass rate, n (%)^	704 (91.5)	273 (85.8)	249 (88.3)	5.7% change**; χ^2 (1, n = 1087) = 8.0, p = .005	3.2% change; χ^2 (1, n = 1051) = 2.6, p = .11	2.5% change; χ^2 (1, n = 600) = 0.8, p = .37
TG fastest time	9.6 (8.1)	10.6 (8.7)	10.9 (8.5)	−0.2 (−0.5, 0.1) [−0.1]	0.05 (−0.3, 0.4) [0.03]	0.3 (−0.1, 0.6) [0.2]

NZE = New Zealand European players

*p < 0.05; **p = 0.01; ***p < 0.001; Games-Howell adjusted *p* for multiple independent t-tests; SSS = symptom severity score; ESS = endorsed symptom score; ^χ^2 test for months in reverse and tandem gait pass rate

NZRCA normative data

The diagnosis of a concussion is a clinical decision that is based on a number of information sources including clinical examination, injury, and medical history (18). A concussion diagnosis can be facilitated by the use of normative data (20,22,34). This study, whilst specific to the needs of our clinical management pathway in NZ, adds to the growing international literature on norms surrounding the SCAT family of tools (20,34,35). Unlike one-off normative studies the NZR concussion management pathway is designed and being developed as an iterative process to feed data into a continuously expanding normative database, thus sharpening normative values and allowing for more refined norms for different subgroups of players as the data accumulates. This study has provided normative ranges for the NZRCA items in 1428 high-school rugby players that reflect the NZ ethnic (46% of players identified as being of Non-European decent) and socioeconomic landscape (39% of players were from "low" to "moderate" socioeconomic areas) of this target population. While several studies have been published in rugby relating to the normative values of professional players (20), there are limited data at the community level, with a single Canadian study looking at 380 high-school players (35). The component of the NZRCA where the highest percentage of players that tested "broadly normal" was the tandem gait (90%) and the lowest – the months in reverse (58%). These results may suggest that an abnormal test on the tandem gait may be clinically useful during a concussion assessment. Examination of the normative ranges for all the components of the NZRCA revealed on average approximately 75% of the cohort tested "broadly normal" and 7% tested in "unusually" or "extremely" low/high categories. The percentage of players that fall into the "broadly normal" range in the current study for the common components in the NZRCA and the SCAT3 approximates the values reported in professional rugby players except for digits backwards and months in reverse (20).

To our knowledge, this is the first study to employ the child symptom score and scale (25) in a high school aged cohort; thus, we acknowledge that caution is needed when making direct comparison to previous studies. While the SCAT5 has been validated for ages 13 and above (18), our sample population contains players from a wide range of ethnicities and socioeconomic backgrounds. Future research may want to explore the validity of this symptom checklist in these populations. The current study failed to observe any difference in the symptom severity score (SSS) between high-school males and females, which was reported by Black et al. (35) where females were more symptomatic. One possible explanation for the observed difference in SSS between these studies other than the symptom checklist used was the age ranged included, the current study included players aged 11–19, while Black et al. (35) included 15–18-year-old players. Additionally, Black et al. (35) reported that females endorsed more symptoms than their male counterparts. The opposite was observed in the current study where males endorsed more symptoms than females, a finding that has been observed in multi-sport high-school athletes' baseline SCAT3 values (36). However, while our observed difference between genders was statistically significant, the difference was small (approximately one symptom), which may not be clinically relevant. Consistent with results reported by Black et al (35). The SSS and number of endorsed symptoms are substantially higher (current study 95% of population was symptomatic at baseline) than those reported at the professional rugby level where a mean SSS of 1.6 and only a single symptom being endorsed has been documented (20). This level of symptom reporting in professional rugby players is consistent with what has been reported previously in other professional players in sports such as ice hockey (37). These results may indicate motivational differences between amateur and professional-level athletes where greater coping skills are observed in professional players (38) or may reflect an exposure or practice effect where professional players are more familiar with the baseline assessment (20). Nevertheless, examination of symptom assessments at baseline and post-injury has consistently supported the value of self-reported symptom burden as a key component of a concussion assessment (19). As baseline assessments were conducted at lunch time or the end of the day prior to rugby training it is likely that fatigue, lack of sleep and school-related stress may have also contributed to the symptom pattern observed in the current study (39,40).

The baseline results of this study demonstrate that all 21 symptoms can be present in non-concussed healthy high-school players, supporting a previous report based on the SCAT5 symptom scale (39,40). As the majority of players were symptomatic at baseline this must be a consideration when evaluating individuals post-injury and highlights the importance of a clinical assessment to determine the cause of symptoms rather than the presence of symptoms being diagnostic (35,40). This also highlights the value of normative data or the presence of baseline scores for GPs who must often make a concussion diagnosis under time pressure and with patients they are unfamiliar with.

Impact of age on NZRCA performance

Examination of the effect of age on the components of the NZRCA in the current study suggests significant differences where players ≤15 years of age were more symptomatic, endorsed more symptoms, and overall reported feeling less than normal than their older counterparts. In addition, younger players achieved lower scores on the digits backwards, months in reverse and total concentration score. The effect size for these age-related differences were small so caution should be used in their interpretation. A similar result was reported by Glavaino et al. (41), who examined baseline scores in athletes of a similar age range using the SCAT2 and reported similar differences where younger athletes achieved lower scores on the concentration component. A systematic review of the effect of age on the SCAT assessment across a number of studies indicates that results seem to be inconclusive; however, studies that include large age ranges in their sample appear to demonstrate an effect for age that can be attributed to the end ranges of the sample (42). Thus, when interpreting the results of the

NZRCA for clinical use, considerations should be made for younger players who may report being more symptomatic and achieve lower scores on the concentration components.

Impact of gender on NZRCA performance

With the exception of the SSS and the total concentration score, gender differences were seen for every component of the NZRCA, with small effect sizes ranging from 0.1 to 0.4. Females scored significantly higher on the SAC50 (1.7-points), with both immediate (1.1-points) and delayed recall (0.6-points) accounting for the majority of this difference; although, all components were significantly different. These findings are very similar to those from 514 college students that showed females scored 1-point higher on immediate and 0.6-points higher on delayed recall (23). These results appear to align with other studies where females appear to outperform males on the SAC score based on the 5-item word list, although this is not consistently reported (42,43). For example, no sex differences were observed for the SAC50 using a 10-item word list in high-school players (35) or a 5-item list in professional players (20). In addition to the SAC50 score difference males tested significantly faster on the tandem gait compared to females. This may be due, in part, to the observed age difference between genders in the current study, where males were significantly older which may explain the performance difference.

Impact of ethnicity on NZRCA performance

The sampling strategy used in the current study allowed us to obtain a sample that reflects the NZ's high school rugby player demographic and may facilitate clinical decisions that are informed by representative normative data. Our study cohort consisted of players of different ethnicities including Māori, Pasifika and others, which explores potential variations based on ethnic backgrounds that has previously been observed in collegiate student-athletes in the United States (23). In the current study, we found that when the NZRCA scores were stratified by ethnicity, Pasifika players tended to score lower than NZE on the SAC50 by 1.8-points. Pasifika players also achieved lower scores on the immediate and delayed recall when compared to NZE (1.4-points and 0.4-points, respectively), and Māori on immediate recall (1.0-point). Differences in results in relation to ethnicity have also been reported on the SCAT5 where Black/African Americans scored significantly lower on both immediate and delayed recall when compared to Caucasians (23). These results suggest that clinicians should be aware of ethnic differences when interpreting NZRCA performance as a 1-point difference on the SAC has been reported to be 95% sensitive and 76% specific for assisting with the detection of a concussion (44,45). The ability to compare post-injury scores to normative data that considers ethnic background may help clinicians make a more informed decision.

Impact of concussion history on NZRCA s performance

While male players with a history of concussion had faster tandem gait times and pass rate, they performed better on months in reverse and total concentration score that is in contrast to other studies (35). However, a recent study in elite rugby players found reduced symptom endorsement and improved cognitive performance in players who had previously sustained a concussion (46). While the current study did not observe a change in the number of endorsed symptoms our results parallel the improvements seen for the concentration score. It can be speculated that this improvement may be due to a learning effect resulting from previous exposure to the SCAT during a formal concussion assessment (46). In contrast, no significant findings were observed for history of concussion in the female players in the current study.

This study forms part of a larger body of work that NZR is conducting to operationalize the Recognize, Remove, Refer, Recovery and Return recommendations from World Rugby (https://playerwelfare.worldrugby.org/concussion) through the use of technology and related protocols (9). The technology centers on the use of a bespoke mobile App that enables baseline testing of players using recognized items from the SCAT family of concussion assessment tools. The baseline data collected from the App feeds into a web-based portal system that allow GPs to access and use individual player and/or cumulative normative reference data during their clinical concussion assessment (8,12). Primary care is very different to the sports medicine environment where concussions are seen on a more frequent basis by doctors who are experienced in concussion diagnosis and management (12). From an NZR perspective an integral part of the concussion management process is the removal of players from play and their referral to a GP for a diagnosis and medical clearance prior to their return to contact training. To achieve these outcomes, we have worked collaboratively with GPs to support this process which long term will results in improved concussion management irrespective of its origin. The normative data captured as part of this study will provide some context for the interpretation of the components and subcomponents of the NZRCA and hopefully provide some normative ranges that will assist GPs in the interpretation of post-injury patient scores.

Strengths and limitations

A strength of this study is that it is part of a larger NZR community concussion initiative which is an iterative process where the data presented, and future data collection will continue to inform both the normative data and the pathway itself. The current study included a robust sample size and heterogeneous sample demographic. We suggest that the combination of these factors means the normative ranges reported here are generalizable with respect to high school rugby players in NZ, particularly males. These results may also be generalizable to other countries with similar cultural and sociodemographic characteristics. An additional strength is the NZRCA was developed in collaboration with GPs and consists of items from the SCAT/Child SCAT family of assessments that are useful to their clinical practice and easy to administer. Finally, we used a mobile App to standardize our collection of NZRCA baseline data, contributing to our confidence with the quality of the data reported here.

A limitation of this study was that baseline testing occurred during times where players may have been distracted (e.g., during school lunch time or prior to training), which may have impacted on their performance. Another limitation was the comparatively smaller sample of females included in this study, while this is representative of NZR playing population, inclusion of more females to ensure that the normative data is representative should be a focus of future research. Our results are also limited to schools that chose to participate, which may have favored those schools who had the resources and capacity to be involved as demonstrated by the larger proportion of "high" decile schools vs "low." Future work will also look to explore the interaction between various sociodemographic characteristics such as ethnicity, socioeconomic status or history of mental health condition and NZRCA component scores to better understand the role these variables have on baseline performance and the implication this has on clinical interpretation.

CONCLUSION

This study provides normative reference values for high-school rugby players in NZ. Age, gender and ethnicity were associated with NZRCA performance; however, the differences were small, and unlikely to be clinically meaningful. These data may aid healthcare providers in their identification of suspected concussion in the absence of individualized baseline test data. Future research is needed to validate this approach as a clinical screening tool.

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Supplementary material

Supplemental data for this article can be accessed on the publisher"s website

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