Original research

Sport Concussion Assessment Tool—5th Edition (SCAT5) normative reference values for professional men's rugby league players

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ABSTRACT

Objectives: To provide normative reference values for the Sport Concussion Assessment Tool – 5th Edition for elite-level male rugby league players.
Design: A descriptive cross-sectional study.
Methods: Baseline Sport Concussion Assessment Tool – 5th Edition scores were obtained from 1005 National Rugby League players during the 2018 and 2019 preseasons. Normative values were calculated for the Standardized Assessment of Concussion, Symptom Evaluation (i.e., severity and number), and the Modified Balance Error Scoring System for each group and in total. Players self-identified their cultural heritage or ethnicity to be 'Pasifika (Pacific Islander) or Maori' ($n = 243$; 24.2 %) or 'Indigenous Australian' ($n = 82$; 8.2 %). Those who identified as any other race, ethnicity, or cultural heritage were combined into a single group ($n = 680$; 67.7 %).
Results: In total the median Standardized Assessment of Concussion score was 27 (interquartile range = 25–28), the median symptom severity was 0 (interquartile range = 0–2), the median symptom number was 0 (interquartile range = 0–1), and the median the Modified Balance Error Scoring System error score was 3 (interquartile range = 1–5). Reporting 4 of 22 symptoms and 6 of 132 on the total severity score was uncommon. There was no significant difference between the cultural heritage or ethnicity groups for Standardized Assessment of Concussion scores, symptom severity or number, or Modified Balance Error Scoring System errors (p-values > 0.05).
Conclusions: This normative data will assist with the clinical interpretation of Sport Concussion Assessment Tool – 5th Edition scores following a concussion in the National Rugby League.
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Practical implications

- Normative reference values for professional men's rugby league players are provided. Using these normative data will improve clinical interpretation of SCAT5 scores following a concussion.
- There were no statistically significant or clinically meaningful differences on the components of the SCAT5 in professional rugby league players of differing cultural heritages or ethnic backgrounds.
- Healthcare providers in the NRL may be able to use the single normative dataset that includes all players, rather than separate cultural normative data.

1. Introduction

Rugby league is a fast-paced, full-contact collision sport[1] with a relatively high rate of concussions, compared to other collision sports.[2] The Sport Concussion Assessment Tool—Fifth Edition (SCAT5) has a central role in the assessment process for concussion management in the National Rugby League (NRL) (for men) and NRL Women's (NRLW) competitions.[3] In other sports, such as professional hockey, cross-cultural normative data has been produced stratified by diverse language groups.[4] Australia is a multicultural society made up of individuals and communities from a diverse range of nations, cultural heritages, and ethnicities.[5] Approximately 29 % of Australian residents were born overseas, and have permanently migrated to Australia.[6] Sensitivity to cultural heritage and ethnicity is an important part of social equality and plays a key role for improving health outcomes for all Australians.[5] Cultural and ethnic diversity is also prevalent in Australian sports, including in the National Rugby League (NRL), which is the elite rugby league club competition in Australia and New Zealand. In 2020, approximately 45 % of first grade NRL players identified as Pasifika (Pacific Islander) or Māori, 43 % as White, and 12 % identified as Indigenous Australian.[7] This breakdown was similar in 2024, with 51 % of first grade NRL players identifying as Pasifika or Māori, 41 % as White, and 8 % as Aboriginal or Torres Strait heritage.[8] To enhance and promote cultural competence (i.e., "the set of behaviours, attitudes, and policies that come together to enable a system, agency, or professionals to work effectively in cross-cultural situations"[9]), it is important to evaluate clinical tools, like the SCAT5, in diverse cultural heritage or ethnicity groups. The purpose of this study was to provide normative reference values for the SCAT5 for professional men's rugby league players. As part of this process, we examined whether there were differences in any SCAT5 scores that were associated with players' cultural heritage or ethnicity.

2. Methods

2.1. Participants

All men registered in the National Rugby League (NRL) during the 2018 and 2019 seasons, across the 16 clubs, were included in this study. Preseason, baseline SCAT5 data were examined. If a single athlete performed a baseline SCAT5 assessment at the beginning of both seasons, only the performance of the first season was included in this study. Players self-identified whether they considered their cultural heritage or ethnicity to be 'Pasifika (Pacific Islander) or Māori,' or 'Indigenous Australian.' Those who identified as being from any other race, ethnicity, or cultural heritage were combined into a single group. All NRL players are provided with the opportunity to disclose their cultural heritage or ethnicity to the NRL. Responses are kept in an NRL database. The NRL provided the lead researcher with access to this information to merge the two databases (i.e., the SCAT5 baseline database and the cultural heritage or ethnicity database) to carry out the objectives of this study. The merging of the two databases was achieved via the use of unique participant numbers, so the data remained deidentified throughout the process. Each player's age was recorded at the time of the administration of the SCAT5.

2.2. Measure

The SCAT5[3] has nine sections: (i) potential signs of concussion (which include loss of consciousness and amnesia); (ii) the Glasgow Coma Scale,[10] which is used to document any neurological impairment; (iii) five Maddocks questions,[11] which are sport-specific orientation and amnesia questions; (iv) a background section that comprises of demographic variables, self-reported concussion history, potential outcome modifiers, and medications; (v) a 22-item symptom checklist, with the severity of each symptom rated on a scale from 0 (none) to 6 (severe); (vi) a cognitive assessment using the Standardized Assessment of Concussion (SAC)[12] consisting of time orientation, immediate memory, concentration, and delayed recall; (vii) a cervical/neck examination; (viii) a measure of postural stability using the Modified Balance Error Scoring System (M-BESS)[13] and/or tandem gait; and (ix) a coordination task using the finger-to-nose test.

2.3. Procedure

As part of the NRL concussion management protocol preseason medical evaluations, all players were administered the SCAT5, in a standardized manner in accordance with published instructions, to establish a baseline performance from which a post-injury assessment can be compared to aid in-game clinical decision-making.[3] All players were in a rested state for the administration of the SCAT5. In accordance with the NRL and Rugby League Players Association (RLPA) Collective Bargaining Agreement, all athletes consented a priori to allow for deidentified injury data to be used in research endorsed by the Rugby League Research Committee. As such, participants did not sign written informed consent for their data to be included in this study. Participants were able to withdraw their data from the study if requested. The study was conducted independently of the NRL (i.e., no funding was sought or provided). The research program has previously been endorsed by the Rugby League Research Committee. This study was approved by the Institutional Human Ethics Committee (Ref No. H-2012-0344) and conducted in accordance with the ethical principles regarding human research outlined in the Declaration of Helsinki.

The SCAT5 was performed during pre-season with the testing conducted by the team medical staff. If a player sustained a concussion within the few months prior to testing, the player had to have been asymptomatic and participated at least one month in normal game play after the concussion and before the SCAT5 baseline was administered. If any score on a subcomponent of the SCAT5 was incomplete, the data for that participant was excluded from the analyses of this subcomponent.

2.4. Statistical analyses

The statistical approach adopted for the NRL SCAT5 normative reference values was similar to that conducted in creating the NRLW SCAT5 normative reference values.[3] That is, we computed descriptive statistics including means, medians, standard deviations (SDs), interquartile ranges (IQRs), and ranges for the components of the SCAT5. Visual inspection and Kolmogorov–Smirnov tests were used to assess for normality of SCAT5 components. Normative cutoffs were selected based on the natural distribution of the scores because SCAT5 scores are not normally distributed.[14] For each score, we classified the score into one of four classification labels, with the percentile cutoffs depending on the direction of the SCAT5 scale: (1) Broadly Normal, either at the 25th or 75th percentile ranks, (2) Below Average or Above Average (i.e., the 10th–24th percentile or the 76th–90th percentile, respectively), (3) Unusually Low or Unusually High (i.e., the 3rd–9th percentile or 91st to 98th percentile), and (4) Extremely Low or Extremely High (i.e., the lowest 2 % or highest 2 %). It was not always possible to

make these classifications at the precise percentile level. Lower scores on symptom ratings, number of balance errors, and tandem gait are referred to as Broadly Normal, while higher scores on cognitive testing are referred to as Broadly Normal. Kruskal–Wallis tests (i.e., one-way analysis of variance on ranks) were used to compare SCAT5 components between the different cultural heritage or ethnicity groups. Pairwise comparisons were done using Mann–Whitney *U* tests. We did not adjust the significance level for multiple comparisons because we wanted to reduce the likelihood of Type 2 errors (i.e., not detecting a possibly meaningful difference between groups when one was present). If differences were identified, we considered the effect size to be more practically and clinically relevant than the *p* value. IBM SPSS Statistics 28.0 (IBM Corp. Armonk, NY, USA) was used to perform the analyses.

3. Results

The total number of individual players participating in the league over the two seasons was 1010. One player was excluded due to missing data, one was excluded as an extreme outlier, and three were excluded due to other general medical conditions noted at the time of their baseline evaluation. After exclusions, there were 1005 (99.5 % of the total sample) players included in the final sample for this study.

Players' self-identified cultural heritage or ethnicity included Pasifika or Māori (*n* = 243; 24.2 % of the total sample), Indigenous Australian (*n* = 82; or 8.2 % of the total sample), and 'combined' (*n* = 680; or 67.7 % of the total sample). There were no significant differences between the groups on total symptoms (*H* = 0.84, *p* = 0.66), symptom

Table 1
Descriptive statistics for the SCAT5 stratified by cultural heritage/ethnicity group.

Test component	Cultural heritage/ethnicity group	Scale	*n*	Mean	SD	Median	IQR	Range
Symptom severity	Total sample	0–132	1005	1.87	4.79	0	0–2	0–50
	Other combined[a]		680	1.70	4.21	0	0–2	0–50
	Pasifika or Māori		243	2.38	6.34	0	0–2	0–50
	Indigenous Australian		82	1.71	3.81	0	0–2	0–25
Number of symptoms	Total sample	0–22	1005	1.20	2.72	0	0–1	0–22
	Other combined		680	1.13	2.57	0	0–1	0–22
	Pasifika or Māori		243	1.46	3.30	0	0–1	0–22
	Indigenous Australian		82	0.96	1.92	0	0–1.25	0–13
SAC total	Total sample	0–30	1005	26.60	2.39	27	25–28	13–30
	Other combined		680	26.73	2.31	27	25–28	13–30
	Pasifika or Māori		243	26.37	2.55	27	25–28	16–30
	Indigenous Australian		82	26.17	2.51	27	25–28	16–30
- Orientation	Total sample	0–5	1005	4.77	0.49	5	5	2–5
	Other combined		680	4.80	0.44	5	5	3–5
	Pasifika or Māori		243	4.71	0.56	5	5	2–5
	Indigenous Australian		82	4.71	0.58	5	4.75–5	2–5
- Immediate Memory	Total sample	0–15	1005	14.22	1.20	15	14–15	5–15
	Other combined		680	14.27	1.13	15	14–15	5–15
	Pasifika or Māori		243	14.04	1.36	15	14–15	8–15
	Indigenous Australian		82	14.30	1.16	15	14–15	8–15
- Concentration	Total sample	0–5	1005	3.60	1.15	4	3–5	0–5
	Other combined		680	3.61	1.15	4	3–5	0–5
	Pasifika or Māori		243	3.63	1.15	4	3–5	0–5
	Indigenous Australian		82	3.39	1.17	4	2.75–4	1–5
- Digits Backward	Total sample	0–4	1005	2.79	0.98	3	2–4	0–4
	Other combined		680	2.81	0.96	3	2–4	0–4
	Pasifika or Māori		243	2.82	0.99	3	2–4	0–4
	Indigenous Australian		82	2.57	1.04	3	2–3	0–4
- Delayed Recall	Total sample	0–5	1005	4.02	1.02	4	3–5	0–5
	Other combined		680	4.05	1.01	4	3–5	0–5
	Pasifika or Māori		243	4.00	0.98	4	3–5	1–5
	Indigenous Australian		82	3.77	1.18	4	3–5	0–5
mBESS total errors	Total sample	0–30	1005	3.31	2.95	3	1–5	0–18
	Other combined		680	3.18	2.89	3	1–5	0–18
	Pasifika or Māori		243	3.55	3.12	3	1–5	0–17
	Indigenous Australian		82	3.72	2.98	3	1–6	0–12
- Double stance	Total sample	0–10	1005	0.11	0.55	0	0	0–6
	Other combined		680	0.10	0.52	0	0	0–6
	Pasifika or Māori		243	0.16	0.62	0	0	0–5
	Indigenous Australian		82	0.10	0.60	0	0	0–5
- Single stance	Total sample	0–10	1005	2.27	1.91	2	1–3	0–10
	Other combined		680	2.19	1.86	2	1–3	0–10
	Pasifika or Māori		243	2.38	1.92	2	1–4	0–9
	Indigenous Australian		82	2.61	2.31	2	1–4.25	0–10
- Tandem stance	Total sample	0–10	1005	0.93	1.21	1	0–1	0–6
	Other combined		680	0.89	1.19	0	0–1	0–6
	Pasifika or Māori		243	1.01	1.28	1	0–2	0–6
	Indigenous Australian		82	1.01	1.17	1	0–2	0–5
Tandem (best time)	Total sample	N/A	850	10.84	1.83	11.00	9.80–12.20	6.00–14.00
	Other combined		569	10.82	1.86	11.00	9.70–12.20	6.00–14.00
	Pasifika or Māori		215	10.93	1.76	11.00	9.80–12.30	6.00–14.00
	Indigenous Australian		66	10.77	1.85	11.00	9.70–12.42	6.30–13.90
Tandem (mean time)	Total sample	N/A	850	11.11	2.01	11.30	10.00–12.40	6.00–35.00
	Other combined		569	11.11	2.11	11.3	10.00–12.40	6.00–35.00
	Pasifika or Māori		215	11.14	1.79	11.30	10.00–12.40	6.00–16.75
	Indigenous Australian		66	11.05	1.77	11.35	9.90–12.50	6.30–13.90

Note. IQR: interquartile range; mBESS: Modified Balance Error Scoring System; *n*: number; N/A: not applicable; SAC: Standardized Assessment of Concussion; SD: standard deviation.
[a] Those who identified as being from any other race, ethnicity, or cultural heritage were combined into a single group.

severity ($H = 0.98$, $p = 0.61$), SAC total score ($H = 5.46$, $p = 0.65$), or mBESS total score ($H = 4.51$, $p = 0.11$). Careful examination of the median scores and the interquartile ranges for each component of the SCAT5 for each group, in Table 1, did not reveal differences that seemed clinically or psychometrically meaningful. These results suggest that normative reference values for the SCAT5 can be based on the total sample, and they do not need to be stratified by cultural heritage or ethnicity.

The baseline results for the total sample for the SCAT5 components are presented in Table 1. All SCAT5 components were non-normally distributed (Kolmogorov–Smirnov tests $p < 0.001$ for all analyses). The individual frequency distributions and associated normative classification ranges for the SCAT5 subscores for all players are presented in Table 2. Normative reference guides for interpreting SCAT5 performance are presented in Tables 4–7. Example sideline SCAT5 results from six men (two Pasifika or Māori, two Indigenous Australian players, and two players for the combined cultural heritage or ethnicity group) who were medically diagnosed with concussion during their season are presented in Table 8.

3.1. Baseline SAC scores

The median SAC total score for the total sample was 27 out of 30 (IQR = 25–28). A SAC total score of 30 out of 30 was obtained by only 8.1 % of the total sample. SAC total scores of less than or equal to 23 were considered uncommon (i.e., occurring in fewer than 10 % of the sample), while scores of 24–25 were considered Below Average and scores of 26–30 were considered Broadly Normal (Table 3).

The median Orientation score was 5 (IQR = 2–5), with 79.4 % of the sample obtaining 5 out of 5 possible points. The median Immediate Memory score was 15 (IQR = 14–15), with 56.5 % obtaining 15 out of 15 points. The median Concentration score was 4 (IQR = 3–5), with 25.5 % of the sample obtaining 5 out of 5 points. The median Digits Backwards score was 3 (IQR = 2–4), with 28.3 % obtaining 4 out of 4 points. The median Delayed Recall score was 4 (IQR = 3–5), with 40.2 % of the sample obtaining 5 out of 5 possible points.

3.2. Baseline SCAT5 symptom reporting

The distributions of the individual symptoms reported on the 22-item symptom scale are presented in Table 4. The median total number of symptoms for all NRL players was 0 (mean = 1.20, SD = 2.72, IQR = 0–1). Reporting greater than 3 out of 22 symptoms was uncommon, while 0 to 1 out of 22 symptoms was Broadly Normal. The median symptom severity score was 0 (mean = 1.87, SD = 4.79, IQR = 0–2). Symptom severity scores greater than 5 out of 132 were considered uncommon, while a symptom severity score of 0 or 1 was Broadly Normal. In the total sample, 67.3 % of players endorsed no symptoms (thus also obtaining a 0 for symptom severity). The most commonly endorsed baseline symptoms were fatigue or low energy (17.1 %), neck pain (12.6 %), trouble falling asleep (11.9 %), difficulty remembering (8.9 %), and difficulty concentrating (8.2 %). Sensitivity to noise (1.0 %; $n = 10$), feeling like "in a fog" (1.7 %; $n = 17$), confusion (1.7 %; $n = 17$), and nausea or vomiting (1.7 %; $n = 17$) were uncommon

Table 3
SCAT5 normative values quick reference guide for men's national rugby league players.

Test component	Broadly Normal	Uncommon
Symptom severity	0–1	≥6
Number of total symptoms	0–1	≥4
SAC score total	26–30	≤23
mBESS total errors	0–4	≥7

Note: mBESS: Modified Balance Error Scoring System; SAC: Standardized Assessment of Concussion. Broadly Normal scores for each test are provided in the first column and reflect the range of scores that most players obtain during baseline preseason testing. Scores in the "uncommon" column occur in approximately 10 % or fewer men during baseline testing. A man can have some scores in the Broadly Normal range following a concussion. These are normative reference values and they have not been validated as cutoff scores for diagnostic purposes following concussion.

(i.e., endorsed by fewer than 2 % of the sample). Individual symptom endorsement is summarized in Table 8.

3.3. Baseline SCAT5 balance and tandem gait scores

The median mBESS total score was 3 (IQR = 1–5). An mBESS total score of 0 (indicating no errors) was obtained by 17.2 % of the total sample. Total mBESS scores greater than or equal to 7 were considered uncommon (i.e., occurring in less than 10 % of the sample), while scores of 0 to 4 were considered Broadly Normal.

The median Double stance score was 0 (IQR = 0), with 93.6 % of the sample obtaining no errors. The median Single stance score was 2 (IQR = 1–3), with 21.5 % of the sample obtaining no errors. The median Tandem stance score was 1 (IQR = 0–1), with 49.1 % of the sample obtaining no errors. The median Tandem Gait best time was 11.00 (IQR = 9.80–12.20) and the median Tandem Gait average time was 11.30 (IQR = 10.00–12.40).

4. Discussion

The SCAT5 has been widely used as a standardized acute clinical assessment for athletes suspected of concussion in amateur and professional sports.[15–20] Clinicians can interpret post-injury SCAT5 scores by comparing to the athlete's personal pre-injury baseline scores, normative reference values, or both. While previous research on the cognition portion of the SCAT5 has showed that most healthy, non-concussed individuals score well,[3,17,21] there have not been previous efforts to empirically evaluate if professional rugby league players from different backgrounds have different scores on this test. Here we provide normative reference values for the SCAT5 for professional men's rugby league players stratified by cultural heritage or ethnicity. The Australian general population includes a diverse range of cultural heritage and ethnicity groups, with 3.8 % of the Australian population identifying as Indigenous, 1.6 % identifying as Pasifika or Māori, and 94.6 % as a combination of other cultural heritage or ethnicity groups.[22] The NRL player population is more diverse than the Australian general population.[23] In this study sample, 24.2 % of participants identified as Pasifika or Māori, 8.2 % of participants identified as Indigenous Australian, and 67.7 % of participants identified as a combination of other cultural

Table 2
Cutoff scores and classification ranges for SCAT5 components for the total sample.

Test component	Broadly Normal		Below/Above Average		Unusually Low/High		Extremely Low/High	
	Cutoff	% in range	Cutoff	% in range	Cutoff	% in range	Cutoff	% in range
Symptom severity	0–1	74.0 %	2–5	15.3 %	6–15	8.5 %	≥16	2.2 %
Number of symptoms	0–1	78.0 %	2–3	10.6 %	4–10	9.2 %	≥11	2.2 %
SAC total	26–30	72.8 %	24–25	16.8 %	22–23	7.7 %	≤21	2.7 %
mBESS total errors	0–4	71.2 %	5–6	16.2 %	7–9	8.8 %	≥10	3.8 %

Note: %: percentage; mBESS: Modified Balance Error Scoring System; SAC: Standardized Assessment of Concussion. Broadly Normal contains values within the interquartile range. Below/Above Average reflects the cutoff corresponding *approximately* with the 25th and 75th percentile ranks. Unusually Low/High reflects the cutoff corresponding approximately to the 10th and 90th percentile ranks. Extremely Low/High approximates the cutoff corresponding approximately to the 2nd and 98th percentile ranks.

heritage or ethnicity groups. The SCAT5 results were grouped into three cultural heritage or ethnicity categories based on the self-identified cultural and ethnicity diversity in NRL players.[7] There were no differences in SCAT5 scores for different cultural heritage or ethnicity groups on any of the SCAT5 components, suggesting that pooling the SCAT5 score into one set of normative reference values is acceptable.

Preseason, baseline normative data examining healthy professional NRL players may help future healthcare providers identify abnormal scores in players suspected of sustaining a concussion. Approximately one-third of the sample (32.7 %) endorsed at least one baseline symptom, while only one in 12 men (8.2 %) endorsed four or more symptoms at baseline (Table 5). This appears to be different than elite women's rugby league players from the NRLW, such that 59 % of women players endorsed at least one baseline symptom, with approximately 32 % endorsing four or more symptoms at baseline.[3] In this sample of elite men's rugby players, the most commonly endorsed baseline symptoms were fatigue or low energy (17.1 %), neck pain (12.6 %), trouble falling asleep (11.9 %), difficulty remembering (8.9 %), and difficulty concentrating (8.2 %). These findings are generally commensurate with previous studies that have identified fatigue as one of the most frequently reported symptoms during baseline administration of the SCAT.[14,17,21,24,25] In the NRLW Premiership players, the most common symptoms were fatigue or low energy (33 %), trouble sleeping (24 %), headache (23 %), neck pain (22 %), and difficulty remembering (21 %).[3]

NRL players scored well on the SAC and mBESS, which is broadly consistent with prior normative studies.[3,14,17,21,26–29] The majority of this sample did not obtain the highest possible score, with only 8.1 % obtaining a SAC total score of 30 out of 30 and only 17.2 % obtaining no errors on the mBESS. In male Finnish hockey players, only 24.2 % of athletes scored perfectly on SCAT3 delayed recall and 27.7 % of athletes scored perfectly on digits backward (the percent of athletes who scored perfectly on the SAC was not reported).[14] In a study of SCAT5 baseline scores in 1203 international professional men's rugby union players, only 0.7 % ($n = 8$) players scored perfectly on all of the sub-scores evaluated. In this study, 16 % of players' ($n = 193$) native tongue was not English, but language stratification for the normative reference values was not able to be evaluated.[17] Significant differences on the total symptoms, symptom severity, immediate memory, and concentration subcomponents of the SCAT5 were found between English and non-English language preference groups from a sample of professional ice hockey players from the National Hockey League (NHL).[4] These differences were considered to support the notion that language-specific normative data would be more appropriate for NHL players.[4]

4.1. Case examples of acutely concussed athletes

Sideline SCAT5 results from six men, two Pasifika, two Indigenous Australian, and two 'other combined' players, who were medically diagnosed with a concussion are presented in Table 9. These case examples further highlight the variability of scores at both baseline and following a concussion. For instance, at baseline, some athletes may report experiencing symptoms (player #2) or they may perform lower than expected on cognitive testing (player #5). These worse-than-expected scores may be their true, stable level of functioning or may be due to situational factors. If a healthcare provider believes that an athlete's baseline score may have been affected by situational factors, it may be helpful to re-administer that portion of the SCAT5. Second, on sideline testing immediately following removal from play for suspected concussion, some athletes endorse very few symptoms and perform well overall on all components of the SCAT5 (player #4), which may make it clinically challenging to determine whether they are experiencing any post-concussion deficits. Having the baseline data may help contextualize changes in functioning, but such changes may not be present in all concussion cases.

4.2. Limitations

The SCAT5 has now been superseded by the SCAT6. A number of changes have been made from the SCAT5 to the SCAT6, meaning that the current study findings may not directly translate to every component of the SCAT6. While the Symptom Evaluation and mBESS are the same between the two versions, the SAC on the SCAT6 has several changes including mandating the use of the 10-word list for the immediate and delayed memory, so the scores from the memory testing on the SCAT5 and the SCAT6 are not comparable. Similar to the NRLW normative reference values,[3] full demographic information (aside from cultural background), as well as concussion and medical/psychological history, was unavailable to the research team so that it could be incorporated into data analyses. For the small percentage of players who reported several symptoms at baseline, we do not have access to the possible reasons for this symptom reporting, including overtraining, life stress, mental health difficulties, or possibly overreporting. As a result, it was not possible to evaluate whether there were any associations between the SCAT5 symptom ratings and test performance and any of these clinically relevant variables. These data may not be generalizable to other sports, or to non-professional rugby league athletes. It is possible that players had completed the SCAT5 and the previous version, the SCAT3 on multiple occasions, and as such practice effects may be contributing to SCAT5 scores; however, this information was not available to verify or consider these potential effects on test scores.

5. Conclusions

Although an individual's cultural background may influence their symptom reporting and test performance on the SCAT5, we did not find evidence that professional rugby league players of differing cultural heritages or ethnic backgrounds had statistically significant or clinically meaningful differences on the components of this test. We present normative data stratified by cultural heritages or ethnic background for both completeness and to increase potential cultural sensitivity in the interpretation of these data but are reassured that these separate cultural normative data are nearly identical across groups thus suggesting that healthcare providers in the NRL may be able to use a single normative dataset that includes all players. The availability of normative reference values is useful in helping the clinician interpret an individual's SCAT5 performance following a concussion. Clinical expertise, including the careful consideration of a broad range of factors that can influence symptom reporting and test performance is critical when interpreting SCAT5 scores.[3]

CRediT authorship contribution statement

Andrew J. Gardner: Conceptualization, methodology, resources, data curation, writing — original draft, writing — review and editing, supervision, project administration (including securing regulatory ethics), and funding acquisition.

Julia E. Maietta: Conceptualization, Formal analysis, and writing — original draft, and writing — review and editing. She also assisted with interpretation of results.

Grant L. Iverson: Conceptualization, methodology, writing — original draft, writing — review and editing, and supervision.

David R. Howell: Conceptualization, Formal analysis, and writing — original draft, and writing — review and editing.

Paul Bloomfield: Data curation, project administration, supervision, and writing — review and editing.

Gordon W. Fuller: Assisted with interpretation of results and writing — review and editing.

Ben Jones: Assisted with interpretation of results and writing — review and editing.

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Supplementary data

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