Baseline SCAT Performance in Men and Women: Comparison of Baseline Concussion Screens Between 6288 Elite Men’s and 764 Women’s Rugby Players

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Objective: This study compared Sports Concussion Assessment Tool (SCAT) performance in elite male (6288 players) and female (764 players) rugby players, to determine whether reference limits used for the management and diagnosis of concussion should differ between sexes. Design: Cross-sectional census sample. Setting: Data from World Rugby’s Head Injury Assessment management system were analyzed. This data set covers global professional rugby. Participants: All professional players who underwent baseline SCAT testing as part of World Rugby’s concussion management requirement formed the study cohort. Ten thousand seven hundred fifty-four SCAT assessments from 6288 elite male rugby players and 1071 assessments from 764 elite female players were analyzed. Intervention: Elite men and women rugby players are independent variables. Main Outcome Measures: Sports Concussion Assessment Tool performance, including symptoms endorsed, cognitive submode performance, and balance performance. Results: Women endorsed significantly more symptoms, with greater symptom severity, than men (relative ratio 1.34, 95% confidence interval, 1.25-1.45 women vs men). Women outperformed men in cognitive submodes with the exception of immediate memory and delayed recall and made fewer balance errors than men during the modified Balance Error Scoring System. Clinical reference limits, defined as submode score achieved by the worst-performing 50% of the cohort, did not differ between men and women. Conclusions: Women and men perform differently during SCAT baseline testing, although differences are small and do not affect either the baseline or clinical reference limits that identify abnormal test results for most submodes. The greater endorsement of symptoms by women suggests increased risk of adverse concussion outcomes and highlights the importance of accurate evaluation of any symptom endorsement at baseline. Key Words: concussion, SCAT, Rugby Union, neurological screening, concussion management

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Ethics approval and consent to participate: The research plan for this study was approved by the World Rugby Institutional Ethics committee (REF 19007). Players had provided written informed consent for all data gathered as part of the World Rugby Concussion management program to be used for research in a unidentified manner.

Availability of data and material: Original participant data belong to the players and the clubs/unions that generate such data. This may be provided upon request to third parties. World Rugby (the corresponding author) may facilitate the provision of that data, in terms of permissions and contacts, although there is not a single point of contact, since the data are generated globally from multiple teams and unions.

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INTRODUCTION
The Sports Concussion Assessment Tool (SCAT), developed after the Second International Conference on Concussion in Sport,1 and subsequently revised and modified through a series of iterations to the present SCAT5,2–4 is used in Rugby Union in various stages of its concussion management strategy.5,6

During match play, an abridged version of the SCAT5 is used to guide return-to-play decisions after a head impact event with the potential to cause concussion. The abridged version includes the same orientation, cognitive and tandem gait subtests as the full SCAT5, but excludes the balance subtests, months in reverse assessment, the neck and neurological screens used during SCAT5, and it assesses only 9 symptoms rather than 22 assessed during SCAT5. During subsequent diagnostic screens, complete versions of the SCAT5 support the diagnosis of concussion,5 as part of World Rugby’s head injury assessment (HIA) protocol. During these screens, symptom endorsement and the player’s performance in the cognitive and balance submodes that make up the SCAT5 are assessed relative to a player’s previously recorded baseline assessment, or, if such a baseline is absent, against clinical reference limits derived from normative baseline data obtained in a large cohort of professional rugby players.7,8 Reference limits may also be used to indicate when...
a submode performance is abnormal during baseline assessments, thus requiring it to be repeated to enhance its validity and resultant clinical utility.

We propose that the submode reference limits used to indicate that baseline should be repeated should be set at a submode score that is achieved by the worst-performing 5% of players, while a clinical reference limit, used during return-to-play and diagnostic screens, should correspond to that submode score achieved by the worst-performing 50% of the cohort. This latter measure represents a more conservative concussion management strategy, reducing false negatives in clinical screening, however, at the expense of more false positives.

To date, these reference limits have been similar for female and male players. Studies have found, however, that women and girls endorse more symptoms, report higher symptom severity scores, have different symptom profiles, and improved performance in cognitive submodes and balance submodes compared with men and boys. These performance differences may influence the thresholds at which baseline assessments, return-to-play screens, and diagnostic screens are deemed abnormal in women compared with men. Although World Rugby recommends that all concussion testing during the HIA protocol be compared with baseline data, baseline and clinical reference limits may assist with the interpretation of diagnostic screens when baseline data are absent and with the identification of abnormal performances during baseline screens.

Accordingly, the aim of this study was to compare SCAT5 baseline performance in large groups of professional men’s and women’s rugby players to identify differences in submode performance and to determine whether clinicians should apply different clinical standards to women’s SCAT performance.

**METHODS**

**Study Design, Setting, and Study Population**

A cross-sectional study was performed using data from the World Rugby HIA database, which contains baseline and diagnostic concussion screen results from the professional game. To use the HIA process, a competition must adhere to mandatory competition player welfare standards [World Rugby Player Welfare Site] that ensures a standardized approach to concussion detection and management as well as data collection. The source population thus comprises most eligible professional male players in domestic and international competitions, as well as International Women’s squads that underwent mandatory baseline SCAT assessment between 2016 and 2019.

**Baseline Assessments**

All baseline, SCAT assessments were administered before commencement of the relevant competition season or tournament, according to methods described previously. For the present analysis, we excluded baseline SCATs performed after exercise, as well as any player who had a diagnosed concussion during the sampling period.

We chose to include players even if they had conducted multiple baseline SCATs. We recognize that this may create a learning effect due to test repetition. However, because Rugby Union requires annual baseline assessments in addition to multiple screens at the time of head impact events, most rugby players will perform multiple SCATs in their careers. Therefore, any normative reference ranges or clinical limits that are established should account for the fact that players are likely to be repeating submodes on multiple occasions, and so, for the external validity of the data, these players with multiple tests are included, with further research studies required to quantify how submode performance changes as a result of repeat testing.

Data for each submode are presented as mean values, SDs, medians, and the 5th and 95th percentile. Mean scores were compared using Mann–Whitney tests, and the null hypothesis (Men = Women) was rejected when \( P < 0.004 \), based on a Bonferroni correction of the original \( P < 0.05 \), divided by the 12 subdomains assessed (0.05/12 = 0.004).

Symptoms were analyzed using a Fisher’s exact \( \chi^2 \) analysis, comparing the proportion of each of the 22 symptoms of the SCAT5 were reported by men and women, with significance accepted when \( P < 0.002 \) based on a Bonferroni correction (\( P < 0.05 \) divided by the 22 symptoms). SCAT assessments were excluded from symptom analysis because we have previously shown that symptom endorsement is 32% greater using the SCAT5 than the SCAT3 (In review) likely owing to the requirement to report “trait symptoms” (how the player typically feels), compared with the “state symptoms” requested by SCAT3.

The magnitude of symptom differences between men and women was assessed by calculating a ratio (95% CI) of the proportion of women’s SCAT5s in which each symptom was endorsed compared with the proportion of men’s SCAT5s in which that symptom was endorsed.

**Reference Limits**

A baseline reference limit was determined for both men and women by identifying the submode score that would place the player into the worst-performing 5% of their cohort for that submode. That is, the fifth or 95th percentile guided the identification of a submode result that would achieve as close to 5% abnormal results as possible.

A clinical reference limit was identified similarly, but using the 50th percentile to guide the identification of the submode score. This clinical reference limit thus identifies the submode score achieved by as close as possible to the worst-performing half of each cohort. Classifications were defined based on direction of scoring for abnormality in each subtest, with higher symptom scores and modified Balance Error Scoring System (mBESS) errors referred to as high and lower cognitive test performances referred to as low.

The research plan for this study was approved by the World Rugby Institutional Ethics committee (REF 19007). Players had provided written informed consent for all data gathered as part of the World Rugby Concussion management program to be used for research in a deidentified manner.

**RESULTS**

A total of 10 754 SCAT assessments (4747 SCAT3 and 6008 SCAT5) were conducted in 6288 men’s players, with 3660 players doing one test, 2628 performing 2 or more baseline SCATs during the sampling period. In women, 1071 SCATs were available, comprising 263 SCAT3s and 808 SCAT5s in a total of 764 players.

Table 1 summarizes the performance in the SCAT5 submodes for men and women. The sample size for each
submode is shown, accounting for the exclusion of SCAT3 assessments for symptoms, and 5-Word lists for immediate memory and delayed recall, since these have been replaced by a 10-Word list after a ceiling effect was found to limit their utility.12,14

On average, women report more symptoms, with higher symptom severity than men, and outperform men in most submodes with the exception of immediate memory and delayed recall, where scores are similar, and Tandem Gait, which men complete faster than women (Table 1). Absolute differences in submode performance are small, but statistically significant, and a greater proportion of women achieve perfect scores (no incorrect answers in cognitive submodes and no balance errors) more frequently than men.

On average, women were more likely to endorse symptoms (2.2 ± 2.3 symptoms in women vs 1.4 ± 2.7 for men, P < 0.001). Consequently, women had a higher symptom severity score (3.5 ± 5.9 vs 2.2 ± 4.7 for women and men, respectively, P < 0.001). Women more frequently reported higher symptom scores, although the proportion of cases where symptoms were assessed at a score of 2 or more (“Moderate” or “Severe” on the 7-point Likert scale) was low, at 1.3% in women, compared with 0.8% for men. The 95th percentile for symptom number and severity in women was 9 and 14, respectively, compared with 7 and 11 in men (Table 1).

Table 2 shows the proportion of men and women who endorsed no symptom, any symptom, and each of the 22 symptoms, while Figure 1 displays the ratio of SCAT5s in which women endorsed each symptom to SCAT5s in which men endorsed each symptom. Symptoms were grouped into physical, cognitive, vestibulo-ocular, and psychological subgroups.

Men were more frequently asymptomatic compared with women (60.7% vs 47.2%, P < 0.001, Table 2). Of the 22 symptoms, 13 were more likely to be endorsed by women, the most common symptoms in women being fatigue or low energy (30.0% women vs 19.4% men), neck pain (20.9% women vs 16.2% men), nervous/anxious (16.7% women vs 9.6% men), and trouble sleeping (15.6% women vs 13.5% men).

Overall, women were 34% more likely to endorse any symptom (Figure 1, M:W symptom ratio = 1.34 (1.25-1.45, P < 0.001), with relative likelihood of reporting a symptom ranging between 1.29 (neck pain) and 2.70 (more emotional) greater for women than men in the symptoms endorsed more in women than in men (Figure 1 and Table 2).

Reference Limits

Table 3 displays the derived baseline reference limits and clinical reference limits in men and women. The baseline reference limits were similar between men and women, with the exception of concentration score (comprised digits backward and months in reverse), tandem gait time, and total balance errors. Clinical reference limits were similar with the exception of total errors made during balance tests.

To explore baseline reference limit differences, Figure 2 shows the proportion of men and women who achieved submode scores at approximately 5% for each of the 3 submodes identified as different and for immediate memory for comparative purposes. For clarity, only one submode score either side of the baseline reference limit is shown.
For final concentration, the baseline reference limit was a score of 2 or fewer, achieved by 6.1% of women, compared with a baseline reference limit of 1 or fewer for men (achieved by 1.8%). More men scored 2 or fewer (9.6%), compared with 1.2% of women’s players scoring 1 or fewer.

Tandem gait time was significantly faster in men (Table 1), resulting in a baseline reference limit of 13s compared with 14s for women. At a limit of 13s, 93.3% of men and 88.8% of women’s baseline limit, with 98.8% of women completing the test in under 14s.

All balance mode errors were fewer in women than in men (Table 1), although a difference in baseline limit implication was found only for total errors, where women would be classified as abnormal at 8 or more errors, compared with 9 or more errors for men. This difference is small, however, with 6.7% of men making 8 or more total balance errors (compared with 5.0% of women) and 4.4% of men making 9 or more errors (Figure 2). Total balance errors were also different at the clinical reference limit (3 or more for men, 2 or more for women). A total of 60.9% of men recorded 2 or more total balance errors, compared with 44.4% at 3 or more balance errors. In women, 53.3% of players made 2 or more balance errors.

**DISCUSSION**

This study compared baseline SCAT performance in large cohorts of professional men’s and women’s rugby players. We find that women endorse more symptoms than men, report symptoms with a higher severity than men, and perform better than men in orientation and concentration, and balance submodes. Differences between women and men are, however, small, resulting in similar baseline reference limits for all submodes with the exception of concentration, tandem gait time, and total balance errors. Clinical reference limits were similar with the exception of total balance errors.

**Symptom Endorsement**

The greater endorsement of baseline symptoms by women, both in number and severity, is consistent with numerous previous studies. One exception is Asken et al., who found no statistically significant differences in symptom severity between men and women using the SCAT3 or the SCAT5 assessment. However, the study included just 94 athletes compared with 6008 men and 808 women in this study. Our work benefits from large cohorts, which results in large statistical power.

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| TABLE 2: Proportion of Mens and Womens Baseline SCAT5s Reporting Each Symptom |
|-----------------------------------------------|
|                  | Men (N = 6008) | Women (N = 808) | P        |
| Asymptomatic     | 60.7%          | 47.2%           | <0.001   |
| Any symptom      | 39.3%          | 52.8%           |          |
| Physical         | 21.2%          | 31.9%           | <0.001   |
| Neck pain        | 16.2%          | 20.9%           | 0.001    |
| Headache         | 7.1%           | 12.9%           | <0.001   |
| Pressure in head | 6.0%           | 11.3%           | <0.001   |
| Nausea or vomiting | 1.7%       | 2.2%            | 0.336    |
| Fatigue or low energy | 19.4%      | 30.0%           | <0.001   |
| Cognitive        | 18.7%          | 23.9%           | 0.002    |
| Don’t feel right | 4.1%           | 4.7%            | 0.403    |
| Difficulty concentrating | 8.6%       | 13.0%           | <0.001   |
| Difficulty remembering | 9.4%        | 15.2%           | <0.001   |
| Confusion        | 2.0%           | 1.5%            | 0.294    |
| Drowsiness       | 6.1%           | 6.6%            | 0.603    |
| Feeling slowed down | 5.7%      | 8.4%            | 0.002    |
| Feeling like in a fog | 1.9%     | 2.8%            | 0.084    |
| Vestibulo-ocular | 11.1%          | 17.9%           | <0.001   |
| Dizziness        | 3.3%           | 4.1%            | 0.267    |
| Blurred vision   | 2.8%           | 3.7%            | 0.162    |
| Balance problems | 4.2%           | 7.3%            | <0.001   |
| Sensitivity to light | 4.6%      | 7.8%            | <0.001   |
| Sensitivity to noise | 2.2%      | 5.0%            | <0.001   |
| Psychological    | 20.9%          | 29.6%           | <0.001   |
| Trouble sleeping | 13.5%          | 15.6%           | 0.099    |
| Nervous/anxious  | 9.6%           | 16.7%           | <0.001   |
| More emotional   | 4.5%           | 12.3%           | <0.001   |
| Irritability     | 5.7%           | 7.5%            | 0.036    |
| Sadness          | 2.8%           | 6.1%            | <0.001   |

Bold text highlights the comparison results that are statistically significant. We highlighted them because we applied a Bonferroni correction, so the value for statistical significance is not the normal 0.05, and highlighted the ones that meet the threshold in bold.
The greater endorsement of symptoms by women has implications for clinical outcomes after concussion. It has been suggested that pre-existing psychological factors may influence the incidence of injury, particularly the severity of persistent symptoms after sports-related concussion and perhaps the incidence of sports-related concussion itself.\(^\text{17}\) Specifically, baseline traits of irritability, sadness, nervousness, and depressive symptoms, which we found to be greater in women (Figure 1 and Table 2), predisposed athletes to worse symptomology after concussions.\(^\text{17,18}\) It has also been found that women report more symptoms and perform worse in neurocognitive tasks after concussion\(^\text{19-21}\) and suffer greater time loss than sports-matched men after concussion.\(^\text{22}\)

Postulated reasons for these greater adverse outcomes in women include reporting behaviors and social norms,\(^\text{21}\) and attitude differences toward concussion that lead men to disclose concussions less often.\(^\text{23}\) These include not wanting to be kept out of practice or matches, not wanting to let teammates and coaches down, and minimization of the seriousness of injury, possibly the result of lack of understanding.\(^\text{23}\) This study assesses symptoms at baseline, rather than after concussion, but the same factors may be present during annual medical assessments, in which players may downplay symptoms they fear will negatively affect their prioritized participation in the future, resulting in the lower symptom endorsement we describe among men.

With respect to management, World Rugby recommends that the team doctor reviews all symptoms endorsed at baseline. If these are confirmed as “trait” symptoms, their cause should be investigated. Physical symptoms may have an underlying orthopaedic cause. Psychological symptoms may indicate an underlying affective disorder, and doctors are directed to the World Rugby online screening resource in the Player welfare site.

### Cognitive and Balance Submode Performances

Our second finding was that women outperform men in cognitive submodes with the exception of immediate memory and delayed recall, and in the mBESS submodes, making fewer errors. This too confirms previous research, although these previous studies have largely focused on collegiate and high school women athletes.\(^\text{9,12,13}\) The specific reasons for these differences are not clear but may be related to years of education, innate differences between women and men, and possibly language differences between the men’s and women’s groups. Unfortunately, we cannot account for these differences because the HIA database does not identify the potential characteristics that may influence cognitive and balance performance.

### TABLE 3. Baseline and Clinical Reference Limits for Men and Women

| Submode | Men | Women | Men | Women |
|---------|-----|-------|-----|-------|
| **Baseline Limit, 5%, During Baseline Testing** | | | | |
| **Men** | **Women** | **Men** | **Women** |
| Cognitive submodes | | | | |
| Orientation | 3 or fewer correct answers | 3 or fewer correct answers | All correct answers | All correct answers |
| Immediate memory | 15 or fewer correct answers | 15 or fewer correct answers | 21 or fewer correct answers | 21 or fewer correct answers |
| Delayed recall | 3 or fewer correct answers | 3 or fewer correct answers | 7 or fewer correct answers | 7 or fewer correct answers |
| Digits backward | 1 or fewer correct answers | 1 or fewer correct answers | 3 or fewer correct answers | 3 or fewer correct answers |
| Concentration | 1 or fewer correct answers | 2 or fewer correct answers | 4 or fewer correct answers | 4 or fewer correct answers |
| Balance submodes | | | | |
| Tandem gait | 13 s or slower | 14 s or slower | 11 s or slower | 11 s or slower |
| Double-leg balance | 1 or more errors | 1 or more errors | None | None |
| Single-leg balance | 6 or more errors | 6 or more errors | 2 or more errors | 2 or more errors |
| Tandem stance balance | 4 or more errors | 4 or more errors | None | None |
| Total balance | 9 or more errors | 8 or more errors | 3 or more errors | 2 or more errors |

Baseline reference limits indicate a submode that requires repeat testing at baseline and correspond to the submode score achieved by the worst-performing 5% of the population. Clinical reference limits indicate abnormal submode results during clinical settings and correspond to the worst-performing 50% of the cohort.
Reference Limits

Baseline Reference Limits

Baseline reference limits are set at the submode score achieved by the worst-performing 5% of the cohort. Effectively, this corresponds to a submode score between unusually low and extremely low using the Wechsler classification. We find that despite the better performance of women than men in most submodes, there was no impact on the baseline reference limits method we have proposed to identify abnormal baseline screens, with 3 exceptions—concentration, tandem gait, and total balance errors (Table 3). This is the result of the small size of the differences we find between men and women, which are unlikely to affect normative ranges, or cause an error in determining when a concussion has occurred, particularly given that the repeatability and inter-rater reliability of balance errors has been found to be quite low.

For final concentration, however, the difference between men and women did result in a difference in the baseline reference limit. The baseline limit for men was 1 or fewer correct answers, compared with 2 or fewer correct in women. When men and women are combined, the baseline reference limit for the entire professional rugby playing population is 2 or fewer correct answers. This is to some extent an artifact of the method used, which identifies the reference limit as the submode performance that is achieved by as close to 5% of the entire cohort as possible. For concentration, a relatively large change from 1 or fewer to 2 or fewer correct answers, as illustrated in Figure 2, results in a reference limit at a score of “1 or fewer,” achieved by 1.8% of men, rather than at 9.6% achieved by “2 or fewer.” Given the non-normal distribution of concentration performance (Table 1), this may not warrant the application of difference baseline limits for men and women, and it may be prudent to set a limit of 2 or fewer
correct answers for both men and women, although this would result in 9.6% of men being deemed abnormal and requiring repeated baseline testing (Figure 2). Tandem gait time was significantly faster in men, sufficient that the 5% limit for men was set at slower than 13s and for women at slower than 14s (Table 3). The reasons for this performance difference are unknown, although the opposite finding for balance errors, where women make fewer errors than men (Table 1), suggests that a direct balance reason is not responsible. The difference may relate to foot size, where the larger average man’s foot size reduces the number of steps required to complete the test.

Clinical Reference Limits

Clinical reference limits are to be applied during clinical screens at HIA1, HIA2, and HIA3. We propose that the reference limit for these settings be more challenging than for repeating baseline screens and thus identify as the submode score that is achieved by the worst-performing 50% of the cohort. This more stringent clinical limit will ensure that false negatives during diagnostic screens are minimized. We do recognize that this is likely to increase the number of false positives, but we suggest that this would be in line with a conservative approach to concussion management and also believe it will create incentives for teams to conduct baseline testing on players, as is stipulated by World Rugby’s participation guidelines. We have found that only total errors differ between men and women. This is true for both baseline reference limits and clinical reference limits and is the result of the improved balance performances observed in women (Table 1).

Limitations

In each cohort, given the size and global nature of the sample, there exists a wide spread of education level, ages, languages, and ethnic differences. It has previously been found that language and racial/ethnic differences do significantly impact on recall during immediate memory and delayed recall tests12 and symptom endorsement,16 and these may have implications for concussion assessment.12 Similarly, age has been found to influence cognitive performance and symptom11,13 while fitness affects symptom endorsement26 and existing psychological conditions such as depression affect memory and symptoms.11 Unfortunately, we cannot yet categorize the players in our cohorts into these groups, which would allow us to explore such differences in a larger cohort than has been investigated before. It is thus a recognized limitation that our men’s and women’s groups may differ with respect to native English speakers, ethnic groups, age, fitness, and educational background.

CONCLUSIONS

At baseline, Elite women rugby players endorse more symptoms, with greater symptom severity, than elite men players. Orientation, concentration, and balance scores are also higher in women compared with men during baseline assessment. These differences are small and do not impact significantly on the baseline or clinical reference limits we propose to guide return-to-play decisions and identify abnormal submode performances during baseline and diagnostic screens, with the exception of concentration, tandem gait, and total balance errors. The differences between women and men for symptom report and cognitive performance, both at baseline as documented in this study and postconcussion as described in previous research, means that women may have increased risk of concussion and worse concussion outcomes. This further emphasizes the importance of an accurate and valid baseline assessment, focusing in particular on symptoms, and any underlying causes for them.

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