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RESEARCH ARTICLE

Examining the Effects of Exercise and Practice on the SCAT3, and Association between Mood, Pain & SCAT3 Symptom Report

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Abstract

Objective: To examine the influence of exercise and practice on the Sport Concussion Assessment Tool 3 (SCAT3) and King-Devick (KD), and the association between mood, pain and SCAT3 symptom report.

Design: Crossover repeated-measures design across two time periods (T1 & T2).

Setting: Community.

Participants: 16 male and 14 female (M*age* = 22.7 years, SD*age* = 3.6) moderately active non-contact sports athletes, randomly allocated to two groups.

Interventions: An exercise protocol, consisting of five minutes each of skipping and running, was administered at T1 or T2: Group 1 (T1 Exercise present → T2 Exercise absent) and Group 2 (T1 Exercise absent → T2 Exercise present).

Main outcome measures: SCAT3 and KD.

Results: Exercise did not influence SCAT3 or KD performance. Practice effects were shown on the KD [44.8 (7.4) vs. 41.2 (6.1), $P = 0.001$] but not on SCAT3 cognitive or physical assessments. Mood was positively correlated with symptom reporting, explaining 18.6% of the variance in SCAT3 symptom severity at T1 and 21.2% at T2. Most frequently reported symptoms were 'fatigue or low energy', 'feeling slowed down', 'difficulty concentrating' and 'nervous or anxious'. Pain showed no correlation with symptom reporting.

Conclusions: Study assists in validating the SCAT3 and KD as sideline assessments by demonstrating a level of robustness to the effects of exercise and practice. Findings suggest caution is needed when interpreting the SCAT3 in athletes with mood disturbance. This study highlights the need for further research into potential modifiers of SCAT3 performance, specifically mood disturbance.

Keywords

Concussion, SCAT3, King-Devick, Modifiers, Non-contact, Non-concussed

Introduction

In the field of sports medicine, concussions can be one of the most complex and difficult injuries to diagnose, assess and manage [1]. This is due to the signs and symptoms often being subtle, varied and non-specific with only 10% of sport-related concussions resulting in a loss of consciousness [2]. A multidimensional assessment model which encompasses the athlete's concussion history, presenting symptoms, cognitive capability, balance, comorbidities or other complicating factors has been suggested as best-practice [3]. The Sports Concussion Assessment Tool, 3rd Edition (SCAT3) has been recommended internationally as the optimal sideline sports concussion assessment tool [4]. The SCAT is designed to augment clinical decision making regarding a diagnosis of concussion [5]. Whilst the instrument can be scored, there are no existing cut-off points to determine the presence/absence of a concussion [6,7], instead post-injury performance is typically compared to pre-season performance. Therefore, knowledge of likely "other" potential modifiers of SCAT performance (e.g. exercise, practice effects) is critical in improving the reliability of clinical decision making [8,9].

Individuals without a history of concussion have been demonstrated to endorse symptoms on post-

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concussive symptom evaluations including fatigue or low energy, drowsiness and difficulty concentrating and remembering [10]. These findings highlight the potential for confounding lifestyle and individual factors to influence the diagnosis of concussions in healthy individuals [11].

Exercise has been shown to increase the reporting of post-concussive symptomology, with symptoms appearing to decline and subside following several minutes of rest [12]. Exercise has been shown to have no influence on the Standardized Assessment of Concussion (SAC) [13], however a study administering the 'Immediate Post-Concussion Assessment and Cognitive Testing' suggested exercise may result in declines in recall ability [14]. Preliminary findings suggested the physical assessment, the modified Balance Error Scoring System (mBess), is influenced by exercise [15], however limited research exists in this area. Whilst the effects of exercise on SCAT3 performance are uncertain, it has been proposed that prescribing a rest period prior to conducting SCAT3 examinations should allow for immediate exercise effects to subside [14].

The SCAT3 endeavours to control for practice effects through the option of alternate word and digit lists [16] however, the possibility for serial practice effects still exists in the likelihood that previous exposure to an activity develops cues that influence performance [17]. Improved performance has been seen following repeat administration of the SCAT3 'tandem gait' physical assessment [18]. The existence of practice effects in the mBESS is yet to be examined, however practice effects can be seen across serial administration of the original BESS [19,20]. Conversely, the cognitive assessment administered in the SCAT3, the SAC, has demonstrated robustness to practice effects across serial administrations [19-21]. Clarification is crucial given some have suggested that rather than a performance decrement being associated with a concussion, it may be that a concussive injury manifests as a lack of expected practice effects on certain measures [22].

Previous research has demonstrated the potential for pre-existing mood disturbance to impact on sideline assessment results [23-25]. Pain has also been linked to higher symptom reporting on post-concussive symptom evaluations [8,26]. These complex, multidimensional issues highlight the need to screen and control for mood and pain factors prior to conducting sideline assessments.

It has been suggested that contact sports athletes may intentionally perform lower at baseline testing to "mask" performance declines associated with concussive injuries or underreport concussion symptoms to remain on the sporting field and in play [27-29]. Through the recruitment of a non-contact athlete sample, participants in the present study had no such motives influencing their performance. Additionally, to the best of our knowledge our study is the first to examine exercise and practice effects, as well as the potential influence of mood and pain on SCAT performance in one comprehensive study, and few to date have included female athletes [30]. Normative data is needed given female athletes may be at higher risk of sustaining a concussion during play than male athletes [31], with current findings suggesting females tend to report greater rates of concussion symptomatology following a suspected concussive injury [32].

The KD has been found to compliment sideline assessments [33] and when used alongside the SCAT, has assisted in identifying cognitive impairments in athletes without clinically observable symptoms [34]. Time taken to complete the KD has been shown to reduce with practice and as such, an increase in the time taken to complete the KD indicates potential impairment [35].

Objectives

In light of the research gaps identified, this study will address three key aims: (1) Establish whether exercise influences the reporting of post-concussion symptoms, and/or cognitive or physical performance on the SCAT3 and KD in non-concussed athletes; (2) Determine whether practice effects on the cognitive components of the SCAT3 are seen in the administration across time periods; and (3) Examine whether a relationship exists between pain, mood disturbance and the reporting of symptoms on the SCAT3.

It is hypothesised that: (1) Following 15-minutes rest, exercise will not significantly influence SCAT3 performance or KD time; (2) Improved SCAT3 cognitive and physical performance, and reduced KD time from T1 to T2 will be demonstrated with practice; and (3) There will be an association between mood, pain severity and symptom reporting on the SCAT3.

Method

Participants

Participants were recruited via advertisements placed on an online site and posters displayed at sporting facilities. The sample consisted of 30 non-contact sports athletes engaged in at least 2-3 days of exercise per week at a moderate-to-high intensity (60%-80% of maximum heart rate). Participants did not participate in contact or collision sports and were excluded if they had sustained a concussion in the previous twelve months.

Materials

Demographics*:* Demographic information collected included: age, gender, education level, ethnicity and self-reported concussion history. The Advanced Clinical Solutions Test of Premorbid Functioning (TOPF) was administered to estimate the intellectual functioning of participants.

Sideline assessment: The SCAT3 was administered using the iPad delivered X2 Interactive Concussion Examination, or X2 ICE® (Version 3.2.18), an iOS-based software.

The SCAT3 self-report Symptom Evaluation was used to ascertain the severity of 22 post-concussive symptom scores for the present study (0-132; higher score = greater symptom severity). The SAC was used to assess four components of participant's cognitive ability (orientation, immediate recall, concentration and delayed recall). The SAC alternate word and number lists were used at T2, to reduce potential practice effects. Physical components consisted of mBESS and Tandem Gait task. The remaining domains (Glasgow Coma Scale, Maddocks Score and neck and coordination examination) were excluded given the present study was interested in a 'healthy' non-concussed sample and as such assessments were redundant. The KD was used to assess saccadic eye movement.

Mood disturbance: Symptoms of depression, anxiety and stress were measured using the Depression, Anxiety and Stress scale short-form (DASS21). Higher total scores are indicative of greater levels of mood disturbance.

Orthopaedic pain: Higher scores on the Brief Pain Inventory (BPI) reflect greater levels of pain.

Exercise risk: The Physical Activity Readiness Questionnaire (PARQ) was administered to mitigate the risk of adverse reactions occurring during the exercise protocol.

Exercise intensity: The Borg Rate of Perceived Exertion scale (BorgPRE) was used to measure participant perceived level of exertion pre- and post- the exercise protocol.

A Garmin HR monitor provided an objective measure to ensure participants remained within a moderate-to-high training zone.

Design

A crossover repeated measures (T1 and T2 four weeks apart) design allowed for the present study to investigate exercise and practice effects in the same cohort of participants. A random number generator assigned 30 participants to either Group 1 (T1 Exercise present → T2 Exercise absent) or Group 2 (T1 Exercise absent → T2 Exercise present).

Procedure

Testing was conducted at a mutually convenient community location for each participant (e.g. local football oval). Participants self-reported the number of hours' sleep had the night before as well as alcohol and drug consumption over the preceding 24 hours. Participants also completed the TOPF at T1.

When participating in the exercise protocol, participants were asked to rate their level of perceived exertion according to the BorgRPE before engaging in exercise (see Figure 1). They were requested to remain within aged determined training zones throughout the duration of exercise.

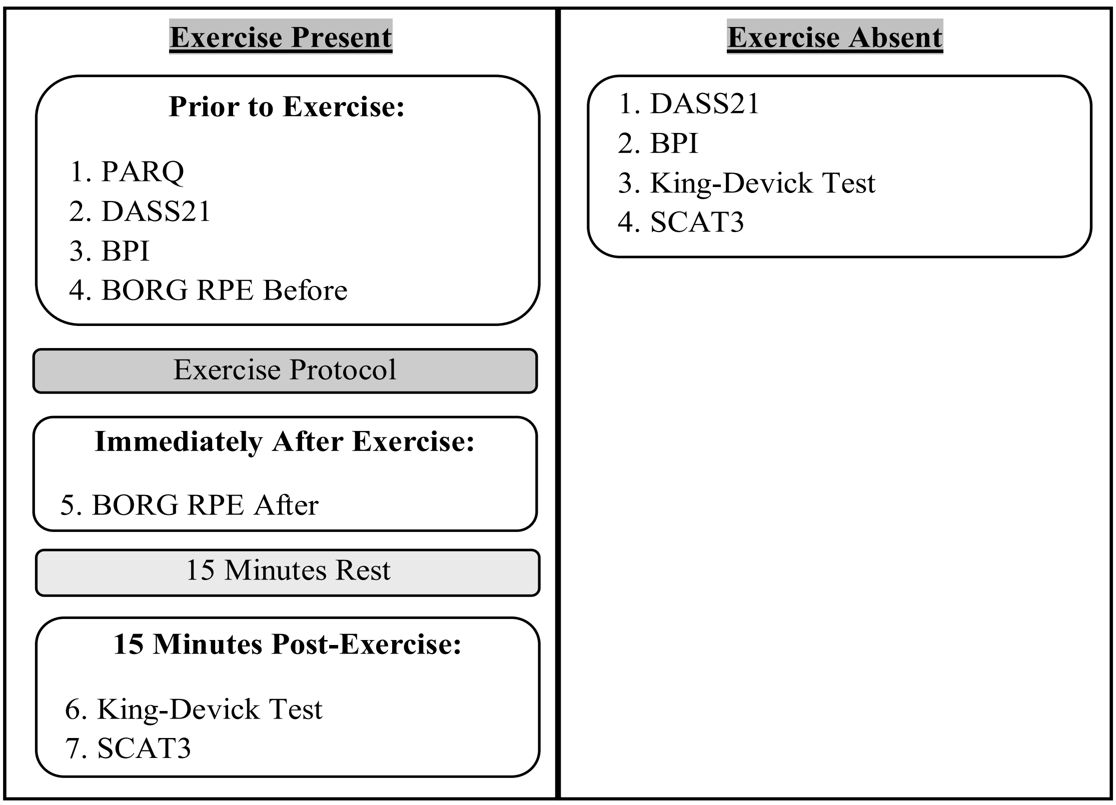

Figure 1: Diagram displaying the test administration order based on the presence or absence of exercise.

The exercise component consisted of five minutes of rope skipping followed by five minutes of running. No rest was allowed between activities. Immediately after exercise, participants competed the BorgRPE, and were required to rest for 15-minutes before conducting KD and SCAT3 testing.

Results

Participant demographics

Participants consisted of males (53%) and females (47%) with a mean age of 22.7 (3.7) years. Ethnicity was Caucasian (63%); Aboriginal and/or Torres Strait Islander (23%); Asian (14%). Eighty-six percent had a tertiary education and mean estimated FSIQ was 115.13 (5.7). Seventy-three percent reported no previous history of concussion. A paired samples t-test revealed no significant difference between participants sleep the night before T1 and T2 assessments, t (29) = 0.68, p = 0.50. A two-way chi-square revealed no significant difference across time points on participants self-reporting of alcohol use, x^2 (1, N = 60) = 0.10, p = 0.75, Cramer's V = 0.04. No participants reported drug use.

Influence of exercise

Participants were working at approximately 78% of their maximum heart rate (M = 154.2 (18.5)). Exercise intensity increased on average by 7.4 points when comparing the BorgRPE before exercise (M = 7.3 (1.9)) to after exercise (M = 14.7 (2.0)), indicating participants were working in the desired training zone.

Four one-way repeated measures ANOVAs were conducted to examine whether the presence of exercise influenced the reporting of severity of post-concussive symptoms, SAC total score, mBESS score or Tandem Gait performance on the SCAT3, and KD. No significant influence of exercise on SCAT3 or KD performance was found across the domains investigated (see Table 1). Results suggest exercise has no significant influence on the mean scores of the SCAT3 or KD.

Influence of practice

Three one-way repeated measures ANOVAs were conducted to explore practice effects from T1 to T2. No significant influence of practice was found on the three components of the SCAT3 assessed (see Table 2).

Table 1: Descriptive and inferential statistics for SCAT3 and King-Devick for Exercise absent and present.

Variable	Exercise Absent, M (*SD*)	Exercise Present, M (*SD*)	*F*	*p*-value
Post-Concussive Symptom Severity	04.63 (*6.09*)	5.00 (*5.80*)	0.08	0.79
SAC Total Score	27.33 (*1.52*)	27.20 (*1.85*)	0.12	0.73
MBESS Score	03.07 (*2.94*)	3.30 (*2.78*)	0.34	0.56
Tandem Gait*	12.58 (*1.52*)	12.65 (*1.64*)	0.06	0.80
King-Devick Test 1	14.36 (*2.60*)	14.03 (*2.41*)	1.28	0.27
King-Devick Test 2	14.21 (*2.18*)	13.94 (*2.51*)	0.88	0.36
King-Devick Test 3	15.09 (*2.60*)	15.10 (*2.15*)	0.00	0.99
King-Devick Overall	43.66 (*7.03*)	43.07 (*6.79*)	0.64	0.43

N = 30, **N* = 25.

Table 2: Descriptive and inferential statistics for SCAT3 and King-Devick at T1 and T2.

Variable	*N*	Time 1, M (*SD*)	Time 2, M (*SD*)	*F*-statistic	*p*-value	η_p^2
SAC Total Score	30	27.00 (*1.78*)	27.53 (*1.55*)	2.07	0.16	
Orientation		4.90 (*0.31*)	4.67 (*0.48*)			
Immediate Recall		14.43 (*0.78*)	14.73 (*0.58*)			
Digit Backwards		2.90 (*0.92*)	3.07 (*0.94*)			
Months Reversed		0.83 (*0.38*)	0.90 (*0.31*)			
Delayed Recall		3.80 (*1.13*)	4.17 (*1.02*)			
SAC Total Score^	30	26.03 (*1.79*)	26.87 (*1.43*)	5.39	0.03	0.15
MBESS Score	30	3.47 (*2.65*)	2.90 (*3.03*)	2.13	0.16	
Tandem Gait	25	12.83 (*1.30*)	12.40 (*1.79*)	2.22	0.15	
King-Devick Test 1	30	14.64 (*2.80*)	13.76 (*2.10*)	12.41	< 0.00	0.30
King-Devick Test 2	30	14.54 (*2.52*)	13.62 (*2.07*)	15.01	< 0.00	0.34
King-Devick Test 3	30	15.57 (*2.45*)	14.61 (*2.21*)	11.42	< 0.00	0.28
King-Devick Overall	30	44.75 (*7.39*)	41.99 (*6.10*)	24.87	< 0.00	0.46

^ = Orientation date item excluded.

Further analysis of individual SAC components revealed that at T2 a third of participants were unable to correctly answer the Orientation question "what is the date today?" As such, the ANOVA was run again excluding the 'date' question. When excluded, there was a trend towards an improvement on overall SAC performance from T1 to T2 with participants scoring an average of 0.84 points higher at T2. There was some indication that practice improved performance on the cognitive component of the SCAT3, however, this did not withstand Bonferroni corrections.

Four one-way repeated measures ANOVAs were undertaken to examine the influence of practice on KD performance. A significant influence of practice on KD performance was evident in that participants were faster to complete the tasks at T2.

Association between mood disturbance, pain and symptom reporting

Whilst approximately 80% of participants indicated normal mood or mild levels of mood disturbance across sub categories, 7 (T1) -17 (T2) % did report moderate-severe mood disturbance. To examine the association between mood disturbance, pain and SCAT3 symptom reporting, two linear regression analyses were undertaken.

At T1 participants' average SCAT3 symptom severity score was M = 5.2 (6.5), with the most commonly endorsed symptoms being 'fatigue or low energy' (57%), 'feeling slowed down' (23%) and 'nervous or anxious' (23%). Furthermore, at T1 participants recorded an average BPI score of M = 0.4 (0.7) and a DASS21 total score of M = 17.4 (12.2). The linear regression model at T1 was significant, $R = 0.51$, $R^2 = 0.26$, F (2,29) = 4.81, $p = 0.02$. The Pearson's r correlation showed a weak non-significant correlation between the BPI score and SCAT3 symptom severity score, $r = 0.203$. Conversely, as can been seen in Figure 2, a significant moderate correlation was found between the DASS21 total score and SCAT3 symptom severity score, $r = 0.432$. This finding suggests at T1, 18.6% of the variance in SCAT3 symptom severity can be explained by the level of mood disturbance on the DASS21.

At T2 participants average SCAT3 symptom severity score was M = 4.4 (5.4), with 'fatigue or low energy' (50%), 'difficulty concentrating' (27%) and 'nervous or anxious' (23%) the most commonly endorsed symptoms. Furthermore, at T2 participants recorded an average BPI score of M = 0.7 (0.9) and DASS21 total score of M = 18.5 (18.1). The linear regression model at T2 was significant, $R = 0.47$, $R^2 = 0.22$, F (2,29) = 3.84, $p = 0.03$. Consistent with the pattern evident at T1, a Pearson's r correlation showed a weak non-significant correlation between the BPI score and SCAT3 symptom severity score, $r = 0.226$. As can been seen in Figure 3, a significant moderate correlation was again found between the DASS21 total score and SCAT3 symptom severity score, $r = 0.460$. Suggesting at T2, 21.2% of the

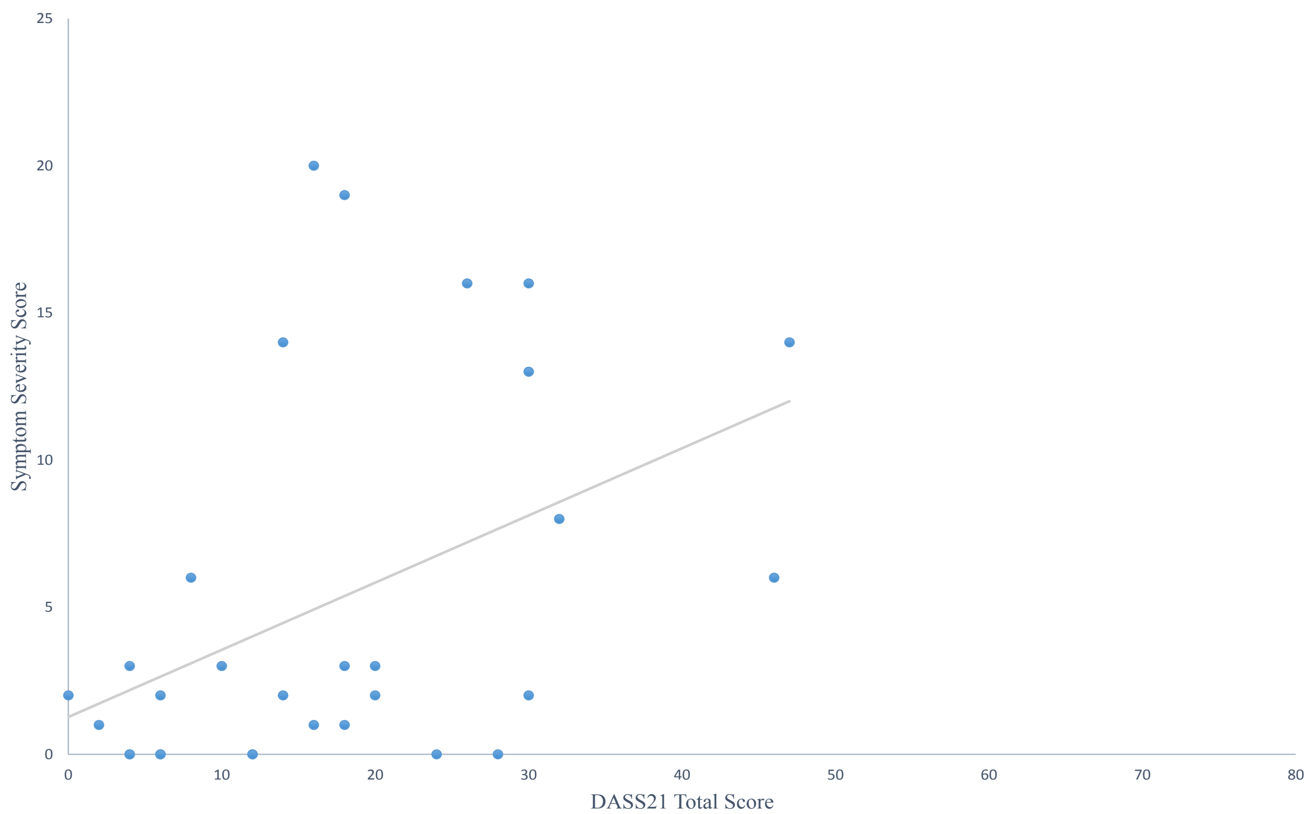

Figure 2: Distribution of data depicting the association between SCAT3 Symptom Severity Score and DASS21 Total score at Time 1.

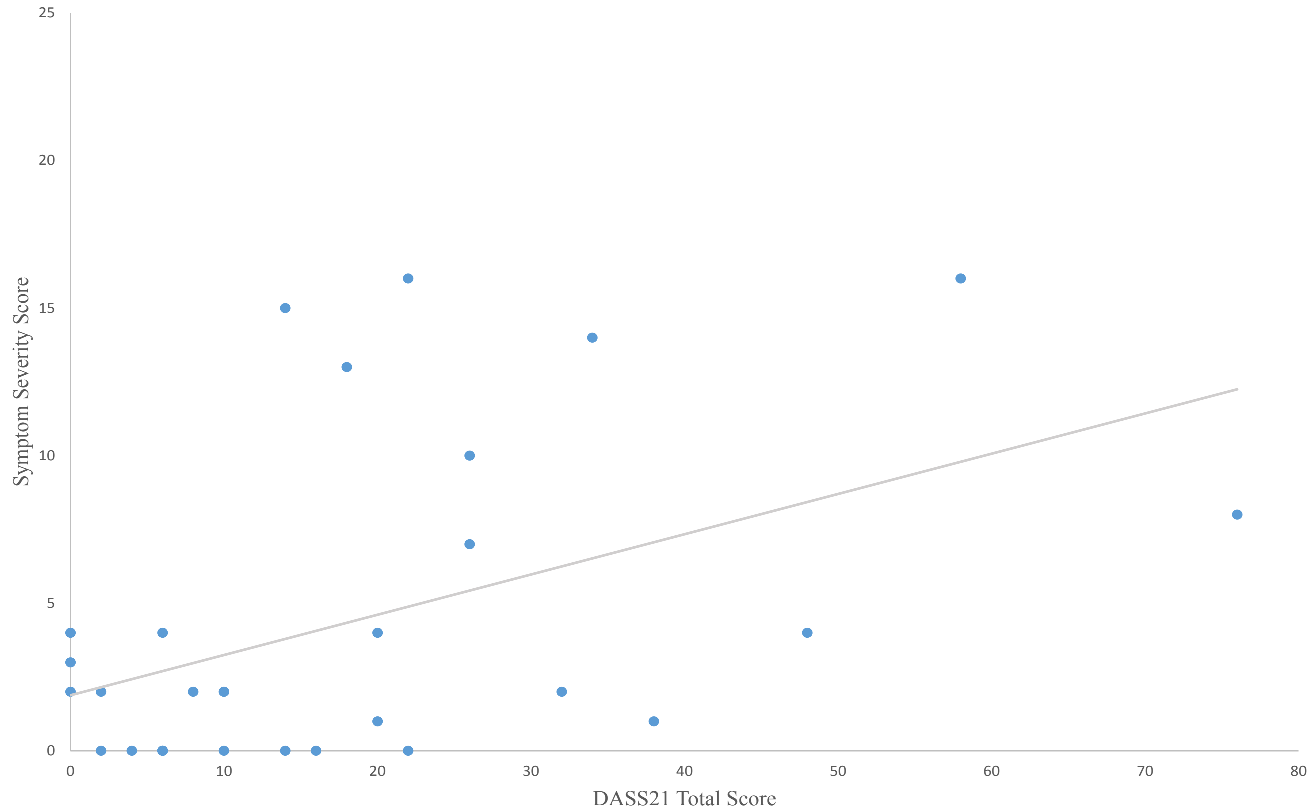

Figure 3: Distribution of data depicting the association between SCAT3 Symptom Severity Score and DASS21 Total score at Time 2.

variance in SCAT3 symptom severity could be explained by the level of mood disturbance on the DASS21.

Discussion

To the best of our knowledge, this study was unique in utilizing a crossover repeated measures design to test the effects of exercise and practice across multiple components of the SCAT3, across two time periods and including both male and female participants.

Results indicated that following 15-minutes of rest, exercise did not influence symptom reporting, cognitive or physical performance on the SCAT3 or KD. In line with previous research, our findings suggest that the acute effects of exercise on concussive screening assessments diminish following a brief period of rest [12,14,36]. Generalisation of these findings is partially limited however, given the current study did not assess symptom reporting immediately after exercise. As such, it is difficult to determine whether the exercise protocol would have provoked post-concussive symptoms without the period of rest. Comparison with a cohort who complete the assessments immediately after exercise, without rest, would be recommended for future studies.

Whilst performance on the overall cognitive and physical assessments appeared to improve, with practice, it was not significant. The absence of practice effects across two administrations of the SCAT3 cognitive assessment in the current study does not reflect the notion put forward by Echemendia, et al. [22] who suggested that an absence of practice effects is potentially indicative of impairment associated with concussion, although this may in fact be the case for individual athletes. It is however possible that multiple serial administrations across an entire season (> 2) may be associated with practice effects. Further research is needed to determine the length of time between administrations of assessments for which practice effects will prevail. The present study demonstrated that one month between assessments reduced the likelihood of practice influencing results, however, throughout the sporting season there may not be as much time between repeat assessments. Given that athletes in play may be suspected of sustaining more than one concussion across a season, it is important for research to improve understanding on how practice effects can be controlled for and the length of time it is likely to remain an issue of assessment.

One third of our non-concussed participants were unable to correctly state the date at T2. Given such finding, future research should further examine and critique the inclusion of the 'date' question. Ponsford, et al. [37] reported similar findings (i.e. inability to recall date) when examining a mild head injury assessment tool in a healthy control sample. Removal of the item resulted in a significant improvement in the validity and reliability of the assessment. As such, the present study draws attention to the need to determine if the inability to correctly answer such a question is predictive of cognitive impairment or a concussive injury, or is a common finding in the general population.

Our study is the first to examine the influence of practice on the mBESS. The study's preliminary findings suggest that the mBESS and tandem gait appear to be robust against the influence of practice effects. Previous findings which suggested repeat administration on the same day is likely to result in learning effects [18], suggest that timing is an important determinant.

The present study found a significant decrease in KD time on all three subtests and subsequently on the overall test time, thus further supporting the notion that an increase in the time taken to complete the KD indicates potential impairment [35]. As such, the present study adds to validating the KD as a reliable sideline screening assessment.

Finally, this study found higher levels of mood disturbance were associated with an increase in post-concussive symptom reporting. This highlights the need for clinicians to collect additional data on individual life factors, which may influence assessment on the day. Clinicians' failure to collect such information may result in mood disturbance not related to the injury itself, driving false positive results when screening for concussions. The study also found no association between pain and SCAT3 symptom reporting. A possible explanation for this is a potential floor effect. Given the level of pain reported by participants was minimal to no pain at all, the measure used may not have been sensitive enough to detect whether a positive association exists between pain and increased symptom reporting.

Additionally, the study's methodology was restricted in its ability to ensure that no participants had sustained a concussion in the 12 months prior to their participation in the study, Makdissi, et al. [38] assert that self-reporting of concussion history is only an estimate and consequently may reduce the integrity of findings.

These findings are beneficial in supporting changes seen in the development of the SCAT5 [6]. The revised SCAT5 asks athletes to rate what percentage they are feeling out of 100% and provide a justification if they are not feeling 100%. This development allows clinicians to better gauge the symptoms reported and potential modifiers that may be implicating results. The SCAT5 also introduced additional alternate word and digits backwards lists with the added possibility of a 10-word immediate memory recall test, with a view to reducing ceiling effects.

Limitations

The present study aimed to determine whether effects of exercise were present following the prescribed period of rest prior to test administration as outlined in the SCAT3 & KD instructions, however the methodology did not allow of assessment of such potential effects immediately following an exercise protocol in which performance decrement may be more likely to manifest. Concussion history has been noted as a potential modifier of baseline testing performance, and whilst the current methodology attempted to control for this by excluding participants with a history of concussion in the preceding 12 months, this was reliant upon self-report. The length of time between assessment administrations resulting in practice effects remains to be elucidated as the one month timeframe in the present study may not reflect common practice and is likely to differ across sporting codes with variable concussion incidence rates.

Conclusion

Failure to determine the correct protocols for clinicians to follow when diagnosing and managing concussions on the sporting sideline may see premature return to play by concussed athletes [12]. This study advanced the current understanding of the SCAT3 symptom reporting, cognitive assessment and physical assessment and KD by demonstrating a level of robustness to the effects of exercise and practice. Our findings highlight the need for further research into potential modifiers of these concussion assessment tools which may contribute to profile variability.

Contributions

Authors Paxton & Willmott were involved in the study development and design, overall project oversight, data collection and analysis, preparation of the manuscript for publication, and dissemination of findings.

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