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Arts et Métiers Institute of Technology

What Is the Impact of Physical Effort on the Diagnosis of Concussion?

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Abstract

Objective: Sport-related concussion commonly occurs in contact sports such as rugby. To date, diagnosis is based on the realization of clinical tests conducted pitch-side. Yet, the potential effect of prior physical effort on the results of these tests remains poorly understood. The purpose of this study was to determine whether preceding physical effort can influence the outcome of concussion assessments. **Design:** Prospective observational study. **Setting:** University Medicine Center. **Patients:** A cohort of 40 subjects (20 rugby players and 20 athletes from a range of sports). **Intervention:** A concussion assessment was performed immediately after physical activity. After a period of 6 months and under the same experimental conditions, the same cohort performed the same tests in resting conditions. **Main outcome Measures:** Results of concussion tests. **Results:** In both cohorts, the comparison for postexercise and rest assessments demonstrated a *most likely moderate-to-very large* increase in the number of symptoms, severity of symptoms, and balance error scoring system score. In the rugby cohort, scores for concentration, delayed memory and standardized assessment of concussion (SAC), *likely-to-most likely* decreased following completion of physical activity compared with baseline values. The between-cohort comparison reported a most likely greater impact after exercise in the rugby players for delayed recall (0.73 ± 0.61) and SAC score (0.75 ± 0.41). **Conclusions:** Physical activity altered the results of concussion diagnostic tests in athletes from a range of sports and notably in rugby players. Therefore, physical efforts before the concussion incident should be accounted for during pitch-side assessments and particularly during rugby competition and training.

Key Words: concussion, physical exertion, SCAT, HIA, rugby

INTRODUCTION

Concussion is a traumatic condition that has received much attention in medical literature in recent years and particularly in the sport of rugby.[1] It is defined as "trauma resulting in the rapid onset of short-lived impairment of neurological function that resolves spontaneously."[2] Signs of concussion observed in the acute phase indicate a brain dysfunction that in general recovers spontaneously within a few days. However, traumas can occur repeatedly over the course of a player's career. The occurrence of a second concussive event within a short time period can lead to second impact syndrome (SIS), which is due to incomplete recovery after the first concussion. Despite occurring only rarely, SIS can prove fatal.[3] Over a longer period, the accumulation of concussion incidents may lead to disabling pathologies such as prolonged postconcussive syndrome[4,5] and/or neurodegenerative disorders.[6]

These concerns have prompted international sports governing bodies to adopt guidelines based on expert-based consensus.[2] These expert recommendations first emphasize the importance of not disregarding the risk that a concussive event might have occurred while proposing a battery of clinical tests to aid pitch-side diagnosis immediately after an event. These procedures aim to reduce the risk that a player who is concussed continues to compete. This battery of tests, known as the Sport Concussion Assessment Tool (SCAT) was proposed in its first version in 2005.[7] Regarding the sport of rugby, the protocol is broken down into a 3-stage diagnostic process known as the Head Injury Assessment (HIA). According to Raftery: "this 3-stage process was introduced, recognising that concussion has […] evolving symptoms."[8] If a concussion event is confirmed pitch-side using the HIA first stage (HIA1), the player is immediately and permanently removed from play. In the case of normal HIA1, the athlete is allowed to go back to the field, but 2 additional assessments are required: at 3 hours after the accident (HIA2) and at 48 hours (HIA3). In an international rugby tournament, 18.3% of concussion events were diagnosed only by this delayed assessment.[9]

The HIA1 is a 10-minute off-field assessment tool used when a player has potentially incurred a head injury and for which the immediate diagnosis is unclear.[10] The assessment includes several tests from the SCAT battery (Table 1). The results derived from these tests are compared with those from a preseason baseline assessment conducted away from

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TABLE 1. Battery of Tests Employed in the HIA and SCAT Protocol

Test	Protocol	
	HIA1	SCAT
Maddocks score	X	X
No. of symptoms	X	X
Gravity score of symptoms		X
BESS		X
Tandem gait assessment	X	X
Finger-to-nose test (coordination)		X
SAC	Only immediate and delay recall + digit backward	X

BESS, Balance Error Scoring System; HIA, Head Injury Assessment; HIA1, Head Injury Assessment first stage; SAC, Standardized Assessment of Concussion; SCAT, Sport Concussion Assessment Tool.

any concussion episode. Since the publication of the first concussion-specific diagnosis tool proposed by McCrea et al,[11,12] it is recommended that this baseline assessment is performed immediately after physical effort to imitate in-competition conditions occurring before assessment. However, to our knowledge, there is no study that has investigated the potential impact of prior physical exertion on the entire HIA1 diagnostic protocol.

The main objective of this study is to determine if results derived from the HIA1 assessment are affected by physical exertion outside of any concussion event in both rugby players and other sports participants. Secondary objectives are to evaluate the effects of physical fatigue on the entire SCAT diagnostic battery and determine whether differences exist in the results of these tests between a high-risk group (rugby players) and athletes from other sports.

METHODS

Design

This prospective observational study investigated the effects of physical exertion on the diagnosis of concussion in a cohort of male athletes from a range of sports. The sample cohort included 40 athletes who were assessed individually on 2 occasions: (1) participants performed diagnostic concussion tests immediately after exercise commonly involving strenuous physical effort; (2) they then performed the same tests in resting conditions outside of any physical activities. This second assessment was conducted 6 months after the initial one under the same experimental conditions (time and location). For each clinical test the postexercise and resting values were compared.

Inclusion and Exclusion Criteria

The cohort included male athletes between the ages of 20 and 40 inclusive (mean age: 31.5 SD 4.1 years). Athletes were divided into 2 groups according to their sport: group 1 (rugby) consisting of 20 amateur rugby players (national standard) and group 2 consisting of 20 participants (other sports) regularly performing sports activities (at least 3 times per week) including track and field, cycling, or cross-fit. Exclusion criteria were: presence of neurological, vestibular, or psychiatric pathologies and diagnosis of a concussion event either in the previous 6 months before or during the study. The number to obtain a necessary sample size was calculated a priori using the central limit theorem.

Analysis Criteria

Each participant underwent a full evaluation including the diagnostic tests of the HIA battery. This included the following evaluations conducted in the following order:

1. Maddock score
2. Immediate memory (5 words)
3. Concentration test (digits backward and months in reverse order)
4. Tandem walk (walk heel-to-toe down a 3-m line and back)
5. Symptoms score (from a list of 22 symptoms at the time of the test)
6. Delayed recall (5 words)

The sum of the recall test results (immediate and delayed) and concentration test provided the Standardized Assessment of Concussion (SAC) score.[11] The modified version of the Maddock score was used for the other sport athletes.[13] This test was not repeated during the rest assessment.

Additional tests in the SCAT battery were also used:

1. Severity of symptoms experienced (scale 0-6)
2. Temporal orientation
3. Balance test using the Balance Error Scoring System (BESS)
4. Finger–nose test

Method

The concussion diagnostic tests were first conducted immediately after a sustained physical effort of at least a 30-minute duration: pitch-side at the end of match-play for the rugby group, or immediately in the changing room, following cessation of activity for the other sports athletes. In all cases this delay was less than 5 minutes respecting the HIA protocol adopted by World Rugby.[10] All tests were performed by the same physician, trained in the management of concussion episodes. At the end of the first evaluation, if no concussion was determined, the athlete was allowed to participate in the second part of the study. The second evaluation was conducted 6 months later, under resting conditions with a minimum of 24 hours interval respected after the last sporting activity. The tests were conducted by the same investigator, under comparable conditions, notably for the order of the clinical tests. To limit test/retest, learning the list of words to be recalled immediately and delayed was modified between the 2 parts of the study.

Statistical Analysis

Data in text and figures are presented as mean with SD and 90% confidence limits/intervals. Differences between rest and postexercise results in the different variables and between-group (rugby vs other athletes) differences in the changes were examined using standardized differences [effect size (ES)], based on Cohen ES principle. A contemporary statistical approach was used with probabilities used to make a qualitative probabilistic mechanistic inference about the true changes/differences in the changes, which were assessed in comparison to the smallest worthwhile change (0.2 × pooled SDs).[14,15] The scale was as follows: 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; and >99%,

almost certain. Threshold values for standardized differences were >0.2 (small), >0.6 (moderate), >1.2 (large), and very large (>2).

ETHICAL CONSIDERATION

All participating athletes were explained the study requirements and signed a consent form between November 01, 2016 and January 31, 2017. This study was endorsed by the local ethics committee.

RESULTS

The final analysis included 37 athletes; 2 did not continue participation and 1 was excluded after a concussion episode sustained in the second part of the study. Physical and clinical characteristics of the 2 groups are presented in Table 2. Overall, at rest, there were no clear clinical differences between the 2 groups. Rugby players presented a very likely moderately lower concentration score than the other athletes (3.5 ± 0.9 vs 4.1 ± 0.6, −19.6% ± 15.4%), but a likely slightly higher recall memory score (4.1 ± 0.9 vs 3.6 ± 1.2, +16.1% ± 15.5%). The immediate memory score was likely slightly different between the 2 groups, but this was not clinically substantial (14.8 ± 0.4 vs 15 ± 0).

Within-Group Differences Between Baseline and Posteffort Values

Differences between baseline and posteffort values in the different tests are presented in Figure 1 for the 2 groups (rugby and other athletes). Symptoms encountered after physical effort are listed in the Table 3 for both groups. There was no clear difference between posteffort orientation score and immediate memory score in both groups. In the rugby group, the score for concentration (3.5 ± 0.9 vs 3.1 ± 0.9, ES = −0.44 ± 0.43, % chances: 1/17/82), delayed memory (4.1 ± 0.9 vs 3.7 ± 1.2, −0.40 ± 0.45, 2/21/78), and SAC (27.4 ± 1.7 vs 26.3 ± 1.5, −0.61 ± 0.23, 0/0/100), likely-to-most likely decreased following completion of physical activity compared with baseline values. In the rugby group, there was also a most likely moderate-to-very large increase in the number of symptoms (0.1 ± 0.2 vs 2.1 ± 1.6, 1.69 ± 0.54, 100/0/0), severity of symptoms (0.1 ± 0.2 vs 3.5 ± 2.8, 1.68 ± 0.53, 100/0/0), and BESS score (1.7 ± 1.6 vs 3.3 ± 2.2, 0.76 ± 0.30, 100/0/0) following physical effort compared with baseline values.

In the other sports group, the concentration score was likely moderately decreased (4.1 ± 0.6 vs 3.7 ± 1.0, ES = −0.82 ± 0.83, % chances: 2/8/90), whereas the recall memory score likely slightly increased (3.6 ± 1.2 vs 3.9 ± 1.0, 0.33 ± 0.41, 71/27/2) following physical effort compared with baseline values. No clear differences were observed between SAC score posteffort and baseline values. In the other sports group, there was also a most likely moderate-to-very large increase following physical effort in the number of symptoms (0.1 ± 0.5 vs 2.6 ± 2.3, 1.39 ± 0.54, 100/0/0), severity of symptoms (0.1 ± 0.5 vs 3.8 ± 3.6, 1.38 ± 0.53, 100/0/0), and BESS score (1.5 ± 1.2 vs 2.7 ± 1.9, 0.72 ± 0.30, 99/1/0) compared with baseline values.

Between-Group Differences in the Changes Between Baseline and Posteffort Values

Between-group (rugby vs other sports) differences in the changes between baseline and posteffort values are presented in Table 2 and Figure 2. There was no clear difference between changes in posteffort and baseline values in scores for immediate memory, concentration, symptoms, severity of symptoms, and SAC between the rugby and other sports groups. Differences between baseline and posteffort in orientation scores were possibly slightly higher in the rugby group compared with the other sports group (ES = 0.26 ± 0.45, 59/37/5). Recall memory score changes were likely largely higher (0.73 ± 0.61, 93/7/1) and changes in SAC score were very likely moderately higher (0.75 ± 0.41, 98/2/0) in the rugby group versus the other sports group.

TABLE 2. Clinical Characteristics of Rugby Players and Athletes From Other Sports (Mean, SD)

Variable	Rugby (n = 19)	Other Activities (n = 18)	Between-Group Difference		
			% Difference ± 90% CL	ES ± 90% CL	Qualitative Outcome
Level of education (until middle school, high school, college/university)	4/19; 4/19; 11/19	2/18; 1/18; 15/18			
Age (yr)	31.5 ± 4.7	31.2 ± 3.5	−1% ± 8%	−0.7 ± 0.55	Unclear
Theorical maximum heart rate (bpm)	188.5 ± 4.7	188.8 ± 3.5	0% ± 1%	0.07 ± 0.55	Unclear
Postexercise heart rate (bpm)	125.0 ± 17.6	141 ± 16.5	12% ± 7%	0.90 ± 0.55	Very likely +
Orientation score	5.0 ± 0.0	4.9 ± 0.2	−1.2% ± 2.1%	−0.32 ± 0.55	Unclear
Immediate memory	14.8 ± 0.4	15 ± 0	1.1% ± 1.0%	0.57 ± 0.54	Likely +
Concentration score	3.5 ± 0.9	4.1 ± 0.6	19.6% ± 15.4%	0.76 ± 0.54	Very likely +
Delayed recall	4.1 ± 0.9	3.6 ± 1.2	−16.1% ± 3.5%	−0.53 ± 0.55	Likely−
SAC score	27.4 ± 1.7	27.4 ± 1.5	−0.1% ± 3.5%	−0.0 ± 0.55	Unclear
Symptoms (n)	0.1 ± 0.2	0.1 ± 0.5	0.0 ± 0.0	0.0 ± 0.3	Unclear
Symptoms severity	0.1 ± 0.2	0.1 ± 0.5	0.0 ± 0.0	0.0 ± 0.3	Unclear
BESS score	1.7 ± 1.6	1.5 ± 1.2	−12.5% ± 50%	0.16 ± 0.54	Unclear

Results of concussion tests at rest.
BESS, Balance Error Scoring System; CL, confidence limit; SAC, Standardized Assessment of Concussion.

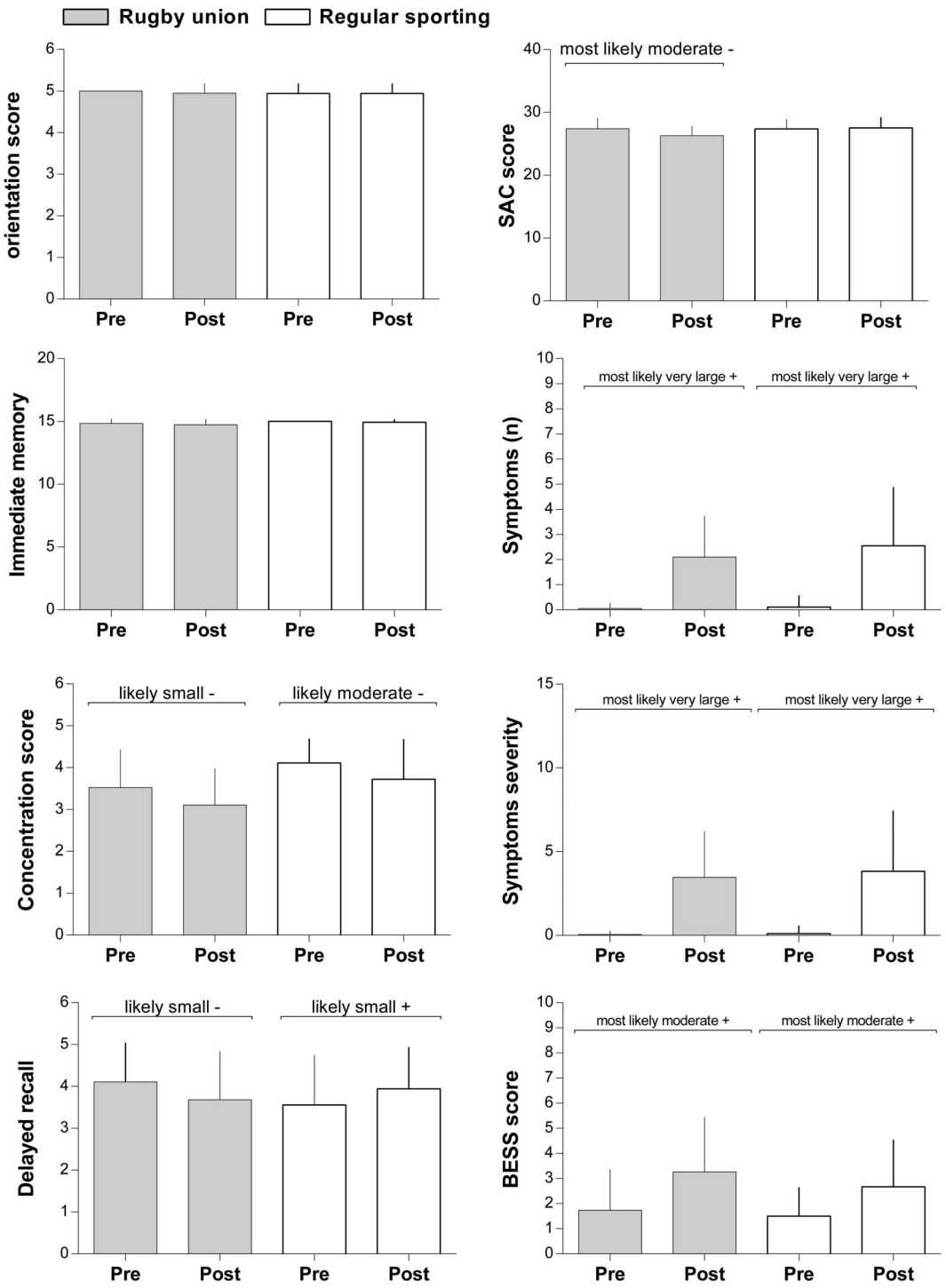

Figure 1. Differences between baseline and posteffort values in the different tests in the rugby union and regular sporting groups. The bars represent the values obtained at rest and after effort. The average and SD are indicated. BESS, Balance Error Scoring System; SAC, Standardized Assessment of Concussion.

DISCUSSION

The present results suggest modification in the outcome of several concussion diagnostic tests when accounting for significant physical exertion. Change occurred for the concentration tests, delayed recall, SAC score, and BESS equilibrium break number, number of reported symptoms and their severity score. The present findings tend to confirm those reported by McCrea[12] who first proposed physical stress tests to account for the effects of physical exertion on diagnosing concussion events.

A study by Lee et al,[16] investigated the effects of fatigue on 82 professional athletes in whom the SCAT 3 protocol was applied. Their study showed that physical exertion caused an increase in the number of symptoms and errors in the balance test. Unlike the present report, however, no alteration in performance in the cognitive tests was observed. Two criticisms

TABLE 3. Comparison of Symptoms Between Rugby Players and Athletes From Other Sports

Symptoms	Rugby (n = 19)	Other Sports (n = 18)	Total (n = 37)
Headache	1	1	2
Pressure in head	0	0	0
Neck pain	2	2	4
Nausea or vomiting	1	1	1
Dizziness	1	3	4
Blurred vision	0	0	0
Balance problems	1	0	1
Sensitivity to light	0	1	1
Sensitivity to noise	0	1	1
Feeling slowed down	6	5	11
Feeling "like in a fog"	1	5	6
Don't feel right	2	4	6
Difficulty concentrating	5	5	10
Difficulty remembering	5	6	11
Fatigue or low energy	8	7	15
Confusion	1	1	2
Drowsiness	0	1	1
More emotional	0	0	0
Irritability	3	3	6
Sadness	0	0	0
Nervous or anxious	3	1	4
Trouble falling asleep	NA	NA	

can be directed at Lee's study: first, the 2 assessments (rest and posteffort) were performed at 3-week intervals; thus, there was a possible learning effect. Second, the postexercise test conducted after 5 minutes of cycling at 75% of the maximum heart rate of the participants may not be representative of the type of physical effort encountered when assessing potentially concussed athletes pitch-side, particularly in rugby players.[17]

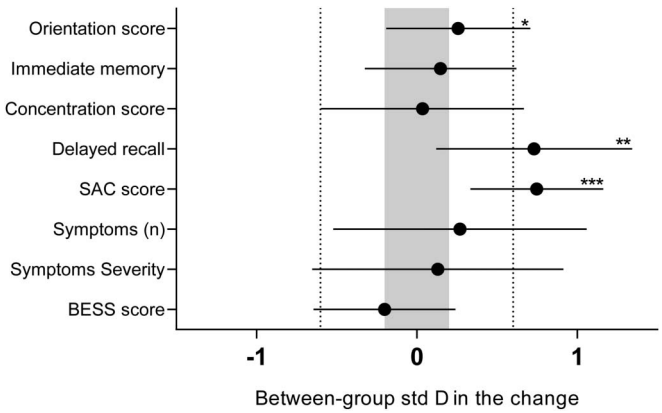

Figure 2. Between-group (rugby vs regular sporting) differences in the changes between baseline and posteffort values. Delayed recall and SAC score are the most affected by physical effort. *Possibly; **Likely; ***Most likely. Grey zone stands for trivial zone (effect size ± 0.2). BESS, Balance Error Scoring System; SAC, Standardized Assessment of Concussion.

Other studies evaluating the impact of an aerobic type physical effort on balance tests specifically have reported a clear postexercise alteration,[18–20] whereas moderate intensity exercise seemed to improve performance.[21] The manifestation of concussion symptoms following intense physical exertion has led to one of the notable changes in the latest version of the SCAT; symptoms must be examined in a state of rest several minutes after leaving the field of play.[2]

Head Injury Assessment Protocol and Sport Concussion Assessment Tool Diagnostic Value

The SCAT battery has been available since 2004[7] and is regularly revised to ensure improvements in its diagnostic capacity.[22,23] Although normative reference values are now available to help judge the results of the SCAT in top athletes,[24] gold standard values are derived from comparisons of results against benchmark values recorded at the beginning of the season. The present findings confirm that this individual baseline assessment must be conducted under conditions that are highly similar to the athletes' habitual sporting activities. It is noteworthy that previous publications evaluating performance in baseline assessments frequently do not report the methodologies used to perform these fatigue protocols. This discrepancy may explain inconsistencies regarding their sensitivity and specificity.[25] Regarding the HIA protocol, initial assessments are also based on video observations that are useful in identifying concussion although identification is dependent on observer experience.[26,27] The 3-step evaluation process to diagnose (or rule out) concussion is of note as it accounts for the evolution of symptoms.[8] However, World Rugby regulations allow a player to leave the field of play for 10 minutes to perform a concussion test (HIA1), whereas the 2017 Berlin recommendations advise execution of the test after 10 minutes of rest.[2] To our knowledge, the diagnostic performance of the full HIA protocol has not been evaluated.

Difference Between Rugby and Other Sports Participants

Here, SAC changes were more substantial following rugby participation compared with the other sports. A closer analysis of the results reveals that the values for the "delayed recall" variable were affected more in the rugby players. This suggests that the impact of physical exertion on concussion diagnostic tests was dependent on sports activity and potentially its physical demands. This finding also raises the question regarding the potential role of repeated nonconcussive (nonconcussion impact) head injuries on cognitive performance in rugby players immediately after rugby play.[28–30] The design of our study does not allow us to formulate conclusions on this issue and to this effect research is warranted. Finally, the latest version of the HIA protocol adopted by World Rugby indicates that the baseline assessment is performed after a sustained effort of 10 minutes. However, our results suggest that the results obtained are not comparable to those obtained following a rugby match.

Limitations and Bias

The latest version of the SCAT (SCAT 5) was published after the start of the current study.[2] However, the latter was conducted using assessments from the previous version which are very similar to those in the SCAT 5, because the only

modification concerns the immediate memory and delayed recall parts to avoid a potential ceiling effect. To minimize the "practice effect", we modified the lists of words and numbers presented, and observed a period of 6 months between the 2 test phases. This duration is longer than the time needed to clear this bias, which is habitually around 1 week.[22] Further potential limitations were that the current study population included amateur male athletes with a relatively high mean age of 31.53 ± 4.10 years and who participated in 3 training sessions per week. It is reasonable to suggest that the impact of physical exertion on the present test results may be associated to a better recovery capacity in younger and/or professional athletes. Extending this work to a larger population including participants of different ages, gender, and practice levels would provide a more comprehensive analysis of the potential influence of fatigue in relation to these parameters.

CONCLUSIONS

This work demonstrates the effect of physical exertion on the results from HIA and SCAT concussion diagnostic assessments. Findings indicate that a baseline assessment should be conducted as frequently as possible following a physical effort resembling that of the sport activity in question to facilitate analysis of potential concussion events pitch-side. Results also confirm that any search for symptoms following a potential event must be performed after a rest period of several minutes duration because of the effects of prior physical effort.

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