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original research

Does an Individual's Fitness Level Affect Baseline Concussion Symptoms?

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Context: Variables that may influence baseline concussion symptoms should be investigated.

Objective: To evaluate the effect of physical fitness on self-report of baseline concussion symptoms in collegiate athletes and students.

Design: Controlled laboratory study.

Patients or Other Participants: A total of 125 undergraduates, including 95 collegiate athletes and 30 recreational athletes (83 males, 42 females).

Intervention(s): Participants completed the Standardized Concussion Assessment Tool 2 (SCAT2; symptom report) at baseline, within 10 minutes of completing the Leger test, and within 24 hours of the initial baseline test. The Leger (beep) test is a shuttle-run field test used to predict maximal aerobic power.

Main Outcome Measure(s): The total symptom score on the SCAT2 was calculated and analyzed with a repeated-measures analysis of variance. A linear regression analysis was used to determine if 3 variables (sport type, sex, or fitness level) accounted for a significant amount of the variance in the baseline symptom report.

Results: Participants reported more symptoms postactivity but fewer symptoms at 24 hours compared with baseline, representing a time effect in our model ($F_{2,234} = 47.738$, $P < .001$). No interactions were seen among the independent variables. We also found an effect for fitness level, with fitter individuals reporting fewer symptoms at all 3 time intervals. The regression analysis revealed that fitness level accounted for a significant amount of the variance in SCAT2 symptoms at baseline ($R^2 = 0.22$, $F_{3,121} = 11.44$, $P < .01$).

Conclusions: Fitness level affected the baseline concussion symptom report. Exercise seems to induce concussion symptom reporting, and symptom severity may be a function of an athlete's level of conditioning. Sports medicine professionals should consider an athlete's level of fitness when conducting baseline concussion symptom assessments.

Key Words: sports, traumatic brain injuries, assessment, self-report symptoms

Key Points

- Participants in better physical condition had lower SCAT2 symptom scores at baseline and immediately and 24 hours after exertion.
- Conditioning level may affect concussion symptom severity self-report.
- During baseline testing, the clinician should take the athlete's fitness level into account.

Baseline testing has become a core component of concussion management within organized sports. Data obtained from baseline testing enhances a clinician's assessment and ability to make return-to-play decisions by allowing direct comparisons between an athlete's postinjury status and premorbid level of functioning. An important aspect of baseline testing is the measurement of symptoms commonly associated with concussions.[1,2] Current instruments recommended for the standard of care (eg, Standardized Concussion Assessment Tool 2 [SCAT2]) have sections devoted to evaluating the presence and frequency of these symptoms. After injury, an athlete's level of functioning (including report of symptoms) is continually monitored and compared with the baseline assessment, which helps the clinician guide the athlete through recommended return-to-play activities.[3] Thus, obtaining valid and reliable baseline assessment data is essential for sound clinical decisions.

Measuring an athlete's symptoms through self-report is complex, given the many variables that can influence an individual's perception of how symptoms are experienced. Concussion-like symptoms are nonspecific and can be influenced or compounded by a number of clinical, demographic, and methodologic variables. For instance, an individual's premorbid health history, including psychiatric difficulties, previous brain trauma, learning disorders, migraine headaches, and motivation variables, has been shown to influence the report of symptoms.[4,5] Sex differences exist for both baseline and postinjury symptoms.[6] One group[7] found that the symptom report remained consistent throughout a woman's menstrual cycle, but women using oral contraceptives reported fewer symptoms. Another study[8] identified dehydration as the cause of both increased symptoms reporting and deteriorated cognitive functioning. Other research[9] has demonstrated that a small percentage of athletes have invalid baseline concussion evaluations due to questionable effort. A recent study[10] considered the effect of exercise on self-report of symptoms in healthy participants. Involvement in even short-lived physical exertion resulted in more reported neurologic symptoms than in those who engaged in moderate activity.

Collegiate athletes often engage in off-season conditioning to prepare for the upcoming competitive season. However, considerable variability exists in which conditioning programs athletes use, how compliant they are, and subsequently, how physically fit they are. Moreover, an athlete's fitness level is likely to change during the competitive season. Because an athlete's baseline test results are essential for subsequent comparison should he or she sustain a concussion, the relationship between fitness level and symptoms may be an important variable that could influence SCAT2 results. To our knowledge, no authors have directly investigated the link between fitness and baseline concussion symptom measures. Thus, the purpose of our study was to evaluate whether the level of fitness serves as a moderating variable to an individual's report of concussion symptoms at baseline. Specifically, we hypothesized that athletes with higher fitness levels would report fewer symptoms at baseline and after their participation in an exertional activity.

METHODS

Procedures

A total of 125 undergraduate university students were recruited at the start of the 2009–2010 year. Of the group, 95 were student-athletes who were recruited during scheduled preseason fitness evaluations, when they were screened for medical and psychological conditions by sports medicine physicians who consult with the university's athletic program. Athletes who had a history of a medical or psychological condition were excluded. A history of previous concussion was reported by 14 student-athletes, but none of the concussions had occurred within 60 days of the preseason medical examination. No differences were found in baseline SCAT2 scores between those with a history of concussion and those without ($P < .05$).

Undergraduate students who were recreational athletes ($n = 30$) were included in this study to ensure a more heterogeneous range of physical fitness, as we expected that collegiate athletes were likely to be more homogeneous in their fitness levels. These students were recruited by advertisements posted in the athletic facilities and included individuals engaging in moderate physical activity for a minimum of 30 minutes at least twice per week. All recreational athletes were screened for medical and psychological conditions and asked to sign a waiver indicating that they had no problematic injuries or health conditions. None reported a history of concussion.

All participants were informed of the voluntary nature of their involvement, received an information letter concerning the research project, and provided informed consent. An incentive of $10 was offered for taking part in this project, which was approved by the University of Alberta's Ethics Review Board.

Participants completed the Standardized Concussion Assessment Tool, second edition (SCAT2),[11] before fitness testing. The SCAT2 is a standardized evaluation tool for concussions that measures self-report symptoms, balance, and cognitive functioning. To determine fitness levels, participants completed the Leger (beep) test in an indoor facility at the University of Alberta. Leger and Lambert[12] created a shuttle-run field test that gradually increases in velocity and can be used to predict maximal aerobic power, or $\dot{V}O_{2max}$. The Leger 20-m shuttle-run test has been validated and proven to be reliable[13,14] and is now used extensively by a number of sporting groups as an inexpensive field test for aerobic fitness. The test requires participants to run between cones 20-m apart, paced by a loud auditory signal. When a participant fails to reach the end line by a certain tone, the test moderator disqualifies him or her from continuing. This test uses running velocity at the highest stage reached in a regression formula to predict $\dot{V}O_{2max}$ and also provides an estimate of anaerobic threshold. The original prediction formulas have been shown to underestimate $\dot{V}O_{2max}$.[15] Approximately 10 minutes after the Leger test, participants again completed the SCAT2 symptom report. They were asked to return the next day (approximately 24 hours later) to complete the SCAT2 symptom report 1 final time. A total of 138 participants completed the initial testing, but 13 did not return to complete the final SCAT form and therefore were not included in the final analysis.

Groups were collapsed into those participating in contact sports (hockey, rugby, and basketball) versus those participating in noncontact individual sports (swimming, tennis, and recreational athletes). We believed this dichotomy would provide a reasonable distinction between participants in sports with a higher likelihood of concussions (ie, contact sports) versus a lower likelihood (noncontact individual sports). Each participant was assigned to the high- or low-fitness group depending on $\dot{V}O_{2max}$ score, using the criterion established by the American College of Sports Medicine.[16] Specifically, those with $\dot{V}O_{2max}$ scores above the 60th percentile were assigned to the high-fitness group, whereas those below the 60th percentile were assigned to the low-fitness group. The American College of Sports Medicine identifies athletes below the 60th percentile as in fair or poor condition and those above the 60th percentile as in good, excellent, or superior condition. Because $\dot{V}O_{2max}$ scores vary between sexes, a participant's individual $\dot{V}O_{2max}$ score was compared with normative values from the same sex to determine placement in the high- or low-fitness groups. The low-fitness group had an equal number of collegiate and recreational athletes (20 from each group), and 33% of recreational athletes (10 participants) were in the high-fitness group. We felt these ratios suggested the 2 groups were not exclusive and justified the inclusion of recreational athletes to analyze a wider range of fitness levels.

A regression analysis was used to predict if the independent variables (sport type, sex, and fitness level) accounted for a significant portion of the variance in SCAT2 symptom reporting at baseline. Because we had few variables and this was an exploratory study, the enter method was used. In addition, a repeated-measures analysis of variance using the Huyhn-Feldt correction was conducted to measure change in SCAT2 symptom reporting over time and to measure interactions among the independent variables. Post hoc comparisons (using the Sidak method to

Table 1. Predictions of Baseline Symptom Report[a]

Predictor Variable	β	*t*	*P*
Group contact versus noncontact	–0.01	–0.12	.91
Sex	–0.39	2.92	.04
Fitness level, $\dot{V}O_{2max}$	0.24	–4.60	.00

[a] $R = 0.47$, $R^2 = 0.22$, $P < .01$.

adjust for multiple comparisons) were calculated to measure differences across the time periods.

RESULTS

A primary hypothesis of this study was that fitness level would affect SCAT2 symptom reporting at baseline. This is similar to measuring the effect of an athlete's off-season fitness level on symptom reporting just before the start of a competitive season. The regression analysis was significant ($R^2 = 0.22$, $F_{3,121} = 11.44$, $P < .01$), with fitness level accounting for the greatest proportion of the variance ($P <$ .0001), sex accounting for a smaller portion of the variance ($P < .04$), and sport type not reaching statistical significance ($P = .9$; Table 1).

Results from the repeated-measures analysis of variance identified a main effect for time ($F_{2,234} = 47.738$, $P < .001$) for SCAT2 symptom scores but no significant interactions among the variables of sport group, sex, and fitness level (Figure). As hypothesized and consistent with the Alla et al study,[10] the post hoc analysis identified an increase in reported symptoms postactivity compared with baseline ($P < .001$) and a reduction in symptoms from postactivity to 24 hours later ($P < .001$; Table 2). A smaller number of SCAT2 symptoms were reported at 24 hours compared with baseline ($P < .047$). Possible factors include response fatigue or minimizing symptoms with repeated exposure to the SCAT2 symptom report.

Consistent with previous research,[6] between-subjects effects were significant for sex ($F_{1,117} = 7.5$, $P < .01$), with females reporting more SCAT2 baseline symptoms than males. Fitness level was a significant variable differentiating SCAT2 baseline symptom reports, with fitter individuals reporting fewer symptoms ($F_{1,117} = 13.3$, $P < .01$). Moreover, the difference between the high- and low-fitness groups persisted over time, indicating that, even after activity, participants continued to show differences in symptom reports. The lack of interaction among the within-subject variables suggested that both groups responded in similar fashion to the exertional activity.

Table 2. Total Symptom Score on SCAT2 Across Time

Variable	Participants, No. (N = 125)	Total Symptom Score, Mean ± SD		
		Baseline	Postactivity	24 h
Sport group				
Team	68	3.4 ± 4.3	8.5 ± 8.1	2.2 ± 3.3
Individual	57	5.3 ± 5.5	14.4 ± 10.3	3.9 ± 6.2
Sex				
Males	84	3.3 ± 4.1	9.5 ± 8.1	2.8 ± 4.1
Females	41	6.0 ± 5.9	14.5 ± 11.5	4.9 ± 6.3
Fitness level				
High	85	2.8 ± 4.2	9.1 ± 9.0	2.4 ± 3.5
Low	40	7.1 ± 5.2	15.7 ± 9.4	5.8 ± 6.7

DISCUSSION

As expected, participants in better physical condition had lower SCAT2 symptom scores before, immediately after, and 1 day after exertional activity. In addition, fitness level accounted for a significant portion of the variance in the baseline SCAT2 symptom report. No significant interactions were seen among the independent variables (sport type, sex, and fitness level). Although these results are somewhat intuitive (ie, that individuals with higher fitness levels reported fewer symptoms), they have not previously been demonstrated in the scientific literature. As indicated by another study,[17] the cluster of symptoms used by current concussion assessment tools (such as SCAT2) is nonspecific and influenced by variables apart from concussion, which can be challenging for the clinician making return-

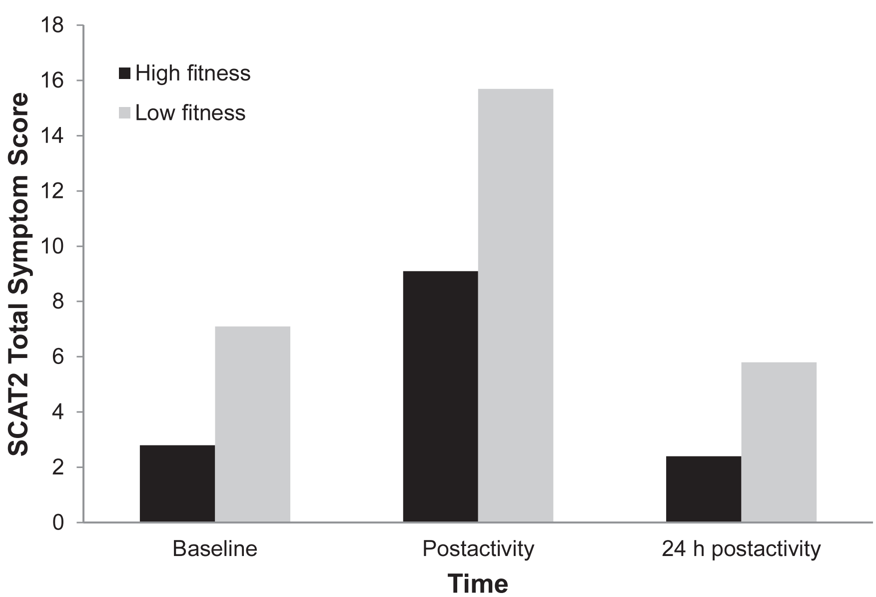

Figure. Standardized Concussion Assessment Tool 2 (SCAT2) total symptom report by fitness level across time.

to-play decisions. These findings underscore the importance of understanding the unique characteristics of athletes and identifying variables that may influence self-reports. In this case, fitness level appears to be a variable that influences symptom reporting during baseline testing.

Our study was conducted among collegiate athletes during preseason medical screening and with recreational athletes. We assumed that most athletes were in reasonably good physical condition given the importance of off-season training regimen before the competitive season. Approximately 15% of the athletes were in the low-fitness group. Thus, the question is whether conducting a baseline concussion assessment on an athlete who is in poor physical condition might result in more reported symptoms and a less reliable baseline assessment. If such an individual sustains a concussion during the season, the challenge is determining when the athlete has reached a true baseline level of functioning as opposed to the measured baseline. It would be important to investigate an athlete's preseason training regimen to ensure reasonably good physical condition before concussion baseline testing.

Our results are consistent with those of other researchers[10] showing an increase in symptoms reported after exertional activity. The symptom report spiked after exertional activity but then returned to below baseline level within 24 hours in both groups, regardless of fitness level. The drop in SCAT2 symptoms reported to below-baseline level was an unexpected outcome and suggests that participants may experience test fatigue with repeated exposure or minimize symptoms.

In many instances, especially in professional sports, concussion baseline testing is conducted with other preseason medical tests. In this setting, athletes complete a circuit of evaluations as they rotate among various stations. Having athletes complete baseline testing before engaging in exertional activity is an important provision to ensure more reliable data. To date, no guidelines have recommended how soon after exertional activity an athlete can undergo baseline concussion testing. When baseline concussion testing should occur during the preseason evaluation is an important question to be addressed by future concussion guidelines.

A limitation of this study is that we investigated symptoms reported only at baseline. What effect fitness level might have on an athlete's symptom report after a concussion is unknown. Current practice standards strongly recommend that an athlete suspected of having sustained a concussion be removed from play and refrain from activity until symptoms subside. In many cases, this process lasts several days. However, athletes who experience more complex concussions are restricted from participating in exertional activities for a longer time, which may result in deconditioning. Fatigue is a common symptom after concussion that may also be reported by deconditioned athletes. Current standards suggest that all symptoms should have improved (ie, returned to baseline levels) before the athlete is cleared for exertional activity.[3] If an athlete begins to return to exertional activity and experiences fatigue, the clinician must determine whether the fatigue is a function of being deconditioned or related to the concussion. Future researchers who investigate the relationship between fitness level and symptoms postinjury should address this question.

Another limitation to this study is the small sample size. Recreational athletes were included to ensure a wider range of fitness levels. However, including recreational athletes might have skewed the results because, as a whole, they were less fitness-minded and potentially more likely to experience increased symptoms than the athletes. Thus, the findings cannot be easily generalized, given the small sample size and relatively homogeneous population. A small number of students did not return for the 24-hour symptoms report, and this attrition could also have influenced test results. The criterion used for categorizing participants with high or low levels of fitness was the 60th percentile compared with their norm group. The results might have differed if more fitness levels had been defined instead of, for example, grouping individuals with excellent fitness (estimated $\dot{V}O_{2max}$ above the 80th percentile) with those who had good and fair fitness. Finally, this was a cross-sectional study, and we used the athletes' reports of symptoms at the start of a competitive season. An athlete's level of fitness may vary over time and influence the report of symptoms. Other situational variables, such as levels of stress, pain tolerance, and other orthopaedic injuries, may also influence the reporting of symptoms. A repeated-measures design would help to control for some of these variables.

Overall, our results provide preliminary evidence that fitness levels influence the baseline concussion symptom report. Further study is needed to evaluate the extent to which fitness level moderates the symptom report and whether it is an important variable in predicting recovery from concussion.

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