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Concussion Baseline Testing: Preexisting Factors, Symptoms, and Neurocognitive Performance

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Context: Neurocognitive test scores are often considered an important aspect of concussion management. To best use these data, clinicians must understand potential factors that may influence baseline performance on these tests.

Objective: To determine preexisting factors that may influence performance on the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT).

Design: Cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: A total of 486 National Collegiate Athletic Association Division I collegiate student-athletes.

Main Outcome Measure(s): To determine neurocognitive functioning and total symptom score at baseline, ImPACT was administered. Outcomes were verbal memory, visual memory, visual motor speed, reaction time, and total symptom score. A self-report demographic section at the beginning of ImPACT was used to gather information concerning previous treatment for headaches, migraines, and psychiatric conditions; diagnosis of attention-deficit/hyperactivity disorder; and exposure to previous strenuous exercise. We conducted multivariate analyses of variance to determine if the ImPACT composite and total symptom scores differed according to preexisting factors ($P < .0083$).

Results: Sex showed an effect on verbal memory ($P = .001$), visual motor speed ($P < .001$), and reaction time ($P = .006$), with women performing better than men. A previous diagnosis of attention-deficit/hyperactivity disorder affected visual motor speed ($P = .008$). Previous treatment for headaches ($P < .001$), migraines ($P = .001$), a psychiatric condition ($P < .001$), or a diagnosis of attention-deficit/hyperactivity disorder ($P < .001$) all showed effects on the total symptom score. Strenuous exercise did not affect neurocogntive performance or total symptom score.

Conclusions: Based on our findings and the previous literature, we suggest that many preexisting factors influence baseline neurocognitive data. Baseline testing is an important aspect of concussion management. Sports medicine professionals should be cognizant of these factors when developing concussion-management protocols.

Key Words: neurocognitive testing, ImPACT, return to play

Key Points

- Baseline neurocognitive testing is an important aspect of concussion management.
- Preexisting factors, such as sex and a diagnosis of attention-deficit/hyperactivity disorder, influenced neurocognitive performance on ImPACT in collegiate student-athletes.
- Treatment for headaches, migraines, or a psychiatric condition or a diagnosis of attention-deficit/hyperactivity disorder was associated with a higher total symptom score.

Concussion management, which includes the diagnosis, treatment, and return-to-play (RTP) protocol, is continuously changing based on current research and best practice. One important component of concussion management is objective baseline evaluation, which should include an assessment of neurocognitive performance and self-reported symptoms for comparison postconcussion.[1] Schmidt et al[2] found that, if baseline results were not available, normative data provided an acceptable set of scores for comparison with postconcussion test results. However, some comorbidities or preexisting factors, such as a history of migraine, depression, or other mental health disorder or attention-deficit/hyperactivity disorder (ADHD), are factors that may modify the risk of concussion and the duration of recovery.[3] Yet the empirical evidence to support these claims is limited and weak based on the Strength of Recommendation Taxonomy.[1,4] There is evidence that headaches,[5,6] migraines,[7] depression,[8–10] and ADHD[6,11,12] may influence cognitive function and symptoms related to concussion, which are the cornerstone of concussion management. Reporting the symptom of headache can have a significant effect on baseline neurocognitive performance and symptoms.[5] Covassin et al[8] showed that those who reported severe depression performed worse on a neurocognitive task and cited more symptoms of concussion at baseline. These findings suggest that understanding how these factors affect baseline assessments may be crucial in concussion management.

One commonly used computerized neurocognitive test is the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT; ImPACT Applications, Inc, Pittsburgh, PA). The first part is a demographic section in which participants self-report a number of health factors (eg, diagnosis of ADHD); the second part measures neurocognitive function. Neurocognitive function is based on 6 modules; from these modules, 4 composite scores are

generated: visual memory, verbal memory, visual motor speed, and reaction time. Concussion symptoms are also often used to track concussion recovery and make RTP decisions. With its good test-retest reliability, ImPACT is a common tool in RTP protocols.[13–15]

Evidence suggests that preexisting factors such as sex,[8,16,17] depression,[8] headaches,[5,6] and ADHD[6,11,12] can influence neurocognitive performance and symptoms as measured on ImPACT. Sex influences baseline neurocognitive performance on ImPACT: females performed better in verbal memory and males performed better in visual memory.[16,17] Compared with a control group, athletes who self-reported a diagnosis of ADHD or a learning disability had worse neurocognitive performance and higher total symptom scores.[6,11,12] Mrazik et al[18] observed that athletes who participated in maximal aerobic exercise showed symptoms related to concussions 10 minutes later. Although headache and depression influenced neurocognitive performance and symptoms,[5,8] the effects of a self-reported diagnosis of a psychiatric condition on ImPACT have not been examined extensively. In a small sample of National Football League players, Solomon and Haase[6] noted that the self-reported treatment of headaches and the diagnosis of ADHD influenced neurocognitive performance and symptom scores.

The purpose of our study was to determine whether preexisting factors of sex, self-reported previous treatment of headaches, migraines, or a psychiatric condition (eg, depression, anxiety); diagnosis of ADHD; or strenuous exercise within the previous 3 hours influenced baseline neurocognitive composite results and total symptom scores on ImPACT. We hypothesized that these factors might influence the baseline neurocognitive results, thereby supporting the importance of baseline testing and an awareness of preexisting factors.

METHODS

Study Design

A cross-sectional design was used to compare baseline neurocognitive test results and total symptom score with preexisting factors. The independent variables were sex; treatment for headaches, migraines, or a psychiatric condition (eg, depression, anxiety); diagnosis of ADHD; or strenuous exercise within the previous 3 hours. The dependent variables were the 4 composite ImPACT baseline scores (verbal memory, visual memory, visual motor speed, and reaction time) and total symptom score.

Participants

The participants in this study were collegiate student-athletes attending a National Collegiate Athletic Association Division 1 university between the 2009–2010 and 2013–2014 academic years (n = 503). However, 17 participants lacked a valid baseline ImPACT, so the final sample was 486 participants. Invalidity was based on an index developed by ImPACT Applications, Inc.[19,20] Of the 486 participants, 176 were female (age = 18.9 ± 1.3 years, height = 170.4 ± 8.0 cm, weight = 65.6 ± 10.6 kg) and 310 were male (age = 19.0 ± 1.3 years, height = 184.1 ± 10.9 cm, weight = 92.6 ± 17.9 kg). The student-athletes were drawn from football (n = 181), women's soccer (n = 59), baseball (n = 55), men's soccer (n = 53), softball (n = 25), women's lacrosse (n = 25), men's basketball (n = 21), women's basketball (n = 21), women's track and field (n = 19), women's volleyball (n = 18), and women's tennis (n = 9). Before testing began, the study received institutional review board approval and all participants completed informed consent forms.

Measures

We used ImPACT to assess neurocognitive function and total symptom scores and collect self-reported demographic data (version 2.0 was used until 2011 and then version 2.1 was used; the important difference between the 2 programs was greater internal security to better comply with Health Insurance Portability and Accountability Act [HIPAA] regulations). The demographic data provided information concerning previous treatment for headaches, migraines, or psychiatric conditions; diagnosis of ADHD; and recent strenuous exercise. Both versions of ImPACT offer 6 test modules to produce 4 composite scores: verbal memory, visual memory, visual motor speed, and reaction time. Higher composite scores on visual and verbal memory and visual motor speed and a lower score on reaction time indicate better performance. The 6 modules measure attentional processes, verbal recognition memory, visual working memory, learning, and other measures of cognitive functioning. Total symptom score was based on responses to the 22-symptom list. Although some have suggested that ImPACT has poor reliability,[21] most studies have demonstrated good test-retest reliability.[13–15]

Procedures

As part of the university's concussion-management protocol, student-athletes were required to participate in baseline testing. Typically, baseline testing occurred before the first year of competition and was completed on a computer in a closed laboratory. No more than 2 student-athletes and 2 test administrators were present because testing in a group setting has been shown to negatively influence performance.[22] Testing was administered at various times during the day, depending on the availability of the participants. Generally, ImPACT was completed within 30 minutes.

Data Analysis

A series of multivariate analyses of variance (MANOVAs) were conducted using preexisting factors of sex; self-reported previous treatment for headaches, migraines, or a psychiatric condition; diagnosis of ADHD; and recent strenuous exercise as independent variables. Dependent variables from ImPACT were verbal memory, visual memory, visual motor speed, and reaction time composite scores and total symptom score. If the MANOVA was significant, then univariate analyses were conducted to determine which factor(s) accounted for statistical significance. Because 6 separate MANOVAs were performed in these analyses, we used a Bonferroni correction to determine statistical significance ($P < .0083$).

Table. ImPACT Scores by Demographic Variables (Mean ± SD)

Variable	Verbal Memory	Visual Memory	Visual Motor Speed	Reaction Time	Total Symptom Score
Sex					
Female (n = 176)	87.7 ± 9.5[a]	75.0 ± 13.6	41.5 ± 5.7[a]	0.57 ± 0.06	5.3 ± 10.1
Male (n = 310)	84.6 ± 9.9[a]	76.0 ± 12.9	39.5 ± 6.0[a]	0.59 ± 0.08	4.0 ± 7.8
Treatment for headaches?					
Yes (n = 29)	82.8 ± 9.8	71.0 ± 12.9[b]	39.7 ± 7.5	0.57 ± 0.10	12.9 ± 18.9[a]
No (n = 445)	86.0 ± 9.8	76.0 ± 12.1[b]	40.3 ± 5.9	0.59 ± 0.07	3.9 ± 7.4[a]
Treatment for migraines?					
Yes (n = 29)	84.4 ± 10.4	75.8 ± 13.8	42.9 ± 8.0[b]	0.57 ± 0.09	9.5 ± 16.0[a]
No (n = 444)	85.8 ± 9.8	75.7 ± 13.2	40.1 ± 5.8[b]	0.58 ± 0.08	4.0 ± 7.6[a]
Treatment for a psychiatric condition?					
Yes (n = 11)	83.7 ± 13.8	73.1 ± 14.7	39.2 ± 6.1	0.59 ± 0.07	15.2 ± 12.7[a]
No (n = 461)	85.8 ± 9.7	75.8 ± 13.2	40.3 ± 6.0	0.58 ± 0.08	4.1 ± 8.2[a]
Diagnosis of attention-deficit/hyperactivity disorder?					
Yes (n = 29)	82.5 ± 11.4	70.8 ± 13.6[b]	37.4 ± 5.7	0.60 ± 0.06	9.5 ± 16.0[a]
No (n = 327)	85.9 ± 9.7	76.9 ± 13.2[b]	40.4 ± 5.8	0.59 ± 0.08	4.0 ± 7.6[a]
Strenuous exercise in previous 3 h?					
Yes (n = 104)	85.8 ± 9.7	75.2 ± 13.2	39.4 ± 6.2	0.58 ± 0.08	5.2 ± 8.5
No (n = 255)	85.5 ± 9.9	76.9 ± 13.5	40.5 ± 5.7	0.59 ± 0.08	3.7 ± 8.1

Abbreviation: ImPACT, Immediate Post-Concussion Assessment and Cognitive Test (ImPACT Applications, Inc, Pittsburgh, PA).

[a] $P \leq .001$.

[b] $P < .05$.

RESULTS

Each participant self-reported sex (n = 176/486 females [36.2%], 310/486 males [63.8%]); history of treatment for headaches (n = 29/474, 6.1%), migraines (n = 29/473, 6.5%), or a psychiatric condition (n = 11/472, 2.3%); diagnosis of ADHD (n = 29/356, 8.1%); and strenuous exercise within the previous 3 hours (n = 104/359, 29.0%) as part of the demographic section completed at the beginning of ImPACT. The distribution of preexisting factors and the ImPACT scores are shown in the Table.

The ImPACT composite scores were different by sex ($F_{5,480} = 6.98$, Wilks $\lambda = .93$, $P < .001$, partial $\eta^2 = .07$). Univariate analyses demonstrated effects of sex on verbal memory ($F_{1,484} = 11.2$, $P = .001$, partial $\eta^2 = .02$), visual motor speed ($F_{1,484} = 12.37$, $P < .001$, partial $\eta^2 = .03$), and reaction time ($F_{1,484} = 7.64$, $P = .006$, partial $\eta^2 = .02$), with females performing better than males on these tasks. Sex did not affect the total symptom score ($F_{1,486} = 2.76$, $P = .098$, partial $\eta^2 = .01$).

Treatment for headaches was associated with a difference in ImPACT scores ($F_{5,468} = 7.3$, Wilks $\lambda = .93$, $P < .001$, partial $\eta^2 = .07$). Total symptom score showed a difference ($F_{1,472} = 30.23$, $P < .001$, partial $\eta^2 = .06$): those who had undergone previous treatment for headaches reported more symptoms than those who reported no such treatment. Although the differences were not significant, those with previous treatment for headaches performed worse on visual memory ($F_{1,472} = 3.94$, $P = .048$, partial $\eta^2 = .01$) and verbal memory ($F_{1,472} = 3.01$, $P = .083$, partial $\eta^2 = .01$).

Treatment for migraines also had an influence on ImPACT composite scores ($F_{5,467} = 4.28$, Wilks $\lambda = .96$, $P = .001$, partial $\eta^2 = .04$). Univariate analyses demonstrated that those with previous treatment for migraines reported more symptoms than those without such treatment ($F_{1,471} = 11.78$, $P = .001$, partial $\eta^2 = .02$). Visual motor speed performance was worse in those who reported previous treatment for migraines, but the value did not achieve significance ($F_{1,471} = 5.94$, $P = .015$, partial $\eta^2 = .01$).

Treatment for psychiatric conditions was associated with a difference in ImPACT scores ($F_{5,466} = 3.81$, Wilks' $\lambda = 0.96$, $P = .002$, partial $\eta^2 = .04$). Those with previous treatment for a psychiatric condition reported more symptoms than those without such treatment ($F_{1,470} = 19.16$, $P < .001$, partial $\eta^2 = .04$).

A diagnosis of ADHD affected ImPACT composite scores ($F_{5,350} = 7.32$, Wilks' $\lambda = .91$, $P < .001$, partial $\eta^2 = .10$). Univariate analyses indicated effects for visual motor speed ($F_{1,354} = 7.21$, $P = .008$, partial $\eta^2 = .02$) and total symptom score ($F_{1,354} = 29.75$, $P < .001$, partial $\eta^2 = .08$). Those with a previous diagnosis of ADHD performed worse on visual motor speed and reported more symptoms than those who reported no such diagnosis. Visual memory ($F_{1,354} = 5.76$, $P = .017$, partial $\eta^2 = .02$) and verbal memory ($F_{1,354} = 3.20$, $P = .075$, partial $\eta^2 = .01$) were worse in those with a previous diagnosis of ADHD, but the values did not achieve statistical significance. No differences were noted for strenuous exercise in the previous 3 hours ($F_{5,353} = 1.47$, Wilks' $\lambda = 0.98$, $P = .200$, partial $\eta^2 = .02$).

DISCUSSION

The aim of our study was to determine whether preexisting factors influenced baseline neurocognitive performance and total symptom scores on ImPACT. As we hypothesized, many of the preexisting factors studied influenced neurocognitive performance and total symptom score. The only 2 factors that affected ImPACT baseline neurocognitive performance were sex and a previous

diagnosis of ADHD. Treatment for headaches, migraines, or a psychiatric condition or a previous diagnosis of ADHD affected total symptom score.

Our finding that females performed better than males on certain aspects of the neurocognitive test was consistent with previous data.[8,16,17,23] Covassin et al[16] observed that at baseline, females performed better on verbal memory, but males performed better on visual memory. In our study, males did not perform better on neurocognitive testing. The differences in visual motor speed and reaction time we noted are consistent with those found by Covassin et al,[17] who hypothesized that estrogen may be one explanation for better performance in females.[16] Another possible explanation is that female student-athletes exert more effort or take baseline testing more seriously than their male counterparts.[24] Additionally, our finding that a previous diagnosis of ADHD influenced visual motor speed is supported by earlier researchers who found that visual motor speed[11,12] was influenced by ADHD. Visual memory,[6,11,12] reaction time,[11,12] and verbal memory[6,12] were also affected in other investigations, but we did not observe these differences. A possible explanation for these deficits in neurocognitive performance is that those with a diagnosis of ADHD have problems with impulsivity and inattention, which could influence their results. Further, we do not know if they were taking medications for their ADHD; a recent study by Littleton et al[25] demonstrated that those with ADHD who were taking medication performed as well on ImPACT as the control group.

No differences in neurocognitive performance were evident for those who self-reported being treated for headaches, migraines, or a psychiatric condition. This result contrasts with previous research demonstrating that neurocognitive performance was influenced by depression[8–10] and headaches.[5,6] These variables may not have been factors in our study because they can be transient states and the participants may not have been experiencing them at the time of testing. Covassin et al[8] showed that current depressive symptoms influenced neurocognitive performance. However, Register-Mihalik et al[5] did not find headache symptoms at baseline to influence neurocognitive performance.

We failed to find a difference in total symptom score at baseline in females, which is inconsistent with the data of previous investigators,[8,16] who noted that females had higher scores. Our observation that total symptom score was influenced by headaches,[5,6] a psychiatric condition,[8] and ADHD[6,11,12] is consistent with the literature. This makes sense: those who were diagnosed with and had received treatment for these conditions reported more of the same symptoms that overlap with postconcussion symptoms.

The only factor that did not affect neurocognitive performance or total symptom scores was strenuous exercise 3 hours before baseline testing. Few investigators have addressed the effects of exercise on neurocognitive test scores specific to baseline concussion testing despite the strong evidence[26] demonstrating the influence of exercise on cognitive function. Although Mrazik et al[18] found that maximal aerobic exercise influenced symptom score, their tests were administered 10 minutes postexercise, whereas most of the athletes participating in our study took ImPACT at least 1 hour or more postexercise, as planned by the sports medicine staff scheduling the baseline tests for these student-athletes. Mrazik et al[18] did not examine any outcomes of neurocognitive tests other than symptoms. Although this finding is not in accordance with our hypothesis, it does have clinical implications. Our results suggest that previous exercise need not be taken into consideration when scheduling and administering ImPACT. Strenuous exercise within 3 hours of testing might not influence neurocognitive performance outcomes, so the test could be taken after an intense practice or conditioning session.

Ultimately, all of the preexisting factors analyzed, except for sex and exercise, showed an influence on total symptom score. These results stress the importance of baseline neurocognitive testing as part of concussion management. Symptom reporting is also important in concussion management and when determining RTP. Often athletes are not allowed to begin their RTP protocol until they are asymptomatic; however, if an athlete reports symptoms on a daily basis when healthy, the RTP decision might be incorrectly delayed.

Several limitations were associated with this study. As mentioned earlier, the preexisting factors of previous treatment for headaches, migraines, or a psychiatric condition or a diagnosis of ADHD were reported by only a small number of participants. Additionally, the percentages reported in this sample for previous treatment of headaches, migraines, and psychiatric conditions were smaller than those in the general population.[27,28] The incidences of headaches and migraines (6% in our study compared with 16%)[27] and mental health disorders (2% in our study compared with 18%)[28] were less than the national estimates, but the incidence of ADHD was slightly higher than national estimates (8% in our study compared with 4%).[29]

Along the same lines, all of the preexisting conditions were self-reported. Although self-reporting can be reliable, it is not the best method for obtaining a medical history, but we did not have access to medical records. Therefore, it was not possible to determine who was currently receiving treatment for many of these conditions. Another limitation was the distribution of participants across sports: we tested a large number of football student-athletes, yet many other sports were underrepresented. Finally, we examined each variable independently and did not analyze the combined effects of the preexisting factors. Some of the effects seen could be due to a combination of variables instead of 1 variable alone.

CONCLUSIONS

Our results suggest that preexisting factors, including sex and ADHD, can influence neurocognitive performance on ImPACT in collegiate student-athletes. Also, most preexisting factors increased total symptom scores. These findings stress the importance of baseline testing as part of concussion management. Even though normative data are available for most neurocognitive tests, including ImPACT, our observations indicate that preexisting factors can negatively influence baseline scores. Normative data may not be sufficiently reliable for use in determining RTP. Neurocognitive data for athletes with certain preexisting factors may differ from normative data and demonstrate a

higher total symptom score, leading to incorrect RTP decisions.

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