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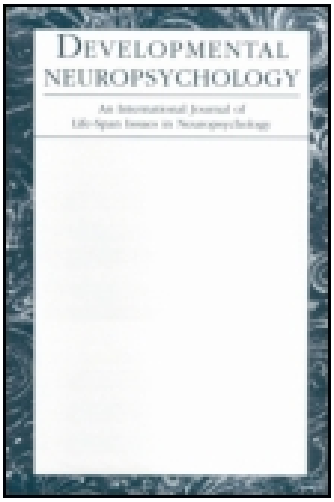

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Changes in Symptoms in Concussed and Non-Concussed Athletes Following Neuropsychological Assessment

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Changes in Symptoms in Concussed and Non-Concussed Athletes Following Neuropsychological Assessment

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Collegiate athletes tested at baseline and post-concussion were administered a self-report measure of post-concussion symptoms pre- and post-testing. Athletes tested post-concussion were significantly more likely to demonstrate an increase in symptoms post-testing, suggesting that the cognitive exertion involved in neuropsychological assessment may exacerbate symptoms in some athletes.

The negative effects of physical exertion on post-concussion symptoms have been well established, but there is little research on the effects of cognitive exertion. The possible negative effects of cognitive exertion on post-concussion symptoms has implications for recovery protocols and also may influence decision making about when to conduct the cognitively taxing process of neuropsychological assessment.

The most recent international consensus statement on concussion in sport includes a recommendation for cognitive rest following concussion (McCrory et al., 2013); however, few studies have examined the effects of cognitive exertion on post-concussive symptoms directly. In a study in which cognitive and physical exertion were studied, athletes with the highest levels of exertion post-concussion showed the largest decrease in neurocognitive scores and the highest post-concussion symptom scores. The authors of this study noted anecdotally that cognitive activity related to school was commonly reported for many athletes (Majerske et al., 2008). Another study found that physical and cognitive rest led to improved performance on neuropsychological testing and decreased symptom reporting (Moser, Glatts, & Schatz, 2012). Like physical exertion, cognitive exertion can add to the neurometabolic demand in the brain, such that cognitive exertion could exacerbate the energy crisis caused by the neurometabolic cascade that occurs after concussion (Valovich McLeod & Gioia, 2010).

More research is needed to establish the effects of cognitive exertion on post-concussive symptoms and cognitive performance. Engaging in a long neuropsychological testing session can be conceptualized as an experimental manipulation of cognitive exertion, and may have negative effects on concussion symptoms and recovery. The most appropriate time to test athletes post-concussion is unknown. Some have argued that testing athletes who are still symptomatic is necessary for establishing the severity of the injury and tracking progress throughout recovery (Van Kampen, Lovell, Pardini, Collins, & Fu, 2006). Additionally, many athletes may be motivated to underreport symptoms, in order to expedite return to play, so cognitive testing can provide a more objective measure of

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their concussion status (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; Williamson & Goodman, 2006). Others, however, have suggested that if athletes are symptomatic, neuropsychological testing is not necessary because they will not be returning to play regardless of cognitive status (Randolph, McCrea, & Barr, 2005).

The present study aimed to evaluate changes in symptom reporting pre- and post-testing in athletes at baseline and post-concussion. While neuropsychological testing is a cognitively taxing process, even for healthy participants, we hypothesized that a greater proportion of athletes tested post-concussion would show a significant increase in symptoms after testing compared with athletes tested at baseline. Thus, our study provided an experimental manipulation of cognitive exertion on symptom reporting in concussed compared with non-concussed collegiate athletes.

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METHOD

Participants

One-hundred-fifty-five athletes tested at baseline and 23 athletes tested post-concussion were included from a university-based sports concussion program. All athletes participating in contact sports that utilize the university-based sports concussion program are administered baseline tests prior to the start of their athletic participation. Athletes are referred back for post-concussion testing by their team doctor or athletic trainer when they have sustained an American Academy of Neurology (AAN) Grade 2 or 3 concussion. The baseline sample was comprised of 119 males (77%) and 36 females (23%) with an average age of 18.9 years (SD = 1.49) and an average of 0.57 previous concussions (SD = 0.84). The post-concussion sample was comprised of 18 males (78%) and 5 females (22%) with an average age of 19.0 years (SD = 1.60) and an average of 1.05 previous concussions (SD = 1.23). The samples had a comparable representation of ethnic backgrounds and sports played. Athletes tested post-concussion were tested an average of 36.2 days after injury (SD = 81.5) and therefore represented both athletes recovering from acute concussion and athletes suffering from more prolonged post-concussion symptoms.

Measures

The Post-Concussive Symptoms Scale (PCSS) was administered before and after testing during both the baseline and post-concussion testing sessions (Lovell et al., 2006). This self-report measure assesses physical, emotional, and cognitive symptoms using a 0–6 Likert scale. The scale contains 22 items and thus has a maximum score of 132. All athletes underwent a comprehensive neuropsychological testing battery in between the two PCSS assessments. The battery was approximately 2 hours in length and was comprised of both paper and pencil and computerized tests.

Analyses

Symptom difference scores were calculated by subtracting the pre-testing symptom score from the post-testing symptom score. A cutoff of 1 standard deviation from the mean difference of symptom scores at baseline (increase of 5 or more points on the PCSS) was used to determine

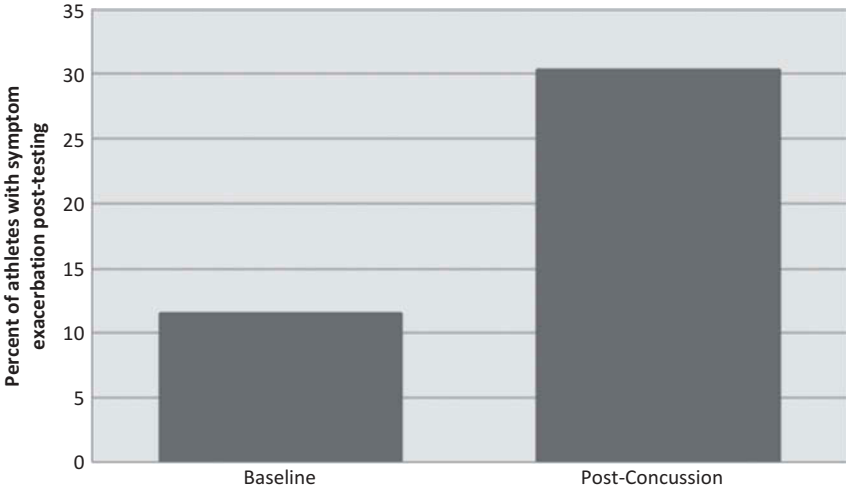

FIGURE 1 Symptom exacerbation following neuropsychological assessment.

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significant increase in symptoms. Fisher's Exact Test was used to evaluate the difference in the proportion of athletes tested at baseline versus post-concussion who displayed significant symptom increases following testing.

RESULTS

At baseline, athletes reported comparable levels of symptoms pre-testing ($M = 6.26$, $SD = 10.07$) and post-testing ($M = 5.65$, $SD = 8.08$), and at the post-concussion assessment athletes showed a slight mean change in symptoms from pre-testing ($M = 8.26$, $SD = 11.71$) to post-testing ($M = 9.48$, $SD = 11.41$); neither change was statistically significant ($p > .10$ for both). However, when the data were evaluated on an individual level, significantly more concussed athletes demonstrated an increase in symptoms post-testing compared with athletes at baseline (30.4% versus 11.6%, respectively, $p < .05$, Fisher's Exact Test; Figure 1). A comparable number of athletes showed a decrease in symptoms at baseline (11.6%) and post-concussion (13.0%).

DISCUSSION

Our findings support our hypothesis that the cognitive exertion involved in neuropsychological assessment may exacerbate concussion symptoms in a subset of athletes. While this suggests that in some cases neuropsychological testing may worsen post-concussion symptomology, it does not seem to be a universal phenomenon.

Some researchers have asserted that symptom exacerbation following cognitive and physical exertion may not be entirely due to the energy crisis caused by the post-concussive

neurometabolic cascade (Silverberg & Iverson, 2013), as research has demonstrated the presence of postconcussive symptoms in healthy samples at rest and exacerbation of these symptoms after exertion (Alla, Sullivan, & McCrory, 2012). The results of the current study show that, consistent with the findings of Alla et al. (2012), a subset of participants tested at baseline do experience a significant increase in symptoms following cognitive exertion due to neuropsychological assessment. However, the number of participants who experienced symptom increase after neuropsychological testing following a concussion was significantly greater than those tested at baseline, indicating an increased vulnerability to symptom exacerbation to cognitive exertion post-concussion. The fact that not all concussed athletes experienced increased symptoms post-concussion may reflect individual differences in concussion recovery, as well as differential thresholds for increased energy demands during the postconcussive energy crisis.

While this study provides a foundation for future work in this area, it has several limitations. All athletes were referred for post-concussion assessments by team medical personnel; however, athletes who report symptoms to their team medical personnel may be more likely to report an increase in symptoms post-testing. Future work should evaluate the effects of cognitive testing on symptom exacerbation in the same group of athletes tested at baseline and post-concussion. Further, the group of athletes that comprised the post-concussion group included both athletes recovering from recent concussion (tested within two weeks) and those who were referred for testing after their symptoms did not resolve within the expected two weeks. Due to the small sample size, these groups could not be explored separately. Additionally, it is possible that neuropsychological assessment may only temporarily exacerbate symptoms and not impact the recovery trajectory of the individual. Lastly, this study does not include a "no cognitive load" group for comparison and therefore the changes seen in symptoms due to cognitive exertion cannot be fully disentangled from potential change in symptoms due to time.

Future work evaluating factors influencing the likelihood of symptom exacerbation from cognitive exertion in particular individuals will be illuminating for determining cases in which neuropsychological assessment may do more harm than good. Additionally, future work should monitor symptoms for the days and weeks following the testing session to establish whether the symptom exacerbation observed leads to a new baseline of post-concussion symptom intensity or if the symptoms return to the pre-testing level soon after testing. Lastly, an evaluation of return-to-cognitive exertion procedures, similar to return-to-play procedures, would help to inform optimal concussion recovery protocols.

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