Neuropsychological Testing and Concussions: A Reasoned Approach

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Researchers and clinicians have raised awareness about the serious consequences of sport-related concussion,[1] which occur 1.6 to 3.8 million times per year in the United States alone.[2] Although the concept of the second-impact syndrome (a second head trauma causing brain swelling and death) remains controversial,[3] the published cases do raise concerns.[4] Short-term concussion disabilities (eg, mood, memory, concentration) may last months and have detrimental effects on quality of life at home, school, work, and sport.[5] Repeated concussions may affect cognition decades later.[6,7]

Despite this evidence, it remains unclear when physicians should allow return to play (RTP) after a concussion. More than 20 years ago, Cantu[8] recommended RTP only when a patient had been symptom free for 1 week, both at rest and with exertion; similar recommendations have followed.[1,9,10] The results of neuropsychologic (NP) testing, however, suggest that cognitive deficits may persist long after symptoms have resolved,[1] and some question whether the older recommendations are appropriate. The most recent international consensus conference[1] considered NP testing to be "an important component in any RTP protocol." Others (with some conflict of interest) suggest that NP testing is a "cornerstone of concussion management" and, in addition, that baseline neuropsychologic (BNP) testing should be performed whenever possible.[11] The National Football League began BNP in 1995 and the National Hockey League in 1997, and some have recommended it for university, high school, and other sport organizations.[12] At least 1 jurisdiction in the United States has considered legislating BNP for athletes (State of New Jersey 214th Legislature Senate Resolution No. 74).

Given these recommendations, NP with or without BNP may come to be perceived as a "standard of medical care," with obvious medicolegal implications for both the sport medicine practitioner and sport organizations. But do the results of NP testing change patient management or provide other clinical benefit to the patient? Is there sufficient evidence to mandate it as standard of medical care?

GENERAL CONSIDERATIONS ABOUT NP TESTING

Standard concussion assessment includes gross measures of orientation, memory, and concentration (and the physical examination of balance and coordination).[1] Both paper-and-pencil and electronic NP tests identify more subtle brain deficits in cognitive, affective, and memory domains and reaction time.[11] Neuropsychologic testing is effective for its intended purpose: measuring brain function. However, the objective in concussion management is to measure brain injury, and brain injury is only 1 cause of decreased brain function. Limb injuries, for example, result in mood change and can cause a decline in NP test scores (and delay their return to normal).[13] This suggests that part of the decline in NP test scores with concussion may be nonbrain-injury related. That said, some argue that expert neuropsychologists may be able to distinguish brain injury from other causes of decreased brain function.[14] Assuming this is true, there are simply not enough neuropsychologists with this expertise available for mandatory effective NP testing to be feasible on a population level or for it to be considered a standard of medical care.

Submitted for publication September 11, 2011; accepted January 24, 2012.
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The author reports no conflict of interest.
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Some have shown that NP testing had no meaningful predictive value in professional football players regarding prognosis due to the high variability in results.[15] Although Lau et al[16] found that visual memory and processing speed were predictive of recovery time by themselves, the usefulness of NP testing requires that it provide added information beyond that of clinical symptoms. This has only been reported once, and only among high school football players.[17] In that study, the presence of clinical symptoms alone predicted 63.9% of the protracted recovery cases [positive predictive value (PPV)], whereas the presence of clinical symptoms with NP testing had a PPV of 73.2%. In the absence of clinical symptoms, 62.9% of athletes did not have a protracted recovery [negative predictive value (NPV)], whereas the absence of clinical symptoms with NP testing had an NPV of 73.8%. These mild gains in PPV and NPV may help a team better manage resources over the long-term but strongly suggest the test has minimal value for an individual athlete and does not support mandating its use.

The usefulness of NP testing can be explored in 3 specific concussion contexts: symptomatic at rest, asymptomatic at rest but symptomatic on exertion, and asymptomatic even with intense activity. In each context, targeted NP testing may be indicated when patients are extremely anxious despite a normal clinical evaluation or when the patient or third party requires objective brain function data to be convinced of the diagnosis.

Athletes Symptomatic at Rest

Although some recommend NP testing in symptomatic patients,[11] such testing does not affect clinical management. Published guidelines over the last 20 years,[8–10] including the most recent consensus guidelines,[1] recommend rest (physical and cognitive) until symptoms subside. Targeted NP testing could (1) give added assurance for RTP decisions when clinicians believe persistent symptoms are not concussion related (eg, trigger points, neck pain causing headaches), or (2) avoid over diagnosing concussions and over treating athletes; in these cases, the patient is not in danger if testing is omitted.

Athletes Asymptomatic at Rest but Symptomatic on Exertion

Some recommend that a postconcussion exercise program (with no risk of head trauma) begin only when NP tests are normal.[18] This reasoning presupposes that any physical stress provokes symptoms more easily than cognitive stress; there are no published data addressing this question. Furthermore, reading, watching television, or attending school or work for long periods can provoke symptoms.[1] However, proponents of NP testing only ask patients to reduce these tasks to a level that does not provoke symptoms, not refrain completely. It seems reasonable to apply the same principles to physical activity without risk of head trauma; therefore, NP testing is not necessary.

Athletes Asymptomatic on Exertion

Is full cognitive function required for safe RTP where brain injury is possible? The underlying premise of such an approach is that asymptomatic patients with subtle NP deficits remain at increased risk of further injury or prolonged disability if they receive subsequent head trauma.

It should be noted that all cases of second-impact syndrome have occurred in symptomatic patients.[19] Given the millions of sport-related concussions that occur each year,[2] the absence of a single report in an asymptomatic patient makes it difficult to believe asymptomatic patients with abnormal NP testing are at increased risk. For all other injuries, subtle reaction time (or other) deficits may be important in certain high-risk sports like downhill skiing and car racing. That said, what is an acceptable reaction time? What if athlete A is 0.2 seconds slower than usual (0.3 seconds vs normal = 0.1 seconds), and athlete B is 0.15 seconds slower than usual (0.4 seconds vs normal = 0.25 seconds)? Is athlete A at greater risk because of the larger change in their reaction time? Alternately, is athlete B more at risk because their absolute reaction time is slower? Furthermore, should we exclude athletes with diminished reaction time due to other reasons[20] (eg, fatigue, lack of sleep)?

Second, insofar as prolonging disability is concerned, it must be noted that there are no data investigating differences between asymptomatic patients with abnormal NP tests and asymptomatic patients with normal NP tests.

Finally, NP tests generally return to normal within 3 days of symptom resolution.[21,22] In a recent review, Johnson et al[11] concluded that NP testing was more sensitive than symptoms because cognitive resolution occurs after symptom resolution. However, the article cited 5 studies in which cognitive resolution occurred before (or at the same time as) symptom resolution and 3 studies where cognitive resolution took between 3 and 9 days longer than symptom resolution[23–25]; however, none of these 3 latter articles actually measured the time from symptom resolution to cognitive resolution. Finally, readers should remember that the clinically important comparison is between resolution of cognitive deficits and resolution of symptoms during intense exercise; studies that simply say asymptomatic may only be referring to asymptomatic at rest.

Other Issues

Because there is often self-imposed internal as well as external pressure on athletes to RTP, they may not always report their symptoms.[26] When this is a concern, targeted testing is appropriate. Although there is no research on how to identify athletes who may be minimizing symptoms, the fact that the intensity of symptoms increases with high-intensity exercise (the basis for graduated exercise programs during concussion recovery) could be a useful adjunct. If one carefully observes athletes during the intense exercise session required for RTP decision making (ie, the athlete must be asymptomatic with high-intensity exercise such as sprinting or heavy weightlifting), it would likely be difficult for many to appear normal in the face of an acute exercise-induced increase in headache, nausea, dizziness, or balance disturbance.

Some argue that baseline NP testing of every athlete is efficient and economical and reduces error.[11] However, the same authors note that baseline tests (actually any NP test) may be invalid for many reasons,[11] which may be 1 reason for

the poor reliability that has been reported.[19] Furthermore, the same proponents of baseline NP testing acknowledge that "baseline testing is not required to successfully determine that an athlete has fully recovered because neuropsychological tests are constructed to compare injured athlete scores with healthy individuals of their same normative group (eg, age, gender)."[11] Therefore, mandating baseline NP testing of all athletes does not appear justifiable because (1) there is no evidence that subtle deficits identified by NP testing provide information on safety for RTP, (2) population standards are adequate to diagnose full recovery, and (3) the only potential benefit occurs in the few cases to be targeted.

CONCLUSIONS

Even assuming acceptable reliability (which has been challenged[19]), NP testing provides only a small increase in prognostic information and does not change the management of athletes who are symptomatic at rest or with exercise. There is no evidence that abnormal NP testing is associated with increased risk of further injury or delayed recovery in athletes who are asymptomatic at rest and exertion. Targeted testing may provide added value when an athlete is overly anxious, symptoms are not believed to be brain injury related, there is still concern about symptom underreporting, or added assurance is desired for aggressive RTP decisions in professional athletes. Given the 20-year-old recommendation of 1-week symptom free at rest and exertion,[8] those with available data are strongly encouraged to conduct analyses to determine if this recommendation is appropriate (too long or too short)[27] and if adolescents are different from adults. Finally, because expertise (and funding) is required to obtain the data and interpret NP test results, making NP testing (especially at baseline) a standard of medical care could do harm if those working within limited budgets were forced to drop existing effective prevention/treatment programs.

ACKNOWLEDGMENT

The author would like to acknowledge Steven Stovitz, David Coppel, and Lyn Charland for helpful comments on early drafts of this article.

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