Research Report

Neurocognitive Impairments Among Athletes with a History of Multiple Concussions

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Introduction
Approximately 1.8 to 3.6 million sports-related concussions occur each year in the United States (Langlois, Rutland-Brown, & Wald, 2006). Researchers have suggested that athletes with a history of concussion are at a greater risk for a subsequent concussion (Abrahams, McFie, Patricios, Posthumus, & September, 2014; Guskiewicz et al., 2003). With the escalated opportunities for athletes to sustain multiple concussions, determination of related ensuing problems and deficits is warranted. Despite indications that the vast majority of people will recover from a single concussion, there is concern that sustaining multiple concussions over time will result in cumulative or lingering effects on neurocognitive performance and symptoms. The lasting effects of subjective symptom scores are typically higher in individuals with multiple concussions along with increased neurocognitive function, however the literature reveals mixed results. Therefore, the purpose of this article is to review literature on symptom reporting and neurocognitive impairments assessed using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery among athletes with a history of multiple concussions.

Self-Reported Symptoms in Athletes with Multiple Concussions.
Symptoms are evaluated within the ImPACT neurocognitive test battery using the Post-Concussion Symptom Scale (PCSS). The PCSS assesses symptoms using a seven-point Likert scale, which allows individuals to self-report the severity of their symptoms (Lovell et al., 2006). Research suggests that athletes with a history of multiple concussions differ on total self-reported symptoms at both baseline and post-concussion compared to athletes without a history of concussion (Brooks et al., 2016; Covassin, Moran, & Wilhelm, 2013; Schatz, Pardini, Lovell, Collins, & Podell, 2006). In high school athletes with no history of concussion, average total baseline symptom scores were lower compared to athletes with a history of one, two, three, or four or more concussions (Mannix et al., 2014). Similar, Brooks and colleagues (2016) reported baseline symptom scores were significantly higher for athletes reporting three previous concussions compared to athletes with no history of a concussion. In addition, athletes with four or more previous concussions had significantly higher baseline symptom scores when compared to athletes with one previous concussion (Brooks et al., 2016).

Recently, self-reported symptoms have also been categorized into clusters. Specifically, researchers suggest athletes’ symptoms can be grouped into four clusters that include cognitive-sensory, vestibular-somatic, sleep-arousal, and affective domains (Kontos et al., 2012). Total symptom scores within these domains have varied among athletes with and without a history of concussion. Not only did Brooks and colleagues (2016) report that athletes with a history of concussion reported greater symptoms but they also had higher symptom scores within all four domains (Brooks et al., 2016). The greatest percentages of symptoms reported among athletes with a history of multiple concussions included headache, sensitivity to light, sensitivity to sound, visual problems, fogginess, and difficulty concentrating (Brooks et al., 2016).

Numerous researchers have also examined self-reported symptoms in athletes with a history of concussion. In the acute stage of a concussion (i.e., within three days following a concussion) and subacute (i.e., up to eight days post-concussion), athletes with a history of three or more concussions reported significant differences in migraine cluster symptoms compared to baseline scores (Covassin et al., 2013). More specifically, athletes with a history of concussion have demonstrated greater deficits in loss of balance, excess drowsiness, visual disturbances, insomnia, and tinnitus (Wasserman, Kerr, Zuckerman, & Covassin, 2015). Other researchers have also reported athletes with a history of multiple concussions experience longer symptom resolution times compared to athletes.
with no history of concussion (Wasserman et al., 2015). Therefore, early return to activity should be cautioned in athletes with a history of multiple concussions in order to prevent possible detrimental brain damage due to second impact syndrome.

**Baseline Neurocognitive Performance in Athletes with Multiple Concussions.**

Despite the observed differences in symptom reporting, a point of contention among researchers is the degree to which prior concussion history affects baseline neurocognitive performance. Recent studies examining baseline neurocognitive performance in high school athletes have reported no differences between those with and without a history of concussion (Tsushima, Geling, Arnold, & Oshiro, 2016). Similar results have also been found at the Division I college level with athletes with and without a history of concussion reporting no differences in baseline neurocognitive performance (Brown & Guskiewicz, 2007; Bruce & Echemendia, 2009). However, in the aforementioned studies athletes were only divided into two groups, either a history of previous concussion or no history of concussion. Therefore, a dose-response relationship could not be evaluated in these studies. With the division of athletes into subsequent concussion groups (i.e. one, two, three or more concussions), this dose-response relationship may be better evaluated, indicating a possible impact of sequential concussions on neurocognitive function.

Several researchers have examined the influence of the number of previous concussions and baseline neurocognitive performance. Early reports suggest that a history of a single concussion does not appear to influence baseline performance. However in athletes with a history of two and three or more concussions showed decreased neurocognitive performance. More specifically, high school and collegiate athletes with multiple concussions have demonstrated diminished performance on baseline ImPACT composite scores of verbal and visual memory (T. Covassin, Elbin, Kontos, & Larson, 2010). Likewise, noticeable deficits in processing speed have been found in baseline results of football players with two or more concussions when compared to those with zero or one prior concussive injury (Collins et al., 1999).

In contrast to the previous studies, other researchers using similar neurocognitive measures have failed to find any evidence of impaired cognitive function in athletes with and without a history of multiple concussions. In the evaluation of 867 athletes, Iverson and colleagues (2012) reported no differences in baseline neurocognitive performance among athletes with zero, one, or two previous concussions. However, it was reported that athletes with a history of three or more concussions demonstrated decreased verbal memory (Iverson, Echemendia, Lamarre, Brooks, & Gaetz, 2012). In a comparable study, Solomon and colleagues (2013) divided participants into concussion groups based on their respective concussion histories. Athletes were studied over the course of three separate football seasons, with ultimately no differences reported on any of the ImPACT composite scores (Solomon, Haase, & Kuhn, 2013). However these findings are not without limitations, as the time since last concussion and severity of previous concussions were not addressed. This information may directly influence these findings and conclusions.

**Post-Concussion Neurocognitive Performance in Athletes with Multiple Concussions.**

Multiple concussions are not only accompanied by more severe symptoms, but also a slower post-concussion recovery (T. Covassin, Stearne, & Elbin, 2008; Guskiewicz et al., 2003; Guskiewicz, Weaver, Padua, & Garrett, 2000). A history of multiple concussions are associated with prolonged recovery of neurological function following subsequent concussion (Guskiewicz et al., 2003). An early study assessing baseline and post-concussion neurocognitive function within 5 days of injury suggested athletes with a history of
three or more concussions were eight times more likely to experience a major decline in memory function compared to athletes with no history of concussion (Iverson, Gaetz, Lovell, & Collins, 2004). Moreover, there were a greater number of athletes from the multiple concussion group that exhibited a major decline in memory function. However, no significant differences in reaction time and visual-motor processing speed were exhibited among athletes with various concussion histories. Overall, this study substantiated that not only does initial injury effect neurocognitive function, but also each subsequent concussion may have a deleterious cumulative effect on neurocognitive function (Iverson et al., 2004).

Furthering these contentions, Covassin and colleagues (2008) examined athletes with a history of two or more previous concussions compared to athletes with no history of previous concussion at 1 and 5 days post-concussion. Athletes with a history of two or more concussions presented with worse verbal memory and reaction time composite scores compared to their counterparts with no concussion history. Improvements toward return to baseline were apparent at day 5 in both groups, although the two or more concussions group showed continued deficits in verbal memory and reaction time components.

Similar results were reported in a more recent study of 598 high school and collegiate athletes. Participants were divided into one of four groups (i.e. zero, one, two three or more concussions) based on previous concussion history and were assessed using the ImPACT test battery at baseline, 3 days, and 8 days post-concussion. Athletes with one or two previous concussions demonstrated impairment at 3 days following a concussion in verbal memory, but returned to baseline by 8 days post-concussion. Increased deficits were still evident in athletes with a history of three or more previous concussions at 8 days following concussion. Similarly, athletes with one previous concussion exhibited slower reaction times at day 3, but demonstrated full recovery by day 8. Athletes with two or more previous concussions demonstrated persistent problems at day 8 on reaction time. These results suggest neurocognitive impairments are apparent in athletes with greater numbers of previous concussions. Also, a delayed return-to-play is indicated with longer recovery times in athletes with a cumulative concussion history (Covassin, Moran, & Wilhelm, 2013).

**Conclusion**

Numerous researchers have examined the relationship between history of concussion and the subsequent risk and outcome from future concussive episodes. In sum, athletes with a history of at least two or more concussions have been found to be at a higher risk for subsequent concussion, and are likely to demonstrate a prolonged recovery from future concussive injuries. However, the extant literature investigating more long-term or residual cognitive impairments associated with a history of multiple concussions has uncovered many issues and left many questions unanswered. Therefore, a more comprehensive longitudinal study is warranted. Future research should also aim to examine age and sex differences on multiple concussed athletes on both neurocognitive performance and concussion symptoms.
References


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