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Enduring effects of concussion in youth athletes

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Abstract

The purpose of this study was to explore the mild, enduring effects of concussion in otherwise healthy youth athletes. Reported history of concussion and cognitive functioning was examined in an initial sample of 35 youth athletes, 21 of whom were considered healthy volunteers (*No Recent Concussion* within the past 6 months) with no identified medical or neuropsychological difficulties related to concussion. The remaining 14 volunteers had each sustained a concussion within 1 week of testing (*Recent Concussion*). Significant differences in performances on a general cognitive measure, and specifically in the area of attention, were found as a function of number of concussions reported by the *No Recent Concussion* athletes. Furthermore, on some of the measures, *No Recent Concussion* athletes with a history of two or more concussions appeared to resemble *Recent Concussion* athletes more so than *No Recent Concussion* athletes with a history of one or no concussion. The importance of assessment of youth concussion and the use of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) for this purpose are discussed. © 2001 National Academy of Neuropsychology. Published by Elsevier Science Ltd.

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1. Introduction

Sports-related head injury has received significantly more attention over the past few years. The effects of repeated concussions have been demonstrated in a number of high-profile athletes (Grady, 1998; LaPointe, 1998). With multimillion dollars and careers at stake,

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professional athletic associations have supported the implementation of preseason baseline testing and neuropsychological evaluation to assist in return-to-play decision making and to assess the cognitive sequelae of concussive head injuries (Lovell, 1999). Such comprehensive programs are infiltrating college athletics (Lovell & Collins, 1998) and most recently have begun to manifest themselves in high school athletics (Echemendia, 1999). It is clear that mild head injury is a growing concern in the popular high school contact sports (Powell & Barber-Foss, 1999).

Barth's (1998) and Barth et al.'s (1989) groundbreaking research focused on college athletes in the 1980s and evaluated the cognitive effects of mild concussion where there was no loss of consciousness. Tested at three postconcussion time intervals (24 h, 5 and 10 days), Barth discovered that recently concussed athletes demonstrated significant increases in memory difficulties, dizziness, and headaches, as well as significant decreases in attention and problem solving abilities, as measured by the Trail Making Test A and B, from the Halstead–Reitan Neuropsychological Test Battery, the Symbol Digit Test, and the Paced Auditory Serial Addition Task (PASAT). He further noted that within 5–10 days after the injuries, these athletes returned to their preseason baseline abilities.

Typically, research has focused on immediate and short-term effects of sports concussion, some of which include alteration in consciousness, amnesia, confusion, delayed cognitive responses, memory and learning difficulties, headache, and irritability (Macciocchi, Barth, & Littlefield, 1998; Moser, 1998). Long-term follow-up of sports concussion sequelae has been limited. More recent research on adult soccer players has documented the persisting cognitive effects of concussions. In amateur soccer players, concussions were related to poorer performance on a number of neuropsychological measures including Digit Span, Facial Recognition, Complex Figures, Digit Symbol, and Logical Memory (Wechsler Memory Scale; Matser, Kessels, Lezak, Jordan, & Troost, 1999). Weaker planning and memory abilities were also observed in these soccer players when compared to control athletes. In an earlier study in which professional soccer players were compared to elite noncontact sport athletes, impaired memory, planning, and visuospatial abilities were related to frequency of heading the ball and number of concussions (Matser, Kessels, Jordan, Lezak, & Troost, 1998).

Research on adults has revealed some possible long-term sequelae of repeated mild head injury, such as an association with the development of Alzheimer's disease. A link between Apolipoprotein 4, a factor associated with Alzheimer's disease, and exposure to contact sports has been posited (Jordan et al., 1997). Biochemical and genetic factors are receiving greater attention in recent research (Kutner & Barth, 1998). Concussion is now understood in terms of ionic influx that suddenly activates or increases glycolysis in the brain (Hovda et al., 1999). Metabolic dysfunction appears to be important in understanding the vulnerability of the brain during recovery.

Recently, research has documented deficits in the neuropsychological performance of college football players and a link to concussion and the synergistic effects of learning disability (Collins et al., 1999). In this research, male college football players were assessed regarding their histories of concussion and learning disorder. Of 393 players, 208 had a history of one or more concussions, approximately 53%. The authors suggested that having a history of learning disorder further compromised those individuals who had a history of two

or more concussions. These findings echo that of Gronwell (1976) who over 20 years prior suggested that premorbid intelligence might mitigate the effects of concussion. In this study, concussed university students (in active academic study) performed better than concussed nonstudents on measures of vocabulary and verbal fluency after a period of recovery, even though there was no significant difference between the groups on measures immediately after concussion.

The bulk of neuropsychological research has focused on the college or professional athlete rather than adolescent youth. The prevalence of traumatic brain injury in high school athletes has only recently been comprehensively documented. Powell and Barber-Foss (1999) noted that of 23,566 reported sports injuries in 235 high schools during the period of 1995–1997, 5.5% were mild traumatic brain injuries. The greatest percentages of brain injury occurred in football (63.4%), girls' and boys' soccer (11.9%), and wrestling (10.5%).

Outcome assessment regarding the cognitive effects of sports-related concussion in youth has been limited. McCrea, Kelly, Kluge, Ackley, and Randolph (1997) presented their use of standardized sideline assessment as a baseline and screening tool for concussion. Although neither designed to be sensitive to the identification of postconcussion symptoms nor developed to be a neuropsychological test, this sideline assessment tool has provided a quick mental status examination that has generated a formidable body of research. In their study, McCrea et al. assessed orientation, immediate memory, concentration, and delayed recalled in 141 high school football athletes. Six of the 141 were reported to have sustained concussions during one season. These six as a group scored lower on their postconcussion screenings.

The lack of knowledge regarding the effects and management of concussion is pervasive in the general medical community, as well as in the general public. Genuardi and King (1995) concluded that in a sample of 33 youth athletes with sports-related concussions, hospital discharge instructions were appropriate for only 30.3% of the Grade 1 concussions, for 20.0% of the Grade 2 concussions, and for none of the Grade 3 concussions.

Lack of consensus regarding the management of concussion may be related to the scarcity of scientific evidence to support the determination of severity of concussion and guidelines for return to play (Roos, 1996). A number of concussion severity scales have been offered, the most recent of which was published by the Quality Standards Subcommittee of the American Academy of Neurology (AAN) (1997). This scale defines a Grade 1 concussion as symptoms lasting less than 15 min, with transient confusion and no loss of consciousness. A Grade 2 concussion requires symptoms lasting more than 15 min, no loss of consciousness, and transient confusion. In contrast, in a Grade 3 concussion, there is loss of consciousness, which is either brief (s) or prolonged (min). Return-to-play guidelines are based on the severity and frequency of concussions. The scale and accompanying guidelines represent an effort to provide a standardized approach to the evaluation of concussion. However, the AAN concussion scale and accompanying return-to-play guidelines have not yet been scientifically validated.

With a number of concussion scales in use, it may be difficult to compare findings across studies. The fleeting bell-ringing that lasts seconds occurs all too frequently in high school, college, and professional sports and is thus often dismissed and unreported. This event,

although categorized as a Grade 1 concussion by AAN Guidelines, may not be included in the determination of concussion frequency within a research population sample.

More often than not, neurological and radiological procedures reveal lack of significant findings and are not sensitive to the effects of mild brain injury. In contrast, neuropsychological testing appears to be more sensitive even to the very subtle effects (Kutner & Barth, 1998). Thus, it is not uncommon for the health care provider to dismiss the effects of concussion early on, not realizing that the athlete may be still recovering. It is suggested that repeated concussions, with short time intervals in between, place the athlete at greater risk, exposing the vulnerable brain to another contact insult before it has healed. In children, the possibility of Second Impact Syndrome, a rare, catastrophic effect usually resulting in fatal outcomes for youth, has been suggested in certain cases of closely spaced repeated concussions (Cantu, 1998; McCrory & Berkovic, 1998). Perhaps in some ways, the young brain is more vulnerable to insult than the adult brain.

Much of the neuropsychological and medical research to date regarding concussion in athletes has focused on the adult or young adult population. Many of the participants in these studies may have sustained concussions through participation in precollege or “youth” athletic activities. It is currently unclear whether there are any enduring, prolonged effects of concussion in these youth athletes, who have otherwise had no concussion complaints and who have been considered unaffected by any past concussion.

The present study set forth to explore a number of the above concerns. In particular, it sought (1) to gather more information about concussion in youth athletes and (2) to look at the possible mild, enduring effects of concussion in youth. Specifically, do symptom-free youth athletes, with no history of concussion in the past 6 months, significantly differ in neuropsychological functioning depending on the number of past concussions sustained? Furthermore, how does the neuropsychological status of recently concussed (i.e., within 1 week) youth athletes compare with the status of the reportedly asymptomatic youth athletes with a past history of concussion?

2. Method

2.1. Participants

Participants were derived from an initial sample of 35 youth athlete volunteers who were part of an ongoing education, prevention, and research study. These student athletes consisted of 14–19-year-olds who played in a number of sports, predominantly ice hockey, football, field hockey, lacrosse, and soccer. Most of these individuals participated in multiple sports throughout the school year and summer vacation. Twenty-one of them had not experienced a concussion of any grade within the past 6 months and none of the 21 complained of symptoms or difficulties related to concussion. Four of the 21 were female students. The group of 21 comprised the *No Recent Concussion* group. The remaining 14 participants, of the initial sample of 35, had experienced a Grade 2 or 3 concussion within 1 week prior to testing and comprised the *Recent Concussion* group. Three of the 14 were female students.

2.2. Procedure

Concussions were documented by information gathered from open-ended questioning and interviews of the student and/or parent and/or school physician, employing the AAN guidelines for classification as described above. Concussion history included all concussions sustained throughout childhood and adolescence. All students in the *Recent Concussion* group were referred for voluntary participation through the school physician after they sustained a Grade 2 or 3 concussion.

Voluntary participation was solicited from a highly academically competitive, private, college preparatory boarding school during the 1998–1999 school year. The sample of 35 comprised all the volunteers from the school that year. Informational mailings were sent to parents/guardians from the school's infirmary. Participating parents/guardians and students completed Informed Consent Participation forms, which described the purpose, objective, and details of the testing and research participation. For youth younger than 18 years, a parent/guardian signature was required in addition to that of the participant. In cases of joint parental custody, both parent signatures were required. Student Data forms were also completed, which requested background demographics, Academic Grade Point Average (GPA), Verbal and Math Achievement Percentiles (V% and M%), and history of head injury or concussion. GPA and Achievement Percentiles were based on student and parent/guardian reports. At the time of testing, a thorough interview was conducted to solicit information regarding history of concussion.

2.3. Measures

All participants completed the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) Form A (Randolph, 1998). The RBANS is a relatively new instrument that assesses a variety of cognitive areas and has been validated for the adult population. These areas include Immediate Memory (List Learning and Story Memory), Visuoconstructional Ability (Figure Copy and Line Orientation), Language (Picture Naming and Semantic Fluency), Attention (Digit Span and Coding), and Delayed Memory (List Recall, List Recognition, Story Recall, and Figure Recall). This instrument was utilized, as it offered a practical, timesaving route to the assessment of youth athletes. The RBANS assesses a variety of cognitive functions in a concise, short battery. Also, it provides an alternate form for future retesting, especially after an injury. Raw scores were employed to examine relative differences among youth concussion sample groups, with no need for diagnostic comparison to a normal reference population.

3. Results

Table 1 presents descriptive demographics for this youth sample. Overall, these student athletes tended to be high achievers, with mean achievement percentiles in the above average range. GPA mean was also above average, although it must be interpreted within the context

Table 1
Demographics for youth athlete participants

Variable	N	Range	Mean	S.D.
Age (years)	35	14–19	16.65	1.20
Reported GPA (0–4.0 scale)	35	0–4.0	3.20	0.52
Reported V%	32	65–99	83.94	10.83
Reported M%	32	55–98	85.55	11.81
Sport years	35	1–16	6.97	4.15

of the academically selective population of students from which the sample is derived. There was great variation in participation in sports, with a range of 1–16 years reported.

Table 2 presents the prevalence of concussion in the sample of 35 participants. Number of concussions is reported without regard to grade or severity. Thirty-four of the 35 participants (97%) reported a history of one or more concussions. This figure included the uneventful, quickly resolved Grade 1 concussions that are often not reported in other studies. It may be this inclusion, as well as a possible self-selection factor that resulted in such a high frequency of concussion. Fourteen athletes (*Recent Concussion*) were referred for participation by the school physician after they had sustained a Grade 2 or 3 concussion. If these 14 students are excluded, the frequency remains high at 95%.

Table 3 presents analyses that were conducted to help determine whether those students who suffered recent concussions were demographically different than those who suffered previous concussions. Due to the small sample size, and for the analysis of test data, three concussion groups were formed: I, *No Recent Concussion* and history of one or no concussion; II, *No Recent Concussion* and history of two or more concussions; and III, *Recent Concussion* within the past week. One-way analyses of variance revealed no significant differences between the groups for age, GPA, achievement percentiles, or number of years in sports.

Analyses were then performed to answer two questions: (1) With regard to cognitive functioning, does the RBANS discriminate healthy, asymptomatic student athletes, who have not sustained a concussion within the last 6 months (Groups I and II) from student athletes who have suffered a *Recent Concussion* (Group III)? (2) Do these otherwise healthy, asymptomatic student athletes differ on measures of cognitive functioning depending on their concussion history (Groups I vs. II)? It was hypothesized that the Groups I and II athletes would perform better on cognitive tasks than Group III athletes and that Group I athletes would perform better than Group II athletes.

Table 2
Prevalence of concussion in initial youth athlete sample (N=35)

Number of concussions	n	%
0	1	3
1	12	34
2	17	49
3 or more	5	14

Total participants with history of concussion = 34 (97%). Mean number of concussions = 1.86 (S.D. = 1.00).

Table 3
Group comparisons by history of concussions^{a,b,c}

Number and recency of concussions		Age	GPA	V%	M%	Sport years
<i>Group I</i>						
0 or 1 previous concussions	<i>N</i>	8	8	7	8	8
	Mean	16.96	3.11	85.29	83.43	9.38
	S.D.	1.00	0.52	10.29	15.55	3.96
<i>Group II</i>						
2 or more previous concussions	<i>N</i>	13	13	13	13	13
	Mean	16.78	3.18	81.15	85.46	7.15
	S.D.	1.31	0.61	11.42	9.33	5.43
<i>Group III</i>						
Recent concussion	<i>N</i>	14	14	14	13	14
	Mean	16.36	3.27	86.17	86.77	5.43
	S.D.	1.22	0.47	10.83	12.64	4.03

Age: [$F(2,32)=0.71$; $P=.50$]; GPA: [$F(2,32)=0.24$; $P=.79$]; V%: [$F(2,29)=0.72$; $P=.49$]; M%: [$F(2,30)=0.17$; $P=.84$]; Sports years: [$F(2,32)=2.05$; $P=.10$].

^a Groups were collapsed due to small size: zero concussion ($n=1$) and three or more concussions ($n=5$).

^b Groups were arranged according to number and recency of concussions.

^c One-way analyses of variance were two-tailed.

Table 4 presents the statistical analysis for the first question. Results indicated that those students who had been recently concussed (Group III) demonstrated significantly lower RBANS Total scores than the *No Recent Concussion* (Groups I and II combined) students. For the second question, significant differences were also found for RBANS Total, Coding, and Attention raw scores, such that healthy students (*No Recent Concussion*) who had a history of one or no concussions performed significantly better than the recently concussed students (*Recent Concussion*; see Table 5).

One-way analyses of variance were conducted to determine differences among RBANS raw score mean for Groups I, II, and III. The data supported statistically significant differences for RBANS Total raw score [$F(2,31)=3.86$, $P=.032$], for RBANS Coding raw score [$F(2,31)=3.98$, $P=.029$], and for RBANS Attention raw score [$F(2,31)=4.59$, $P=.018$].

A cursory examination of the mean raw scores for RBANS Total, Coding, and Attention in Tables 4 and 5, and the observed difference among Groups in Table 5, suggested a possible similarity between Groups II (healthy, *No Recent Concussion* with a history of two or more

Table 4
RBANS significant findings as a function of recent concussion

Concussion groups	<i>n</i>	Total RBANS score*	
No recent concussion (Groups I and II)	21	Mean	245.14
		S.D.	15.43
Recent concussion (Group III)	13	Mean	233.77
		S.D.	15.92

Higher mean scores = stronger cognitive functioning. Analysis is two-tailed; effect size noted by "ES."

* $t(32)=2.06$; $P=.047$; ES = 0.34.

Table 5
Significant group differences on RBANS

Concussion group	n		RBANS mean raw scores		
			Total	Coding	Attention
0–1 previous concussion	8	Mean	252.63	63.88	77.38
		S.D.	14.10	7.18	9.59
2 or more previous concussions	13	Mean	240.54	55.92	68.69
		S.D.	14.85	6.68	8.10
Recent concussion*	13	Mean	233.77	53.15	65.38
		S.D.	15.92	10.71	9.20

Total RBANS: [$F(2,31)=3.86$; $P=.032$; $ES=0.53$]; RBANS coding: [$F(2,31)=3.98$; $P=.029$; $ES=0.50$]; RBANS attention: [$F(2,32)=4.59$; $P=.018$; $ES=0.55$].

Higher mean scores = stronger cognitive functioning. analyses are two-tailed; effect sizes denoted by “ES.”

* Recent concussion group differed significantly from 0 to 1 previous concussion group on RBANS total, coding, and attention, as per post-hoc Scheffe analysis ($P<.05$).

concussions) and III (*Recent Concussion*). Post-hoc Scheffe analyses for group differences conducted on the three RBANS measures confirmed this observation. While there were no significant differences between Groups I and II or between II and III with regard to RBANS Total, Coding, or Attention raw scores, post-hoc Scheffe analysis supported statistically significant differences ($P<.05$) between Groups I and III for RBANS Total, Coding, and Attention raw scores. It appears that as a group, those youth athletes who had sustained two or more concussions in the past and who denied any physical, medical, or cognitive difficulties related to a history of concussion, resembled the group of youth athletes who had just recently suffered a concussion within the past week, more so than the healthy youths who had a history of one or no concussion.

4. Discussion

There may be possible mild, enduring effects of concussion that can be identified in youth who have experienced a history of two or more concussions. These mild effects may include decreased overall neuropsychological functioning, as well as decreased attention/mental speed. Although the current study offers some glimpses into the possible persistent effects of concussion in youth, it also raises many questions. These findings appear to contrast with those of Barth et al. (1989) who noted recovery in college athletes within 5–10 days. The contrast may be explained by the fact that the present study differs from the previous research, as it considers participation in multiple sports over a considerable period of precollege years. It is not yet clear that high school students are more vulnerable, per se, to postconcussion sequelae. While Barth et al.’s study was clearly “foundational” in the study of sports-related concussion, the present results appear to reflect differences in the speculated recovery curves between adolescent and young adults. As such, the implications of a more vulnerable and susceptible youth brain, perhaps still developing in adolescence, should be further considered.

It is important to note that factors such as severity or grade of concussion were not examined and that this study was clearly limited by its small sample size. Until a more

comprehensive, larger study can produce similar findings as presented here, these results should be interpreted with some caution. Still, the modest effect sizes noted, and potential effects of postconcussion symptoms at this vulnerable developmental stage, warrant further consideration of this neuropsychological screening tool.

Since the RBANS is not normed for youth, there may be a concern that in using this instrument there is no control for different cognitive levels related to age and maturation. Examination of group demographics revealed no significant differences in age, GPA, and achievement percentiles. Analysis also determined the ability of the RBANS to discriminate between students with a limited concussion history (one or no concussions) and those who had suffered a recent concussion. The data presented here are part of an ongoing research, prevention, and education project on youth sports concussion, in which the RBANS was originally chosen for its versatility in intraindividual concussion assessment (baseline vs. postconcussion) without concern for established population norms.

Statistical analysis of the effects of concussion may be problematic in that a variety of concussions can produce a variety of effects across individuals. Whereas one person may suffer from decreased mental efficiency and mental speed, another may experience word-finding difficulties or visual disturbance, and yet another may exhibit inattention as a primary symptom. To capture a homogeneous cognitive pattern that is statistically significant for a group of individuals, with the use of a short screening battery, is a challenge. The heterogeneous effects of concussion may result in lack of significant group findings when comparing mean on particular tests or subtests. This heterogeneity may help to explain why the RBANS Total raw score reached statistical significance in the analyses performed when only two of the raw score measures (Attention and Coding) were significant. Although specific abilities, such as those represented by the Attention and Coding measures, may be most consistently affected by concussion across individuals, assessment of a variety of cognitive abilities is likely necessary in order to capture an individual's general level and pattern of functioning. The importance of baseline screening, identification of premorbid neuropsychological status, and intraindividual pre- and postconcussion comparisons cannot be underestimated in diagnostic decision making.

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