

Evaluation of Executive Function and Mental Health in Retired Contact Sport Athletes

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Objective: To compare retired professional contact sport athletes with age-matched noncontact sport athletes on measures of executive function and mental health. **Setting:** The University Concussion Management Clinic. **Participants:** Twenty-one retired National Football League (NFL) and National Hockey League (NHL) players (mean age 56 years) and 21 age-matched noncontact sport athlete controls. **Designs:** Case control. **Main Measure:** The self- and informant-reported Behavior Rating Inventory of Executive Function-Adult form (BRIEF-A); Wisconsin Card Sorting Test; Delis-Kaplan Executive Function System; Trail Making Part A and B; Wechsler Adult Intelligence Scale; Neuropsychological Assessment Battery; List Learning; Controlled Oral Word Association Test; Beck Depression Inventory; Beck Anxiety Inventory; and Personality Inventory of the DSM-5. **Results:** Former NFL and NHL players perceived themselves to have some impairment in 2 of the 9 domains of executive function on the BRIEF-A; however, their informants reported no difference when compared with informants of noncontact athletes. No significant differences were found when comparing contact sport athletes with noncontact athletes on objective neuropsychological testing. Contact sport athletes qualified as clinically anxious and had more “unusual beliefs and experiences,” although they remained within with age-based norms. **Conclusion:** Participation in contact sports at the professional level may not lead to later-life executive dysfunction, as the popular media and some research currently suggest. **Key words:** athlete, chronic traumatic encephalopathy, concussion, dementia, executive function

CHRONIC TRAUMATIC ENCEPHALOPATHY (CTE) is a progressive neurodegenerative disorder suspected to be due to repetitive concussive or subconcussive blows to the head, similar to the ones received while playing sports with frequent physical contact.¹ There are varying opinions regarding the

clinical manifestations of trauma-induced tau protein deposition versus normal tau deposits as a result of age and other life factors.^{2,3} Deterioration of executive function is considered a hallmark characteristic of early-onset dementia.¹⁰ Executive function is defined as higher cognitive skills that facilitate critical thinking and decision-making. These skills include flexibility, focus, organization, planning, self-awareness, self-control, time management, and working memory.

Gavett et al⁴ conducted interviews of friends and family members of people who had documented CTE and described a consistent pattern of impairment in executive function, cognition, mood, behavior (impulsivity), and signs of motor neuron disease. Stern et al⁵ conducted similar interviews of family members of 36 deceased National Football League (NFL) and National Hockey League (NHL) athletes with confirmed CTE. Three were asymptomatic, 11 had cognitive dysfunction, 13 had behavior alterations that gradually became mood disturbance, and 10 were diagnosed with dementia. Seichepine et al⁶ conducted an online evaluation of former college and professional American football athletes using the Behavior Rating Inventory of Executive Function-Adult (BRIEF-A), a validated self-report questionnaire that assesses executive function. When compared with age-based norms, retired football players

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rated themselves to have significantly worse functioning on 7 of the 9 scales of the BRIEF-A when compared with the general population. The authors also raised concerns about the accuracy of self-reported concussions, with one of the respondents indicating he had 20 000 concussions.

Research to date on CTE implies that all athletes who played contact sport professionally, suffering repetitive concussions and/or sub-concussive blows, will develop or are at risk to develop CTE.^{7,8} It would also appear that most former contact sport athletes will eventually experience abnormal cognitive decline, behavior changes, and significant issues with planning and awareness. Based on this, the purpose of this article is to describe the executive function performance of a sample of former professional contact sport athletes using self-report (BRIEF-A), along with informant reports and objective testing, and compare these results with an age-matched control group of athletes who did not play contact sports. Based on the recent research on CTE,⁷ and the assumed early onset of cognitive and functional deficits, we hypothesized that former contact sport athletes would have significantly impaired executive function on both self-report, informant (spousal) report, and on neuropsychological testing associated with executive function when compared with noncontact athlete controls.

METHODS

The case-control study was completed as part of a larger study of retired athletes,⁹ at the University at Buffalo. Approval was obtained prior to the study from the University at Buffalo institutional review board committee.

Study participants

The contact sport group was composed of former NFL and NHL players who were invited and ultimately recruited through their respective alumni associations. The age-matched noncontact sport athletes (control group) were recruited from local sports associations. The recruitment process and inclusion and exclusion criteria are described in detail in Willer et al.⁹

Instruments

Executive function

The BRIEF-A¹⁰ was used to assess self-reported executive function. The BRIEF-A is a standardized and validated test that assesses cognitive and behavioral regulation^{11,12} and was administered to the participants of both groups as well as their identified key informants. The informants were spouses or close household members. The BRIEF-A includes subscales such as

planning, organization, and emotional control. The subscales are summarized into the broader categories of behavioral regulation, metacognition, and a global score of executive function. None of the participants' results or family members' results on the BRIEF was outside the acceptable range on each of the validity scales.

Executive function was objectively assessed with the Wisconsin Card Sorting Test (WCST),¹³ Delis-Kaplan Executive Function System (D-KEFS),¹⁴ and Trail Making Part B.¹⁵ Working memory was assessed with the Wechsler Adult Intelligence Scale, Third Edition (WAIS-III), using the subtest of Digit Span.¹⁶ Memory was tested with the Neuropsychological Assessment Battery (NAB) List Learning, both immediate and delayed recall.¹⁷ The Controlled Oral Word Association Test (COWAT) was used to evaluate language.¹⁸⁻²⁰ Finally, the domain of perceptual motor skills was tested with the WAIS Digit Symbol¹⁶ and Trail Making, Part A.^{15,21} Administration of these tests was supervised by an experienced neuropsychologist. The authors did not conduct any formal assessment of effort regarding the testing process.

Mental health assessment

The behavioral and mental health protocol of the study focused on assessing personality, mood, and behavior in the athletes. The protocol aimed to identify areas of impairment, as well as preserved areas, and to inform methods of intervention (including education and counseling). For the purpose of evaluation of participant mental health, we used the Personality Inventory for the DSM-5 (PID-5),²² which included normative data for comparison. The PID-5 assesses 25 facets of personality that are organized within 5 broad domains: Negative Affectivity (vs Emotional Stability), Detachment (vs Extraversion), Antagonism (vs Agreeableness), Disinhibition (vs Conscientiousness), and Psychoticism (vs Lucidity).^{22,23}

The scales used for depression and anxiety were the Beck Depression Inventory (BDI)²⁴ and Beck Anxiety Inventory (BAI),²⁵ respectively, 2 validated instruments. Both questionnaires have a maximum score of 63, but up to 13 points of the BDI and up to 9 points on the BAI are considered to be minimal risk for depression and anxiety, respectively.

Statistical analysis

According to the systematic review and meta-analysis by Karr et al,²⁶ an estimated effect size of 0.80 was used for the power analysis. Based on the computed power analysis, the results indicated that in order to achieve a power of 0.80, with a 1-sided test at probability level .05, a total of 20 participants in each group were required.

In the analysis, 2 sample *t* tests (unequal variation) were conducted to examine group differences (contact sport athletes vs noncontact sport athletes, and informants for both athlete groups) for each BRIEF-A variable of the behavioral regulation and cognitive function domains. Similarly, 2 sample *t* tests (unequal variation) were conducted to examine group differences (contact sport athletes vs noncontact sport athletes) for each of the executive function and behavioral variables. All tests are summarized by a 2-sided *P* value, Cohen's *d* effect size, and confidence intervals. *P* values less than .05 were considered significant. All computations were performed using the R programming language.²⁷

RESULTS

Twenty-one retired NFL and NHL athletes made up the contact sport athlete group (mean age 56.7 years). Twenty-one noncontact sport athletes made up the control group (mean age 55.4 years). Detailed demographic data of both groups are presented in Willer et al.⁹

BRIEF-A

The contact sport athletes had worse perceived impairment in executive function than the noncontact athlete group (see Figure 1). This difference was significant for the Working Memory (hold information in mind for the purpose of completing a task, stick to an activity) and Initiate (begin a task and/or generate ideas) subscales. The noncontact athletes' scores on the BRIEF-A were consistent with age-matched normative data.

The same BRIEF-A questionnaire was given to the informants (spouses) of the contact sport athletes and noncontact controls to evaluate how the behavior and cognition of the subject appeared to a close observer (see Figure 2). There was no statistically significant difference in the subscale scores in the informants' perception

of the contact sport athletes and noncontact sport athletes, indicating that the groups function equally when compared with each other and to a normalized adult population.

Cognitive assessments

Executive function was assessed objectively using the WCST, D-KEFS, and Trail Making, Part B, and reported as *t*-scores. No significant difference between the contact sport athletes and noncontact sport athletes was seen in any of the variables assessed (see Table 1). In WCST Perseverative Errors, D-KEFS Inhibition, and D-KEFS Inhibition/Switching, contact sport athletes and noncontact controls performed above the mean, with the contact sport athletes outperforming the noncontact sport athletes in D-KEFS Inhibition/Switching, although this difference was not significant. No significant difference in testing performance was seen between the contact sport athletes and noncontact sport controls in the other 4 cognitive domains: working memory (assessed with WAIS Digit Span), memory (List Learning, immediate and delayed recall), language (COWAT), and perceptual motor skills (WAIS Digit Symbol and Trail Making Part A).

Mental health assessment

The contact sport athletes were significantly worse than the noncontact sport athletes in raw score of depression (BDI) and anxiety (BAI) (see Table 2). When comparing presence or absence of clinical depression (>13 on the BDI) and clinical anxiety (>9 on the BAI), however, only clinical anxiety was significant. Of the 5 domains of the PID-5, only psychoticism was significantly higher in the contact sport athlete group. A closer examination of the facets of the psychoticism factor indicated that the difference between groups was accounted for by one facet: unusual beliefs and

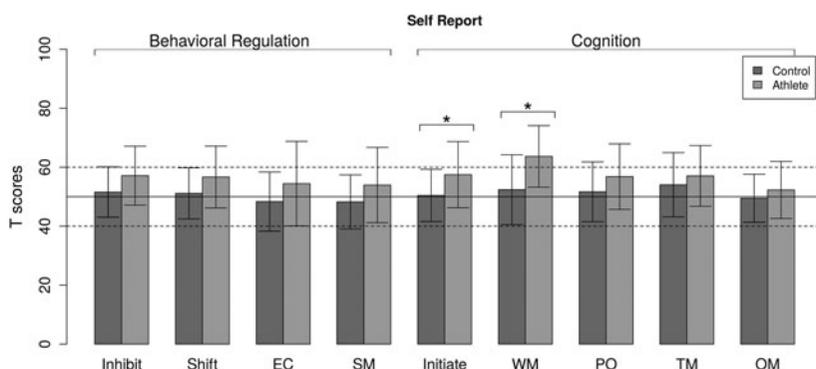


Figure 1. Behavioral Regulation and Cognition scores of the BRIEF-A self-assessment. A *t*-score of 50 and below is considered the normal range, 50 to 65 approaches clinical significance, and over 65 is rated as clinically elevated. Significance is denoted with * ($P < .05$). Horizontal lines indicate mean \pm 1 standard deviation. BRIEF-A indicates Behavior Rating Inventory of Executive Function-Adult.

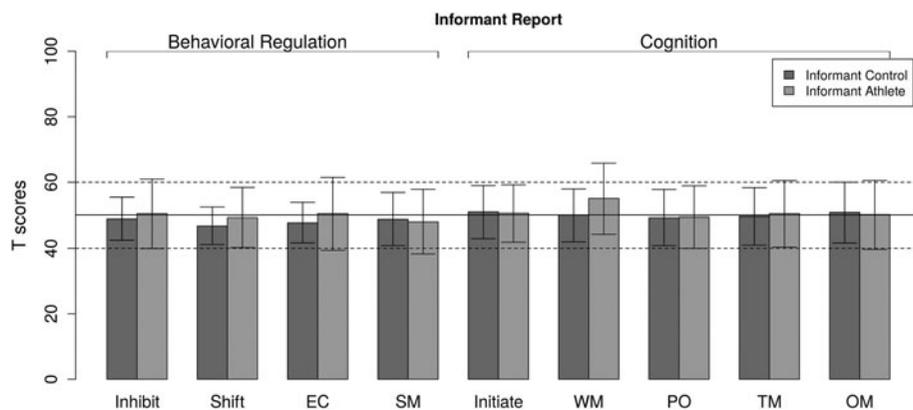


Figure 2. Behavioral Regulation and Cognition subscales of the BRIEF-A as reported by Informants. A t-score of 50 and below is considered the normal range, 50 to 65 approaches clinical significance, and over 65 is rated as clinically elevated. There are no significant differences in informant reports between contact sport athletes and noncontact athletes. Horizontal lines indicate mean \pm 1 standard deviation. BRIEF-A indicates Behavior Rating Inventory of Executive Function-Adult.

experiences. It also turns out that contact sport athletes' scores were well within the normal range for psychoticism but the noncontact athletes were significantly below the norm, especially for "unusual beliefs and experiences." When the contact sport athletes are compared with the normative population, they are not different.

DISCUSSION

The purpose of our study was to extensively evaluate the physical and mental health of athletes who had professional careers playing contact sports and that, according to prior research, left them vulnerable to CTE.^{4-6,28-32} In this study, we used a comparison sample of athletes who participated in competitive noncontact sports such as swimming, running, and biking in their

younger years and who remained physically active up to the point of participating in this study. These controls represent a superior aging population who are healthier based on common indicators like body mass index, have superior cognitive reserve based on education, and are at a lower risk of cognitive decline when compared with normal age-matched individuals, due to their history of endurance training.³³⁻³⁶ If our former professional athletes were in the early stages of cognitive decline or early-onset dementia due to their professional involvement in contact sports, we hypothesized that they would be inferior to the comparison group on measures of executive function. Contrary to our hypothesis, we did not find any statistically significant impairment of executive function in the retired professional contact sport athletes when compared with the noncontact sport control

TABLE 1 Mean t-scores of athlete and control groups on tests of executive function and measures of working memory, memory, language, and perceptual motor skills

	Contact athletes (SD)	Noncontact athletes (SD)	P values	Cohen's effect size (95% CI)
WCST Errors	49.4 (9.9)	52.5 (6.3)	.25	-0.36 (-1.00 to 0.27)
WCST Perseverative	50.0 (9.5)	51.3 (6.1)	.59	-0.17 (-0.80 to 0.46)
D-KEFS Inhibition	57.7 (4.6)	57.2 (8.3)	.82	0.07 (-0.55 to 0.69)
D-KEFS Inhibition/Switching	59.1 (5.9)	56.5 (8.1)	.23	0.38 (-0.25 to 1.00)
Trails Part B	48.5 (23.1)	53.4 (9.9)	.38	-0.27 (-0.90 to 0.35)
List Learning (immediate)	54.5 (10.2)	56.7 (9.0)	.46	-0.23 (-0.86 to 0.39)
List Learning (delayed)	56.1 (11.5)	59.4 (8.1)	.29	-0.33 (-0.96 to 0.30)
COWAT Letter	53.0 (11.0)	47.4 (6.8)	.06	0.60 (-0.03 to 1.24)
WAIS Digit Span	54.9 (11.7)	57.3 (9.7)	.47	-0.23 (-0.85 to 0.40)
WAIS Digit Symbol	55.0 (10.0)	53.4 (8.4)	.57	0.18 (-0.45 to 0.80)
Trails Part A	55.5 (13.1)	54.9 (10.2)	.87	0.05 (-0.57 to 0.68)

Abbreviations: CI, confidence interval; COWAT, Controlled Oral Word Association Test; D-KEFS, Delis-Kaplan Executive Function System; SD, standard deviation; WAIS, Wechsler Adult Intelligence Scale; WCST, Wisconsin Card Sorting Test.

TABLE 2 BDI, BAI, and psychological domain mean scores of PID-5

	Contact athletes (SD)	Noncontact athletes (SD)	P values	Cohen's effect size (95% CI)
BDI score	10.24 (8.11)	3.81 (5.05)	.004	0.95 (0.29 to 1.61)
BDI Positive ^a	5/21	1/21	.06	0.60 (−0.78 to 0.15)
BAI	5.95 (6.27)	2.62 (3.07)	.04	0.67 (0.03 to 1.32)
BAI Positive ^b	7/21	0/21	.003	0.96 (−0.55 to −0.12)
PID-5 Negative Affectivity	0.80 (0.42)	0.66 (0.36)	.28	0.34 (−0.29 to 0.97)
PID-5 Detachment	0.73 (0.31)	0.61 (0.23)	.16	0.45 (−0.19 to 1.08)
PID-5 Antagonism	0.65 (0.48)	0.58 (0.43)	.63	0.15 (−0.47 to 0.78)
PID-5 Disinhibition	0.89 (0.35)	0.76 (0.30)	.19	0.41 (−0.22 to 1.04)
PID-5 Psychoticism	0.50 (0.46)	0.22 (0.20)	.02	0.80 (0.15 to 1.45)

Abbreviations: BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; CI, confidence interval; PID-5, Personality Inventory for the DSM-5; SD, standard deviation.

^aBDI score of greater than 13.

^bBAI score of greater than 9.

group, with the exception of self-report on 2 factors of the BRIEF-A.

On the BRIEF-A, contact sport athletes rated themselves as more impaired on working memory and initiation than controls, a finding that is similar to that of Seichepine et al.⁶ The differences between the 2 groups of athletes were not supported by the objective tests or the perceptions of their informants (mostly spouses). There are several explanations for this finding that we considered. It has been suggested that athletes in general have distinct personalities that include high expectations for themselves, and thus any weakness may be emphasized.³⁷ In addition, there has been considerable discussion of CTE and the vulnerabilities of former contact-sport athletes in the public media.² Therefore, it is possible that the former contact sport athletes have come to believe that they are deteriorating in line with media accounts. Certainly, the athletes who signed up to participate in our research expressed their worries about their mental health and most indicated this was a primary reason for participation. This observation might also explain the slightly higher rate of anxiety in this population.

To provide an objective assessment of executive function between the contact sport athletes and noncontact athletes, each group underwent neuropsychological testing composed of flexibility (WCST), working memory (WAIS Digit Span), memory (NAB List Learning: immediate and delayed recall), language (COWAT), and perceptual motor skills (WAIS Digit Symbol, Trail Making Test Part A). There were no differences between the contact sport athletes and noncontact athlete controls on any objective measures of executive function or components of executive function. Esopenko et al³⁸ performed a similar study of former NHL players, measuring

cognitive function with both questionnaires and neuropsychological tests. Although there were some group differences that positively correlated executive and intellectual function with concussion exposure, they found no significant differences from the nonathlete control group. A study performed by Hume et al³⁹ had different results. They performed a larger cross-sectional study using an online version of CNS Vital Signs,⁴⁰ a computerized neurocognitive assessment, and found significant decreases in complex attention, processing speed, executive function, and cognitive flexibility in retired elite rugby players when compared with retired community rugby players and age-matched noncontact sport athletes.

Raw BDI scores of the 2 groups of athletes in our study indicated more symptoms of depression and anxiety in the contact sport athlete group, which is consistent with several previous studies.^{41,42} However, when we used raw BDI scores to define clinical depression, differences between the groups were not significant. Although the contact sport athletes have more symptoms than noncontact athletes, their scores were within the normal range. The presence of anxiety symptoms was considerably higher in the contact sport athlete group, and they were significantly more likely to qualify as clinically anxious, something that might be explained by the chronic pain and chronic sleep disturbance reported by these athletes. The finding that former contact sport athletes have higher scores on anxiety measures warrants further investigation. One possibility is that retired athletes who were anxious about their state of mental health were more likely to volunteer for the study.

Of the 5 domains that make up PID-5, Psychoticism was the only personality domain that was significantly higher among the contact sport athletes than among the

noncontact athletes. This difference was due to one facet of the domain called “unusual beliefs and experiences,” being much higher among contact sport athletes but still within the normative range. The estimated effect sizes for the PID-5 Psychoticism is large (>0.80), but the confidence intervals for effect size are also rather large. An explanation for the finding is that the noncontact athletes scored significantly lower than the normative population on the personality facet of “unusual beliefs and experiences.” This facet, interestingly, includes a number of questions that might understandably be agreed to by former professional athletes: unusual abilities, ability to sense the presence of others, having had weird experiences, seeing unusual connections between things, and can influence others by sending thoughts. In order to achieve success on the world stage of professional sport, athletes have to have an unusual belief in their capabilities. It is also reasonable to expect that the adoration of thousands of fans also affected their sense of having an influence over others.³⁷

This study has a number of limitations that are described in more detail in Willer et al.⁹ The sample size is small, but in the overview we observed that the career length of our sample was the same or greater than the general population of retired athletes. We conclude that our sample is reasonably representative of the population of retired professional athletes who played contact sports.

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CONCLUSION

Although contact sport athletes have perceived executive function impairments, in this cohort of former professional players we found no evidence to support their perception. Participating in contact sports may not lead to later-life executive dysfunction, as the media and some research currently suggest. Contact sport athletes did have higher depression scores than healthy controls, but are still within the normative range. Former professional football and hockey athletes do appear to have a high rate of anxiety, which warrants further investigation. We found no evidence of executive dysfunction or behavior that would indicate early signs of dementia.

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