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Profile of Self-Reported Problems with Executive Functioning in College and Professional Football Players

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Abstract

Repetitive mild traumatic brain injury (mTBI), such as that experienced by contact-sport athletes, has been associated with the development of chronic traumatic encephalopathy (CTE). Executive dysfunction is believed to be among the earliest symptoms of CTE, with these symptoms presenting in the fourth or fifth decade of life. The present study used a well-validated self-report measure to study executive functioning in football players, compared to healthy adults. Sixty-four college and professional football players were administered the Behavior Rating Inventory of Executive Function, adult version (BRIEF-A) to evaluate nine areas of executive functioning. Scores on the BRIEF-A were compared to published age-corrected normative scores for healthy adults Relative to healthy adults, the football players indicated significantly more problems overall and on seven of the nine clinical scales, including Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, and Task Monitor. These symptoms were greater in athletes 40 and older, relative to younger players. In sum, football players reported more-frequent problems with executive functioning and these symptoms may develop or worsen in the fifth decade of life. The findings are in accord with a growing body of evidence that participation in football is associated with the development of cognitive changes and dementia as observed in CTE.

Key words: chronic traumatic encephalopathy; executive function; football; traumatic brain injury

Introduction

Traumatic brain injury (TBI) is a significant public health problem. It is estimated that approximately 1.7 million TBIs occur in the United States annually, resulting in emergency department visits, hospitalization, or death, with direct and indirect costs totaling approximately $76.5 billion a year.[1–3] Moderate to severe TBI (sTBI) is associated with a wide range of long-term cognitive deficits.[4] Though early research focused on the effects of moderate to sTBI, attention has increasingly turned to the long-term consequences of repetitive mild TBI (mTBI), such as that experienced by contact-sport athletes. It has been estimated that 1.6–3.8 million sport-related mTBIs occur annually,[5,6] with the greatest number occurring in football.[7,8] With over 60 million youth and adolescents participating in organized sports each year, a number that increased by 16 million from 1997 to 2008, sport-related TBI is an important and growing public health concern.[9,10]

The recent deaths of several high-profile athletes have resulted in significant public and scientific interest in the long-term effects of mTBI and chronic traumatic encephalopathy (CTE), a progressive neurodegenerative disease linked to repetitive brain trauma. Helmet sensor data indicate that football players can experience more than 1000 hits to the head over the course of a season.[11] This repetitive exposure has been associated with the development of CTE and changes in cognition, mood, and behavior that begin in the fourth to fifth decade of life and eventually progress to dementia.[12–17] Epidemiological studies indicate that professional football players are at least four times more likely to receive a diagnosis of memory impairment or dementia and have at least a three times greater risk of dying from a neurodegenerative disease, compared to the general population.[17,18] To date, all cases of neuropathologically confirmed CTE have had a history of repetitive brain trauma; therefore, repetitive brain trauma appears necessary for the development of the disease.[15,19] However, brain trauma alone is insufficient to lead to

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neurodegeneration in all individuals (i.e., not everyone with repetitive TBI gets CTE).[15]

To date, relatively few studies have examined cognitive functioning in football players during life. Amen and colleagues found that active and retired football players scored in the bottom 50th percentile on three indices (attention/mental control, memory, and reasoning) of a computerized assessment of neuropsychological status.[20] Former university hockey and football players who sustained concussions have been found to perform worse on measures of memory and attention/executive function decades after their last concussion.[21] These studies indicate that executive functioning is impaired in former contact-sport athletes many years after the athlete's last exposure to brain trauma.

The long-term effects of repetitive brain trauma on cognition have yet to be examined using a standardized self-report measure of executive function. The Behavior Rating Inventory of Executive Function, adult version (BRIEF-A) was chosen for this study because of its use in clinical neuropsychological assessments and well-established normative data. Additionally, reports indicate that the BRIEF-A is sensitive to early executive deficits, before they might typically present on objective measures of cognitive function.[22] The aim of this study was to examine executive function in current and retired college and professional football players, a group at high risk of exposure to repetitive mTBI, using the BRIEF-A. We hypothesized that these football players would report more-frequent problems with executive functioning than healthy, same-age control participants. Because CTE symptoms typically present in the fourth or fifth decade of life, we hypothesized that football players over 40 years of age would report more-frequent problems than younger athletes.

Methods

This project was part of an ongoing longitudinal study examining cognitive function in current and former athletes. Inclusion criteria include being at least 18 years old and having a history of participation in organized sports at any level of competition. Recruitment methods include the following: (1) inclusion of the study on the Center's website and the website of the Sports Legacy Institute; (2) lectures and presentation at a variety of events for athletes at all levels of play; and (3) word of mouth. All participants are self-referred. This larger project (the Longitudinal Examination to Gather Evidence of Neurodegenerative Disease; LEGEND), requires completion of yearly telephone interviews and online questionnaires. Participants are sent an e-mail link to complete the online questionnaires, which include self-report measures of cognition, mood, and performance on activities of daily living. Demographic characteristics, athletic experience, and concussion history, as well as participant and family medical and psychiatric history, are also obtained. Subsequent to completion of the online questionnaires, participants are contacted by phone to complete the telephone interview. The present study included all college and professional football players in the LEGEND study at the time of data analysis.

Participants

Participants included 64 male current and retired football players, ranging from 25 to 81 years of age (mean, 47.0; standard deviation, 13.6). All LEGEND participants with a history of participation in college or professional football were selected for analysis. The football players were grouped by highest level achieved and age greater than or equal to 40. Demographic and athletic characteristics of the groups are listed in Table 1. All participants provided informed consent for the protocol approved by the Boston University Medical Center Institutional Review Board (Boston, MA).

Measures and procedures

Participants completed an online version of the BRIEF-A, a 75-item self-report measure of executive functioning in everyday activities over the past 30 days. Participants were instructed to answer the following question for each statement: ''During the past month, how often has each of the following behaviors been a problem?'' Responses use a three-point scale, scored as follows: never = 1; sometimes = 2; and often = 3. Higher scores indicate worse executive function. These responses yield an overall composite score (Global Executive Composite; GEC), two index scores [Behavioral Regulation Index (BRI) and Metacognition Index (MI)], and the following nine clinical scales: Inhibit; Shift; Emotional Control; Self-Monitor; Initiate; Working Memory; Plan/Organize; Task Monitor; and Organization of Materials. Each clinical scale includes 6–10 items. The BRI index is composed of the Inhibit, Shift, Emotional Control, and Self-Monitor

Table 1. Demographic Characteristics

Characteristic	*AP* (n = *64*)	*CF* (n = *35*)	*PF* (n = *29*)	*<40* (n = *22*)	*≥40* (n = *42*)
Mean age, years (SD)	47.0 (13.6)	45.9 (14.1)	48.3 (13.0)	33.0 (3.9)†	54.3 (10.8)
Age range	25–81	25–78	27–81	25–39	41–81
Education (terminal degree)					
High school/GED, %	1.6	0	3.4	0	2.4
Associates/certification, %	1.6	2.9	0	4.5	0
Bachelor's degree, %	65.6	57.1	75.9	68.2	64.3
Master's or doctoral degree, %	31.3	40	20.7	27.3	33.3
Athletic history					
Total years of football (SD)	13.0 (5.1)	9.5 (2.7)	17.2 (3.9)*	11.8 (4.3)	13.6 (5.4)
Years played in college (SD)	3.7 (1.0)	3.3 (1.3)	4.2 (.51)*	3.7 (1.1)	3.9 (0.85)
Years played professionally (SD)	3.0 (4.1)	N/A	6.4 (3.6)	2.2 (3.8)	3.6 (4.2)
Professional: college	N/A	N/A	N/A	8:14	21:21
Number of concussions (SD)	350.8 (2516.0)	24.9 (23.8)	758.1 (3771.7)	22.8 (223.2)	526.7 (3117.8)

<40 indicates players 39 years of age and younger, whereas ≥40 indicates players 40 or more years of age.
*Significant differences between CF and PF (alpha = 0.05).
†Significant differences between <40 and ≥40 ($p < 0.05$).
AP, all players; CF, college players; PF, professional players; SD, standard deviation; GED, General Educational Development.

subscales, and the MI index is composed of the Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials subscales.

Concussion history was obtained during a phone interview. Participants were provided the following definition of concussion:

> ''Some people have the misconception that concussions only happen when you black out after a hit to the head or when the symptoms last for a while. But, in reality, a concussion has occurred anytime you have had a blow to the head that caused you to have symptoms for any amount of time. These include: blurred or double vision, seeing stars, sensitivity to light or noise, headache, dizziness or balance problems, nausea, vomiting, trouble sleeping, fatigue, confusion, difficulty remembering, difficulty concentrating, or loss of consciousness. Whenever anyone gets a ding or their bell rung, that too is a concussion''

Based on this definition, participants were asked to state approximately how many total concussions they have had during their life.

Statistical analysis

Scores on the BRIEF-A were converted to age-appropriate T scores based on published normative data, which include 1050 participants selected to proportionally represent the U.S. population in regard to sex, race/ethnicity, education, and geographic region.[23] Elite football players may differ from this normative population in several ways, including exposure to repetitive brain trauma, physical stature (height and weight), educational attainment (generally higher), health (alcohol use, heart disease, arthritis, chronic pain, orthopedic issues, number of surgeries, depression, dementia, and use of medications), and health-related behaviors (increased alcohol use, decreased smoking, and illicit drug use).[24] For comparison of mean scores with normative data, one-sample *t*-tests were performed. For between-group comparisons, *t*-tests for two independent samples were performed. When indicated by Levene's test for equality of variances, degrees of freedom were adjusted to account for unequal variances. Because there were cases with zero counts in some cells, rates of clinically elevated scores (i.e., percent of individuals with a T score ≥ 65) were compared to additional normative data using Fisher's exact test. For the overall composite score (GEC) and index scores (BRI and MI), an alpha level of 0.05 was adopted. To control for type I errors, analyses of the nine clinical scales were conservatively adjusted for multiple comparisons using Bonferroni's correction (0.05/9 = 0.006). Analyses of the individual clinical scales were performed when significant group effects were observed on the overall composite score or one of the two index scores.

Results

Comparison between college and professional football players

Effects of competition level (i.e., professional vs. college) on the overall composite score and the two index scores were examined by independent sample *t*-tests. Scores on the GEC were similar between groups ($t(44.2) = 2.0$; $p = 0.06$). Professional and college football players indicated similar functioning on the BRI index ($t(49.3) = 1.9$; $p = 0.06$), but the professional athletes reported more-frequent executive functioning problems on the MI index ($t(42.7) = 2.4$; $p < 0.05$). Analyses of clinical scales revealed similar ratings between groups at each of the nine scales (all p values > 0.006). Given the similarity between groups, data from college and professional football players were combined for subsequent analyses.

Comparison between football players and normative data for healthy adults

Effects of participation in football were examined by one-sample *t*-tests comparing age-adjusted T scores with the known population mean of 50. Significant group differences were observed on GEC ($t(63) = 5.4$; $p < 0.05$), MI ($t(63) = 5.3$; $p < 0.05$), and BRI ($t(63) = 5.2$; $p < 0.05$). Analyses of the clinical scales indicated significant group effects on seven of the nine scales: Inhibit ($t(63) = 5.8$; $p < 0.006$); Shift ($t(63) = 4.4$; $p < 0.006$); Emotional Control ($t(63) = 4.9$; $p < 0.006$); Initiate ($t(63) = 4.6$; $p < 0.006$); Working Memory ($t(63) = 6.6$; $p < 0.006$); Plan/Organize ($t(63) = 3.9$; $p < 0.006$); and Task Monitor ($t(63) = 4.8$; $p < 0.006$). Differences between groups on Organization of Materials reached the corrected alpha level of 0.006, but was not below this threshold ($t(63) = 2.8$; $p = 0.006$), and groups were similar on Self-Monitor ($t(63) = 1.4$; $p = 0.16$). Across all scales, the football players indicated worse functioning than the normative sample.

Rates of clinically elevated scores (i.e., T scores ≥ 65) between groups were examined by Fisher's exact test. Significant group differences emerged on GEC ($x^2(1, n = 90) = 9.1$; $p < 0.05$), MI ($x^2(1, n = 90) = 13.3$; $p < 0.05$), and BRI ($x^2(1, n = 90) = 8.5$; $p = 0.05$). Analyses of the clinical scales indicated significant group effects on five of the nine scales: Inhibit ($x^2(1, n = 90) = 8.5$; $p < 0.006$); Shift ($x^2(1, n = 90) = 7.9$; $p < 0.006$); Initiate ($x^2(1, n = 90) = 9.1$; $p < 0.006$); Working Memory ($x^2(1, n = 90) = 13.3$; $p < 0.006$); and Plan/Organize ($x^2(1, n = 90) = 11.1$, $p < 0.006$). The rate of clinically elevated scores was similar between groups on the remaining four scales: Emotional Control ($x^2(1, n = 90) = 5.9$; $p = 0.02$); Self-Monitor ($x^2(1, n = 90) = 5.6$; $p = 0.02$); Task Monitor ($x^2(1, \text{n} = 90) = 4.5$; $p = 0.05$); and Organization of Materials ($x^2(1, n = 90) = 2.0$; $p = 0.27$). Across all scales, the football players had higher rates of clinically elevated scores than the normative sample.

Comparison between younger and older football players

Effects of age group (i.e., < 40 vs. ≥ 40 years) on the overall composite score and the two index scores were examined by independent sample *t*-tests. Older athletes indicated more-frequent problems overall ($t(62) = 2.7$; $p < 0.05$), on the BRI ($t(56.0) = 3.3$; $p = 0.05$); and on the MI indices ($t(62) = 2.1$; $p < 0.05$), when compared to younger athletes. Analyses of clinical scales revealed group differences on two of the nine scales. Older football players indicated experiencing more problems on the Emotional Control ($t(62) = 2.9$; $p < 0.006$) and Initiate ($t(55.8) = 3.2$; $p < 0.006$) clinical scales. Scores on the remaining scales were similar between groups, including Inhibit ($t(57.7) = 1.8$; $p = 0.08$), Shift ($t(62) = 2.5$; $p = 0.01$), Self-Monitor ($t(62) = 2.7$; $p = 0.01$), Working Memory ($t(62) = 1.4$; $p = 0.16$), Plan/Organize ($t(62) = 1.9$; $p = 0.07$), Task Monitor ($t(62) = 2.5$; $p = 0.02$), and Organization of Materials ($t(62) = 1.5$; $p = 0.14$; see Table 3).

Correlations between BRIEF-A and athletic history

Correlations between BRIEF-A scores, self-reported concussions, and years playing football were determined by Pearson's correlation coefficients for all participants, separately for level of play and age groups. The number of self-reported concussions was log-transformed because of the non-normal distribution of these data. Overall, 56 of the 64 participants (87.5%) reported experiencing 55 or fewer concussions. For the remaining 8 participants, 6 reported experiencing between 100 and 140 concussions, 1

Table 2. Comparison of Age-Adjusted T Scores between Football Players (College and Higher) and Normative Data for Healthy Adults on the BRIEF-A

	Football players[a]		*Football*[a] *vs. healthy adults*[b]		
	Mean (SD)	*Percent of T scores ≥65*	*T-score* p *value*	*Cohen's d*	*T scores ≥65* p *value*
Index scores					
BRI	58.2 (12.8)	26.6	0.000*	0.81	0.004*
MI	59.4 (14.2)	37.5	0.000*	0.91	0.000*
GEC	58.9 (13.2)	28.1	0.000*	0.87	0.002*
Clinical scales					
Inhibit	58.4 (11.5)	26.6	0.000*	0.85	0.004*
Shift	56.3 (11.4)	25.0	0.000*	0.63	0.005*
Emotional Control	58.0 (13.0)	26.6	0.000*	0.79	0.015
Self-Monitor	52.3 (13.0)	18.8	0.159	0.23	0.018
Initiate	58.1 (14.1)	28.1	0.000*	0.79	0.002*
Working Memory	62.4 (15.0)	37.5	0.000*	1.20	0.000*
Plan/Organize	56.9 (14.1)	32.8	0.000*	0.67	0.001*
Task Monitor	57.6 (12.6)	28.1	0.000*	0.75	0.035
Organization of Material	54.3 (11.9)	14.1	0.006	0.43	0.162

Scores from football players were compared to age-adjusted normative data published in the BRIEF-A manual.
[a]$n = 64$.
[b]$n = 1050$.
*Significant group differences (index scores, alpha < 0.05; clinical scales, alpha < 0.006).
BRI, Behavioral Regulation Index; MI, Metacognition Index; GEC, Global Executive Composite; SD, standard deviation.

reported experiencing approximately 350 concussions, and 1 reported experiencing approximately 20,000 concussions. These analyses were performed to determine if total years of play and/or number of concussions contributed to the between-group findings. In the overall sample, total number of years played correlated with Working Memory ($r = 0.29$; $p < 0.05$), and number of self-reported concussions correlated with Emotional Control ($r = 0.26$; $p < 0.05$) and Initiate ($r = 0.32$; $p < 0.05$). In the younger than 40 group, number of self-reported concussions correlated with Inhibit ($r = 0.54$; $p < 0.05$). In the older than 40 group, total number of years played correlated with Working Memory ($r = 0.37$; $p < 0.05$). No other correlations were significant.

Table 3. Comparison Between Age-Adjusted T Scores on BRIEF-A between Players Younger and Older Than 40 Years

	Football players less than 40 years of age (n = 22)	*Football players 40 and older* (n = 42)	p *value*
Index scores[a]			
BRI*	52.0 (9.4)	61.5 (13.2)	0.002
MI*	54.5 (13.9)	62.0 (13.8)	0.043
GEC*	53.1 (10.7)	62.0 (13.5)	0.010
Clinical scales[b]			
Inhibit	55.3 (8.5)	60.1 (12.5)	0.075
Shift	51.5 (9.9)	58.8 (11.4)	0.014
Emotional Control*	51.9 (9.9)	61.2 (13.4)	0.005
Self-Monitor	46.5 (10.1)	55.4 (13.4)	0.008
Initiate*	51.4 (10.5)	61.6 (14.6)	0.002
Working Memory	58.7 (12.0)	64.3 (16.2)	0.158
Plan/Organize	52.4 (11.8)	59.2 (14.7)	0.067
Task Monitor	52.4 (10.9)	60.4 (12.7)	0.015
Organization of Material	51.2 (10.3)	55.9 (12.5)	0.138

All means and standard deviations are reported.
[a]Alpha level = 0.05.
[b]Alpha level was adjusted to 0.006.
*Statistically significant.
BRI, Behavioral Regulation Index; MI, Metacognition Index; GEC, Global Executive Composite.

Discussion

In this study, we examined a self-report measure of executive function in current and retired college and professional football players, a group with high exposure to repetitive brain trauma. Overall, we found that football players reported more-frequent problems with executive function in everyday activities, when compared to published normative data for healthy individuals of the same age and representative of the U.S. population in regard to sex, race/ethnicity, education, and geographic region. Scores were elevated overall, as well as on specific indices of the ability to control behavior and emotional responses and the ability to methodically solve problems through planning, organization, and sustaining effort. Despite higher scores overall, considerable variability was observed across participants, indicating that not all elite football players experience executive dysfunction.

It should be highlighted that the football players reported a normal frequency of problems on monitoring the effects of their behavior on others. Taken together, this profile suggests that football players may be aware of any effects they may have on others, but are unable to change their behavior because of weaknesses in thinking flexibly and inhibition. It is plausible that this may contribute to depression observed in former athletes with CTE.[15] It should be emphasized that executive dysfunction has several etiologies, and not all football players with these symptoms will develop CTE.

Consistent with our hypothesis, football players 40 years of age and older reported more frequent problems with the ability to control behavior and emotional responses, even after the data were corrected for age. This finding provides additional evidence to suggest that problems with executive function in football players develop or worsen after 40 years of age. Alternatively, differences between age groups could be a cohort effect, reflecting changes in professional football over the decades (e.g., development of new protective equipment or differences in individuals that choose to participate). Longitudinal studies are needed to better understand this finding.

Although we believe this study has several strengths, there are also a number of important limitations that require discussion. Scores on the BRIEF-A were compared to normative data, which is not an ideal comparison group for elite athletes. Future studies would benefit from having a comparison group of elite non-contact-sport athletes. If results were similar, the findings would further suggest that this executive dysfunction results from repeated mTBI. Because of recent publicity surrounding CTE and the self-referral in our study, it may be that only symptomatic individuals who were concerned about their cognitive functioning volunteered. If this were the case, however, we would have expected to observe very few scores in the normal range. In contrast, nearly one third (31.3%) of the participants had overall scores at or below the expected value for their age (i.e., T score of 50), and for the majority of participants (71.8%), the overall score was below the clinically meaningful threshold (i.e., T score of 65). Because of the inclusion of current and recently retired players, it is possible that some of the executive function problems reported stem from residual postconcussive syndrome. In this case, we would have expected to find higher scores in the younger players. In contrast, we observed higher scores in football players older than 40. Given the retrospective nature of this study, it is impossible to determine whether these findings stem from the effects of participation in football or whether individuals with these characteristics seek out this sport initially. Future prospective studies examining change in executive function over time are needed. Although the BRIEF-A has good convergent validity with other questionnaires, future studies will benefit from also using objective measures of executive functioning in addition to self-report measures. Finally, we did not exclude individuals with a history of repeated brain trauma from participation in other contact sports or non-sport-related TBIs, which may have also affected the results.

In summary, our results indicate that college and professional football players experience more problems with executive functions in everyday activities than would be expected for their age, and these symptoms appear to develop or worsen in the fifth decade of life. Future longitudinal studies are needed to confirm these initial results. The findings are in accord with a growing body of evidence that participation in football may be associated with the development of cognitive changes and dementia observed in individuals with CTE.

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Author Disclosure Statement

No competing financial interests exist.

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