Estimated Age of First Exposure to Contact Sports Is Not Associated with Greater Symptoms or Worse Cognitive Functioning in Male U.S. Service Academy Athletes

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Abstract

This study examined the association between estimated age of first exposure (eAFE) to contact sport participation and neurocognitive performance and symptom ratings in U.S. service academy National Collegiate Athletic Association (NCAA) athletes. Male cadets ($N=891$), who participate in lacrosse ($n=211$), wrestling ($n=170$), ice hockey ($n=81$), soccer ($n=119$), rugby ($n=10$), or non-contact sports ($n=298$), completed the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test before the season. Generalized linear modeling was used to predict each neurocognitive domain score and total symptom severity score. Predictor variables were entered in the following order: group (contact vs. non-contact); eAFE (eAFE <12 years vs. eAFE ≥12 years); group-by-eAFE; and covariates for learning accommodation status, concussion history, and age. The group-by-eAFE interaction was not significant for any of the ImPACT composite scores (Verbal Memory, Wald $\chi^2=0.073$, $p=0.788$; Visual Memory, Wald $\chi^2=2.71$, $p=0.100$; Visual Motor Speed, Wald $\chi^2=0.078$, $p=0.780$; Reaction Time, Wald $\chi^2=0.003$, $p=0.955$; Symptom Severity, Wald $\chi^2=2.87$, $p=0.090$). Learning accommodation history was associated with lower scores on Visual Motor Speed ($\chi^2=6.19$, $p=0.013$, $B=-2.97$). Older age was associated with faster reaction time ($\chi^2=4.40$, $p=0.036$, $B=-0.006$) and lesser symptom severity ($\chi^2=5.55$, $p=0.019$, $B=-0.068$). No other parameters were significant. We observed no association between eAFE, contact sport participation, neurocognitive functioning, or subjectively experienced symptoms in this cohort. Earlier eAFE to contact sport participation is not related to worse neurocognitive performance or greater subjectively experienced symptoms in male U.S. service academy NCAA athletes.

Keywords: concussion, mild traumatic brain injury, neurocognitive; repetitive head impacts

Introduction

SPORTS SUCH AS AMERICAN FOOTBALL, ice hockey, soccer, wrestling, rugby, and lacrosse carry an inherent risk for both orthopedic injury^{1,2} and concussion.^{3,4} At least 2 million adoles-

cents and young adults play these contact sports each year in the United States^{5,6} and millions more worldwide.⁷ In recent years, amateur athletes have been fitted with accelerometers in a number of sports, such as American football,^{8,9} ice hockey,^{10,11} soccer,^{12,13} rugby,^{14,15} and lacrosse.¹⁶ In addition to American football players,

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participants in other contact sports are also exposed to hundreds of traumatic brain injuries (TBIs) per year, many of which have considerable peak linear and rotational acceleration.¹⁷ The possible long-term effects of sport-related concussion and these repetitive TBIs on brain health are not well understood.¹⁸

In 2015, Stamm and colleagues¹⁹ published a study of 42 former National Football League (NFL) players with self-reported complaints of cognitive, behavioral, and mood symptoms for at least the last 6 months and reported that those who started playing organized football before the age of 12 ($n=21$) performed more poorly on neurocognitive testing (measures of verbal learning and executive functioning) than those who started playing at age 12 or older ($n=21$). They reported that age 12 was selected as a cutoff because ages 10–12 are considered a critical neurodevelopment period, indicated by peak myelination rates and increased cerebral blood flow.^{20,21} They concluded that their “findings suggest that incurring repeated head impacts during a critical neurodevelopmental period may increase the risk of later-life cognitive impairment.”¹⁹

This research group followed up their first study with three studies showing that playing football before the age of 12 was associated with differences in the microstructural integrity of white matter in the brain, as inferred from lower fractional anisotropy metrics derived from diffusion tensor imaging of the corpus callosum²²; greater self-reported symptoms of depression, apathy, and executive dysfunction²³; and smaller volumes measured in the thalamus²⁴ in former football players. Considering the prevalence of youth contact sport participation, understanding the later-life effects on cognition is a major public health concern.

To date, both our research group and other research groups have examined whether estimated age of first exposure (eAFE) to football is associated with differences in neurocognitive functioning, subjectively experienced symptoms, and neuroimaging findings and they have not found an association.^{25–27} Solomon and colleagues²⁵ studied 45 former NFL players and reported that neurological, neuroradiological, and neurocognitive outcome measures were not associated with earlier eAFE to football. Caccese and colleagues²⁶ studied a cohort of 4376 men who were participating in the National Collegiate Athletic Association (NCAA)/Department of Defense (DoD) Concussion Assessment, Research and Education (CARE) Consortium. Athletes were divided by sport participation (American football [$n=3462$] or non-contact sports [$n=914$]) and eAFE (<12 years [$n=3022$] or ≥ 12 years [$n=1354$]). Football players who started at an earlier age did not show worse neurocognitive test performance or greater subjectively experienced symptoms. Brett and colleagues²⁷ studied 1802 active high school and collegiate football players and reported that AFE <12 years was not associated with worse behavioral, neurocognitive, psychological, or physical (oculomotor functioning and postural stability) outcomes.

Beyond football, adolescents and young adults that participate in contact sports, such as ice hockey, soccer, wrestling, rugby, and lacrosse, may also be exposed to hundreds of TBIs per year.^{11–17} It is unknown whether playing contact sports, other than football, before the age of 12 is associated with lower neurocognitive test scores or greater symptom ratings in college student athletes. The aim of this study is to replicate and extend the study by Caccese and colleagues²⁶ in a large cohort of collegiate male athletes from the U.S. service academies participating in contact sports other than football. Participants were athletes from the United States Military Academy (West Point, NY), United States Air Force Academy (Colorado Springs, CO), and the United States Coast Guard Academy (New London, CT). The service academies are aca-

demically elite and have an extremely competitive admissions process, drawing top students and athletes from across the United States. We hypothesized that exposure to contact sports before the age of 12 would not be associated with worse baseline neurocognitive test performance or greater symptom reporting in these athletes.

Methods

Participants

There were 891 men from the U.S. service academies that met inclusion/exclusion criteria and completed the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test between June 2014 and August 2018, before beginning the sport season. Athletes were included if they competed in contact sports (i.e., varsity ice hockey [$n=81$], soccer [$n=119$], wrestling [$n=170$], rugby [$n=10$], and lacrosse [$n=211$]) or non-contact sports ($n=298$), they were enrolled in the NCAA-DoD CARE Consortium,²⁸ and they had valid pre-season ImPACT scores. Invalid ImPACT scores were excluded by the database (QuesGen Systems, Inc) based on the ImPACT embedded validity indicators.²⁹ Non-contact sports included baseball, cross-country/track, fencing, field events, gymnastics, volleyball, golf, rifle, rowing/crew, sailing, swimming, and tennis.³⁰

Participants were divided by sport type and eAFE: contact, eAFE <12 years ($n=500$, age = 19.3 ± 1.3 years, weight = 80.7 ± 10.1 kg, height = 180.1 ± 7.4 cm, concussion history $n=157$, and learning accommodation history $n=12$); contact, eAFE ≥ 12 years ($n=91$, age = 18.7 ± 1.1 years, weight = 81.0 ± 10.5 kg, height = 179.3 ± 8.7 cm, concussion history $n=22$, and learning accommodation history $n=5$); non-contact, eAFE <12 years ($N=194$, age = 19.6 ± 1.6 years, weight = 76.8 ± 10.1 kg, height = 180.1 ± 8.6 cm, concussion history $n=28$, and learning accommodation history $n=10$); and non-contact, eAFE ≥ 12 years ($n=104$, age = 19.1 ± 1.3 years, weight = 75.6 ± 9.0 kg, height = 183.0 ± 7.6 cm, concussion history $n=5$, and learning accommodation history $n=2$).

Exclusion criteria included non-contact sport athletes with a history of contact-sport participation (i.e., basketball, diving, field hockey, football, ice hockey, lacrosse, martial arts, rugby, soccer, water polo, and wrestling) and individuals who provided incomplete or invalid sport participation or concussion history ($n=399$). For participants who completed baseline testing more than once, only year 1 data were included. Participants provided written informed consent approved by the University of Michigan Institutional Review Board (IRB), the US Army Medical Research and Materiel Command Human Research Protection Office, as well as the local IRB at each of the performance sites.

Estimated age of first exposure

We defined the eAFE as the participant's age at the time of assessment minus the number of years the participant reported playing contact or non-contact sports.²⁶ We assumed that the participant continuously participated in sport from when they first began. The eAFE was used to divide participants into two cohorts, eAFE <12 years and eAFE ≥ 12 years, similar to past studies.^{19,22–24,27,30} The minimum eAFE for this study was 4 years old because this is the youngest age at which athletes can engage in organized youth sports, such as many youth soccer leagues.

Immediate Post-Concussion Assessment and Cognitive Testing

The ImPACT (ImPACT Applications Inc., Pittsburgh, PA) is a computerized neurocognitive test that is widely used for the management of sport-related concussions.^{28,30,32} The normative data,³⁰ reliability (intraclass correlation coefficient = $0.34\text{--}0.72$),³² and

validity^{33,34} of the ImPACT test have been discussed in the literature. The ImPACT test provides composite scores for verbal memory (higher is better), visual memory (higher is better), visual motor speed (higher is better), and reaction time (lower is better) and a total symptom severity score (lower is better) derived from the Post-Concussion Symptom Scale (PCSS).

Statistical analysis

We replicated the analyses described by Caccese and colleagues in NCAA American football players in a distinct cohort of male U.S. service academy NCAA contact and non-contact sport athletes.²⁶ We used generalized linear modeling to examine the association between sport type, eAFE, and ImPACT composite scores and symptom severity profiles. Predictor variables were entered in the following order: a binary variable for group (contact vs. non-contact), a binary variable for eAFE (eAFE <12 years vs. eAFE ≥12 years), an interaction term (group-by-eAFE), and covariates for learning accommodation status, concussion history, and age.²⁶ The learning accommodation status (Y/N) was determined through a self-reported history of an Individualized Education Program (IEP), 504 Plan, or other learning accommodation. Generalized linear models for verbal memory, visual memory, and visual motor speed were fit based on normal (Gaussian) distributions and identity link functions. Reaction time was fit based on an inverse Gaussian distribution with a power link function. Symptom severity was fit based on a negative binomial distribution with a log link function. Significance was defined *a priori* as $p < 0.05$. All analyses were conducted using SPSS software (version 24; IBM, Armonk, NY).

Results

The results of the generalized linear modeling for ImPACT scores are presented in Table 1. Descriptive statistics for groups and subgroups also are presented in Table 1. The means and standard deviations (SDs) for each neurocognitive composite score, stratified by subgroups, were similar. The group-by-eAFE interaction was not significant for any of the ImPACT composite scores (Verbal Memory, Wald $\chi^2 = 0.073$, $p = 0.788$; Visual Memory, Wald $\chi^2 = 2.71$, $p = 0.100$; Visual Motor Speed, Wald $\chi^2 = 0.078$, $p = 0.780$; Reaction Time, Wald $\chi^2 = 0.003$, $p = 0.955$; Symptom Severity, Wald $\chi^2 = 2.87$, $p = 0.090$). Learning accommodation history was associated with lower scores on Visual Motor Speed ($\chi^2 = 6.19$, $p = 0.013$, $B = -2.97$). Older age was associated with faster reaction time ($\chi^2 = 4.40$, $p = 0.036$, $B = -0.006$) and lesser symptom severity ($\chi^2 = 5.55$, $p = 0.019$, $B = -0.068$). No other parameters were significant.

Discussion

The aim of this study was to determine whether exposure to contact sports before the age of 12 was associated with worse performance on neurocognitive testing or greater symptom reporting in a large cohort of male U.S. service academy athletes participating in contact sports other than football. As hypothesized, earlier exposure to contact sports was not associated with worse neurocognitive test performance or greater symptom reporting. Our findings are consistent with previous work that found no association between eAFE to football and differences in neurocognitive functioning in current high school and collegiate athletes ($N = 1802$, mean age = 18.0 years, SD = 1.8 years), in collegiate athletes only ($N = 4376$, mean age = 19.3 years, SD = 1.5),²⁶ and in retired NFL players ($N = 45$; mean age = 46.7 years, SD = 9.1).²⁵

In contrast, Stamm and colleagues¹⁹ reported that former NFL players who started playing organized football before the age of 12 performed more poorly on neurocognitive testing ($N = 42$; ages 40–69). Alosco and colleagues reported that middle-aged men who played high school, college, or professional football, and started playing football before the age of 12, self-reported greater symptoms of depression, apathy, and executive dysfunction ($N = 214$; mean age = 50.7 years, SD = 13.3), but they did not perform more poorly on neurocognitive testing.²³ Therefore, at present, there have been six studies,^{19,23,25–27} sampling from different populations and using different methodologies, that have examined the association between playing contact or collision sports before the age of 12 and later neurocognitive functioning. Five^{23,25–27} (including the study herein) of the six studies did not find statistically significant or clinically meaningful associations.

A striking methodological issue regarding the Stamm and colleagues study¹⁹ was whether the two groups differed during childhood, and whether those long-standing pre-existing differences accounted in whole or in part for the group differences.³⁵ Specifically, 15.8% of the sample who started playing football before the age of 12 had diagnosed learning disabilities compared to 0% of the sample who started playing football after the age of 12. People with learning disabilities are known to perform more poorly on neurocognitive testing.^{36–39} Moreover, those who started playing football at an earlier age performed more poorly on a word reading test, and performance on this word reading test is known to correlate positively with both intellectual and neurocognitive functioning.^{40,41} To our knowledge, there is no published scientific evidence showing that playing football causes a person to have worse single-word reading skills. Therefore, a reasonable alternative explanation, or at least a contributing factor for the findings in their sample, was that youth with learning difficulties, and at least modestly lower reading skills, were more likely to start playing football at a younger age.³⁵

We also observed no association between contact sport participation and worse performance on neurocognitive testing or greater symptom reporting. Similarly, two recent large-scale CARE Consortium studies compared individuals competing in contact sports versus non-contact sports on neurocognitive test performance (on ImPACT) and symptom ratings (on the PCSS) and found no clinically meaningful differences in NCAA athletes (i.e., the effect sizes were small and negligible).^{30,42}

In contrast, Hume and colleagues⁴³ investigated differences in neurocognitive function between former rugby union and non-contact sport players and reported that the elite rugby group ($n = 103$, mean age = 41.3 years, SD = 7.5) had small-to-moderate deficits on tests of complex attention, processing speed, executive functioning, and cognitive flexibility compared to the non-contact sport group ($n = 65$, mean age = 42.1 years, SD = 7.7). Willer and colleagues reported no significant differences in neurocognitive testing between former NFL and National Hockey League players ($n = 21$, mean age = 56.7 years) and age-matched non-contact sport athletes ($n = 21$, mean age = 55.4 years), and on some neurocognitive assessments former contact sport athletes performed better than former non-contact sport athletes.⁴⁴ These studies suggest that differences in neurocognitive function between contact and non-contact sport athletes are small and may not be clinically meaningful.

This is the third large-scale study relating to eAFE to contact or collision sports and neurocognitive functioning and symptom reporting in NCAA athletes and the first to focus on young men from the U.S. service academies. This study has important limitations.

TABLE 1. NEUROCOGNITIVE PERFORMANCES AND SYMPTOM RATINGS AMONG COLLEGIATE MALE CADET CONTACT- AND NON-CONTACT SPORT ATHLETES

<i>ImPACT composite</i>		<i>Verbal memory</i>		<i>Visual memory</i>		<i>Visual motor speed</i>		<i>Reaction time</i>		<i>Symptom severity</i>	
		$\chi^2_6 = 3.063$, $p = 0.801$		$\chi^2_6 = 6.567$, $p = 0.363$		$\chi^2_6 = 11.251$, $p = 0.081$		$\chi^2_6 = 11.354$, $p = 0.078$		$\chi^2_6 = 11.834$, $p = 0.066$	
		N = 889		N = 889		N = 889		N = 889		N = 826	
<i>Overall model</i>		<i>Mean ± Std. deviation</i>	<i>Sig</i>	<i>Mean ± Std. deviation</i>	<i>Sig</i>	<i>Mean ± Std. deviation</i>	<i>Sig</i>	<i>Mean ± Std. deviation</i>	<i>Sig</i>	<i>Mean ± Std. deviation</i>	<i>Sig</i>
Group	Contact	89.0 ± 9.9	0.479	81.7 ± 12.2	0.940	41.9 ± 6.5	0.225	0.60 ± 0.12	0.183	3.4 ± 6.5	0.439
	Non-contact	88.3 ± 9.9		80.6 ± 11.3		41.3 ± 5.9		0.60 ± 0.10		3.3 ± 5.7	
eAFE	eAFE <12y	88.9 ± 9.9	0.697	81.5 ± 12.1	0.490	41.8 ± 6.2	0.990	0.60 ± 0.10	0.393	3.4 ± 6.4	0.954
	eAFE ≥12y	88.2 ± 9.8		80.5 ± 11.5		41.5 ± 6.6		0.61 ± 0.14		3.3 ± 5.7	
Interaction	Contact, eAFE <12y	89.1 ± 9.8	0.788	82.0 ± 12.2	0.100	41.9 ± 6.3	0.780	0.60 ± 0.10	0.955	3.4 ± 6.7	0.090
	Contact, eAFE ≥12y	88.7 ± 10.5		79.8 ± 12.5		41.7 ± 7.6		0.61 ± 0.18		3.0 ± 5.4	
Covariates	Non-contact, eAFE <12y	88.5 ± 10.2		80.3 ± 11.7		41.4 ± 6.1		0.59 ± 0.09		3.2 ± 5.6	
	Non-contact, eAFE ≥12y	88.7 ± 9.2		81.1 ± 10.6		41.2 ± 5.6		0.60 ± 0.10		3.5 ± 6.0	
	Learning accommod.	87.6 ± 10.9	0.492	79.3 ± 10.5	0.335	38.9 ± 9.5	0.013*	0.64 ± 0.17	0.058	4.3 ± 7.4	0.174
	No learning accommod.	88.8 ± 9.9		81.3 ± 12.0		41.8 ± 6.2		0.60 ± 0.11		3.3 ± 6.2	
	Concussion history	89.1 ± 10.5	0.581	81.9 ± 12.7	0.686	41.6 ± 6.8	0.508	0.59 ± 0.10	0.293	3.7 ± 6.9	0.095
	No concussion history	88.7 ± 9.7		81.1 ± 11.7		41.7 ± 6.2		0.60 ± 0.11		3.2 ± 6.0	
	Age		0.216		0.556		0.144		0.036*		0.019*

Except for reaction time scores, higher scores represent better or stronger cognitive abilities. Greater symptom scores represent worse symptom ratings.

*Represents significant associations.

ImPACT, Immediate Post-concussion Assessment and Cognitive Testing; eAFE, estimated age of first exposure; y, years; learning accommod, learning accommodation; Sig, significance.

First, as with all other studies on the topic, eAFE was based on self-reporting in which athletes were asked to report the number of years of participation in their primary sport. Second, we assumed that the participant continuously participated in sports from when they first began, which may not be true for some athletes. These are the two fundamental limitations of our study and of past research in this area. However, considering that all participants were NCAA Division I athletes, it is reasonable to assume that a very large percentage participated in their primary sport continuously from the time they began participation, although some might have had brief gaps.

Third, as with all other studies on the topic, only men were included. Future studies will replicate and extend this study in women. Fourth, the outcome measures, computerized neurocognitive testing and symptom reporting (physical, cognitive, and psychological symptoms), might not be sufficiently sensitive to detect small differences in neurocognitive functioning or perceived symptoms. Fifth, there might be some degree of reporting bias, pre-season, in which some participants are not comfortable endorsing symptoms. Sixth, this was a cross-sectional study and may not reflect long-term neurocognitive functions and symptom scores. Finally, it is possible that there is a subgroup of people who played certain sports longer who have had greater previous exposure to ImPACT testing, and this previous exposure could have at least a subtle influence on their current test performance.

In conclusion, concern has been expressed that younger eAFE to contact and collision sports is related to later-in-life brain health problems.^{19,22–24} We examined the association between eAFE to contact sport and neurocognitive performance and symptom ratings in male collegiate U.S. service academy NCAA athletes and observed no association between eAFE, contact sport participation, neurocognitive functioning, or subjectively experienced symptoms in this cohort. Four^{23,25–27} out of five¹⁹ previously published studies have not found an association between younger eAFE to contact and collision sports and later neurocognitive test performance in men. We also observed no association between contact sport participation and worse performance on neurocognitive testing or greater symptom reporting, compared to athletes competing in non-contact sports. Future research is needed, using different populations and methodologies, to better understand whether, or the extent to which, earlier exposure to contact or collision sports might be associated with differences in brain physiology or functioning that persist for years or decades. Specifically, research is needed to examine the association between AFE to contact sport participation and measures of neurocognitive function, balance, symptom severity, and neuroimaging across the life span in both men and women.

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