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Division III Collision Sports Are Not Associated with Neurobehavioral Quality of Life

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Abstract

We sought to determine whether the exposure to the sub-concussive blows that occur during division III collegiate collision sports affect later life neurobehavioral quality-of-life measures. We conducted a cross-sectional study of alumni from four division III colleges, targeting those between the ages of 40–70 years, using several well-validated quality-of-life measures for executive function, general concerns, anxiety, depression, emotional and behavior dyscontrol, fatigue, positive affect, sleep disturbance, and negative consequences of alcohol use. We used multivariable linear regression to assess for associations between collision sport participation and quality-of-life measures while adjusting for covariates including age, gender, race, annual income, highest educational degree, college grades, exercise frequency, and common medical conditions. We obtained data from 3702 alumni, more than half of whom (2132) had participated in collegiate sports, 23% in collision sports, 23% in non-contact sports. Respondents with a history of concussion had worse self-reported health on several measures. When subjects with a history of concussion were removed from the analyses in order to assess for any potential effect of sub-concussive blows alone, negative consequences of alcohol use remained higher among collision sport athletes (β-coefficient 1.957, 95% CI 0.827-3.086). There were, however, no other significant associations between exposure to collision sports during college and any other quality-of-life measures. Our results suggest that, in the absence of a history of concussions, participation in collision sports at the Division III collegiate level is not a risk factor for worse long-term neurobehavioral outcomes, despite exposure to repeated sub-concussive blows.

Key words: athletics; chronic traumatic encephalopathy; concussions; head injury

Introduction

Recently published case reports have described former athletes who participated in collision sports, like boxing and American football, and later in life developed difficulties with cognition, mood disorders, gait disturbance, headaches, suicidal ideation, speech problems, and aggressive behavior.[1–3] It is broadly assumed that these represent consequences of traumatic brain injuries sustained during their careers. In the absence of a history of repeated concussions, it is assumed that the neurobehavioral findings may result from repeated blows to the head that are not associated with the signs and symptoms necessary for making a diagnosis of concussion, so-called sub-concussive blows.[4–9] Although the long-term risks of engaging in collision sports at the high school and collegiate level are not known, studies have suggested that high school and collegiate football players may sustain as many as 1400–1800 head impacts during a single season.[10,11] The short-term clinical significance of these sub-concussive blows remains unclear, with some studies suggesting an association with neuropsychological assessments,[9] while others found no such association.[12,13] Despite limitations in the current understanding of quantifiable risks associated with sub-concussive blows to the head, concern stemming from existing case reports has led some to suggest that collision sports should be banned.[14,15]

There is no doubt that traumatic brain injury can cause neurobehavioral difficulties and these may be long lasting. We are aware of little data, however, assessing whether exposure to collision sports, and thus repeated sub-concussive blows to the head, in the absence of a clinical diagnosis of concussion is associated with an increased risk of neurobehavioral symptoms.[16] In this

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study, we sought to determine whether the exposure to collision sports of certain division III alumni was associated with later life quality-of-life measures, particularly those assessing the neurobehavioral symptoms hypothesized to be associated with repeated sub-concussive blows to the head.

Methods

Study design

The study protocol was approved by the institutional review board of Boston Children's Hospital. Each participant consented electronically, in writing. We conducted a cross-sectional study of alumni from four New England division III institutions, targeting alumni between the ages of 40–70 years of age. We chose this age range because a prior study suggested that cognitive decline is evident in middle age.[17] Each participating institution sent their alumni an introductory email containing a link to an online questionnaire that was developed using Assessment Center^{SM}. Participating institutions only allowed for one electronic request to be sent. Therefore, no reminder emails were used to prompt non-responders and no other forms of contact (e.g., phone calls, U.S. Postal Service) were used.

Assessment Center^{SM} is a free, online research program that allows researchers to design a secure, customized, data collection tool using several well-validated measures including the Patient-Reported Outcomes Measurement Information System (PROMIS), the National Institutes of Health (NIH) toolbox, and Neuro-QOL. Assessment Center^{SM} houses a library of measures to assess health-related quality of life. These measures parallel each other and comprise an array of instruments derived mostly from calibrated item banks that enable users to administer computerized adaptive testing or short forms to assess health-related quality of life. In addition, responses are automatically scored in reference to the general population or a defined clinical population.

We utilized instruments from Neuro-QOL and PROMIS on the basis of their construction and psychometric properties. Both systems identified relevant health-related quality-of-life domains through a comprehensive literature review, expert interviews, as well as patient and caregiver focus groups. Large calibration studies were conducted in clinical samples and samples from the general population of the U.S. to determine the final item banks and scales. Developers then administered additional sampling to validate the measures in disease populations. The resulting item banks and scales have been shown to reliably assess multiple domains of functioning, including physical, mental, and social well-being.[18]

We focused our analysis on domains purported to be associated with exposure to sub-concussive blows. We used the Neuro-QOL measures for executive function, general concerns, anxiety, depression, emotional and behavior dyscontrol, fatigue, positive affect, and sleep disturbance. Negative consequences of alcohol use were measured using the PROMIS measure Alcohol: Negative Consequences short form 7a. For most domains of interest, item banks were available. This allowed for computerized adaptive testing, which is the most precise and efficient means of measurement.

Individual item responses were given a numerical value, ranging from 1 to 5. A total score for each scale was calculated by summing the value of individual responses. Assessment Center software automatically converted total scores to a standardized T-score with a mean of 50 (standard deviation = 10) based on comparison to the general public. For positive attributes (e.g., mobility) higher scores reflect better functioning, whereas higher scores on undesirable attributes (e.g., anxiety) reflect worse functioning.

Risk factors, outcomes, and covariates

Alumni were asked whether they participated in sports during college. The sport(s) participated in and number of seasons played was recorded. We categorized responses into: 1) collision sports, 2) contact sports, and 3) non-contact sports. Collision sports were defined as those during which routine, purposeful, body-to-body collisions occur as a legal and expected part of the game. We included the following as collision sports: football, rugby, men's ice hockey, and men's lacrosse. Contact sports were defined as those during which body-to-body contact occurs as a recognized part of the game, but purposeful body-to-body collisions are not allowed. We included the following as contact sports: soccer, basketball, baseball, softball, women's ice hockey, women's lacrosse, and field hockey. Non-contact sports were defined as those during which body-to-body contact is a rare, unexpected occurrence. We included the following as non-contact sports: swimming, cross country, golf, tennis, squash, Frisbee, and volleyball. Those athletes who participated in multiple sports were categorized as collision sport athletes if any of their sports were collision sports. Of the alumni who did not participate in a collision sport, any athlete who participated in at least one contact sport was categorized as a contact sport athlete.

Our primary outcome was patient reported Neuro-QOL/PROMIS measures. Our main predictor variable was exposure to collision sports. Covariates were chosen a priori based on clinical judgment and previous research suggesting a potential association with our chosen quality-of-life measures, and included age, gender, race, annual income, highest educational degree, college grades, exercise frequency, and the presence of common medical conditions, including heart disease, hypercholesterolemia, obesity, diabetes, hypertension, and a family history of dementia.

Our study aim was to determine whether the exposure to sub-concussive blows (as opposed to concussions) that occur during collision sports were associated with later life neurobehavioral quality-of-life measures. Therefore, respondents who reported a history of concussion at any point in their lives, whether sport-related or not, were excluded from the primary analysis and considered separately. As the definition of concussion, incidence of diagnosed concussions, and assessments used to make the diagnosis of concussion have changed substantially over the years, we included athletes reporting a history of concussions that were diagnosed by a medical professional, as well as athletes reporting ''undiagnosed'' concussions, defined as any blow to the head or face that was not diagnosed as a concussion but resulted in loss of consciousness, amnesia, headache, difficulty concentrating, emotionality, irritability, slowed reaction times, sleep problems or trouble in school, in our definition of concussion. Subjects who reported other types of head injury that required treatment in a hospital (skull fracture, epidural bleed, subdural bleed, subarachnoid bleed, intracranial hemorrhage) were excluded.

Statistical analysis

Descriptive statistics were used to report the number and percentage of respondents in each variable category. As not all participants responded to each question, percentages were calculated using the number of respondents to a given survey item as the denominator. We used multivariable linear regression to adjust for the effect of potential covariates in separate models for each patient-reported outcome measure. Since former collegiate athletes have the potential to differ from non-athletes with respect to quality of life and overall health, and since there is some level of sub-concussive blows associated with contact sports, albeit lower than with collision sports, we chose non-collision, non–contact sport athletes as our referent group.

Results

A total of 47,836 alumni were contacted and asked to participate in the study; 3702 (8%) responded. Respondents were predominantly white and male (Table 1). There were few respondents older than 70 years, but otherwise respondents were fairly evenly distributed

Table 1. Characteristics of Respondents

	Collision sport athletes n *(%)*	*Contact sport athletes* n *(%)*	*Non-contact sport athletes* n *(%)*	*Non-athletes* n *(%)*	*Total participants* n *(%)*
Age (years) $n=3652$					
<40	102 (2.8)	65 (1.8)	173 (4.7)	198 (5.4)	538 (14.7)
40–44	107 (2.9)	50 (1.4)	121 (3.3)	174 (4.8)	452 (12.4)
45–49	139 (3.8)	81 (2.2)	151 (4.1)	200 (5.5)	571 (15.6)
50–54	150 (4.1)	112 (3.1)	155 (4.2)	327 (9.0)	744 (20.4)
55–59	119 (3.3)	79 (2.2)	109 (3.0)	244 (6.7)	551 (15.1)
60–64	107 (2.9)	38 (1.0)	77 (2.1)	160 (4.4)	382 (10.5)
65–70	114 (3.1)	49 (1.3)	56 (1.5)	148 (4.1)	367 (10.0)
>70	14 (0.4)	5 (0.1)	13 (0.4)	15 (0.4)	47 (1.3)
Gender $n=3656$					
Male	755 (20.7)	246 (6.7)	456 (12.5)	575 (15.7)	2,032 (55.6)
Female	99 (2.7)	235 (6.4)	398 (10.9)	892 (24.4)	1,624 (44.4)
Race/ethnicity $n=3618$					
Asian	6 (0.2)	4 (0.1)	7 (0.2)	32 (0.9)	49 (1.4)
Black	17 (0.5)	4 (0.1)	10 (0.3)	19 (0.5)	50 (1.4)
Hawaiian	2 (0.1)	0 (0.0)	1 (0.0)	0 (0.0)	3 (0.1)
Multiple	15 (0.4)	4 (0.2)	16 (0.5)	18 (0.5)	53 (1.4)
Native American	0 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)
Declined answer	11 (0.3)	9 (0.2)	20 (0.6)	25 (0.7)	65 (1.8)
White	801 (22.1)	459 (12.7)	767 (21.2)	1,370 (37.9)	3,397 (93.9)
Annual income $n=3382$					
<$20,000	13 (0.4)	3 (0.1)	20 (0.6)	28 (0.8)	64 (1.9)
$20,000–35,000	10 (0.3)	12 (0.4)	21 (0.6)	42 (1.2)	85 (2.5)
$35,000–54,000	64 (1.9)	61 (1.8)	121 (3.6)	195 (5.8)	441 (13.0)
$55,000–74,000	10 (0.3)	6 (0.2)	13 (0.4)	35 (1.0)	64 (1.9)
$75,000–99,000	76 (2.2)	63 (1.9)	91 (2.7)	178 (5.3)	408 (12.1)
$100,000–250,000	327 (9.7)	168 (5.0)	277 (8.2)	524 (15.5)	1,296 (38.3)
>$250,000	306 (9.0)	134 (4.0)	226 (6.7)	358 (10.6)	1,024 (30.3)

among age categories (Table 1). More than half of respondents (2132) participated in collegiate sports; 23% were collision sport athletes, 13% were contact sport athletes, 23% were non-contact sports athletes, and 40% were non-athletes. Hypercholesterolemia and hypertension were the most commonly reported medical conditions (Table 2). The majority of respondents (86%) continued to exercise more than once per week (Table 2). Respondents were relatively high wage earners, with 69% earning more than $100,000 annually (Table 1). Over a third had a history of concussion, either diagnosed or undiagnosed (Table 2).

When subjects with a history of concussion were removed from the analyses in order to assess for any potential effect of sub-concussive

Table 2. Health Habits and Medical Conditions of Respondents

	Collision sport athletes n *(%)*	*Contact sport athletes* n *(%)*	*Non-contact sport athletes* n *(%)*	*Non-athletes* n *(%)*	*Total participants* n *(%)*
Exercise frequency $n=3491$					
No regular	42 (1.2)	25 (0.7)	53 (1.5)	156 (4.5)	276 (7.9)
Once per week	55 (1.6)	28 (0.8)	45 (1.3)	101 (2.9)	229 (6.6)
1–3 times/week	223 (6.4)	132 (3.8)	232 (6.6)	435 (12.5)	1,022 (29.3)
4–6 times/week	349 (10.0)	193 (5.5)	303 (8.7)	454 (13.0)	1,299 (37.2)
Every day	156 (4.5)	96 (2.7)	164 (4.7)	249 (7.1)	665 (19.0)
Medical conditions $n=3697$					
Heart disease	32 (0.9)	11 (0.3)	19 (0.5)	30 (0.8)	92 (2.5)
High cholesterol	219 (5.9)	106 (2.9)	151 (4.1)	344 (9.3)	820 (22.2)
Diabetes	29 (0.8)	9 (0.2)	17 (0.5)	43 (1.2)	98 (2.7)
Hypertension	177 (4.8)	65 (1.8)	113 (3.0)	275 (7.4)	630 (17.0)
Obesity	50 (1.4)	13 (0.4)	43 (1.2)	99 (2.7)	205 (5.5)
Family history of dementia	130 (3.5)	75 (2.0)	108 (2.9)	196 (5.3)	509 (13.8)
Concussion history $n=3702$					
Diagnosed	283 (7.6)	121 (3.3)	177 (4.8)	255 (6.9)	836 (22.6)
Undiagnosed	396 (10.7)	134 (3.6)	102 (2.8)	113 (3.1)	745 (20.1)

Table 3. Effect of Collision Sports Participation on Patient Reported Outcome Measures of Those Participants with No Reported History of Concussion

	*β-coefficient**	*Standard error*	*95% CI*	p *value*
Outcome measure				
General concerns	−0.497	0.505	−1.487, 0.494	0.326
Executive function	0.204	0.563	−0.900, 1.307	0.717
Anxiety	−0.056	0.551	−1.138, 1.025	0.919
Depression	−0.440	0.449	−1.321, 0.442	0.328
Alcohol use†	1.957	0.576	0.827, 3.086	0.001
Sleep disturbance	0.378	0.542	−0.685, 1.441	0.485
Emotion/behavior dyscontrol	0.243	0.608	−0.949, 1.435	0.689
Fatigue	0.330	0.536	−0.721, 1.380	0.538
Positive affect	0.442	0.449	−0.439, 1.323	0.325

*β-coefficients represent the effect of collegiate collision sport participation using non-collision, non-contact sport athletes as referent group on each of the listed measures.

† All outcome measures from Neuro-QOL except for negative consequences of alcohol use, which was the Patient-Reported Outcomes Measurement Information System's Alcohol: Negative Consequences short form 7a.

CI, confidence interval.

blows, only negative consequences of alcohol use was higher among collision sport athletes. There were no other significant associations between exposure to collision sports during college and any other quality-of-life measures (Table 3).

After adjustment for potential covariates, respondents with a history of concussion, whether diagnosed or undiagnosed, had lower scores (indicating worse self-reported health) on measures of general concerns regarding cognition, executive function, and positive affect, and higher scores (indicating worse reported- self health) on measures of anxiety, depression, negative consequences of alcohol use, sleep disturbance, emotional and behavioral dyscontrol, and fatigue (Table 4).

Discussion

The study was designed to test the hypothesis that the sub-concussive blows sustained during collision sports participation are associated with altered neurobehavioral quality-of-life measures. Our findings do not support this notion.

The association between concussion history and negative self-reported neurobehavioral quality of life was consistent across all domains. However, we are hesitant to draw any conclusions from such data, since the history of concussion is susceptible to recall bias, whereby those currently having neurobehavioral symptoms may be more likely to recall a history of concussion than those who are not experiencing symptoms. We believe athletes are unlikely to inaccurately recall which sports they played during college, making exposure to collision sports less susceptible to recall bias.

Previous studies have assessed the potential effect of sub-concussive impacts to the head on various outcomes in the acute and sub-acute setting including functional magnetic resonance imaging (fMRI), neurocognitive assessment, and symptoms.[6,7,9,11–13,19–23] Although results have been mixed, with some showing an effect of sub-concussive blows and others not, the majority suggest that changes in MRI, fMRI, and magnetic resonance spectroscopy are associated with an increased number of sub-concussive head impacts.[6,21,22]

The association between head impacts and long-term clinical outcomes is even less clear. In a cross-sectional study of 25 NCAA division I collegiate football players with a history of concussion, 25 NCAA division I collegiate football players without a history of concussion, and 25 non–football player healthy controls without a history of brain trauma matched for age, sex, and education, Singh and colleagues reported an association between exposure to collegiate football and decreased hippocampal volume and slower reaction time in active football players.[21] A causal relationship between concussion or sub-concussive blows and hippocampal volume could

Table 4. Effect of History of Concussion on Patient Reported Outcome Measures

	*β-coefficient**	*Standard error*	*95% CI*	p *value*
Outcome measure				
General concerns	−2.353	0.251	−2.845, −1.861	<0.001
Executive function	−2.177	0.281	−2.728, −1.626	<0.001
Anxiety	1.612	0.275	1.073, 2.152	<0.001
Depression	1.158	0.219	0.729, 1.587	<0.001
Alcohol use†	1.554	0.292	0.981, 2.126	<0.001
Sleep disturbance	2.263	0.274	1.725, 2.801	<0.001
Emotion/behavior dyscontrol	1.903	0.301	1.312, 2.494	<0.001
Fatigue	1.668	0.272	1.136, 2.200	<0.001
Positive affect	−0.850	0.223	−1.288, −0.412	<0.001

*β-coefficients represent the effect of history of concussion using respondents without a history of concussion as referent group on each of the listed measures.

† All outcome measures from Neuro-QOL except for negative consequences of alcohol use, which was the Patient-Reported Outcomes Measurement Information System's Alcohol: Negative Consequences short form 7a.

CI, confidence interval.

not be established given the possibility of confounding variables. Other studies also have suggested an association between contact or collision sports and worse performance on certain measures of neurocognitive assessment during active playing years.[9]

Few published data, however, have addressed the potential effect of exposure to collision sports in college on later life outcomes. In a study of 400 college graduates from a Midwestern university, Hinton and colleagues[16] found more self-reported cognitive difficulties among former collegiate football players than controls. Prior participation in collegiate football was associated with lower physical and mental health ratings. The authors note, however, that dietary fat intake among football players appeared to be more significantly associated with self-reported cognitive difficulties than exposure to football alone, and the effect of playing football was possibly confounded by variables such as exercise and income.

In our study, collision sport athletes rated higher scores on the negative consequences of alcohol use. It is unclear, however, whether this association results from exposure to collision sports. It is possible that alcohol use is higher among those who choose to participate in collision sports, than those who choose to participate in non-contact sports. Prior studies at the college level have suggested alcohol use is higher among team sport than individual sport athletes.[24] All of the collision sports in our analysis are team sports, and many non-contact sports are individual sports, raising the possibility that alcohol use was different between collision sport and non-contact sport athletes even prior to completion of their college sports careers. While there also are data suggesting that alcohol use is higher among male athletes than female athletes,[24,25] and a higher proportion of collision sport athletes were male, we were able to adjust for gender in our analyses. Further, we repeated the analysis for only male athletes, and found persistent associations between collision sport participation and negative consequences of alcohol use (data not shown).

Our findings should be considered in light of several limitations. The population was homogeneous with regards to race/ethnicity, education level, annual income, and other parameters, thus limiting the generalizability of our observations. This relative homogeneity, however, also may have served to limit confounding bias. Our low response rate may have introduced response bias. We believe, however, that the low response rate was due, in part, to the inability to send reminders or contact alumni using modalities other than email. Our study was retrospective, and we asked respondents to recall whether or not they had sustained concussions. It is certainly possible that the least-affected subjects responded to the survey, biasing the results to the null hypothesis. If that were the case, however, it also should have blunted the association between concussion history and quality-of-life measures. Instead, we found substantial differences between subjects with a history of concussion and those with no history of concussion across all domains. In addition, the proportion of alumni that reported having sustained a concussion was, as we would expect given the reported incidences of concussions in various sports, greatest for collision sport athletes, followed by contact sport athletes, followed by non-contact sport athletes, with non-athletes being the least likely to report a concussion. In addition, we were unable to quantify participants' exposure to sub-concussive blows. Finally, the demographics of the respondent population were similar to those of the larger population of alumni from these schools (data not shown).

In summary, our data suggest that participation in collision sports in college does not constitute a risk factor for worse long-term neurobehavioral outcomes. Participation in collision sports does increase the risk of concussions, and our results suggest that a history of concussion might be associated with negative long-term neurobehavioral outcomes. However, our long-term retrospective study was not designed to adequately or accurately assess any potential effect of prior concussions on quality of life. The previous diagnosis of concussion is highly susceptible to recall bias and those alumni experiencing a higher burden of neurobehavioral symptoms would thus be more likely to recall a concussion in their past than those alumni with little or no neurobehavioral symptoms. Further prospective population studies are needed to evaluate the effect of concussions on long-term cognitive and neurobehavioral function. In addition, our findings may not apply to division I or, particularly, to professional athletes, who have both lengthier and higher intensity exposure to collision sports and are, in general, faster, stronger, heavier, and exposed to collisions involving higher forces than those playing at typical youth, high school, and division III collegiate levels.

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