The Relationship Between Impulsivity, Sensation Seeking, and Concussion History in Collegiate Student-Athletes

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ABSTRACT

Purpose: To determine the relationship between diagnosed concussions and impulsivity and sensation seeking in collegiate student-athletes.

Methods: A convenience sample of 1,244 collegiate student-athletes (56.5% males; age: 19.52 ± 1.33 years) from four colleges and/or universities. This cross-sectional study used a 10-minute survey that included demographics, previously diagnosed concussion history, the 15-item Barratt Impulsiveness Scale, and the 8-item Brief Sensation Seeking Scale.

Results: Impulsivity and sensation seeking were statistically significant correlates of total diagnosed concussions using Spearman's rho (rho for impulsivity = .08, $P < .01$; rho for sensation seeking = .08, $P < .01$). Impulsivity remained a statistically significant predictor (exp(b) = 1.35, 95% CI = 1.16 to 1.54) in a negative binomial regression model, suggesting that a 1-point difference in impulsivity implies a 35% increase in concussions when adjusting for covariates. High-risk concussion sport type was also a significant predictor (exp(b) 2.02, 95% CI = 1.37 to 2.67). However, sensation seeking (exp(b) = 1.14, 95% CI = 0.94 to 1.34) and sex (1 = male, exp(b) = 1.03, 95% CI = 0.60 to 1.46) were not statistically significant.

Conclusions: There may be a potential association between impulsivity and concussions, but longitudinal research is needed to help clarify the cause-and-effect directionality between concussions and impulsivity.

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Sport-related concussions are a high-profile public health concern that affects athletes at all levels.[1] Concussions are heterogeneous injuries that can present with a variety of physical symptoms (eg, headache, dizziness, and nausea) and impairments (eg, balance, cognitive, ocular, and vestibular).[2] Although most physical and cognitive symptoms resolve within 14 days for adults[3] and 30 days for children,[4] many athletes experience lingering post-concussive symptoms and impairments.[3] Although research suggests that multiple concussions may be associated with the development of mood, behavior, and cognitive changes,[5,6] more research is needed regarding which intrinsic variables may be a risk factor for sustaining a concussion and which variables may be a consequence of injury.

A starting point for concussion prevention is to identify injury risk factors. This may lead to interventions that can be developed to provide at-risk athletes with additional concussion education and sport technique modifications. Risk factors for sustaining a concussion are having a history of previous concussions[7,8] and female sex.[9-12] Athletes who have previously sustained concussions are at a greater risk of sustaining a future concussive injury compared to athletes with no concussion history.[7,8] Females have a higher injury rate of concussions in comparable sports[9-12] and take longer to

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recover than males.[9,11] Regardless of sex, concussion injury rates are higher in sports where contact or collision are inherent to the game in comparison to non-contact athletic activities.[10-12] Although many potential risk factors have been considered, there is minimal evidence regarding how concussion history specifically relates to psychological variables.

Previous investigations have considered personality traits,[13] impulsivity,[14] and sensation seeking related to concussions.[15,16] One study found that none of the Big Five personality traits (ie, conscientiousness, agreeableness, openness, extraversion, and neuroticism) were related to diagnosed concussion history in a sample of collegiate student-athletes.[13] Conversely, Kerr et al[14] found that former collegiate student-athletes with a history of two or more concussions had higher mean adjusted scores of impulsivity than student-athletes who reported no concussions. Kerr et al[14]'s results indicated that student-athletes who sustained two previous concussions had a 5.5% higher mean impulsivity score than former collegiate athletes with no history of concussions.[14] Higher sensation seeking tendencies have also been found to be prospectively related to higher concussion incidence rates in rugby players[15] and retrospectively connected to young adults who reported a history of previous head injuries.[16] Additionally, retired Canadian professional football players with histories of multiple concussions were found to have significantly reduced inhibition and higher mania and aggression scores compared to a healthy control group.[17] Reduced inhibition leads to impulsivity,[18] and these findings are consistent with a study that found increased impulsive life decision-making processes in patients with a traumatic brain injury.[19] The results of these studies collectively suggest that there may be a relationship between impulsivity, sensation seeking, and head injuries that warrants further investigation.

Impulsivity has previously been defined as the "predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions,"[20] whereas sensation seeking refers to "the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take risks for the sake of such experiences."[21] Much of the literature regarding these variables and concussion is characterized by methodological and sampling issues that limit the generalizability of previous findings to collegiate athletics. Such limitations are the inclusion of one sport,[15,17] limited heterogeneity within level of play,[14,15,17] sampling from one institution/location,[14,15] the inclusion of male athletes only,[15,17] and a large range in time between athletic participation and survey completion (eg, 0 to 25 years), which could produce injury recall inaccuracies and biases.[14,17] The current study sought to add to the existing literature by using a large sample of current male and female student-athletes from multiple institutions who represented all three levels of play within the National Collegiate Athletic Association (NCAA). For psychological variables to be considered in concussion awareness and management efforts, the interaction between concussive injury, impulsivity, and sensation seeking must be more clearly defined. Therefore, the primary purpose of this study was to investigate the relationship between the number of diagnosed concussions and impulsivity and sensation seeking in collegiate student-athletes. Based on the findings of the available literature on this topic,[15-19] we hypothesized that impulsivity and sensation seeking scores would increase as the number of previously diagnosed concussions increased.

METHODS

Research Design and Participants

This cross-sectional study included male and female collegiate student-athletes who participated in baseball, basketball, cross country, women's field hockey, football, golf, gymnastics, ice hockey, lacrosse, women's rowing, soccer, softball, swimming and diving, tennis, track and field, volleyball, water polo, or wrestling at the NCAA Division I, II, and III levels from four institutions. All sport types were included to increase the generalizability of study results and to be consistent with NCAA sport inclusion documented in previous literature.[14] Inclusion criteria were collegiate student-athletes between the ages of 18 and 25 years who were able to read and write in the English language. Participants were excluded from this study if they (1) were currently recovering from an acute concussion; (2) had a self-reported history of sustaining a concussion within the 3 months prior to data collection; or (3) had recovered from a musculoskeletal injury. The exclusion criteria were implemented to decrease potential response biases on additional survey instruments that were collected as part of a larger study. These items (ie, mood, Big Five personality domains) were not the focus of the current study, but concussion signs and symptoms and musculoskeletal pain could have influenced responses. Additionally, the 3-month post-concussion timeframe was selected because it was outside the average 10- to 14-day loss of participation in the student-athlete population, thus increasing the likelihood of full recovery.[3]

Data Collection Procedure

Prior to data collection, the institutional review board at Michigan State University approved this study and deemed it exempt. This study used convenience sampling methods for both institution and participant recruitment. The principal investigator (EB) contacted 30 head athletic trainers from a variety of NCAA institutions in the midwestern United States and Pennsylvania by email to inform them of the study. Of those contacted, four NCAA institutions (Division I, n = 1; Division II, n = 2; Division III, n = 1) agreed to participate. Previously approved variations of the data collection plan were employed based on the logistics of sports medicine care at each institution. At three of the participating institutions, survey responses were collected during pre-participation physical examinations in paper and pencil form or via the Qualtrics online survey software (Qualtrics) on a smart device. The remaining institution did not have on-campus pre-participation physical examinations, so paper and pencil survey responses were collected before or after team meetings or practices. The survey took approximately 10 minutes to complete. All data collection occurred in the fall of 2015.

Survey Instrument

The one-time survey included demographic information, concussion history, and two psychological assessments. The primary dependent variable in this study was the total number of diagnosed concussions. This was assessed by asking participants to self-report how many previous concussions they had sustained that were diagnosed by a medical professional. Sex and concussion risk sport type were considered covariates in this investigation. Sex was assessed by asking participants whether they were male or female. For concussion risk sport type, participants were first asked to indicate the collegiate sport they participated in from a list of all NCAA-sanctioned sports. Based on their response, participants were then categorized into sports with a high risk of concussion (> 2.50 concussions per 10,000 athlete-exposures [eg, football, soccer, or lacrosse]) or a low risk of concussion (< 2.50 concussions per 10,000 athlete-exposures [eg, cross country, golf, or tennis]) sport types based on injury rates from an epidemiological study of concussion in NCAA student-athletes.[12] The cutoff point was determined by the categorization of sports by impact expectation in the NCAA Sports Medicine Handbook.[22]

Impulsivity was measured using the 15-item Barratt Impulsiveness Scale (BIS-15).[23] The BIS-15 asks participants to rate each item on a 4-point scale (1 = rarely to never; 4 = almost always) based on the way in which they normally act and think. For example, participants were asked to report how often they "plan for the future" or "do things without thinking." The main outcome from the BIS-15 was the total impulsivity composite score, with a minimum mean score of 1 and a maximum of 4. A higher mean score indicated higher impulsivity. The BIS-15 had a Cronbach's alpha value of 0.82 in a large sample of community-dwelling adults.[23] The estimate for Cronbach's alpha was 0.83 in this sample.

Sensation seeking was determined using the Brief Sensation Seeking Scale (BSSS).[24] The BSSS uses a 5-point scale (1 = strongly disagree; 5 = strongly agree) and asks participants to rank how well each item describes them (eg, "I would like to try bungee jumping" or "I get restless when I spend too much time at home"). The BSSS outcome measure was the total sensation seeking composite score with a minimum mean score of 1 and a maximum of 5. The BSSS had an overall internal consistency of 0.76 in the study by Hoyle et al[24] and was found to be a reliable measure of sensation seeking across sex, age, and ethnicity. In the current study, the estimate for Cronbach's alpha was 0.76.

Statistical Analysis

As a preliminary step, a series of independent-samples *t* tests were completed to investigate the potential differences in impulsivity and sensation seeking between males versus females and high versus low concussion risk sport participants. Effect sizes were calculated for the mean differences in impulsivity and sensation seeking between sexes (males, females) and concussion risk sport type (high, low) groups using Cohen's *d*. The effect sizes were defined by Cohen's recommendations of 0.20 or less as a small effect, 0.50 as a medium effect, and 0.80 or greater as a large effect.[25] A Pearson chi-square analysis was also conducted to determine whether there were associations between sex and concussion risk sport type. An alpha level of .05 was set for all analyses.

We also computed Spearman's rho correlations between total diagnosed concussions and BIS-15 total impulsivity and BSSS total sensation seeking. These coefficients are in an intuitive correlational effect size metric, and researchers have recently argued that coefficients approximately 0.10 are small, approximately 0.20 are typical, and greater than 0.30 are large in relation to the individual difference literature.[26] Because the primary dependent variable was a count variable, a standard ordinary least squares regression analysis was inappropriate.[27] Therefore, we used count regression methods and considered Poisson, negative binomial regression, and zero-inflated negative binomial regression models estimated with the Mplus software package (Muthen & Muthen). We used the sandwich estimator to calculate standard errors because data were collected from four institutions, which raised concerns about non-independence (ie, MLR estimation in Mplus). However, results ignoring the potential clustering of data within institutions were almost identical to those reported here (ie, ML estimation in Mplus). The small number of institutions precluded more complicated multilevel modeling approaches. We predicted the total number of diagnosed concussions from the BIS total, BSSS total, male sex, and concussion risk sport type variables. BIS total and BSSS total were both included in the model because the two variables were correlated (r = 0.36).

The regression model with the lowest Bayesian Information Criterion was selected for final presentation, because the BIC is used for model selection purposes (lower scores are better). A negative binomial model was selected in this case. The negative binomial model is a common approach for dealing with data that are more dispersed than would be assumed by a Poisson regression model. This was evident in the analyses because the dispersion parameter estimates were always statistically significant in the negative binomial model, further attesting to the appropriateness of this model for the data. We also estimated this model with SPSS software (SPSS, Inc) and obtained the same results.

The coefficients from the negative binomial model are used to predict the natural log of a count variable. Because this metric is unfamiliar to many researchers, the coefficients can be exponentiated to facilitate interpretation. The interpretation of such an exponentiated coefficient represents the predicted multiplicative effect of a 1-unit increase for a given variable. For example, if the exponentiated coefficient for sensation seeking was 1.40, the interpretation would be that an individual with a sensation seeking score of 3.50 was predicted to have a 40.0% higher rate of concussions than an individual with a sensation seeking score of 2.50. Similar logic applies to categorical variables. For example, if sex is coded as 1 = males and 0 = females and the exponentiated coefficient is 1.50, the interpretation is that males have 50.0% more concussions than females. Coxe et al[27] provided an accessible introduction to the analyses of count data using regression-type models for those interested in more details.

RESULTS

Participant Demographics

Of the 2,055 collegiate student-athletes approached for participation, 1,398 responses were collected from four different NCAA institutions with a resultant 68.0% response rate. A total of 154 of 1,398 (11.0%) participants were excluded from the statistical analysis because they did not meet the inclusion criteria or they did not complete enough usable survey items. Therefore, survey responses from 1,244 of 1,398 (60.5%) collegiate student-athletes were included in the statistical analysis (age: 19.52 ± 1.33 years; height: 177.02 ± 10.34 cm; weight: 77.71 ± 17.55 kg). The distribution of self-reported diagnosed concussive injuries was as follows: 0, n = 937 (75.3%); 1, n = 204 (16.4%); 2, n = 73 (5.9%); 3, n = 20 (1.6%); 4, n = 6 (0.5%); 5, n = 3 (0.2%); and 6, n = 1 (0.1%). Most participants were male (n = 703, 56.5%) and played sports with a high risk of concussion (n = 726, 58.4%). Males were more likely to report playing sports with a high risk of concussion compared to females (Pearson chi-square = 8.023, df = 1, P = .005, phi coefficient = .08). Additional demographic information can be found in **Tables 1-2**.

Impulsivity and Sensation Seeking by Sex and Concussion Risk Sport Type

The results of an independent-samples t test supported a significant difference in impulsivity scores between the sexes ($t(1,221) = 4.12$, $P < .01$, $d = 0.23$), with male collegiate student-athletes having higher scores than female collegiate student-athletes (2.11 ± 0.41 vs 2.01 ± 0.47, respectively). No sensation seeking sex differences were found (male: 3.35 ± 0.68; female: 3.34 ± 0.73); $t(1,208) = .27$, $P = .79$, $d = 0.01$). As for sport type, athletes playing sports with a high risk of concussion had significantly higher impulsivity compared to athletes playing sports with a low risk of concussion (2.10 ± 0.43 vs 2.02 ± 0.45, respectively) ($t(1,220) = 3.20$,

TABLE 1

Race, Year in College, and NCAA Level Demographics by Sex, Concussion History, and Concussion Risk Sport Type[a]

	Sex, n (%)		Concussion History, n (%)			Concussion Risk Sport Type,[b] n (%)		
Variable	Male	Female	0	1	2+	Low	High	Total n (%)
Race								
White	545 (53.0)	484 (47.0)	773 (75.1)	168 (16.3)	88 (8.6)	445 (43.2)	584 (56.7)	1,029 (82.7)
Black	91 (80.5)	22 (19.5)	88 (77.9)	113 (9.1)	3 (2.7)	23 (20.4)	90 (79.6)	113 (9.1)
Hispanic/Latino	23 (63.9)	13 (36.1)	28 (77.8)	36 (2.9)	4 (11.1)	23 (63.9)	13 (36.1)	36 (2.9)
Asian	5 (63.0)	3 (37.5)	8 (100.0)	8 (0.6)	–	4 (50.0)	4 (50.0)	8 (0.6)
American Indian	2 (50.0)	2 (50.0)	3 (75.0)	4 (0.3)	1 (25.0)	3 (75.0)	1 (25.0)	4 (0.3)
Mixed race	29 (64.4)	16 (35.6)	31 (68.9)	45 (3.6)	5 (11.1)	16 (35.6)	29 (64.4)	45 (3.6)
Unknown	8 (88.9)	1 (11.1)	6 (66.7)	9 (0.7)	2 (22.2)	3 (33.3)	5 (55.6)	9 (0.7)
Total	703 (56.5)	541 (43.5)	937 (75.3)	204 (16.4)	103 (8.3)	517 (41.6)	726 (58.4)	1,244
Year in college[c]								
1st	193 (52.2)	177 (47.8)	296 (80.0)	370 (29.8)	23 (6.2)	144 (38.9)	226 (61.1)	370 (29.8)
2nd	173 (55.1)	141 (44.9)	249 (79.3)	314 (25.3)	18 (5.7)	156 (49.7)	158 (50.3)	314 (25.3)
3rd	164 (59.4)	112 (40.6)	200 (72.5)	276 (22.2)	28 (10.1)	112 (40.6)	164 (59.4)	276 (22.2)
4th	133 (56.8)	101 (43.2)	163 (69.7)	234 (18.9)	25 (10.7)	95 (40.6)	139 (59.4)	234 (18.9)
5th	32 (86.5)	5 (13.5)	21 (56.8)	37 (3.0)	7 (18.9)	5 (13.5)	32 (86.5)	37 (3.0)
Graduate student	6 (60.0)	4 (40.0)	6 (60.0)	10 (0.8)	1 (10.0)	2 (20.0)	8 (80.0)	10 (0.8)
Total	701 (56.5)	540 (43.5)	935 (75.3)	204 (16.4)	102 (8.3)	515 (41.5)	725 (58.4)	1,241
NCAA level								
Division I	158 (48.6)	167 (51.4)	262 (80.6)	325 (26.1)	14 (4.3)	180 (55.4)	145 (44.6)	325 (26.1)
Division II	454 (58.7)	319 (41.3)	574 (74.3)	773 (62.1)	75 (9.7)	330 (42.7)	442 (57.2)	773 (62.1)
Division III	91 (62.3)	55 (37.7)	101 (69.2)	146 (11.7)	14 (9.6)	7 (4.8)	139 (95.2)	146 (11.7)
Total	703 (56.5)	541 (43.5)	937 (75.3)	204 (16.4)	103 (8.3)	517 (41.6)	726 (58.4)	1,244

NCAA = National Collegiate Athletic Association

[a]Percentages calculated by row.

[b]One female participant did not report sport.

[c]Two male participants and one female participant did not report year in college.

TABLE 2

Sport by Sex, Concussion History, and Concussion Risk Sport Type[a]

	Sex,[b] n (%)		Concussion History, n (%)			Concussion Risk Sport Type, n (%)		
Sport	Male	Female	0	1	2+	Low	High	Total, n (%)
Football	163 (100.0)	–	107 (65.6)	37 (22.7)	19 (11.7)	–	163 (100.0)	163 (13.1)
Soccer	75 (54.7)	62 (45.3)	93 (67.9)	32 (23.4)	12 (8.8)	–	137 (100.0)	137 (11.0)
Lacrosse	6 (55.5)	49 (44.5)	59 (53.6)	26 (23.6)	25 (22.7)	–	110 (100.0)	110 (8.8)
Swim and dive	42 (41.2)	60 (58.8)	94 (92.2)	7 (6.9)	1 (0.9)	102 (100.0)	–	102 (8.2)
Track and field	46 (48.4)	49 (51.6)	75 (78.9)	14 (14.7)	6 (6.3)	95 (100.0)	–	95 (7.6)
Basketball	56 (61.5)	35 (38.5)	71 (78.0)	11 (12.1)	9 (9.9)	–	91 (100.0)	91 (7.3)
Baseball	79 (100.0)	–	60 (75.9)	13 (16.5)	6 (7.6)	79 (100.0)	–	79 (6.4)
Cross country	30 (45.5)	36 (54.5)	61 (92.4)	3 (4.5)	2 (3.0)	66 (100.0)	–	66 (5.3)
Wrestling	57 (100.0)	–	47 (82.5)	6 (10.5)	4 (7.0)		57 (100.0)	57 (4.6)
Rowing	–	57 (100.0)	43 (75.4)	11 (19.3)	3 (5.3)	57 (100.0)	–	57 (4.6)
Volleyball	–	52 (100.0)	42 (80.8)	9 (17.3)	1 (1.9)	–	52 (100.0)	52 (4.2)
Ice hockey	26 (56.5)	20 (43.5)	28 (60.9)	13 (28.3)	5 (10.9)	–	46 (100.0)	46 (3.7)
Tennis	18 (40.9)	26 (59.1)	44 (100.0)	–	–	44 (100.0)	–	44 (3.5)
Water polo	22 (57.9)	16 (42.1)	31 (81.6)	6 (15.8)	1 (2.6)	38 (100.0)	–	38 (3.1)
Softball	–	36 (100.0)	27 (75.0)	6 (16.7)	3 (8.3)	–	36 (100.0)	36 (2.9)
Golf	28 (77.8)	8 (22.2)	29 (80.6)	4 (11.1)	3 (8.3)		36 (100.0)	–
Field hockey	–	26 (100.0)	18 (69.2)	5 (19.2)	3 (11.5)	–	26 (100.0)	26 (2.1)
Gymnastics	–	8 (100.0)	7 (87.5)	1 (12.5)	–	–	8 (100.0)	8 (0.6)
Total	703 (56.5)	540 (43.5)	936 (75.3)	204 (16.4)	103 (8.3)	517 (41.6)	726 (58.4)	1,243

NCAA = National Collegiate Athletic Association
[a]Percentages calculated by row.
[b]One female participant did not report sport.

TABLE 3

Mean Impulsivity and Sensation Seeking Scores

Variable	BIS Total (Mean ± SD)	BSSS Total (Mean ± SD)
Sex		
Male	2.11 ± 0.41	3.36 ± 0.97
Female	2.01 ± 0.47	3.34 ± 0.74
Concussion history		
None	2.05 ± 0.43	3.32 ± 0.71
1	2.08 ± 0.44	3.41 ± 0.71
2+	2.22 ± 0.48	3.50 ± 0.68
Concussion risk sport type		
Low	2.02 ± 0.45	3.34 ± 0.68
High	2.10 ± 0.43	3.36 ± 0.73

BIS = Barratt Impulsiveness Scale; BSSS = Brief Sensation Seeking Scale; SD = standard deviation

P < .01, d = 0.18). However, there was no evidence of a difference in sensation seeking between participants who played sports with a high or low risk of concussion (3.36 ± 0.72 vs 3.34 ± 0.68, respectively) (t(1,207) = 0.47, P = .64, d = 0.03). Although analyses found significant impulsivity differences, the degree of clinical relevance of these findings was not substantial because the Cohen's d effect sizes were 0.23 for sex and 0.18 for concussion risk sport type.

Diagnosed Concussion Predictors

The average total impulsivity score for the sample was 2.07 ± 0.44 (median = 2.07, minimum = 1.00, maximum = 3.64, skewness = 0.23, kurtosis = -0.10), and the average total sensation seeking score was 3.35 ± 0.71 (median = 3.38, minimum = 1.00, maximum = 5.00, skewness = -0.11, kurtosis = -0.17). Impulsivity and sensation seeking mean outcome scores by sex, concussion history, and concussion risk sport type are listed in **Table 3**. Spearman's rho correlations found that the included intrinsic variables and diagnosed concussion associations were positive and statistically significant (rho for impulsivity = .08, P < .01; rho for sensation seeking = .08, P < .01). Individuals with higher levels of impulsivity and sensation seeking reported higher numbers of diagnosed concussions. However, these associations were small. Concussion risk sport type classification was also significantly correlated with concussion history (rho = .18, P < .01), but sex was not (rho = .04, P = .20).

We conducted negative binomial regression analyses that included covariates for sex and concussion risk sport type. The results are reported in **Table 4**. Impulsivity was a significant predictor of concussions (the exponentiated coefficient was 1.35), suggesting that a 1-point difference in impulsivity implies a 35% increase in concussions when adjusting for covariates. Sensation seeking was not a statistically significant predictor in this model (the exponentiated coefficient was 1.14). Concussion risk sport type was a significant predictor of concussive injuries such that those playing higher risk sports had twice the rates of concussion than those playing sports with a low risk of concussion after adjusting for the covariates (the exponentiated coefficient was 2.02). Sex was not a statistically significant predictor in this model (the exponentiated coefficient was 1.03). We also conducted exploratory analyses testing whether the association between impulsivity

TABLE 4

Negative Binomial Regression Results Predicting Diagnosed Concussions

Predictor	b[a]	SE	P	exp(b)[b]	95% CI
Intercept	-2.57	0.36	< .01[c]	–	–
BIS-15 total impulsivity	0.30	0.14	.03[c]	1.35	1.16 to 1.54
BSSS total sensation seeking	0.13	.09	0.15	1.14	0.94 to 1.34
Male sex	0.03	0.12	.82	1.03	0.60 to 1.46
Concussion risk sport type	0.70	0.13	< .01[c]	2.02	1.37 to 2.67

SE = standard error; BIS-15 = 15-item Barratt Impulsiveness Scale; BSSS = Brief Sensation Seeking Scale

[a]In negative binomial models, the dependent variable is the natural log of the number of diagnosed concussions. The b column is the regression coefficient predicting to this metric, whereas the exp(b) column is often more interpretable.

[b]The exp(b) reflects the multiplicative effect of a 1-unit difference in the level of an independent variable. A person with an impulsivity score of 3 is predicted to have 1.35 times as many concussions as a person with an impulsivity score of 2.

[c]P < .05.

and concussions was moderated by sex or sport type. No such moderator effects were statistically detectable. The same was true for sensation seeking.

DISCUSSION

This study focused on the relationship between diagnosed concussions, impulsivity, and sensation seeking. This is the first study to investigate these psychological variables in a large, diverse (ie, sex, sport) sample of collegiate student-athletes who were actively participating in college sports at the time of assessment. The study sample also came from four different institutions and represented all competitive levels of NCAA athletics. Results indicated a statistically significant association between concussions and concussion risk sport type and higher impulsivity scores, but the clinical meaningfulness of these findings requires further study due small magnitudes of effect. There was also no association between sensation seeking and concussion history. These findings partially supported our hypothesis that impulsivity and sensation seeking scores would increase as the number of previously diagnosed concussions increased.

There was a small, positive association between an increased number of diagnosed concussions and higher impulsivity in our collegiate student-athlete sample. This finding is similar to Kerr et al,[14] who used the same impulsivity measurement tool. The primary difference between studies was that our population comprised current collegiate student-athletes, whereas Kerr et al[14] investigated a sample of former collegiate student-athletes with approximately 30% having been more than 20 years removed from college sport participation. Compared to Kerr et al's[14] 5.5% increase in impulsivity scores in former collegiate student-athletes, we found a 4.3% increase in our sample of current collegiate student-athletes with histories of multiple diagnosed concussions compared to those with no concussion history. The current study overcame limitations identified in previous literature and found similar results, which suggests that there may be a statistically detectable relationship between concussions and impulsivity, regardless of college sport participation timing.

Both the current study and the study by Kerr et al[14] were limited by retrospective study designs, and it is unclear what is considered a minimal clinical important difference for the BIS-15 assessment tool. Due to this, the magnitude of difference and cause-and-effect directionality cannot be determined, and third variable explanations are possible in all observational studies. The observation that impulsivity remained significant when sport type was in the model suggests that this is not a viable third variable (ie, athletes playing certain sports are more impulsive and more likely to be diagnosed as having concussions). It is unclear whether increased impulsivity is a contributing factor to sustaining concussive injuries or whether the culminating effect of previous concussions led to the adoption of increased impulsive behaviors. Both possibilities have support. A previous study found that individuals who are higher risk takers, in general, have an increased probability for sustaining an injury compared to lower risk takers.[28] Due to their increased impulsiveness, collegiate student-athletes who are higher risk takers may not take the time to think critically about their own physical safety before making a daring play, which could result in injury. This theory is consistent with the study by Mc Fie et al[29] that found that South African high school rugby players with a history of concussions had significantly lower harm avoidance behaviors, which could lead to a greater risk for sustaining an injury when paired with a high level of confidence.

Conversely, previous research using helmet accelerometers found that the frontal region of the cranium sustains the most impacts during contact sport participation.[30] This is also the region of the brain that houses decision-making processes.[31] Therefore, the cumulative effects of head impacts to the prefrontal cortex in the frontal region of the brain may cause a decrease in an individual's protective intuitions, thus leading to the potential adoption of more impulsive behaviors than he or she would have made prior to sustaining multiple head impacts or concussions. Previous literature suggests a connection between traumatic brain injury and increased risk-taking behaviors and poor impulse control,[32,33] but it is unknown whether these results are generalizable to less severe forms of brain injury (eg, concussions).

The same conceptual ideas could also be applied to our sensation seeking findings. The association for sensation seeking was not statistically significant in the multivariate analyses, which suggests that impulsivity was more relevant for concussions than sensation seeking. However, we observed a similar positive association for sensation seeking when impulsivity was not included in the count regression model. These sensation seeking results align with a study by Hollis et al[15] that concluded that rugby players who had higher sensation seeking scores also had higher concussion incidence rates compared to rugby players with low to medium sensation seeking scores. Although there were methodological differences between the two studies, it is possible to make a general comparison of conclusions when impulsivity is omitted from the conversation. In both studies, there was a correlation between higher sensation seeking scores and concussions. Therefore, thrill seekers may be at a greater risk for sustaining concussions, or increased sensation seeking needs may be a byproduct of sustaining concussive injuries. Further research is needed to clarify this relationship.

Concussion risk sport type was also found to be a significant predictor of diagnosed concussions with sports with a high risk of concussion averaging 2.0% higher impulsivity scores than sports with a low risk of concussion. It is inherently logical that individuals playing high concussion risk sports would sustain more concussions compared to those playing sports with a low risk of concussion. On further investigation of our sample, 47.5% of participants who reported a history of two or more diagnosed concussions played equipment-intensive sports (ie, football, lacrosse, or ice hockey). The remaining 52.5% were distributed across 12 different sports. With equipment-intensive sports comes an assumed risk of contact and collision; therefore, athletes will have a greater chance of sustaining an injury due to the physical nature of these sports. Additionally, concussive injury risk may be further magnified in equipment-intensive sports due to the concept of risk compensation. It has been speculated that the use of protective equipment, such as helmets and shoulder pads, may lead an athlete to feel a false sense of protection and subsequently adopt a riskier style of play.[34] Again, although results indicated a statistical relationship between concussion risk sport type and impulsivity outcomes, more research is needed to understand the clinical meaningfulness of this finding.

Limitations

This study had limitations that must be considered. First, this was a retrospective investigation of psychological variables and concussion history. Due to this, the collected variables were largely based on self-reported information. Relying on participants' capacity to remember their previous diagnosed concussions is not as accurate as injury verification through medical documentation; however, concussion self-reporting is commonly used in research and has been found to have moderate reliability across a 9-year time span.[5] This study only accounted for self-reports of diagnosed concussions and does not consider concussions that went unreported or undiagnosed. Additionally, a concussion definition was not provided to the respondents, which could lead to self-interpretation variations of this outcome. These factors should be considered in the future. The cross-sectional nature of this study also limited the ability to define causative relationships between the psychological variables and concussion history, because the level of impulsivity and sensation seeking present prior to injury was unknown. Another possible limitation of this study was the risk-taking instrument selection. There is a lack of previous literature on impulsivity in NCAA sports. The available literature focuses on extreme sport (eg, mountaineering, hang gliding), and the instrumentation used in those studies was not adaptable to more traditional sport (eg, football, soccer). Due to this, a general measure of impulsivity was chosen for this study and the interpretation of results should be from a general perspective rather than a sport-specific one. Although this study included participants from all levels of NCAA competition, the sample originated from only four institutions and participants could only indicate one sport of participation. Results may not be generalizable to the entire collegiate student-athlete population or multi-sport athletes.

More research is needed regarding the potential relationship between concussions, impulsivity, and sport type. To help clarify whether there is a causal relationship between concussions and increased levels of impulsivity, a longitudinal study that includes a pretest and posttest design is warranted. Expanding a longitudinal study to include high school and professional athletes would also be useful to increase generalizability to different levels of athletic competition. It could also be productive to look for differences between demographic sport groups to determine whether there are variations in the psychological profile as the time spent in sport and competition level increase. It is also recommended that future studies consider additional covariates (eg, ADHD, player position, injury mechanisms, race, sleep quality, and mental health history) that could be risk factors for concussion occurrence.

IMPLICATIONS FOR CLINICAL PRACTICE

Overall, this study provides support for a potential small association between impulsivity and concussions that persists when taking sport type into account. If future prospective investigations confirm that impulsivity is a risk factor for concussion occurrence, then this individual difference construct could be considered and addressed in multidimensional injury prevention strategies. There might be value in identifying athletes with higher impulsive tendencies and providing them with additional monitoring and education about concussions. The standardized instruments could be incorporated into pre-participation physical examinations to screen all athletes for higher levels of impulsivity. If subsequent research finds that impulsivity is a byproduct of sustaining concussions, a similar approach could be used to track post-injury outcomes. Poor impulse control has been documented as a sign of more substantial cognitive functioning disorders (eg, chronic traumatic encephalopathy)[35]; therefore, it may be beneficial to assess impulsivity at regular time intervals post-concussion to aid in the identification of more concerning issues that may develop. A caveat in both instances is that the observed effect sizes in this study were small, so using a standardized instrument would be one element of any comprehensive prevention or management strategy.

Further identification of impulsive tendencies in collegiate student-athletes could occur through the visual observation of performance behaviors by sports medicine professionals and/or coaches. Conducting a biomechanical analysis of sport maneuvers for high risk-taking collegiate student-athletes may lead to the prescription of style of play modifications. Video review could also be used to identify dangerous sport actions that subsequently lead to head impacts. Then, a collaborative plan between the student-athlete, coaches, and sports medicine professionals could be developed to alter playing mechanics to avoid injury. Thus, the results of this study expand the findings of previous investigations and further highlight the potential relevance of psychological characteristics related to impulsivity and concussions.

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