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Exploring Sex and Contact Sport Differences in Baseline ImPACT Post-concussion Symptom Scale Scores Among Collegiate Athletes Without a History of Concussion

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Abstract

Introduction: The use of baseline or preseason cognitive testing, including symptom endorsement, to quantify post-injury changes, is a practice supported by most major sports associations. In the absence of baseline data, normative data are used for this purpose and research suggests that those data often fail to accurately represent some groups of athletes, particularly non-concussed female athletes in all sports. In clinical practice, inaccurate normative scores can mask or exaggerate post-injury changes which can result in mismanaged athlete care and inaccurate return-to-play decisions. This study examines differences in baseline symptom scores between male and female athletes in different types of sports and makes comparisons to the extant literature on score differences in the normative dataset. Method: This study used retrospective baseline Post-Concussion Symptom Score data from the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). The sample included NCAA collegiate athletes over the age of 18 without a history of concussion (n=119). A novel multi-level modeling approach was used to examine the relationship between an athlete's sex, contact-level of the sport played, and their baseline concussion symptom scores. Covariates identified in previous research were included to assess their effect on the baseline total symptom score. Results: A history of psychiatric treatment was found to have a significant effect on baseline total symptom score. There were no significant differences between sexes in the severity of symptoms reported at baseline. A significant negative correlation was found between sport contact level and affective symptoms. There was no statistically significant difference by sex within each level of sport contact. Conclusions: The current findings diverge from the normative data and suggest instead that an athlete's sex is unrelated to baseline symptom score reporting. Here, only athletes in contact sports were significantly different and reported fewer mood symptoms.

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Contents

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Keywords: baseline concussion symptom scores, athlete sex, gender, sport contact level, ImPACT PCSS, preseason assessment

Most of the guidelines for managing concussive injuries recommend baseline assessment of cognitive function and symptom reporting. For example, in 2016, the NCAA released the *Diagnosis and Management of Sport-Related Concussion Best Practices Interassociation Consensus Document* (NCAA Sport Science Institute, 2016), which recommends that every athlete, no matter how minimal the risk for concussion, should have a baseline, preseason assessment in their freshman year. That document recommends that the baseline assessment for all varsity student-athletes include a brain injury/concussion history, symptom evaluation, cognitive assessment, and balance evaluation. The *AAN Position Statement on Sports Concussion* (Giza et al., 2013), developed by the American Academy of Neurology, also recommends baseline/preseason assessment to improve the interpretation of post-injury scores. And the *Berlin Consensus Statement on Concussion in Sport* (McCroy et al., 2017), a policy developed by the 2017 Concussion in Sport Group (CISG), suggests that while baseline testing is not mandatory, it adds useful information to the interpretation of post-injury tests.

All told, baseline testing documents an individual athlete's “normal” preinjury performance and provides the most reliable benchmark against which to measure post-injury recovery (Guskiewicz et al., 2004; Register-Mihalik et al., 2009). In this way, the baseline record can be compared with post-injury performance and symptoms to make determinations about injury severity and inform return-to-play decisions (Broglio et al., 2014). If baseline scores are not obtained or are unavailable, normative data consisting of age- and gender-matched population data obtained from a larger group are used to make post-injury score comparisons (Echemendia et al., 2012).

Baseline Norms for Sports

Performance norms for the cognitive domains of ImPACT 2.0 testing were initially published in 2003 (Iverson et al., 2003). Norms for each of four cognitive composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time) were based on a total sample of 931 high school and college student athletes, 751 male athletes and 180 female athletes. Since then, research on the norms has been expanded to include more than 50,000 student athletes across dozens of studies (Elbin et al., 2013; Katz et al., 2018; Reynolds et al., 2016; Tsushima et al., 2008).

Research to support norms for baseline symptom reporting is more limited. Those data include scores from participants with and without a concussion history and male athletes are overrepresented in the samples. The Post-Concussion Symptom Scale (PCSS), originally the *Pittsburgh Steelers Postconcussion Scale*, was created for use by football players (Lovell & Collins, 1998; Lovell et al., 2000). The scale was incorporated into the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery in 2000 for use in baseline and post-injury assessments (Lovell et al., 2000; Lovell & Collins, 1998). The ImPACT 2.0 PCSS normative data include a total of 2,304 athletes, with 2,189 “healthy” athletes, and 115 athletes within three days of concussion, 1,826 (79%) male student athletes and only 478 (21%) female student athletes (Iverson et al., 2003). The athletes were described as “healthy” even though their concussion history was not reported. Research suggests that an athlete’s concussion history directly affects baseline symptom reporting (Covassin et al., 2010; Piland et al., 2010; Register-Mihalik et al., 2009).

Gender Differences in Sport Research

Women in Sports

Title IX of the Education Amendments Act of 1972 states, "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance," (Education Amendments Act of 1972, 2018). Title IX requires all educational institutions that receive federal funding to provide male and female athletes with equitable opportunities to participate in sports, athletic scholarship dollars proportional to participation, and equal treatment. That includes equipment and supplies, scheduling of games and practice times, travel and daily allowance/per diem, access to tutoring, coaching, locker rooms, practice and competitive facilities, medical and training facilities and services, housing and dining facilities and services, publicity and promotions, support services, and recruitment of student-athletes (U.S. Department of Education, 2015). Title IX resulted in a significant increase in female athlete participation across levels of play. The NCAA has tracked participation data since the NCAA first offered championships in women's sports in 1981-82. In 1981, there were a total of 231,445 student athletes of which 167,055 were male and only 64,390 were female (Irick, 2019). In 2018-2019, a record-setting 499,217 students competed in NCAA championship sports (Irick, 2019). Of those, men made up 56% of college athletes and women 44% of college athletes. But, women's NCAA teams make up 54% of NCAA teams, compared with 46% for the men's teams (Irick, 2019). In the most recent season with reported data (2018-2019), 10,660 women's teams competed in NCAA championship sports, compared to 9,226 men's teams. Women's teams have outnumbered men's teams since 1996-97. All told, the number of female student-athletes competing in college sports in 2019 has more than doubled since 1981 and continues to rise every year.

Despite the increase in the number of female athletes, women continue to be underrepresented in exercise science research—both as participants in research studies and as the specific subject of scientific inquiry—creating huge gaps in knowledge about female physiology and performance. In fact, researchers weren't required to include sex in their methodology until 2016. The National Institutes of Health (NIH) released a policy in 2016 that required scientists to include sex as a biological variable in the design, recruitment, analysis, and reporting of all pre-clinical cell, animal, and human research. That NIH policy recognized that the failure to account for sex undermines the rigor, transparency, and generalizability of research findings. But that policy has not generated better research about sex-specific differences in sports and sport-related injuries.

Gender Bias in Sport-Related Concussion Research

One of the specific areas of research that continues to be dominated by male subjects is sport-related concussion. In fact, a recent American Academy of Neurology press release reads "Sport-related concussion is a significant public health problem and research has typically focused on male athletes," (American Academy of Neurology, 2017, para. 2). The omission of female research participants is evident everywhere but was very obvious at the 5th International Consensus Conference on Concussion in Sport in 2016. At that most recent meeting, researchers made 24 oral presentations during the meetings and only one focused on female athletes. And, out of 202 research abstracts, nine, or less than five percent of the abstracts, were from research that studied women specifically (Keating, 2017). In the *2017 Consensus Statement on Concussion in Sport* developed by the 2017 Concussion in Sport Group (CISG; McCroy et al., 2017), the term "gender" never appears, and "sex" appears only once. This consensus statement is the concussion policy followed by most physicians and healthcare providers who are involved in athlete care at any level.

Gender Differences in Baseline Symptom Scores

The normative data for the ImPACT Post-Concussion Symptom Scale includes 2,304 high school and college students (1,826 male athletes and 478 female athletes; Iverson et al., 2003). These norms reflect higher baseline symptom scores for females relative to male athletes. For college-aged athletes, the average total symptom score for females is 8.0 and is 4.5 for males. The normative PCSS data also include a symptom severity classification for each sex and the scale of measurement is different for female athletes. For female athletes, the normal range of symptoms is 1-10, the unusual range is 11-21, the high range is 22-31, and the very high range is >32. For male athletes, the normal range of symptoms is 1-5, the unusual range is 6-12, the high range is 13-20, and the very high range is >21. These data suggest that female athletes have more and more severe complaints at baseline than male athletes.

These norms comport with a body of research that suggests that female athletes experience different and more severe symptoms at baseline compared to male athletes. Covassin et al. (2006) studied 651 male and 558 female NCAA Division I collegiate athletes from five universities. Both male and female athletes endorsed a wide range of mild symptoms at baseline, with 68% of male athletes and 76% of female athletes endorsing at least one symptom. Female athletes, though, endorsed significantly more symptoms compared to male athletes. Female athletes also exhibited higher mean symptom scores for headache, nausea, fatigue, sleeping more than usual, drowsiness, sensitivity to light, sensitivity to noise, sadness, nervousness, feeling more emotional, difficulty concentrating, and visual problems.

Covassin et al. (2012), later explored differences in baseline concussion symptom scores between men and women. In that study, a total of 1,616 collegiate and high school athletes completed the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT), the Post-Concussion Symptom Scale (PCSS), and the Beck Depression Inventory. At baseline, female athletes had more cognitive, emotional, and sleep complaints. A retrospective study by Moser et al. (2019), also reported significant differences in baseline symptom reporting by sex. Their study used baseline assessments from 11,695 10–22-year-old athletes (60% male, 40% female). When baseline ImPACT composite scores and PCSS scores were compared, female athletes (ages 13 to 22) reported more physical and sleep symptoms than male athletes.

However, other studies suggest there is no difference between genders on baseline symptom scores. One cross-sectional study of 486 NCAA Division I athletes, including 176 females and 310 males, failed to find a significant difference in symptom scores between sexes at baseline (Cottle et al, 2017). A meta-analysis of 21 observational cohort studies of high school and collegiate athletes (ages 12–26 years) concluded that, although females had significantly higher odds than males of reporting vision/hearing problems, headache/migraine, difficulty concentrating, energy/sleep disturbances, and emotional disturbances (43% more likely than males to report any symptom), the score differences were within the standard error of measurement so were not likely to be clinically significant (Brown et al., 2015).

And the study of baseline score differences is also confounded by the inclusion of athletes with a history of concussion. This is a critical limitation since there is research to suggest that an athlete’s concussion history directly affects baseline symptom reporting (Covassin et al., 2010; Piland et al., 2010; Register-Mihalik et al., 2009). Despite that limitation and the more recent evidence to suggest there are no sex differences in baseline symptom reporting, gender differences are reflected in the instrument norms and are still noted, and sometimes assumed, in the literature and in clinical practice.

Influence of Sport Played

Another poorly understood characteristic of baseline symptom score differences is the influence of the type of sport played. Sports can be categorized by the level of contact typically associated with the sport. The NCAA Sports Medicine Handbook (2015) labels the three sport contact-levels: high contact and collision, contact, and limited contact. A recent study by Tsushima et al. (2019), compared baseline PCSS scores of 6,732 athletes from low, moderate, and high contact sports. They reported that the high contact group was characterized by higher total symptom scores compared to the moderate and low contact groups.

This area of inquiry is in its infancy and there is even less known about sex differences in preseason symptom reporting among contact and non-contact sport athletes. In a 2018 review of 56 articles examining differences symptom reporting in contact sports, conclusions about female athletes could not be drawn because they were underrepresented in all categories of study (Mainwaring et al., 2018). But, a 2020 review reported that female athletes across all contact sport levels reported more and more severe baseline symptoms compared to male athletes (Sas et al., 2020). In that study, male and female athletes in high contact and collision sports reported fewer baseline symptoms than athletes who participated in non-contact sports (Sas et al., 2020).

Current Study

Understanding whether or not there are differences in symptom reporting between sexes or the contact level of sport imperative. Applying baseline reporting norms to post-injury comparisons assumed that female athletes have more complaints which may result in inaccurate injury identification and poor injury management (Cottle et al., 2017). A better understanding of gender and contact sport differences in baseline symptom scores will help inform the utility of normative data or athlete baseline scores in return-to-play decisions.

Previous research on baseline symptom score reporting has been confounded by the possible inclusion of athletes with a previous concussion history and has been heavily skewed toward male athlete participants. The present study examined the relationships between sex and contact level of sport played in baseline symptom scores among collegiate athletes without a history of concussion.

Methods

Design

Due to the possible confounding effects of pre-existing athlete characteristics on baseline symptom scores, covariates suggested by previous research were identified and controlled to isolate the relationship between the constructs of interest in the present study, and to measure the influence of the other covariates in this unique athlete population. Multilevel modeling was used to examine the nesting of athletes within a sport, while accurately accounting for variance. This study design allowed for the examination of the relationships among constructs of interest pertaining to both individuals and groups.

Covariates. Other factors shown to result in increased baseline Post Concussion Symptom Scale (PCSS) scores include treatment for a headache (Cottle et al., 2017), treatment for a migraine (Cottle et al., 2017), treatment for a psychiatric condition (Cottle et al., 2017), and diagnosis of ADHD (Cottle et al., 2017). Age has been shown to have mixed effects. In one study, Moser at al. (2019) reported higher total symptom scores and higher symptom cluster scores in a 13–17-year-old adolescent group compared to an 18–22-year-old group. But, in another study, Covassin et al. (2012) suggested that the age of the athlete (high school or college) affects only the type of symptoms endorsed, not the number of symptoms. The following covariates were considered in this study: sex, age, headache treatment, migraine treatment, treatment for psychiatric condition, and ADHD diagnosis.

Constructs of Interest. The primary factor of interest in this study included concussion symptom scores at baseline; thus, athletes' items scores were sorted into four symptom clusters: cognitive, physical, affective, and sleep (Merritt and Arnett, 2014). This organization of symptom clusters was been validated by Merritt and Arnett (2014). Sex was used in this study as a predictor of variability to evaluate potential sex-based discrepancies in baseline symptom scores (Merritt & Arnett, 2014; Merritt et al., 2015; Ono et al., 2016). The third variable of consideration is sport contact level. Each player was evaluated as a single sport participant using the categories suggested by the 2014-2015 NCAA Sports Medicine Handbook: high contact and collision sports include ice hockey, lacrosse, skiing, and soccer; contact sports include basketball, diving, gymnastics, and limited contact sports include golf, swimming, volleyball, and tennis.

Multilevel Modeling (MLM). Studies in the field of psychology and sport injury have both increasingly used multilevel models (MLMs, also known as hierarchical linear models, linear mixed models, or mixed-effect models) to examine relationships among variables pertaining to both individuals and groups, and to analyze data with repeated measurements (Cohen et al., 2013; Cornelius et al., 2007). Data can be organized in nested levels and can be extended to nonlinear models (Judd et al., 2012; Raudenbush & Bryk, 2002). Conventional psychological experimental data analysis seeks generalizability from methods relying on the assumption of one random factor (typically participants). Yet two or more random factors are typically involved (participants and stimulus, i.e., persons, images, words), potentially leading to serious testing effects bias with the use of conventional analytics (Judd et al., 2017). By specifically modeling interdependence in the data, these mixed effects models avoid difficulties related to within-participant or within-stimulus mean scores analysis (Judd et al., 2012).

Milroy et al. (2020) recently used multilevel modeling to account for the nesting of athletes (level 1) within athletic team (level 2), since athletes on the same team have the same coach(es) and therefore are not independent of each other. A three-level model was initially proposed; however, nonsignificant variance was found at the school level for each of the three outcomes (all accounted for by teams). MLM is advantageous because it explicitly allows for the evaluation of multiple sources of error variation developing from multiple random factors, which permits the inclusion of athletes with incomplete data, considers multiple assessments simultaneously, thereby accounting for multiple components of variance at once within a single model (Judd et al., 2017; Ono et al., 2016; Raudenbush & Bryk, 2002).

Materials/Procedure

Participants

This retrospective cross-sectional study design used archival data from an ongoing concussion biomarker study (IRB Protocol # 854307-18). Participants in that study were recruited from the University of Denver NCAA Division 1 athletic programs in basketball, diving, golf, gymnastics, hockey, lacrosse, skiing, soccer, swimming, tennis, and volleyball. An amendment to this protocol granted access to baseline ImPACT scores recorded before the start of this study. The most recent baseline test was used for this analysis.

Records from 327 athletes were reviewed for inclusion; the study demographics are presented in **Table 1**. The database included athlete responses to a standardized intake and demographic questionnaire, information about pre-existing mental or physical illness, and history of concussion. The baseline Immediate Post-Concussion Assessment and Cognitive Test 2.0 (ImPACT) battery includes the PCSS and was completed as part of the university's standard Sports Medicine pre-participation assessment of all incoming or transfer athletes. The ImPACT battery was administered following usual clinical practice; athletes were instructed to silence their phones, focus solely on the assessment, and follow the written directions in each section. Athletes completed the initial demographics/background/medical history section of ImPACT before the start of the cognitive testing where possible. All assessments were conducted in a private office/computer lab and administered to athletes in small groups of up to three athletes.

Table 1

Study Demographics

Athlete Sex	Women (*n* = 133)	Men (*n* = 194)	Total (*N* = 327)
High Contact and Collision	62	134	196
Ice Hockey	5	38	43
Lacrosse	51	65	116
Skiing	12	7	19
Soccer	24	24	48
Contact	28	27	55
Basketball	14	20	34
Diving	3	3	6
Gymnastics	11	4	15
Limited Contact	43	33	76
Golf	7	3	10
Swimming	10	18	28
Volleyball	16	2	18
Tennis	10	10	20

Note. n = number of individuals in the demographic category

Records from University of Denver NCAA Division I incoming or transfer undergraduate athletes, over 18, with no self-reported history of mTBI were eligible for inclusion in this study. Specifically, only athletes who responded "NO" to History of mTBI on the Demographics Form were included. After applying these inclusion criteria, this study cohort included 119 records from NCAA Division I athletes comprising 57 male athletes and 62 female athletes.

Participant demographics, including age, and self-reported treatment for headaches and migraines, treatment for a psychiatric condition, and AHHD diagnosis are presented in **Table 2.** The average age of male athletes was 19.73 years (*SD* = 1.52; *n* = 52) the average age of female athletes was 19.13 years (*SD* = 1.27; *n* = 67). Eight athletes reported that they had received treatment for headaches or migraines from a physician. Two athletes reported a history of treatment for psychiatric conditions and six reported a diagnosis of attention deficit hyperactivity disorder (ADHD).

Table 2

Participant Demographics

Demographics	Women (*n* = 67)	Men (*n* = 52)	Total (*N* = 119)
	M (SD)	*M (SD)*	*M (SD)*
Age	19.13 (1.27)	19.73(1.52)	19.40 (1.41)
	n (%)	*n* (%)	*n* (%)
Psychiatric Treatment	2 (2.99)	0 (0)	2 (1.68)
Headache or Migraine Treatment	5 (7.46)	3 (5.77)	8 (6.72)
ADHD Diagnosis	2 (2.99)	4 (7.69)	6 (5.04)

Note. n = number of individuals in the demographic category; % = percentage of the subgroup (women, men, or total) in the demographic category; Mental health diagnosis and treatment history = self-reported.

Table 3 presents the breakdown of the sport contact level by athlete sex. The breakdown of sports by contact level and participant sex was as follows: basketball (*male*=4; *female*= 5; *n*= 9), diving (*male*=0; *female*= 2; *n*= 2), golf (*male*=0; *female*= 2; *n*= 2), gymnastics (*male*=4; *female*= 5; *n*= 9), hockey (*male*=4; *female*= 2; *n*= 6), lacrosse (*male*=12; *female*= 17; *n*= 29), skiing (*male*=5; *female*= 1; *n*= 6), soccer (*male*=10; *female*= 12; *n*= 22), swimming (*male*=8; *female*= 15; *n*= 23), tennis (*male*=3; *female*= 3; *n*= 6), and volleyball (*male*=2; *female*= 3; *n*= 5). The breakdown of sport contact level by participant was as follows: contact and collision group (*male*=31; *female*= 32; *n*= 63), contact group (*male*=8; *female*= 12; *n*= 20), and the limited contact group (*male*=13; *female*= 23; *n*=36).

Table 3

Participant Demographics by Contact Level of Sport

Athlete Sex	Women (*n* = 67)	Men (*n* = 52)	Total (*N* = 119)
High Contact and Collision	32	31	63
Ice Hockey	2	4	6
Lacrosse	17	12	29
Skiing	1	5	6
Soccer	12	10	22
Contact	12	8	20
Basketball	5	4	9
Diving	2	0	2
Gymnastics	5	4	9
Limited Contact	23	13	36
Golf	2	0	2
Swimming	15	8	23
Volleyball	3	2	5
Tennis	3	3	6

Note. n = number of individuals in the demographic category.

Measures

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT; Lovell et al., 2000) is an electronically-administered battery of tests that generates composite scores in five domains: Verbal Memory, Visual Memory, Reaction Time, Visuomotor Processing Speed, and Impulse Control. The Post-Concussion Symptom Scale (PCSS; Collins et al., 1999; Lovell & Collins, 1998) is part of the ImPACT computerized battery.

The Post-Concussion Symptom Score (PCSS) is a subjective measure reflecting the presence and type of symptom as well as the athlete's perceived severity of that given symptom. It is administered during baseline (pre-injury) assessments and post-injury assessments. The 22 unique symptoms include headache, nausea, vomiting, balance problems, dizziness, fatigue, trouble falling asleep, sleeping more than usual, sleeping less than usual, drowsiness, sensitivity to light, sensitivity to noise, irritability, sadness, nervousness, feeling more emotional, numbness or tingling, feeling slowed down, feeling mentally "foggy," difficulty concentrating, difficulty remembering, and visual problems. Each symptom is evaluated on a scale from 0 to 6; endorsement of "0" reflects absence of a symptom and endorsement of "6" reflects the presence of a symptom at a severe level. The total symptom score (TSS) can vary from 0 (no symptoms) to 132 (presence of all symptoms rated as most severe).

While the total symptom score is an overall summary of the severity of an athlete's symptoms, it does not provide information about the type, number, or pattern of symptoms. In order to better characterize an athlete's baseline symptoms and further increase the PCSS's utility as a comparative tool, symptom clusters created by Merritt and Arnett (2014) were used. They previously identified four distinct symptom factors: 1) cognitive symptoms (4 items; possible score range = 0–24), 2) physical symptoms (7 items; possible score range = 0–42), 3) affective symptoms (4 items; possible score range = 0–24), and 4) sleep symptoms (4 items; possible score range = 0–24). The score for each symptom subtest is computed by totaling the scores of the individual items that comprise each cluster. Analyzing these four factors allows a better understanding of the relationships between the sex of the athlete, the contact level of their sport, and the types and severity of baseline symptoms reported.

Data Analysis

Descriptive statistics were generated using SPSS Statistics version 25.0. Statistically significant results were declared at the *a priori* significance level $\alpha = .05$.

Descriptive Statistics

Examination of histograms, normality plots, skewness and kurtosis indicated violations of univariate normality for predictor and outcome variables as expected at baseline for athletes with no reported history of concussion. Outliers were defined as three times the interquartile range above the third quartile or three times below the quartile and were removed prior to analysis. Data imputation was used when more than 5% of total data points were missing ($n = 119$). Duplicate athlete records were removed retaining the most current record.

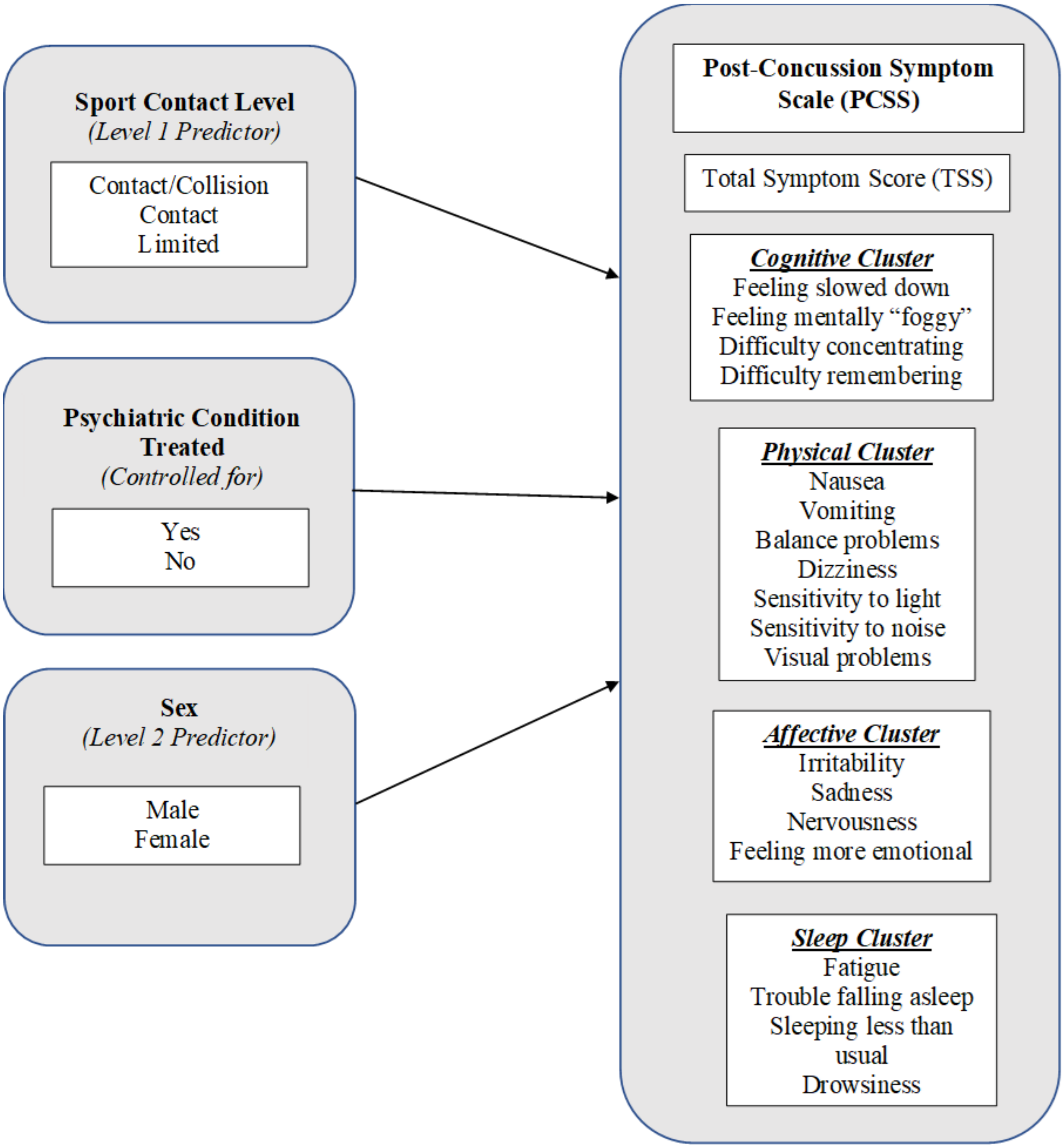
Descriptive statistics were calculated for all variables. Due to normality violations, a series of Kendall's *tau-b* tests were conducted to assess differences in baseline total symptom score, clusters, sex, and sport contact level between participant scores. All covariates were dichotomized except for age. No confounding effects were identified for any covariate following evaluation of covariate influence which was not unexpected in this population. Multiple linear regression models with simultaneous predictor entry for the TSS and each PCSS cluster total score were performed using sex and sport contact levels as predictors. Collinearity diagnostics were run to ensure precise values were obtained, and that reliable baseline symptom assessment was due to the relative performance of each predictor. To evaluate multicollinearity, variable inflation factors (VIF) for each predictor were used. Serious multicollinearity was indicated by VIF close to 10, whereas significant multicollinearity was designated as VIF > 4. Plots of standardized residuals against observed scores were conducted to assess normality for the multilevel regression.

Multi-Level Model

Multi-level modeling (MLM) was used to ensure the examination of multiple sources of error variation that might emerge from our two random factors (athletes and symptom scores), and one fixed factor (sport contact level) to account for nesting of athletes in contact level (Judd et al., 2017; Raudenbush & Bryk, 2002). This allowed for dependency of sex within sport contact level and to examine the extent of between-sport contact level variation in symptom scores (Hox, 2010). Outcome variables were baseline PCSS total symptom scores (TSS) and cluster scores (Cognitive, Physical, Affective, Sleep). **Figure 1** displays a conceptual model for structure clarification.

Figure 1

Conceptual Illustration of Multilevel Model



A series of nonlinear two-level models were run to examine total symptom scores and clusters separately using HLM8 (α = .05). First, a null model was specified using only baseline PCSS cluster and total symptom scores to ensure significant proportion of variance attributed to differences between and within athletes. A second null model was specified using baseline TSS, age, headache diagnosis, migraine diagnosis, psychiatric condition treatment, and ADHD diagnosis to confirm prior covariate results. Notably, results revealed a significant effect for psychiatric treatment, therefore it was included as a level one explanatory variable ($t_{111} = 2.94$, $p < .01$).

At level one, contact level was entered as a grand-mean centered predictor of within-athlete variability in symptoms controlling for psychiatric condition (grand-centered), allowing the examination of the effect of contact level on non-concussed athletes' symptoms at baseline and to adjust for the multicollinearity violation among predictors (Hox, 2010). As dictated by logic and supported by extant literature (Tsushima et al., 2019), contact levels were coded as ordinal level data (Contact/Collision = 3, contact = 2, limited =1), whereas sex and psychiatric treatment were dummy-coded (male = 0, female = 1; yes = 1, no = 0).

At level two, sex was entered as an uncentered predictor of variability in athletes' scores because the primary purpose of this study examined sex-based differences in sport contact levels, and to evaluate whether sex uniquely influenced symptoms at baseline. Extant literature calling for sex-based evidentiary research, prior multilevel model, MANOVA and ANCOVA research supports this method (Merritt et al., 2019; Ono et al., 2016; Sandel et al., 2017). Although existing studies use post-concussion data, this approach is grounded in the literature, can be employed using baseline data, and addresses a gap in the literature.

Results

Table 4 provides descriptive data. Kendall's *tau-b* correlation estimates indicated a statistically significant strong to moderate positive correlation between all baseline clusters and total symptom scores except for the sleep cluster which indicated a weak significant positive correlation. Results for the sex and contact level were nonsignificant meaning these predictors were separate and distinct from all outcome variables. Plots of level one and level two standardized residuals against observed scores indicated close conformity to normality with no extreme outliers.

Table 4

Descriptive Statistics and Correlations for Study Variables using Baseline Scores

Variable	Male			Female			Correlation	
	n	*M*	*SD*	*n*	*M*	*SD*	r^c	*p*
PCSS[a] - TSS	52	0.77	2.16	67	0.57	1.69	1.00	-
PCSS-Cognitive Cluster[b]	52	0.15	0.46	67	0.57	1.77	.52**	.000
PCSS-Physical Cluster[b]	52	0.35	0.88	67	0.87	2.23	.36**	.001
PCSS-Affective Cluster[b]	52	1.29	2.36	67	1.87	3.04	.54**	.002
PCSS-Sleep Cluster[b]	52	2.73	5.16	67	3.96	7.75	.77**	.003
Sex	52	-	-		-	-	- .08*ns*	.361
Sport Contact Level	52	-	-		-	-	- -.11*ns*	.204

Note . All scores calculated using baseline data.

[a]PCSS-TSS = Post-Concussion Symptom Scale-Total Symptom Score. Total Symptom Score (TSS) was calculated by summing the ratings for each individual PCSS item (possible range = 0–132).

[b]PCSS symptom cluster scores were calculated summing the ratings for each individual cluster item

[c]Significant differences in observed scores between tests using Kendall's τ_b.

*p < .05. **p < .01; *ns* = nonsignificant; n = 119.

Table 5 presents correlations between TSS, baseline PCSS cluster scores, sex and sport contact level. Significant associations were indicated for all variables except sex and sport contact level, and the relationship between the physical and affective clusters.

Table 5

Correlations between PCSS Total Symptom Scores (TSS), Cluster Scores, Sex, and Sport Contact Level

Measure	TSS	Cognitive	Physical	Affective	Sleep	Sex	Contact Level
TSS[a]	1.00						
Cognitive Cluster[b]	.52**	1.00					
Physical Cluster [b]	.36**	.35**	1.00				
Affective Cluster[b]	.54**	.35**	.13*ns*	1.00			
Sleep Cluster b	.77**	.55**	.38**	.38**	1.00		
Sex	.08*ns*	.05*ns*	.11*ns*	.09*ns*	.11*ns*	1.00	
Sport Contact Level	-.11*ns*	-.14*ns*	-.03*ns*	-.13*ns*	-.11*ns*	-.06*ns*	1.00

[a]TSS = Total Symptom Score (TSS) was calculated by summing the ratings for each individual PCSS item (possible range = 0–132).

[b]Symptom cluster scores were calculated summing the ratings for each individual cluster item (possible range = 0–42 for Physical cluster; 0-24 for all other clusters) based on the work of Merritt & Arnett, 2014.

$^{**}p < .01$; *ns* = nonsignificant; $n = 119$.

Multilevel Model

Table 6 provides results of the multilevel regression models. Level-one model results indicated significant baseline average symptom scores across all contact levels and athletes. However, sport contact level and affective symptoms were negatively associated, whereas association between contact level and all other symptoms were nonsignificant. This means that as sport contact level increased, ratings of baseline affective symptoms decreased. Specifically, for every unit increase in contact level, there was a .14 unit decrease in reported affective symptoms. No significant differences between sexes were found across all symptoms (γ01).

The level-two model was used to evaluate whether sex uniquely influenced symptoms at baseline. Results revealed no significant differences in scores reported at baseline for any symptoms.

Table 6

Multilevel Model Regression Results for all Factors and the Five Post-Concussion Symptom Scale Outcomes

Characteristic	Cognitive	Physical	Affective	Sleep	Total Symptoms Score
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Intercept (Baseline)	0.82 (.30)**	0.20 (.08)*	0.47 (.14)**	1.32 (.33)***	3.05 (.74)***
Sport Contact Level	-0.28 (.24)	0.07 (.13)	-0.14 (.17)*	-0.12 (.30)	-0.80 (.72)
Psychiatric Condition	1.54 (1.34)	2.47 (2.16)	6.46 (4.81)	0.11 (1.44)	14.11 (12.13)
Sex	-0.26 (.37)	0.35 (.23)	0.28 (.22)	0.60 (.52)	0.78 (1.14)
Deviance	477.4	398.3	429.3	562.5	753.5

Note. n = 116 due to missing data for psychiatric condition.

SE = standard error

*p < .05. **p < .01. ***p < .001.

Discussion

The purpose of the current study was to examine the relationships between sex and contact level of sport on baseline concussion symptom reporting among collegiate athletes without a history of concussion. The study used retrospective ImPACT data, specifically, PCSS scores and athlete demographics, that were collected as part of a larger study examining concussion blood biomarkers in undergraduate NCAA athletes.

The first step in this study was to identify and then control the effect of important covariates. Those covariates included age, history of treatment for headache, history of treatment for migraine headache, history of psychiatric treatment, and history of ADHD diagnosis). Previous studies suggest that all of those variables are significantly related to increased symptom scores at baseline (Cottle et al., 2017; Covassin et al., 2012; Moser et al., 2019). These results suggested that only a history of psychiatric treatment is significantly related to total symptom scores at baseline. This means that athletes who endorsed a history of psychiatric treatment reported more symptoms at baseline regardless of their sex or the contact level of their sport.

This study also made a point to include baseline data from the total symptom scores and symptom score clusters (physical, cognitive, affective/mood, and sleep) of the PCSS in the comparison of sport groups by contact level which allowed for a more detailed comparison of baseline symptom types and severity. With the history of psychiatric treatment controlled, analyses found that the affective symptom cluster differed by sport contact level. The results suggest that sport contact level and mood symptoms were negatively correlated. Here, players in high contact and collision sports (ice hockey, lacrosse, skiing, and soccer) reported the lowest baseline mood symptoms (irritability, sadness, nervousness, feeling more emotional) and players in limited contact sports (golf, swimming, volleyball, and tennis) reported the highest emotional symptom scores at baseline. There were no significant differences in scores between male and female athletes within the affective (mood) cluster, which is consistent with the recent report from Sas et al. (2020).

With the history of psychiatric treatment controlled, analyses also confirmed that baseline symptom scores did not differ by athlete sex. These results suggest there were no significant differences in the types of symptoms (clusters) or the symptom severity. This is inconsistent with previous research that suggests that female athletes have higher specific symptom and symptom cluster scores at baseline (Covassin et al., 2006; Covassin et al., 2012; Moser et al., 2019) and challenges the popular assumption that female athletes are more severely symptomatic at baseline compared to their male counterparts. This finding also challenges the Post-Concussion Symptom Scale normative data that reflect a higher total symptom score mean for college-aged female athletes (8.0) relative to male athletes (4.5; Iverson et al., 2003; Lovell et al., 2006).

Of course, the incidence of concussion is higher for female athletes than male athletes (Covassin et al., 2016) and female athletes report different symptoms after injury (Frommer et al., 2011) and have a longer recovery period from concussion (Covassin et al., 2016; Mondello et al., 2020; Zuckerman et al., 2015). This study was, however, limited to non-concussed athletes so concussion history may have affected female athletes disproportionately in that previous research. This finding of no sex differences in symptom severity at baseline reinforces the directive to use individual baseline scores for post-injury comparisons and it also challenges the accuracy of normative symptom data for female athletes.

Overall, the results of this study suggest that a history of psychiatric treatment is significantly related to increased symptom reporting at baseline and should be controlled for in future research. These results also suggest that an athlete’s sport contact level and their sex are mostly unrelated to baseline symptom scores with the exception of mood symptoms, which are inversely related to sport contact level. That is to say, athletes in the sport group with the most contact and collision potential reported the lowest baseline mood symptoms.

The inverse relationship between sport contact level and affective complaints raises questions that warrant further study. It may be that athletes who choose to participate in higher contact sports have a pre-existing difference in affective symptoms (less irritability, sadness, or nervousness) or that the sport confers a protective mental health benefit. For example, there is research to suggest that athletes in team sports experience fewer negative emotional symptoms than athletes who play individual sports (Hanrahan & Cerin, 2009; Leadbeater & Boone, 2006; Nixdorf et al., 2016). There is also a potential for bias in underreporting in contact sports for reasons related to stigma, sport-culture, or external factors like scholarships and the opportunity for professional play in the future.

Limitations

The decision to study baseline data only from athletes with no history of concussion limited the overall sample size. In this database, only 31% of athletes reported no history of concussion. The sample may not have generated sufficient statistical power to detect small differences in symptom scores. This study also included more athletes in contact sports than in non-contact sports. Future research should examine differences in baseline symptom reporting between larger samples of male and female athletes across different contact/non-contact sports.

Another limitation is embedded in the pre-season assessment of athletes. This study was designed to detect differences in baseline symptom reporting which are self-report measures with some inherent variability. For example, some studies have suggested that athletes may purposefully over-report symptoms (e.g., sandbagging; Covassin et al., 2012; Schatz & Glatts, 2013).

Finally, another limitation in the research of sex differences in symptom reporting is monthly hormonal variability or menstrual cycle phase. In one study (Mihalik et al., 2009), eumenorrheic females endorsed more and more severe symptoms compared to females using oral contraceptive pills. No hormonal data or reports were included in this study.

Conclusion

Overall, these results add to a small body of baseline concussion symptom research examining gender and contact-level sport differences among college athletes with no concussion history. In this study, only one baseline symptom cluster differed by the contact level of the sport. Athletes in high contact sports reported fewer affective/mood symptoms at baseline. A history of psychiatric treatment significantly affected baseline symptom scores, regardless of sex or sport contact level. With psychiatric treatment controlled, there was no difference in baseline symptom reporting between male and female athletes.

This study adds to the growing body of research that highlights the importance of individual baseline testing for use in comparisons after injury. There are practical considerations about when to use baseline symptom norms to make post-injury recommendations but this research suggests that using female norms for post-injury comparisons may lead to spurious conclusions. This research also suggests that an athlete’s baseline symptom reporting may be exaggerated by their history of psychiatric treatment and the contact level of the sport.

The judicious use and interpretation of post-injury scores is predicated on comparisons to baseline or normative scores. Confirming or disproving normative score differences and contributing to the discrepant literature on baseline symptom reporting is essential for the best in athlete care.

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