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Resilience and recovery from sports related concussion in adolescents and young adults

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ABSTRACT

Introduction: Recovery and return to play are important milestones for athletes who sustain sport-related concussions (SRC). Several factors have been shown to influence resolution of post-concussion related symptoms (PCS), but resilience, a trait that reflects the ability to overcome adversity, is another factor that may influence recovery. The aim of this study was to determine the relationship of resilience with resolution of symptoms during recovery in adolescents and young adults following SRC.

Method: This prospective study is part of the North Texas Concussion Registry (ConTex). Subjects (N = 332) aged 13 to 25 years who sustained a SRC within 10 days of presenting to clinic were evaluated at two time points: initial clinical visit and three-month follow-up. Resilience was measured by the self-report Brief Resilience Survey (BRS) and PCS by the Sport Concussion Assessment Tool-5 Symptom Evaluation Post-Concussion Symptom Scale (PCSS). Recovery was determined by self-reported return to sports/physical activity and percent back to normal.

Results: Repeated measures ANCOVA and linear regression models showed that lower resilience ratings at initial visit were associated with a greater number and severity of PCSS symptoms along with higher levels of anxiety and depression symptoms during recovery from SRC. At three months, subjects with lower initial resilience ratings were less likely to report feeling back to normal and had greater aggravation of symptoms from physical and cognitive activity even when they had returned to sports/physical activity.

Conclusions: Lower resilience was associated with greater symptoms and delayed recovery from SRC. Results suggest that resilience may be another important factor to address in recovery from SRC. Future research is needed to examine the extent to which resilience measured after SRC reflects pre-injury characteristics and to better inform the development of interventions to promote resilience during recovery.

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Concussion; resilience; symptoms; recovery; SCAT-5

Introduction

Participation in sports and exercise in the United States has steadily increased since 2003, with 25.9% of those aged 15–24 engaged in some form of sport or exercise (Woods, 2017). With this rise in participation comes concern regarding sport-related concussion (SRC) in athletes and physically active individuals. An estimated 2.5 million high school students in the U.S. reported sustaining a concussion in 2017, with prevalence in athletes being significantly greater than that of non-athletes (DePadilla et al., 2018). In a slightly older population of 954 undergraduate university students, SRC accounted for 35.6% of all concussions (Breck et al., 2019). Recovery and clearance for return to play are paramount for athletes who have sustained SRC, with resolution of post-concussion-related symptoms being a key factor (McCrory et al., 2017). Premorbid psychological factors such as anxiety, depression, and resilience may affect symptom severity and influence recovery (Durish et al., 2019; Iverson et al., 2017; Lange et al., 2011), although not much research has specifically addressed resilience in this context.

Resilience has been defined as a personality trait demonstrating "the ability to bounce back or cope successfully despite substantial adversity" (Rutter, 1985). The definition of resilience has evolved over time and has been conceptualized to include a framework of individual, family, and social protective factors and

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possibly an interaction between risk factors and protective resources (Haase, 2004; Neils-Strunjas et al., 2017). It may function as a developmental process (Gillespie et al., 2007) or a positive adaptation following a significant threat or adversity (Luthar et al., 2000). For the current study, resilience was defined as the ability to "bounce back" or recover from a stress-inducing event such as an injury (Smith et al., 2008). Resilience as such has been measured by several self-rated scales including The Resilience Scale (Wagnild & Young, 1993), the Connor–Davidson Resilience Scale (Connor & Davidson, 2003), and the Brief Resilience Scale (BRS; Smith et al., 2008). Resilience has been found to affect rehabilitation and adaptation to a wide range of acquired brain injuries (Neils-Strunjas et al., 2017), including mild traumatic brain injury (mTBI) or concussion (Durish et al., 2019; Kreutzer et al., 2016; Losoi et al., 2015; McCauley et al., 2013; Rainey et al., 2014).

Low resilience, as specifically assessed by the BRS, has been shown to have a negative association with recovery following various physical injuries and after surgery. Patients with orthopedic injuries and low resilience were found to experience decreased functionality during recovery following surgery compared to patients with higher BRS scores (Tokish et al., 2017). In studies of patients with concussion from various causes, high resilience (BRS) predicted lower scores on the Neurobehavioural Symptom Inventory, a widely used multidimensional symptom measure (Cicerone & Kalmar, 1995; Sullivan et al., 2015). Whether the relationship between resilience and post-concussion recovery applies specifically to SRC has yet to be determined. The objective of this investigation was to determine if low resilience would be associated with higher self-reported post-concussion symptoms, anxiety, depression, and prolonged recovery from SRC in an adolescent and young adult population.

Methods

Study population and participants

This prospective study included 332 participants aged 13–25 years diagnosed with a recent SRC, enrolled within ten days of injury, at one of five North Texas Concussion Registry (ConTex) clinic sites between January 2015 and April 2020 who completed both initial and three-month follow-up assessments. A standardized, multimodal approach was used at all sites to confirm diagnosis (Cullum et al., 2020; Henry et al., 2016; McCrory et al., 2017). The University of Texas Southwestern Medical Center Institutional Review Board provided approval for participating sites and written informed consent was obtained from all subjects. For patients less than 18 years of age, participant assent was obtained with informed consent of the parent/legal guardian for enrollment in the study.

Procedures and measures

Following a diagnosis of concussion at initial clinic visit, eligible participants completed demographic, medical history, and injury related information. The Generalized Anxiety Disorder-7 (GAD-7; Spitzer et al., 2006), Patient Health Questionnaire-8 (PHQ-8; Kroenke et al., 2009), the Sport Concussion Assessment Tool-5 Symptom Evaluation Post-Concussion Symptom Scale (SCAT-5 PCSS; Echemendia et al., 2017), and the BRS (Smith et al., 2008) were completed by participants. They also rated the percent to which they felt "back to normal" at the time of initial evaluation. Three-month follow-up surveys were completed via e-mail, which included these same measures. Data entry from each study site was managed using REDCap (Harris et al., 2019, 2009).

Outcome measures

The primary outcome measures included self-reported severity of symptoms as measured by the SCAT-5 PCSS. Severity for each of the PCSS items was measured on a 7-point scale that ranged 0 (none) – 6 (severe). The total number of endorsed symptoms ranged 0–22 and the total symptom severity ranged 0–122. Exacerbation of PCSS symptoms by physical or cognitive activity was determined by a yes or no answer. Levels of self-reported anxiety and depression post injury were measured by the GAD-7 (0–28) and PHQ-8 (0–32), respectively. Recovery at three months was assessed by subjects' indication that he/she had returned to play or normal physical activities and their report of percent back to normal functioning.

Independent variable

The BRS is a six-item instrument developed to quantify the degree of resilience perceived by an individual and has been shown to be valid and reliable in a variety of populations (Rodríguez-Rey et al., 2016; Smith et al., 2008; Windle et al., 2011). Each item on the BRS is scored on a 1 (low) – 5 (high) Likert scale and the Total BRS score is the average of the six items. To provide clinical utility and align with other research which provided low and high resilience groupings (Tokish et al., 2017), total BRS scores were classified

into three resilience groups: Low (1.00–2.99), Average (3.00 to 4.30), and High (4.31–5.00) based on published guidelines (Smith et al., 2013).

Statistical analyses

Sample means and standard deviations were used to describe continuous variables and frequencies (percentage) were used to characterize categorical variables. Prior to analysis of PCSS, GAD-7, and PHQ-8 outcome measures, statistical assumptions were examined, and log base 10 transformations were performed to address issues of unequal group variances and non-normal distributions on all measures. Analyses were conducted on the transformed variables and then presented in tables and figures by back transforming the measures. For age and time to clinic, t-tests were performed to determine differences between sexes. ANOVA was conducted to determine differences between resilience groups. When the effects for ANOVA were significant, Bonferroni post hoc pairwise group comparisons were performed. Pearson's Chi-Square analyses or Fisher's exact tests, as appropriate, were used to examine differences in participant categorical demographics, medical history, and injury characteristics by sex and resilience groups. Tukey-type post hoc proportions tests for group differences were conducted when Chi-Square was significant (Zar, 1996).

Separate linear mixed models analysis of covariance (ANCOVA) examined resilience groups at two time points (initial evaluation and three-month follow-up) in terms of the total number of endorsed PCSS symptoms, PCSS total symptom severity, GAD-7, PHQ-8, and participants' perception of their recovery (percent back to normal). Because the literature supports outcome differences by sex and history of depression in symptom reporting, both were included as covariates in the model if $p < .15$. When an effect was significant for any of the linear mixed models, Bonferroni post-hoc pairwise comparisons were performed. Stepwise multiple regression analyses were performed last in order to determine the relationship of resilience with other factors which may predict symptom recovery. Separate analyses were conducted to examine prediction of the total number of endorsed PCSS symptoms and PCSS Total Symptom Severity at three-month follow-up using the following measures from initial evaluation: number of PCSS symptoms or total severity of PCSS symptoms, Total BRS score, GAD-7 (anxiety at time of initial evaluation), PHQ-8 (depressive symptoms at time of initial evaluation), sex, history of depression, history of anxiety, and reported amnesia at time of injury. These predictors were chosen *a priori* based on previously published findings (Iverson et al., 2017; Meehan et al., 2016) or presence of significant differences in these measures between resilience groups at initial visit. Pairwise Pearson and point-biserial correlations were performed to examine multicollinearity across measures. All statistical analyses were carried out using SAS Software, version 9.4 (SAS Institute, Cary, N.J.) and SPSS V26. The level of significance was set at $\alpha = .05$ (two-tailed) unless otherwise specified.

Results

Participant demographic and clinical characteristics are summarized in Table 1. There were 332 participants (Male n = 179, 53.9%, Female n = 153, 46.1%), with a mean age at time of injury of 15.1 years (Median = 15). Football (28.3%, n = 94), soccer (24.1%, n = 80), basketball (12.7%, n = 42), volleyball (7.8%, n = 26), wrestling (3.9%, n = 13), and cheerleading (3.3%, n = 11) accounted for 80% of all injuries. Scores on the BRS were used to divide participants into three resilience groups: low (n = 41), average (n = 199), and high (n = 92), with no significant difference in percentage of males and females between groups. Participants identified predominantly as White (78.0%, n = 259) and ethnically as non-Hispanic/Latino (82.5%, n = 274). There were no significant sex differences in terms of demographic, medical history, or injury-related factors. The low resilience group reported a more frequent history of depression (12.2%) than the average (3.0%) and high (2.2%) resilience groups ($p = .013$). At initial visit, all resilience groups differed significantly ($p < .001$) in GAD-7 scores. In post-hoc Bonferroni comparisons the low resilience group (6.63 SD = 4.58) was higher than both the average resilience (3.65 SD = 2.76, $p < .001$) and high resilience (1.82 SD = 3.82, $p < .001$) groups, which were also significantly different from each other ($p = .044$). The resilience groups were also significantly different on the PHQ-8 at initial visit, with the low resilience group scoring higher (6.93 SD = 4.45) than either the average (3.96 SD = 4.03) or high resilience groups (2.93 SD = 3.34), which did not significantly differ from each other ($p = .114$).

A summary of the results of the linear mixed models for PCSS symptoms, GAD-7, PHQ-8, and percent back to normal are found in Table 2 and Figure 1. The multiple regression analyses predicting number of endorsed symptoms and symptom severity at three months are found in Table 3.

Covariates

Sex was a significant covariate for the number of PCSS symptoms ($p = .092$) and PCSS total symptom severity ($p = .027$). History of depression was a significant covariate for GAD-7 ($p < .001$) and PHQ-8 ($p = .035$).

Table 1. Participant characteristics at initial visit post injury

Characteristic	Female	Male	*p*	Low Resilience *n* = 41	Average Resilience *n* = 199	High Resilience *n* = 92	*p*
Female % (n)	46.1% (153)	0		53.7% (22)	48.2% (96)	38.0% (35)	.156
Male % (n)	0	53.9% (179)		46.3% (19)	51.8% (103)	62.0% (57)	
Age: Years (SD)	14.9 (1.4)	15.2 (1.9)	.055[a]	15.0 (2.0)	15.1 (1.7)	15.04 (1.6)	.869[b]
Days to Evaluation: Days (SD)	4.6 (2.64)	4.6 (2.53)	.826[a]	4.8 (2.5)	4.6 (2.6)	4.5 (2.5)	.851[b]
Non-Hispanic/Non-Latino % (n)	81.7% (125)	83.2% (149)	.306	82.9% (34)	82.4% (164)	82.6% (76)	.851
White % (n)	81.0% (124)	75.4% (135)	.060	80.5% (33)	75.4% (150)	82.6% (76)	.892
History of Headaches % (n)	15.7% (24)	13.4% (24)	.639 [c]	22.0% (9)	14.1% (28)	12.0% (11)	.309
Previous Concussion % (n)	34.9% (53)	27.5% (49)	.154 [c]	32.5% (13)	32.8% (65)	26.1% (24)	.499
History of Anxiety % (n)	9.8% (15)	6.1% (11)	.227 [c]	12.2% (5)	8.0% (16)	5.4% (5)	.401
History of Depression % (n)	4.6% (7)	3.4% (6)	.584 [c]	12.2% (5)	3.0% (6)	2.2% (2)	.013
Dyslexia % (n)	5.2% (8)	7.3% (13)	.504 [c]	12.2% (5)	5.5% (11)	5.4% (5)	.257
ADHD % (n)[d]	11.1% (17)	17.3%(31)	.119 [c]	12.2% (5)	15.1% (30)	14.1% (13)	.887
Loss of Consciousness % (n)	11.1% (17)	14.5% (26)	.356 [c]	7.3% (3)	14.6% (29)	12.0% (11)	.428
Amnesia % (n)	20.9% (32)	27.9% (50)	.139 [c]	22.0% (9)	25.6% (51)	23.9% (22)	.865
Vomiting % (n)	5.2% (8)	10.6% (19)	.074 [c]	12.2% (5)	7.5% (15)	7.6% (7)	.596
Emergency Department Evaluation % (n)	26.1% (40)	29.6% (53)	.483 [c]	26.8% (11)	28.1% (56)	28.3% (26)	.984
GAD-7 M (SD)	3.54 (4.04)	2.67 (3.59)	0.414	6.63 (4.58)[e]	3.65 (2.76)[e]	1.82 (3.82)[e]	< 0.001
PHQ-8 M (SD)	4.63 (4.46)	3.54 (3.63)	0.015	6.93 (4.45)[f]	3.96 (4.03)	2.93 (3.34)	< 0.001

Notes: GAD-7 = Generalized Anxiety Disorder-7; PHQ-8 = Patient Health Questionnaire-8. [a] t-test; [b] ANOVA; [c] Fisher's Exact *p*, all other *p* values from Chi-Square Analysis; [d] Attention Deficit Hyperactivity Disorder; [e]All groups significantly different $p < 0.05$; [f] Low Resilience Group significantly higher than Average/High Resilience Groups $p < 0.001$.

PCSS symptoms by resilience group

For the number of PCSS symptoms endorsed, there was a significant interaction for BRS group by visit ($p = .048$). At the initial clinic visit, all three groups were similar in number of PCSS symptoms endorsed ($p > .118$), but at three-month follow-up, the Low Resilience Group endorsed significantly more PCSS symptoms than either the Average ($p = .006$) or High Resilience ($p < .001$) Groups, but the Average and High Groups were not significantly different ($p = .749$).

The main effects for Resilience Group and Visit were both significant for number of PCSS symptoms endorsed ($p < .001$ and $p < .001$, respectively) and PCSS Total Symptom Severity ($p < .001$ and $p < .001$, respectively). As expected with recovery, the number of PCSS Symptoms endorsed and PCSS Total Symptom Severity at the initial visit for each group was significantly higher than at the three-month visit (both $p < .001$). Pairwise analysis showed that the groups at initial visit were not significantly different in terms of the number of PCSS symptoms endorsed (all $p > .118$) or PCSS Total Symptom Severity (all $p > 0.064$). However, at the three-month follow-up, the Low Resilience Group endorsed more PCSS symptoms than either the Average ($p = .006$) or High Resilience ($p < .001$) Groups. Average and High Resilience Groups did not differ at three months ($p = .749$). At three months the Low Resilience Group also had a significantly higher PCSS Total Symptom Severity than both the Average ($p < .004$) and High Resilience Groups ($p = .002$), and the Average and High Groups were again not significantly different ($p > .90$).

Stepwise multiple regression

In the examination of the multicollinearity of the measures, significant Pearson correlations were found between BRS score and initial visit total number of endorsed PCSS symptoms ($r = -0.174$, $p = .001$), PCSS Total Symptom Severity ($r = -0.205$, $p < .001$), GAD-7 score ($r = -0.406$, $p < .001$) and PHQ-8 score ($r = -0.323$, $p < .001$). The point biserial correlation between BRS score and self-reported history of depression was significant ($r = -0.143$, $p < .05$). None of the other factors in the regression models were significantly correlated with BRS or the PCSS measures. Of the measures from the initial visit included in the stepwise regression model predicting number of PCSS symptoms endorsed at follow-up ($R^2 = 0.103$, $p < .001$), two of the nine measures were significant in the model: the initial BRS score ($b = -0.119$, $p < .001$) and GAD-7 score

Table 2. Covariate adjusted means and 95% confidence intervals (CI) for PCSS symptoms, anxiety, depression, and percent back to normal ratings for resilience groups[a]

	Initial Visit Post Injury	Three-Month Follow-up	Interaction	Main Effects		Covariates	
Measure/Level of Resilience	M (95% CI)	M (95% CI)	Resilience Group x Time	Resilience	Visit	Sex	History of Depression
PCSS Number of Symptoms Endorsed							
Low Resilience	12.94 (8.96–18.67)[b]	1.45 (0.80–2.59)[b,e,f]	$F_{2,329} = 3.06$	$F_{2,328} = 12.77$	$F_{1,329} = 379.56$	$F_{1,328} = 2.85$	NS [g]
Average Resilience	8.21 (6.94–9.70)[c]	0.42 (0.30–0.57)[c,e]	$P = .048$	$P < .001$	$P < .001$	$P = .092$	
High Resilience	7.08 (5.53–9.08)[d]	0.23 (0.13–0.38)[d,f]					
PCSS Symptom Severity							
Low Resilience[h,i]	31.02 (19.59–49.09)	1.92 (1.00–3.61)	$F_{2,329} = 1.93$	$F_{2,328} = 12.66$	$F_{1,329} = 430.24$	$F_{1,328} = 4.94$	NS [g]
Average Resilience[h]	16.14 (13.09–19.89)	0.49 (0.34–0.67)	$P = .146$	$P < .001$	$P < .001$	$P = .027$	
High Resilience[i]	13.80 (10.13–18.80)	0.28 (0.16–0.48)					
GAD-7							
Low Resilience[h,i]	7.92 (4.37–14.29)	1.51 (0.79–2.80)	$F_{2,302} = 1.20$	$F_{2,328} = 25.96$	$F_{1,302} = 85.72$	NS [g]	$F_{1,328} = 11.99$
Average Resilience[h,j]	1.72 (1.09–2.68)	0.48 (0.27–0.79)	$P = .303$	$P < .001$	$P < .001$		$P < .001$
High Resilience[i,j]	0.87(0.49–1.49)	0.24 (0.11–0.47)					
PHQ-8							
Low Resilience[i,k]	6.38 (3.53–11.47)	0.96 (0.49–1.82)	$F_{2,301} = 0.35$	$F_{2,328} = 13.19$	$F_{1,301} = 132.64$	NS [g]	$F_{1,328} = 4.48$
Average Resilience[k,l]	2.42(1.56–3.72)	0.43 (0.25–0.71)	$P = .704$	$P < .001$	$P < .001$		$P = .035$
High Resilience[i,l]	1.45 (0.85–2.43)	0.25 (0.11–0.45)					
Percent Back to Normal							
Low Resilience[h,i]	52.5% (45.0%-60.0%)	85.5% (81.0%-90.0%)	$F_{2,298} = 0.77$	$F_{2,329} = 13.21$	$F_{1,298} = 255.41$	NS [g]	NS [g]
Average Resilience[h]	64.4% (60.97%-67.9%)	95.0% (93.0%-97.0%)	$P = .465$	$P < .001$	$P < .001$		
High Resilience[i]	69.2% (64.1%-74.2%)	96.2% (93.3%-99.1%)					

*Notes:*PCSS = Sport Concussion Assessment Tool- Symptom Evaluation Post-Concussion Symptom Scale, GAD-7 = Generalized Anxiety Disorder-7, PHQ-8 = Patient Health Questionnaire-8. [a] Post hoc pairwise adjusted *P*-values and 95% confidence intervals; [b] $p < .001$, Significant interaction effects; [c] $p < .001$, Significant interaction effects; [d] $p < .001$, Significant interaction effects; [e] $p = .006$, Significant interaction effects; [f] $p < .001$, Significant interaction effects; [g] NS = Not Significant ($p > 0.15$), not included in final model; [h] $p < .001$, Significant main effects for Resilience groups; [i] $p < .001$, Significant main effects for Resilience groups; [j] $p = .002$, Significant main effects for Resilience groups; [k] $p = .001$, Significant main effects for Resilience groups; [l] $p = .021$, Significant main effects for Resilience groups.

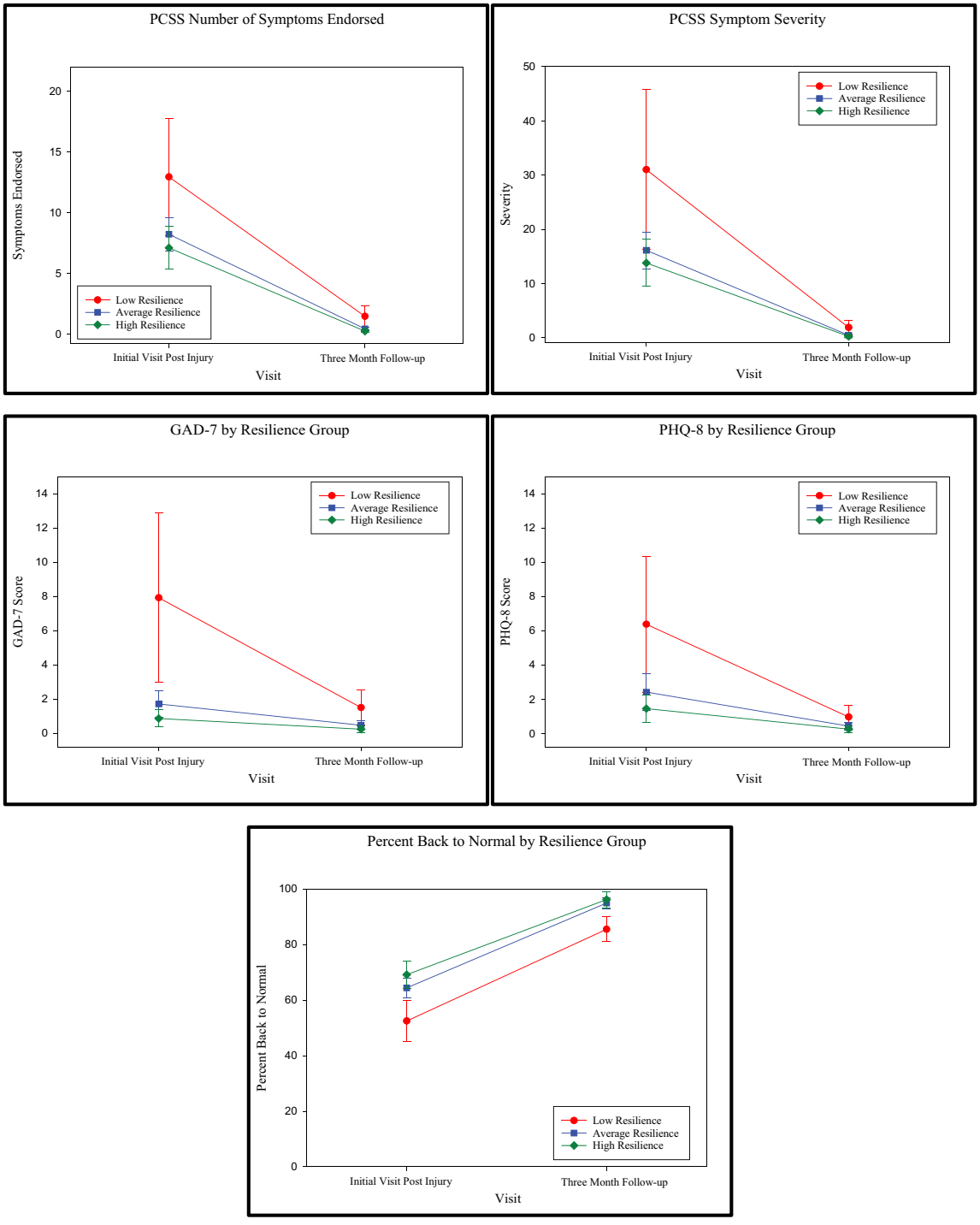

Figure 1. Comparison of resilience groups for PCSS number of symptoms endorsed, symptom severity, GAD-7, PHQ-8, and percent back to normal during recovery. Figure represents separate linear mixed models analysis of covariance (ANCOVA) at two time points with back transformed means and 95% confidence intervals into the collected data scale. The 95% confidence intervals are adjusted using Bonferroni.

(b = 0.015, p = .010). Two measures from initial visit were also significant when included in the stepwise regression model predicting PCSS Total Symptom Severity at three months (R^2 = 0.101, p < .001). These were the initial visit BRS score (b = −0.157, p < .001) and initial visit PCSS symptom total (b = 0.149, p = .003).

Table 3. Multiple regression analyses predicting number of endorsed symptoms and symptom severity at three months, separately from demographic and clinical characteristics with BRS, GAD-7 and PHQ-8, and PCSS Symptoms at initial visit

			Multiple Regression			
			PCSS Number of Endorsed Symptoms		PCSS Symptom Severity	
	Correlations with BRS[a]		$R^2 = 0.103$[c]		$R^2 = 0.101$[c]	
Measures at Initial Visit	r/r_{pb}	*p*	β	*p*	β	*p*
BRS			−0.119	<0.001	−0.157	<0.001
Sex	−0.111[b]	>.05	−0.068	0.197	−0.074	0.165
Age	0.022	0.345	0.041	0.434	0.055	0.290
History of Anxiety	−0.095 [b]	>.05	0.033	0.541	0.061	0.249
History of Depression	−0.143 [b]	< .05	0.014	0.788	0.016	0.758
Amnesia	0.020 [b]	>.05	−0.026	0.614	−0.055	0.292
GAD-7	−0.406	<.001	0.015	0.010	0.111	0.071
PHQ-8	−0.323	<.001	0.036	0.577	0.052	0.396
PCSS Number of Symptoms Endorsed	−0.174	0.001	0.077	0.171		
PCSS Symptom Severity	−0.205	>.001			0.149	0.003

Notes: BRS = Brief Resilience Survey, GAD-7 = Generalized Anxiety Disorder-7, PHQ-8 = Patient Health Questionnaire-8, PCSS = Sport Concussion Assessment Tool- Symptom Evaluation Post-Concussion Symptom Scale. [a] Pearson product-moment correlations reported unless otherwise noted. [b] Point biserial correlation. [c] $p = 0.001$.

Table 4. Return to physical activity, exacerbation of symptoms, and residual symptoms at three-month follow-up

	Low Resilience	Average Resilience	High Resilience	*p*
Returned to Physical Activity at Follow Up % (n)	85.4% (35)	88.9% (177)	91.3% (84)	.589
Physical Activity Increased Symptoms % (n)	22.0% (9)[a]	5.0% (10)	4.3% (4)	< .001
Cognitive Activity Increased Symptoms % (n)	24.4% (10)[a]	7.0% (14)	3.3% (3)	< .001
Symptomatic at Three Months % (n)	36.6% (15)[a]	17.6% (35)	12.0% (11)	.003

Notes: [a] Low Resilience significantly higher than Average or High Resilience groups ($p < .05$).

Impact of physical and cognitive activity on concussion symptoms

The summary of return to physical activity, exacerbation of symptoms, and residual symptoms at three-month follow-up are found in Table 4. There was no difference between Resilience Groups in their return to sports/physical activity at three months ($p = .589$). However, there was a higher percentage of subjects in the Low Resilience Group who reported exacerbation of symptoms with physical activity (22.0%) vs. Average Resilience (5.0%) or High Resilience (4.3%) Groups ($p = .002$). The Low Resilience Group also reported more frequent symptom exacerbation with cognitive activity (24.4%) vs. the Average (7.0%) and High Resilience (3.3%) Groups ($p < .001$). Furthermore, the percentage of participants still reporting as symptomatic at three months in the Low Resilience Group was significantly higher (33.6%) than in the Average (17.6%) and High (12.0%) Resilience Groups ($p = .003$).

Anxiety and depression symptom effects

The main effects of Resilience Group and Visit were significant for both GAD-7 (both $p < .001$) and PHQ-8 (both $p < .001$). The main effect of Visit was significant ($p < .001$) with the mean GAD-7 score and PHQ-8 score being significantly higher for all resilience groups at the initial visit compared to the three-month follow-up. Post hoc pairwise Resilience Group comparisons of GAD-7 scores resulted in the Low Resilience Group scoring significantly higher than either Average ($p < .001$) or High Resilience Groups ($p < .001$) at initial visit. The Average Resilience Group was scored significantly higher on the GAD-7 score than High Resilience Group ($p = .043$). At three-month follow-up the Low Resilience Group was still significantly higher than either Average ($p = .009$) or High Resilience Groups ($p < .001$). These two groups however did not differ at three-month follow-up ($p = .271$).

For the PHQ-8, post hoc pairwise group comparisons revealed that the Low Resilience Group scored significantly higher on the PHQ-8 than either the Average ($p = .015$) or High Resilience Groups ($p < .001$) and there was no difference ($p = .308$) between Average and High Groups at initial visit. At three-month follow-up the only significant difference was higher PHQ-8 scores for Low vs. High Resilience Groups ($p = .009$).

Percent back to normal

The main effects of both Resilience Groups and Visit were significant for percent back to normal ratings ($p < .001$). Overall rating of percent back to normal improved with time (Visit) from initial to follow-up visit. Post hoc pairwise comparisons for Resilience Groups at initial visit showed the percent back to normal for the Low

Resilience Group to be significantly lower than only the High Resilience Group ($p < .001$), with no significant difference between the Average and High Resilience Groups ($p > .9$). At three months, the Low Resilience Group indicated a significantly lower percent back to normal than both the Average ($p = .028$) and High Resilience Groups ($p = .007$), which were similar in their recovery ratings.

Discussion

Our investigation focused on SRC among subjects aged 13–25, a prime age for sports participation in the United States (Woods, 2017). Previous research has shown only limited differences in concussion symptomatology and recovery across this age group of adolescent and young adult athletes, particularly when evaluated within 21 days of injury (Howell et al., 2019; Kara et al., 2020; Nelson et al., 2016). In this large sample of adolescent and young adults who sustained a SRC, level of resilience appeared to be associated with the number and severity of concussion symptoms reported during recovery. At time of initial evaluation, resilience was not associated with number or severity of PCS endorsed but was associated with a greater number and increased severity at three months post injury. Specifically, individuals considered to have low resilience reported both a greater number of symptoms and a higher severity of symptoms than those with average or high resilience at three months post injury. Higher resilience levels did not appear to be associated with a benefit above the average levels of resilience, possibly reflecting a ceiling effect of the BRS. This has been seen in older populations of emergency room mTBI patients where subjects considered to have medium-high resilience levels reported a lower level of post-concussive symptoms compared to those considered to have low resilience (Losoi et al., 2015). In contrast, it has been proposed that high resilience levels actually may be associated with greater post injury anxiety and concussion symptoms immediately following injury before any potential benefit may emerge (McCauley et al., 2013). However, our findings did not support such a notion, as higher levels of resilience did not appear to relate to greater symptoms within ten days post-injury or at three months. Rather, our results indicate that low resilience levels (linear mixed models and regression models) may be associated with greater symptom reporting during recovery and a longer perceived recovery from SRC.

Given the number of psychological factors which have been identified as being associated with concussion symptomology (Broshek et al., 2015; Iverson et al., 2017), it is important to determine if resilience as defined in our study is an independent contributing factor to SRC recovery. Anxiety and depressive symptoms may mediate its role, but previous research has posited resilience as a discrete factor in concussion recovery (Durish et al., 2019; Sullivan et al., 2015). Outside of concussion research it has been shown that adolescents with higher resilience show lower levels of anxiety and depression symptoms (Haddadi & Besharat, 2010; Hjemdal et al., 2007). It is also possible that negative response bias may influence the role resilience might play in SRC recovery. This risk appears low given that in our study, there was no significant correlation between self-reported resilience levels with prior history of anxiety, and the significant correlation with prior history of depression was low ($r = -0.143$). The moderate correlations between resilience and post-injury anxiety (GAD-7), ($r = -0.406$) and depression (PHQ-8), ($r = -323$) scores may pose limitations on our findings and merit further exploration. However, even with these correlations, only post-injury anxiety was a predictor for the number of endorsed PCSS symptoms at three months. The lack of inclusion of these emotional factors in both of the regression models may point to a complex relationship between these factors. As measured, levels of resilience had the strongest relationship with PCSS symptoms, even after accounting for psychological factors in the models, providing some support that resilience appears to be distinct from other psychological factors.

The relationship between resilience and levels of post-injury anxiety (GAD-7) and depression (PHQ-8) was further examined in separate ANCOVAs. At initial evaluation, the relationship between resilience group and level of anxiety was linear, with lower resilience associated with greater anxiety. However, at follow up, the Low Resilience Group still expressed greater anxiety than either High or Average Resilience Groups. In regard to depressive symptoms, at initial evaluation, the Low Resilience Group endorsed higher level of depressive symptoms that still remained higher than the other resilience groups at follow up. It is important to note that although some participants may have reported elevated symptoms of anxiety as measured by the GAD-7, mean raw scores for all three groups were generally low and did not meet established cutoff scores (7–10) for generalized anxiety disorder at either initial evaluation or three-month follow-up (Plummer et al., 2016). Likewise, none of the mean PHQ-8 scores across resilience groups met the suggested cutoff score of ≥ 10 for clinically significant depression (Kroenke et al., 2009). Also, as expected with recovery from concussion, all groups significantly improved in both anxiety and depressive symptoms at follow-up compared to initial

visit. Although perhaps not significant in a clinical sense (in view of mean scores not meeting standard cutoff values), the slightly elevated initial scores for anxiety and depression in subjects with low resilience are concerning. Anxiety and depression have been shown to have an additive effect on endorsed concussion symptoms (Ponsford et al., 2012; R. T. Lange et al., 2011; Yang et al., 2015). As such, if low resilience is associated with self-reported symptoms of anxiety and depression, it should be considered a factor in evaluating emotional PCSS symptoms in clinical interviews at initial evaluation and during recovery (Collins et al., 2014).

Level of resilience was associated with participants' perceived functionality and being back to normal at initial evaluation and at three months. Participants in the Low Resilience Group reported that they were functioning at a lower level in terms of percent back to normal than the other groups at both time points. As with the PCSS, there may also be a resilience "ceiling" effect as high resilience did not provide a benefit in function over that of average resilience. Subjects were also asked whether or not they had returned to play/physical activity at the three-month follow-up, and the percentage of participants who had returned to activity was the same across resilience groups regardless of symptoms. Progressive steps of asymptomatic physical activity are a standard for return to play/physical activity protocol (McCrory et al., 2017), although in concussion recovery, being "asymptomatic" may not mean a complete absence of concussion symptoms, as healthy non-concussed individuals often report some symptoms at baseline (Asken et al., 2017). Even if participants in our study indicated they had returned to play/physical activity, 47% reported at least one PCSS symptom present at three-month follow-up. When applying a standard of "asymptomatic" as measured by symptom severity (male ≤ 5, female ≤ 6) (Alla et al., 2012), a larger percentage of the Low Resilience Group (36.6%) were still symptomatic than the Average (17.6%) or High (12.0%) Resilience Groups (p = .003) at three months. This would be consistent with subject reports regarding their perceived "percent back to normal" at three months, regardless of return to sport/physical activity, as the low resilience group reported a smaller percentage of return to normal function than the other two groups. This group also reported a greater exacerbation of symptoms with physical and cognitive activity compared to the other groups. Symptom "spikes" can occur in this age group after increased mental activity such as return to school and extracurricular activities (Silverberg et al., 2016). Physical and cognitive activity are beneficial to recovery from SRC but only when kept below the threshold that increases symptoms (McCrory et al., 2017; Schneider et al., 2017). It is possible that low resilience may relate to individuals being more sensitive to symptom spikes even if recovered and may also factor into perception of lower functionality. Further research in this area will be important to delineate such a relationship.

Our results suggest that the assessment of resilience may lend an important contribution to the evaluation and management of SRC recovery. Symptom checklists such as the PCSS are important tools which are part of the current Berlin consensus protocols for initial evaluation of SRC and tracking recovery (McCrory et al., 2017), and the BRS, or other measure of resilience, might be a worthwhile adjunct to these checklists. In management of recovery from SRC, comprehensive and targeted approaches have become a standard for rehabilitation strategies (Collins et al., 2014). Widening these strategies to include a specific focus on resilience may prove beneficial to overall recovery (Neils-Strunjas et al., 2017). Residual concussion symptoms and symptom spikes may impede functionality even after release to return to school and work (Silverberg et al., 2016, 2018); quality of recovery and functionality at school and work may be improved by interventions targeting resilience.

As with many concussion studies using self-report measures, our results are subject to a possible "good old days" bias in reporting of concussion symptoms (Lange et al., 2010). Care must also be taken in generalizing results to other populations, as this study focused on SRC and not concussions resulting from other mechanisms or initially evaluated greater than 10 days post injury. Participants were also predominantly Caucasian, which may limit generalizability to other sociodemographic populations. Another limitation of the study is the lack of a pre-injury "baseline" of resilience, as the BRS was only obtained at time of initial post injury assessment.

Conclusion

The objective of this investigation was to examine the relationship between resilience and concussion symptoms, anxiety, depression, and perceived return to normal during recovery from SRC in adolescents and young adults. Low level of resilience was associated with greater concussion symptoms and higher self-reported symptoms of anxiety and depression immediately post injury and during recovery. Low resilience also appeared to be associated with longer reported return to normal following SRC even after controlling for sex and prior history of depression. A patient's resilience, defined as the ability to "bounce back" or recover (Smith et al., 2008)

following SRC may be an important and potentially modifiable factor which may positively impact recovery.

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Statement of clinical relevance

This study found that low resilience was associated with higher post-concussion and emotional symptoms following SRC and should be considered at initial evaluation and when managing SRC recovery.

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