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Psychological Resilience as a Predictor of Persistent Post-Concussive Symptoms in Children With Single and Multiple Concussion

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Abstract

Objectives: To evaluate the relationship of psychological resilience to persistent post-concussive symptoms (PCS) in children with a history of single or multiple concussions, as well as orthopedic injury (OI). **Methods:** Participants ($N = 75$) were children, ages 8–18 years, who sustained a single concussion ($n = 24$), multiple concussions ($n = 25$), or an OI ($n = 26$), recruited from a tertiary care children's hospital. All participants sustained injuries at least 6 months before recruitment, with an average time since injury of 32.9 months. Self-reported psychological resilience was measured using the Connor-Davidson Resilience Scale, and both self- and parent-reported PCS were measured using the Post-Concussion Symptom Inventory. Hierarchical regression analyses examined psychological resilience as a predictor of PCS, both as a main effect and as a moderator of group differences. **Results:** Multiple concussions and low psychological resilience were both significant predictors of persistent PCS. Resilience was not a significant moderator of group differences in PCS. **Conclusions:** Sustaining multiple concussions may increase a child's risk of persistent PCS; however, high psychological resilience may serve as a protective factor, regardless of the number or type of injuries sustained. These findings provide support for developing and testing interventions aimed at increasing psychological resilience as a potential means of improving outcomes for children suffering from persistent PCS after concussion. (*JINS*, 2018, *24*, 759–768)

Keywords: Mild traumatic brain injury, Pediatric, Adolescent, Hardiness, Outcomes, Concussion

INTRODUCTION

Pediatric concussion is a highly prevalent health condition affecting one in six children before the age of 10 years (Langlois, Rutland-Brown, & Thomas, 2006), with even higher incidence rates observed in adolescents and young adults aged 15 to 24 years (Cassidy et al., 2004). Post-concussive symptoms (PCS) often occur following a concussion and include a range of physical, cognitive, and emotional complaints (Sady, Vaughan, & Gioia, 2014). PCS are expected to resolve within approximately 1–3 months post-injury for the majority of children (Barlow et al., 2010); however, 15–30% of children will suffer prolonged PCS beyond that time (Babcock et al., 2013; Barlow et al., 2010; Grool et al., 2016; Zemek et al., 2016). Given this alarming statistic, increasing attention has been paid to examining differences between children who do and do not show delayed recovery (i.e., persistent PCS).

Injury-related factors that predict persistent PCS include the presence of headache, nausea/vomiting, and loss of consciousness at the time of injury (Babcock et al., 2013; McNally et al., 2014; Zemek et al., 2013). Non-injury factors, such as older age at injury (Zemek et al., 2013), being female (Taylor et al., 2010), pre-injury learning and psychiatric problems (Ponsford et al., 1999), ineffective coping strategies (Woodrome et al., 2011), and lower pre-injury cognitive ability (Fay et al., 2010) have also been linked to the presence of persistent PCS in children. The relative contribution of injury versus non-injury factors to persistent PCS is not well understood (McNally et al., 2014).

Another injury-related factor that may contribute to persistent PCS is a history of multiple (i.e., two or more) concussions. Some evidence suggests that multiple concussions may result in greater PCS, although findings are inconsistent and the reasons for any linkage remain controversial (Barker et al., 2017; Bijur, Haslum, & Golding, 1996; Brooks et al., 2013, 2016; Iverson, Gaetz, Lovell, & Collins, 2004; Iverson, Brooks, Lovell, & Collins, 2006; Mannix et al., 2014). Given the inconsistencies in the literature regarding cumulative effects of multiple concussions, the possibility of a dose-response relationship (whether physiological or psychosocial in nature) between number of concussions and persistent PCS cannot be dismissed.

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An additional non-injury factor garnering attention in adult concussion research is psychological resilience. Psychological resilience is conceptualized as the process of harboring interpersonal qualities that enable one to adapt or thrive in the face of adversity (Connor & Davidson, 2003). Such qualities include personal competence, tenacity, trust in one's instincts, and positive acceptance of change (Connor & Davidson, 2003). Psychological resilience can also be thought of as one's ability to "bounce back" from illness, injury, or other stressors. Historically, resilience research focused on identifying interpersonal, societal, and cultural factors that enabled children to adapt and thrive in adverse circumstances, such as poverty, family violence, and poor parenting (e.g., Anthony, 1974; Werner, 1997; Werner & Smith, 1992).

Recently, however, researchers have begun to focus more specifically on psychological resilience as an important, and potentially modifiable (e.g., Steinhardt & Dolbier, 2008), factor in medical populations, and have examined its role in predicting the outcome of several physical ailments, including brain injury. Psychological resilience has been found to predict PCS in adults with a history of concussion, such that lower resilience is related to greater PCS (Losoi et al., 2015; 2016; Merritt et al. 2015; Sullivan, Edmed, Allan, Smith, & Karlsson, 2015). However, the relationship between resilience and PCS has not yet been explored in a pediatric sample.

The current study, therefore, aimed to examine both injury-related (i.e., single *vs.* multiple concussion) and non-injury related (i.e., psychological resilience) factors that may be related to the risk of persistent PCS after pediatric concussion. More specifically, the study sought to explore the role of resilience as a predictor and potential moderator of PCS in the context of single versus multiple concussion, in comparison to orthopedic injury (OI), in children 8–18 years of age.

Both concussion groups were expected to report higher PCS than the OI group, with the multiple concussion group endorsing the greatest PCS. Psychological resilience was predicted to be negatively associated with PCS ratings in all groups. The association between resilience and PCS was hypothesized to vary as a function of injury type, such that the strongest association would be found in children with multiple concussion and the weakest association in children with OI. Thus, resilience would act as a moderator of PCS, such that the groups would not differ significantly in PCS among children with high resilience, but would differ significantly in PCS among children with low resilience, with the highest PCS ratings seen in the multiple concussion group. A secondary analysis examined the relation of resilience to different dimensions of PCS to determine whether resilience would differ in its relationship to different dimensions of PCS (i.e., physical, cognitive, emotional, fatigue).

METHODS

Participants

The present study was a planned sub-study of a larger parent project, which received approval from the Conjoint Health Research Ethics Board. Demographic characteristics of the sample are presented in Table 1. Participants were recruited from existing research databases derived from patients originally presenting to the emergency department, as well as various outpatient clinics (e.g., concussion clinic), at the Alberta Children's Hospital (ACH) in Calgary, Alberta. The participants fell into three groups: (1) children and adolescents with multiple concussions (i.e., a history of two or more prior concussions; $n = 26$), (2) children and adolescents with a single

Table 1. Demographic characteristics of study sample

	Multiple concussion	Single concussion	OI	Significance test	
	$n = 25$	$n = 24$	$n = 26$	F/χ^2	p-Value
Age *M* (*SD*)	15.33 (2.68)	13.42 (2.82)	13.88 (3.02)	4.21*	.019
Sex (% female)	40.0	66.67	50	3.55	.169
Race (% not Caucasian)	4.0	20.83	19.23	8.27	.219
No. of concussions *M* (*SD*)	3.04 (1.62)	—	—	—	—
Time since injury (months) *M* (*SD*)	30.87 (14.76)[a]	35.92 (14.23)	31.70 (30.01)	0.40	.671
Maternal education (years) *M* (*SD*)				3.95	.413
% High school diploma/GED	16.0	8.33	3.85		
% College/vocational certificate	24.0	37.5	23.08		
% University degree	60.0	54.17	73.08		
Paternal education (years) *M* (*SD*)				7.62	.472
% High school diploma/GED	16.0	16.67	7.69		
% College/vocational certificate	40.0	50.0	30.77		
% University degree	44.0	33.33	61.54		

GED = general education development (high school equivalent).
[a]Time since most recent injury.
*Significant group difference ($p<.05$).

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concussion ($n = 24$), and (3) children and adolescents with an OI not involving the head ($n = 25$). The OI group was included as a non-head injury comparison to measure the potential dose-response effect of concussion (i.e., provide a baseline), while simultaneously controlling for the effect of exposure to a medical trauma as well as environmental and behavioral factors that make a child more likely to sustain an injury.

All participants were at least 6 months post-injury at the time of recruitment. Inclusion criteria for the concussion groups are in keeping with the Centers for Disease Control and Prevetion definition of a concussion (National Center for Injury Prevention and Control, 2003), and included injury to the head that occurred greater than 6 months before recruitment, diagnosis of concussion by a health care professional at the time of injury, and report of at least one new symptom at the time of injury (e.g., headache, nausea, dizziness). The time frame for exposure to injury (i.e., >6 months before recruitment) is in keeping with recent data describing expectations for recovery (i.e., 1–3 months; Barlow et al., 2010), indicating that symptoms present after 6 months can be considered persistent and refractory.

Inclusion criteria for the OI group were a minor injury [i.e., Abbreviated Injury Scale (AAAM, 2008) score of 3 or less] to the thorax, upper extremity, or lower extremity, and presentation to a healthcare professional for management of the injury. Exclusionary criteria for all groups included history of a moderate or severe traumatic brain injury (TBI); history of substance abuse, psychiatric hospitalization, or neurological disorder; or visual, hearing, motor, or language deficits that could lessen a child's ability to complete questionnaires. Exclusion criteria for the OI group also included a parent-reported history of any previous TBI.

The majority of participants (i.e., $n = 58$) who were recruited for the parent study were contacted by phone and received a letter inviting them to participate in the study. Additional participants (i.e., $n = 17$) were recruited from the same sources, including any who declined to participate in the parent study. The latter were offered the option to participate in the current sub-study only, which required them to complete all measures *via* mail, as also approved by the Research Ethics Board. All potential participants were screened for inclusion and exclusion criteria and, if eligible, provided signed parental consent and child assent upon enrolment into the study.

A total of 170 participants were contacted between September 2014 and November 2016 *via* letter and phone call and invited to participate in the parent study, and an additional 29 participants were contacted *via* phone call to participate in the mail-out portion of this study, for a total of 199 contacts. Approximately 61% of potential recruits either did not follow up with the research assistant, declined participation, or were not enrolled due to sample limits, and three additional participants were omitted from analyses due to exclusionary criteria (one participant was too old, two participants with concussions less than 6 months before enrollment), leaving 26 children with multiple concussion, 24 with single concussion, and 25 with OI.

Significant differences in age, sex, and injury group (i.e., multiple concussion, single concussion, OI) were observed between those who did and did not participate. Specifically, those who did not participate were more likely to be in the single concussion group ($\chi^2 = 14.18$; $p = .001$), were more likely to be male ($\chi^2 = 7.57$; $p = .006$), and were slightly older ($M = 15.47$; $SD = 2.15$ *vs.* $M = 14.22$; $SD = 3.06$; $t(124.71) = 3.12$; $p = .002$). These differences were due largely to the methodology for the parent study, which used targeted recruitment to attempt to match groups for age and sex for neuroimaging purposes. That is, additional recruitment efforts were made to fulfill goals of equal sample sizes for the three groups, such that a large number of potential participants with a history of single concussion or orthopedic injury (recruited from a previous hockey study, and, therefore, mostly males) were contacted to fill a few remaining spaces in those groups. Although several of these children agreed to participate, only a few were actually enrolled to best match groups for sex and age.

The final sample ($N = 75$) consisted of 39 females (52%) and 36 males (48%). Participants ranged in age from 8 to 18 years ($M = 14.20$; $SD = 2.88$), and time between injury and study recruitment ranged from 6.51 to 130.66 months ($M = 32.94$; $SD = 19.59$). Number of previous concussions in the multiple concussion group ranged from 2 to 8 ($M = 3.04$; $SD = 1.62$). Information on etiology of concussions (e.g., mechanism of injury) was not collected. Participants who completed the full parent study did not differ significantly from those who completed the mail-out portion on demographic, injury, or primary outcome variables (i.e., age, sex, race, number of previous concussions, time since injury, maternal education, paternal education, Post-Concussion Symptom Inventory [PCSI] self-report, PCSI parent-report). Significant demographic differences between injury groups were found only for age ($F = 4.21$; $p = .019$), with the highest mean age in the multiple concussion group.

Measures

Post-concussion symptoms

PCS were measured by having children and parents complete the PCSI. The PCSI is a rating scale that has several versions, including a self-report (child) form and a parent-proxy report form that asks the child or parent to rate the severity of the child's current symptoms (i.e., yesterday and today) by indicating how much of a problem each symptom is for the child. Both the PCSI child report and parent-proxy report forms consist of 26 items rated on a 7-point scale indicating the severity of the problem (0 = Not a problem, 3 = Moderate problem, 6 = Severe problem). Total possible scores range from 0 to 156, with higher scores indicative of more severe PCS. The PCSI has demonstrated moderately high test–retest reliability, strong internal consistency, and good convergent validity (Sady, Vaughan, & Gioia, 2014). Total scores from each version of the PCSI were included in the main analysis to examine the effect of resilience on PCS.

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Given that post-concussion symptoms are multi-dimensional, Sady and colleagues (2014) recently examined the symptom dimensions of the PCSI through factor analysis. They identified four correlated symptom dimensions: physical, cognitive, emotional, and sleep/fatigue. Thus, secondary analyses were performed to identify relationships between resilience and the four symptom dimensions of the PCSI.

Psychological resilience

Psychological resilience was measured by having children complete the Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003). The CD-RISC is a 25-item rating scale that measures factors related to resilience, such as personal competence, tenacity, tolerance of negative affect, positive acceptance of change, control, and spiritual influences (Connor & Davidson, 2003). Each item is measured on a 5-point scale (0 = Not true at all, 2 = Sometimes true, 4 = True nearly all the time). Total possible scores range from 0 to 100, with higher scores indicative of greater resilience. The CD-RISC demonstrates sound psychometric properties in the general adult and adolescent population, as well as in clinical samples (Connor & Davidson, 2003). Limited published studies have examined the psychometric properties of the CD-RISC in children; however, the available evidence supports its construct validity when administered to a pediatric medical sample (Laliberté Durish, Brooks, & Yeates, 2017). The CD-RISC has a Grade 5 reading level; therefore, items were read aloud to participants younger than 10 years of age.

Procedure

Children recruited for the parent study completed the measures in a designated testing room, and parents completed the parent version of the questionnaires in a separate room. Participants recruited to participate in the mail-out portion of the study were mailed a package containing a consent form, all parent and child questionnaires, and instructions for completion (e.g., parent and child forms to be completed separately). Packages were then mailed back to the research lab in a pre-stamped envelope upon completion.

Statistical Analyses

Statistical analyses were conducted using IBM SPSS Statistics software, Version 24 (IBM, 2016). Descriptive statistics of demographic variables (i.e., age, sex, race, parent education), the primary predictor variable (i.e., CD-RISC), and primary outcome variables (i.e., PCSI child report, PCSI parent report) were calculated for each group. An analysis of variance was conducted to examine group differences on primary predictor and outcome variables, followed by Tukey honest significant difference *post hoc* analyses of between-group differences. Hierarchical regression analyses were performed with group and resilience entered as predictor variables and the two total scores for PCS ratings (i.e., PCSI child report, PCSI parent report) examined separately as dependent variables, to assess whether group or resilience predicted PCS. Two dummy variables were created to compare the multiple and single concussion groups to the OI group. Group × resilience interaction terms were created to assess the moderating effect of resilience on PCS.

Predictors were entered in three steps for the primary regression analyses: (1) two dummy variables for group, (2) resilience (i.e., CD-RISC total score), and (3) two group × resilience interaction terms. Similar regression analyses were completed to examine the effect of group and resilience on each of the four child and parent PCSI domain scores (i.e., physical, cognitive, emotional, and sleep/fatigue). Multiple comparisons were controlled for in a family-wise manner using the false discovery rate (Benajmini & Hochberg, 1995).

RESULTS

Group means and standard deviations for the PCSI and the CD-RISC are presented in Table 2. Significant group differences were present for both child- and parent-reported PCS ($F = 4.40$; $p = .016$; $F = 7.72$; $p = .026$), with the difference for child ratings remaining significant after controlling for multiple comparisons. *Post hoc* comparisons indicated that the multiple concussion group reported higher mean child-rated PCS than the OI group. No significant group differences were present on the CD-RISC. Child- and parent-reported PCS were significantly correlated ($r = .54$; $p < .001$), although parents reported lower total PCS scores than

Table 2. Group means and comparisons on the PCSI and CD-RISC

	Multiple	Single	OI	Significance test		Multiple *vs.* OI		Multiple *vs.* single		Single *vs.* OI	
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*F*	*p*-Value	Mean dif.[a]	*p*-Value	Mean dif.[a]	*p*-Value	Mean dif.[a]	*p*-Value
PCSI child	33.52 (29.97)	19.25 (21.52)	17.12 (16.87)	4.40*	.016	18.19*	.018	15.42	.062	2.77	.905
PCSI parent	23.63 (29.93)	14.67 (19.86)	7.72 (9.37)	3.84*	.026	16.84*	.019	9.60	.275	7.25	.454
CD-RISC	68.80 (10.87)	70.75 (16.35)	68.92 (14.32)	.135	.874	—	—	—	—	—	—

PCSI = Post-Concussion Symptom Inventory (total raw score); CD-RISC = Connor-Davidson Resilience Scale (total raw score).
[a]Tukey HSD post-hoc test of multiple comparisons.
*Significant group difference ($p < .05$).

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Table 3. Primary regression analyses

Dependent variable	Regression step	Predictor	Significance test		
			β	*t*	*p*-Value
Child PCSI	1*	Multiple concussion**	0.32	2.51	.014
	$R^2 = .09$, $p = .031$	Single concussion	0.04	0.32	.748
	2*	Multiple concussion**	0.32	2.57	.012
	$\Delta R^2 = .06$, $p = .024$	Single concussion	0.06	0.46	.649
		CD-RISC**	−0.25	−2.31	.024
	3	Multiple concussion	0.75	1.02	.313
	$\Delta R^2 = .01$, $p = .753$	Single concussion	0.46	0.76	.449
		CD-RISC	−0.14	−0.78	.440
		Multiple concussion × CD-RISC	−0.43	−0.59	.558
		Single concussion × CD-RISC	−0.42	−0.68	.496
Parent PCSI	1*	Multiple concussion**	0.34	2.61	.011
	$R^2 = .09$, $p = .038$	Single concussion	0.15	1.14	.258
	2	Multiple concussion**	0.34	2.59	.012
	$\Delta R^2 = .01$, $p = .347$	Single concussion	0.16	1.19	.240
		CD-RISC	−0.11	−0.95	.347
	3	Multiple concussion	0.63	0.82	.415
	$\Delta R^2 = .00$, $p = .925$	Single concussion	0.32	0.51	.615
		CD-RISC	−0.05	−0.28	.781
		Multiple concussion × CD-RISC	−0.29	−0.38	.705
		Single concussion × CD-RISC	−0.17	−0.27	.791

PCSI = Post-Concussion Symptom Inventory (total raw score); CD-RISC = Connor-Davidson Resilience Scale (total raw score).
*Significant effect ($p < .05$).
**Significant after controlling for multiple comparisons (false discovery rate).

children, in contrast to some previous research (Sady et al., 2014).

Primary regression analyses are summarized in Table 3. A significant effect of group (i.e., the contribution of both dummy variables) was found for both child- and parent-reported PCS ($R^2 = .09$; $p = .031$; $R^2 = .09$; $p = .038$). The dummy variable comparing the multiple concussion group to the OI group was a significant predictor of both child- and parent-reported PCS, with the multiple concussion group endorsing greater symptoms than the OI group ($t(72) = 2.51$; $p = .014$; $t(70) = 2.61$; $p = .011$, respectively). Additionally, the CD-RISC was a significant, unique predictor of child-reported PCS ($\Delta R^2 = .06$; $p = .024$), with lower resilience predicting greater PCS, but did not predict parent-reported PCS. None of the group × resilience interactions were significant for either child- or parent-reported PCS.

When specific domains of PCS were analyzed (see Table 4), a significant effect of group (i.e., the contribution of both dummy variables) was found for both child- and parent-reported physical symptoms ($R^2 = .11$; $p = .018$; $R^2 = .11$; $p = .016$) and parent-reported cognitive symptoms ($R^2 = .11$; $p = .020$). In all cases, the multiple concussion group, but not the single concussion group, reported more severe symptoms than the OI group. The multiple concussion group also reported significantly more child-reported cognitive and fatigue-related symptoms, even after accounting for resilience ($t(72) = 2.11$; $\beta = 0.27$; $p = .039$; and $t(72) = 2.16$; $\beta = 0.27$; $p = .034$, respectively). After taking group into account, resilience was a significant predictor of both child- and parent-reported emotional symptoms ($R^2\Delta = .17$; $p < .001$ and $R^2\Delta = .11$; $p = .003$; respectively), as well as child-reported fatigue symptoms ($R^2\Delta = .06$; $p = .029$).

In all cases, lower CD-RISC scores predicted higher PCSI scores. Only the main effect of the multiple concussion group on parent-reported physical symptoms, as well as the effect of resilience on child- and parent-reported emotional symptoms, remained significant after correcting for multiple comparisons. No significant interactions between group and resilience were found for any of the PCS domain scores.

DISCUSSION

This study examined the role of single versus multiple concussions and psychological resilience as predictors of persistent PCS. The results support our hypothesis that multiple concussions would be associated with the highest levels of PCS. The multiple concussion group showed significantly higher levels of both child- and parent-reported PCS than the OI group, but the single concussion group did not. This finding is consistent with previous research suggesting that children with a single concussion do not differ from those with OI on symptom report long after injury, while those with two or more concussions endorse greater PCS (Brooks et al., 2013; Iverson et al., 2017; Rieger et al., 2013). Group differences involving the multiple concussion group were found in several PCS symptom domains. Specifically, the multiple

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Table 4. Prediction of PCSI domain scores

				Significance test		
	Dependent variable	Regression step	Predictor	β	*t*	*p*-Value
Child	Physical	1*	Multiple concussion*	0.36	2.79	.007
		$R^2 = .11$, $p = .018$	Single concussion	0.08	0.64	.524
		2	Multiple concussion*	0.36	2.81	.006
		$\Delta R^2 = .02$, $p = .170$	Single concussion	0.09	0.72	.475
			CD-RISC	−0.15	−1.39	.170
		3	Multiple concussion	0.89	1.20	.233
		$\Delta R^2 = .03$, $p = .256$	Single concussion	1.07	1.78	.079
			CD-RISC	0.07	0.39	.698
			Multiple concussion × CD-RISC	−0.54	−0.73	.467
			Single concussion × CD-RISC	−1.03	−1.67	.100
Parent	Physical	1*	Multiple concussion**	0.38	2.93	.005
		$R^2 = .11$, $p = .016$	Single concussion	0.13	1.03	.309
		2	Multiple concussion**	0.38	2.91	.005
		$\Delta R^2 = .00$, $p = .995$	Single concussion	0.13	1.02	.313
			CD-RISC	0.00	0.01	.995
		3	Multiple concussion	0.77	1.02	.313
		$\Delta R^2 = .01$, $p = .821$	Single concussion	0.46	0.74	.462
			CD-RISC	0.10	0.50	.619
			Multiple concussion × CD-RISC	−0.40	−0.52	.602
			Single concussion × CD-RISC	−0.35	−0.54	.590
Child	Cognitive	1	Multiple concussion*	0.27	2.10	.039
		$R^2 = .07$, $p = .072$	Single concussion	0.02	0.14	.892
		2	Multiple concussion*	0.27	2.11	.039
		$\Delta R^2 = .02$, $p = .217$	Single concussion	0.03	0.20	.839
			CD-RISC	−0.14	−1.25	.217
		3	Multiple concussion	0.63	0.82	.416
		$\Delta R^2 = .01$, $p = .842$	Single concussion	0.35	0.55	.583
			CD-RISC	−0.05	−0.28	.784
			Multiple concussion × CD-RISC	−0.36	−0.47	.640
			Single concussion × CD-RISC	−0.34	−0.52	.603
Parent	Cognitive	1*	Multiple concussion*	0.37	2.85	.006
		$R^2 = .11$, $p = .020$	Single concussion	0.14	1.07	.289
		2	Multiple concussion*	0.37	2.84	.006
		$\Delta R^2 = .01$, $p = .296$	Single concussion	0.15	1.12	.267
			CD-RISC	−0.12	−1.05	.296
		3	Multiple concussion	0.48	0.63	.528
		$\Delta R^2 = .01$, $p = .666$	Single concussion	−0.30	−0.49	.628
			CD-RISC	−0.19	−1.02	.313
			Multiple concussion × CD-RISC	−0.11	−0.15	.881
			Single concussion × CD-RISC	0.47	0.74	.465
Child	Emotional	1	Multiple concussion	0.16	1.22	.228
		$R^2 = .04$, $p = .233$	Single concussion	−0.06	−0.48	.634
		2*	Multiple concussion	0.16	1.32	.192
		$\Delta R^2 = .17$, $p < .001$	Single concussion	−0.04	−0.31	.758
			CD-RISC**	−0.42	−3.96	< .001
		3	Multiple concussion	0.64	0.91	.367
		$\Delta R^2 = .02$, $p = .492$	Single concussion	−0.36	−0.63	.532
			CD-RISC*	−0.44	−2.48	.016
			Multiple concussion × CD-RISC	−0.49	−0.69	.491
			Single concussion × CD-RISC	0.34	0.57	.570
Parent	Emotional	1	Multiple concussion	0.23	1.74	.086
		$R^2 = .05$, $p = .173$	Single concussion	0.20	1.50	.137
		2*	Multiple concussion	0.23	1.79	.078
		$\Delta R^2 = .11$, $p = .003$	Single concussion	0.22	1.74	.086
			CD-RISC**	−0.34	−3.07	.003

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Table 4. (*Continued*)

	Dependent variable	Regression step	Predictor	Significance test		
				β	*t*	*p*-Value
		3	Multiple concussion	0.02	0.03	.980
		$\Delta R^2 = .02$, $p = .519$	Single concussion	0.74	1.22	.226
			CD-RISC	−0.26	−1.42	.160
			Multiple concussion × CD-RISC	0.21	0.29	.771
			Single concussion × CD-RISC	−0.54	−0.87	.386
Child	Fatigue	1	Multiple concussion*	0.28	2.12	.038
		$R^2 = .07$, $p = .085$	Single concussion	0.04	0.34	.738
		2*	Multiple concussion*	0.27	2.16	.034
		$\Delta R^2 = .06$, $p = .029$	Single concussion	0.06	0.47	.643
			CD-RISC*	−0.25	−2.22	.029
		3	Multiple concussion	0.03	0.04	.970
		$\Delta R^2 = .01$, $p = .595$	Single concussion	0.49	0.80	.424
			CD-RISC	−0.19	−1.02	.311
			Multiple concussion × CD-RISC	0.25	0.34	.728
			Single concussion × CD-RISC	−0.45	−0.72	.475
Parent	Fatigue	1	Multiple concussion	0.24	1.79	.078
		$R^2 = .04$, $p = .206$	Single concussion	0.14	1.03	.306
		2	Multiple concussion	0.24	1.78	.080
		$\Delta R^2 = .00$, $p = .963$	Single concussion	0.14	1.02	.311
			CD-RISC	0.01	0.05	.963
		3	Multiple concussion	0.76	0.97	.334
		$\Delta R^2 = .01$, $p = .766$	Single concussion	0.48	0.75	.459
			CD-RISC	0.11	0.58	.566
			Multiple concussion × CD-RISC	−0.53	−0.68	.500
			Single concussion × CD-RISC	−0.36	−0.55	.587

PCSI = Post-Concussion Symptom Inventory (raw score); CD-RISC = Connor-Davidson Resilience Scale (total raw score)
*Significant (i.e., $p < .05$).
**Significant after controlling for multiple comparisons (false discovery rate).

concussion group demonstrated higher levels of physical and cognitive symptoms, as reported by both the child and parent, as well as more child-reported fatigue. The lack of group differences for emotional symptoms suggests that somatic and cognitive symptoms may be more injury-specific.

The current results also provide partial support for our hypothesis that resilience would be negatively associated with PCS. The CD-RISC was significantly associated with child-reported total PCS, such that lower resilience predicted greater PCS. Notably, a similar relationship was not found between resilience and parent-reported total PCS. Therefore, self-report biases or common method variance could be driving these effects (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). That is, children who are more likely to rate themselves as highly resilient may also, by nature of their response style, be more likely to rate themselves as having fewer problems.

On the other hand, resilience was a predictor of both child- and parent-rated PCS at the domain level, but only for emotional symptoms and fatigue symptoms. Specifically, higher resilience predicted fewer emotional symptoms as reported by both child and parent, as well as fewer child-reported fatigue symptoms. Thus, psychological resilience may be less related to physical and cognitive symptoms, and instead may serve to protect primarily against emotional symptoms. In this case, resilience may also predict fatigue because of the known relationship between emotional distress and fatigue (Thomsen, Mehlsen, Christensen, & Zachariae, 2003; Van Dyk, Thompson, & Nelson, 2016). However, the correlation between emotional and fatigue symptoms in the current sample is not greater than the correlations among other symptom domains.

A major question for the current study was whether psychological resilience would act as a moderator of persistent PCS following concussion and OI. Our findings fail to support this hypothesis. The relatively small sample size may provide a methodological explanation for the failure to detect significant interactions indicative of moderation. Interactions require more power to detect than main effects, and the relatively low sample size of the groups may not have provided adequate power to detect significance. Alternatively, no interaction effects may actually exist, and resilience may help to account for symptoms in children with both kinds of injuries.

Strengths and Limitations

A major strength of the current study is that it begins to fill a void in the literature regarding the relationship between both injury and non-injury factors, specifically history of previous concussion and resilience, and long-term outcome following

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concussion in children and adolescents. Furthermore, the study results are consistent with previous findings regarding the relationship between resilience and PCS in adult concussion. Additionally, the findings provide a rationale for developing and testing interventions designed to promote psychological resilience, with the goal of improving outcomes for children with concussion.

However, the results should be interpreted in light of several study limitations. First, the average time since injury was 2.7 years, making it very difficult to determine whether the group differences in PCS are causally related to concussion or to other factors (e.g., expectations about the effects of concussion, premorbid risk factors); thus, a study that uses a prospective, longitudinal methodology may be necessary to confirm the nature of the group differences. Notably, the relationships of psychological resilience to PCS are less likely to be affected by these considerations, given that the groups did not differ in resilience. Second, retrospective pre-injury ratings of PCS were not obtained, and participants were seen long after injury, precluding any comparison of baseline symptoms. Third, the study is limited by the relatively small sample size, which meant it was not adequately powered to detect small effect sizes. Relatedly, to maximize sample size, the age range of participants was purposely broad (i.e., 8–18 years); however, although adolescent age is a significant predictor of PCS (e.g., Zemek, Farion, Sampson, & McGahern, 2013), we examined children and adolescents as a single group because our sample size was not sufficiently large to treat age as a moderator. Thus, we were unable to consider possible age-related variation in our findings. Fourth, the significant effects of resilience for child-reported total PCS were not paralleled by similar findings for parent-reported total PCS. Therefore, shared rater variance may be driving the effects seen for child-reported total PCS scores. However, resilience was a predictor of parent ratings of emotional symptoms, suggesting that the results cannot be attributed entirely to shared rater variance. Finally, the parent study involved neuroimaging, which is a significant incentive for families who may suspect neurological deficits based on the presence of symptoms, potentially biasing the sample to include a larger proportion of highly symptomatic participants.

CONCLUSIONS

Both a history of two or more previous concussions and lower psychological resilience predict increased severity of PCS long after injury. Given that resilience is a dynamic and modifiable construct (Johnston et al., 2015; Steinhardt & Dolbier, 2008), the findings suggest that direct interventions that increase resilience may help to prevent or alleviate PCS after concussion. The prevention or alleviation of PCS may increase quality of life for affected children and families while also reducing the burden of increased health care usage associated with persistent PCS.

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REFERENCES

Anthony, E.J. (1974). The syndrome of the psychologically invulnerable child. In E.J. Anthony & C. Koupernik (Eds.), *The child in his family: Children at psychiatric risk* (pp. 529–545). New York: Wiley.

Association for the Advancement of Automotive Medicine (AAAM). (2008). *Abbreviated Injury Scale 2005, Update 2008*. Barrington, IL: Association for the Advancement of Automotive Medicine.

Babcock, L., Byczkowski, T., Wade, S.L., Ho, M., Mookerjee, S., & Bazarian, J.J. (2013). Predicting postconcussion syndrome after mild traumatic brain injury in children and adolescents who present to the emergency department. *JAMA Pediatrics*, *156*(2), 161–167.

Barker, T., Russo, S.A., Barker, G., Rice, M.A., Jeffrey, M.G., Broderick, G., & Craddock, T.J.A. (2017). A case matched study examining the reliability of using ImPACT to assess effects of multiple concussions. *BMC Psychology*, *5*(1), 14.

Barlow, K.M., Crawford, S., Stevenson, A., Sandhu, S.S., Belanger, F., & Dewey, D. (2010). Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics*, *126*, e374–e381.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B (Methodological)*, *57*, 289–300.

Bijur, P.E., Haslum, M., & Golding, J. (1996). Cognitive outcomes of multiple mild head injuries in children. *Journal of Developmental & Behavioral Pediatrics*, *17*(3), 143–148.

Brooks, B.L., Mannix, R., Maxwell, B., Zafonte, R., Berkner, P.D., & Iverson, G.L. (2016). Multiple past concussions in high school football players: Are there differences in cognitive functioning and symptom reporting? *Journal of Sports Medicine*, *44*(12), 3243–3251.

Brooks, B.L., McKay, C.D., Mrazik, M., Barlow, K.M., Meeuwisse, W.H., & Emery, C.A. (2013). Subjective, but not objective, lingering effects of multiple past concussions in adolescents. *Journal of Neurotrauma*, *30*, 1469–1475.

Cassidy, J.D., Carroll, L.J., Peloso, P.M., Borg, J., von Holst, H., . . . Coronado, V.G. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: Results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine*, *43*(Suppl), 28–60.

Connor, K.M., & Davidson, J.R. (2003). Development of a new resilience scale: The Connor-Davidson Resilience Scale (CD-RISC). *Depression and Anxiety*, *18*, 76–82.

Fay, T.B., Yeates, K.O., Taylor, H.G., Bangert, C., Dietrich, A., Nuss, K.E., … Wright, J.M. (2010). Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. *Journal of the International Neuropsychological Society*, *16*(1), 94–105.

Grool, A.M., Aglipay, M., Momoli, F., Meehan, W.P., Freedman, S.B., Yeates, K.O., . . . Pediatric Emergency Research Canada (PERC) Concussion Team. (2016). Association between early participation in physical activity following acute concussion and persistent postconcussive symptoms in children and adolescents. *JAMA*, *316*(23), 2504–2514.

IBM Corp. (2016). *IBM SPSS Statistics for Windows, Version 24.0*. Armonk, NY: IBM Corp.

Iverson, G.L., Brooks, B.L., Lovell, M.R., & Collins, M.W. (2006). No cumulative effects for one or two previous concussions. *British Journal of Sports Medicine*, *40*(1), 72–75.

Iverson, G.L., Gaetz, M., Lovell, M.R., & Collins, M.W. (2004). Cumulative effects of concussion in amateur athletes. *Brain Injury*, *18*(5), 433–443.

Iverson, G.L., Gardner, A.J., Terry, D.P., Ponsford, J.L., Sills, A.K., Broshek, D.K., & Solomon, G.S. (2017). Predictors of clinical recovery from concussion: A systematic review. *British Journal of Sports Medicine*, *51*, 941–948.

Johnston, M.C., Porteous, T., Crilly, M.A., Burton, C.D., Elliot, A., Iversen, L., … Black, C. (2015). Physical disease and resilient outcomes: A systematic review of resilience definitions and study methods. *Psychosomatics*, *56*(2), 168–180.

Laliberté Durish, C., Brooks, B.L., & Yeates, K.O. (2017). Convergent and divergent validity for a measure of psychological resilience in children with mild traumatic brain injury. *Journal of the International Neuropsychological Society*, *23*(Suppl. 1), 294.

Langlois, J.A., Rutland-Brown, W., & Thomas, K.E. (2006). *Traumatic brain injury in the United States: emergency department visits, hospitalizations, and deaths*. Atlanta: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.

Losoi, H., Silverberg, N.D., Waljas, M., Turunen, S., Rosti-Otajarvi, E., Helminen, M., … Iverson, G.L. (2016). Recovery from mild traumatic brain injury in previously healthy adults. *Journal of Neurotrauma*, *33*(8), 766–776.

Losoi, H., Silverberg, N.D., Waljas, M., Turunen, S., Rosti-Otajarvi, E., Helminen, M., … Iverson, G.L. (2015). Resilience is associated with outcome from mild traumatic brain injury. *Journal of Neurotrauma*, *32*, 942–949.

Mannix, R., Iverson, G.L., Maxwell, B., Atkins, J.E., Zafonte, R., & Berkner, P.D. (2014). Multiple prior concussions are associated with symptoms in high school athletes. *Annals of Clinical and Translational Neurology*, *1*(6), 433–438.

McNally, K.A., Bangert, B., Dietrich, A., Nuss, K., Rusin, J., Wright, M., … Yeates, K.O. (2014). Injury versus non-injury factors as predictors of post-concussive symptoms following mild traumatic brain injury in children. *Neuropsychology*, *27*(1), 12–27.

Merritt, V.C., Lange, R.T., & French, L.M. (2015). Resilience and symptom reporting following mild traumatic brain injury in military service members. *Brain Injury*, *29*(11), 1325–1336.

National Center for Injury Prevention and Control. (2003). *Report to Congress on Mild Traumatic Brain Injury in the United States: Steps to Prevent a Serious Public Health Problem*. Atlanta, GA: Centers for Disease Control and Prevention.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y., & Podsakoff, N.P. (2003). Common method biases in behavioural research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903.

Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Ayton, G., Nelmus, R., … Ng, K.T. (1999). Cognitive and behavioural outcome following mild traumatic head injury in children. *Journal of Head Trauma Rehabilitation*, *14*(4), 360–372.

Rieger, B.P., Lewandowski, L.J., Callahan, J.M., Spenceley, L., Truckenmiller, A., Gathke, R., & Miller, L.A. (2013). A prospective study of symptoms and neurocognitive outcomes in youth with concussion vs orthopaedic injuries. *Brain Injury*, *27*(2), 169–178.

Sady, M.D., Vaughan, C.G., & Gioia, G.A. (2014). Psychometric characteristics of the postconcussion symptom inventory in children and adolescents. *Archives of Clinical Neuropsychology*, *29*, 348–363.

Sherman, E.M.S., & Brooks, B.L. (2015a). *Child and Adolescent Memory ProfileTM (ChAMP)*. Lutz, FL: Psychological Assessment Resources, Inc.

Sherman, E.M.S., & Brooks, B.L. (2015b). *Memory Validity ProfileTM (MVP)*. Lutz, FL: Psychological Assessment Resources, Inc.

Sherman, E.M.S., & Brooks, B.L. (2017). *Multidimensional Everyday Memory Ratings for YouthTM (MEMRY)*. Lutz, FL: Psychological Assessment Resources, Inc.

Steinhardt, M.A., & Dolbier, C. (2008). Evaluation of a resilience intervention to enhance coping strategies and protective factors and decrease symptomatology. *Journal of American College Health*, *445*, 453–456.

Sullivan, K.A., Edmed, S.L., Allan, A.C., Smith, S.S., & Karlsson, L.J.E. (2015). The role of psychological resilience and mTBI as predictors of postconcussional syndrome symptomatology. *Rehabilitation Psychology*, *60*(2), 147–154.

Taylor, H.G., Dietrich, A., Nuss, K., Wright, M., Rusin, J., Bangert, B., … Yeates, K.O. (2010). Post-concussive symptoms

in children with mild traumatic brain injury. *Neuropsychology*, *24*(2), 148–159.

Thomsen, D.K., Mehlsen, M.Y., Christensen, S., & Zachariae, R. (2003). Rumination – relationship with negative mood and sleep quality. *Personality and Individual Differences*, *34*(7), 1293–1301.

Van Dyk, T.R., Thompson, R.W., & Nelson, T.D. (2016). Daily bidirectional relationships between sleep and mental health symptoms in youth with emotional and behavioral problems. *Journal of Pediatric Psychology*, *41*(9), 983–992.

Werner, E. (1997). Vulnerable but invincible: High-risk children from birth to adulthood. *Acta Paediatrica*, *86*, 103–105.

Werner, E.E., & Smith, R.S. (1992). *Overcoming the odds: High risk children from birth to adulthood*. Ithaca, NY: Cornell University Press.

Woodrome, S.E., Yeates, K.O., Taylor, H.G., Rusin, J., Bangert, B., Dietrich, A., … Wright, M. (2011). Coping strategies as a predictor of post-concussive symptoms in children with mild traumatic brain injury versus mild orthopedic injury. *Journal of the International Neuropsychological Society*, *17*(2), 317–326.

Zemek, R., Barrowman, N., Freedman, S.B., Gravel, J., Gagnon, I., McGahem, C., . . . Pediatric Emergency Research Canada (PERC) Concussion Team. (2016). Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. *JAMA*, *315*(10), 1014–1025.

Zemek, R.L., Farion, K.J., Sampson, M., & McGahern, C. (2013). Prognostic indicators of persistent symptoms following pediatric concussion: A systematic review. *JAMA Pediatrics*, *167*(3), 259–265.