

Pupillary Light Reflex Metrics Associated with Affective Neurobehavioral Symptoms in Service Members with Prior Concussion

Katrina Monti^{1,2,3}, Christina Renshaw^{1,3,4}, Katie Williams^{1,2,3}, Jamie Hershaw^{1,4,5}, Brian Guise⁶, Michael Dretsch^{1,3,4}, Stephanie Sloley¹, Katharine Stout¹

INTRODUCTION

Interest in using pupillary light reflex (PLR) to detect mild traumatic brain injury (TBI), or concussion, has increased, but its reliability for diagnosis and prognosis remains unclear. Mounting evidence suggests that PLR is influenced by psychological symptoms that commonly co-occur with post-concussive TBI symptoms, thereby confounding its clinical utility during recovery.¹⁻⁴ This study examined associations between psychological health symptoms and PLR metrics in military service members with a history of concussion and non-exposed controls.

METHODS AND MATERIALS

Three hundred military service members completed questionnaires and PLR assessments (NPi®-300, NeuroOptics®) for this cross-sectional study during soldier readiness processing. Demographics, occupational, medical, and TBI histories (modified Ohio State University TBI Method) were collected.

Psychological health measures administered:

- NSI – Neurobehavioral Symptom Inventory
- PCL-5 – Posttraumatic Stress Disorder Checklist for Diagnostic and Statistical Manual of Mental Disorders-5
- BAI – Beck Anxiety Inventory
- BDI – Beck Depression Inventory-II
- CDRISC – Connor-Davidson Resilience Scale

PLR metrics measured:

- MAX – Maximum/baseline diameter (millimeters [mm])
- MIN – Diameter at peak constriction (mm)
- PCH – Change in diameter from baseline (%)
- CV – Constriction velocity (mm/seconds [s])
- MCV – Maximum constriction velocity (mm/s)
- LAT – Time to peak constriction following onset of light pulse
- DV – Dilation velocity (mm/s)

After data reduction, 216 participants were grouped into non-exposed controls (NEC, *n* = 79), prior concussion with only alteration of consciousness (AOC, *n* = 65), and prior concussion with loss of consciousness (LOC, *n* = 72). Multivariate analysis of variance compared psychological health scores and PLR across groups (age adjusted in covariate analysis for PLR). Spearman’s rank correlation (*r_s*) examined associations between PLR and psychological health total scores and subfactor for significant total scores. Post hoc receiver operating characteristic curve analysis evaluated the accuracy of all seven PLR metrics to distinguish between low and high NSI-affective subfactor tertiles in the LOC group with acceptable threshold area under the curve (AUC) ≥ .70.

Variable	NEC (<i>n</i> = 79) M (SD)	AOC (<i>n</i> = 65) M (SD)	LOC (<i>n</i> = 72) M (SD)	<i>p</i>	<i>η</i> ²
Age, years	25.0 (5.4)	26.8 (6.8)	29.1 (7.1)	< .001*	
Sex, male, <i>n</i> (%)	58 (73.4)	53 (81.5)	69 (95.8)	.005*	
Branch, Army, <i>n</i> (%)	75 (98.7)	64 (100.0)	69 (100.0)	.415	
NSI	9.1 (11.3)	13.4 (13.4)	16.5 (13.6)	.002*	.06
PCL-5	7.4 (12.4)	10.4 (14.3)	13.2 (16.1)	.054	.03
BAI	3.9 (6.5)	5.7 (6.8)	7.8 (8.6)	.007*	.05
BDI	6.5 (7.8)	8.3 (8.4)	9.4 (8.6)	.104	.02
CDRISC	76.3 (18.2)	74.1 (14.3)	77.3 (18.8)	.570	.01

Table 1. Sample characteristics (*N* = 216), **p* ≤ .05

M= Mean; SD= Standard Deviation



Photo by Katrina Monti

Group	MAX	MIN	PCH	CV	MCV	LAT	DV
NEC (<i>n</i> = 79)							
M (SD)	4.84 (0.83)	3.20 (0.54)	33.64 (4.89)	2.87 (0.63)	4.36 (0.89)	*0.22 (0.02)	1.25 (0.25)
Median	4.89	3.10	34.00	2.83	4.38	0.22	1.29
IQR	1.36	0.87	5.50	0.90	1.40	0.03	0.35
(Q1-Q3)	(5.53-4.17)	(3.64-2.77)	(36.50-31.00)	(3.34-2.44)	(5.13-3.73)	(0.23-0.20)	(1.44-1.09)
AOC (<i>n</i> = 65)							
M (SD)	4.87 (0.81)	3.22 (0.55)	33.74 (4.46)	2.94 (0.59)	4.39 (0.83)	*0.21 (0.02)	1.25 (0.26)
Median	5.00	3.20	34.50	2.94	4.57	0.22	1.26
IQR	1.19	0.78	7.00	0.78	0.98	0.03	0.35
(Q1-Q3)	(5.39-4.20)	(3.61-2.83)	(37.50-30.50)	(3.33-2.55)	(4.86-3.88)	(0.23-0.20)	(1.45-1.10)
LOC (<i>n</i> = 72)							
M (SD)	4.78 (0.77)	3.12 (0.50)	34.51 (4.50)	2.86 (0.61)	4.36 (0.88)	0.22 (0.02)	1.24 (0.23)
Median	4.70	3.06	34.75	2.85	4.41	0.22	1.25
IQR	1.16	0.66	6.50	0.98	1.40	0.03	0.36
(Q1-Q3)	(5.39-4.23)	(3.47-2.81)	(38.00-31.50)	(3.29-2.31)	(5.03-3.63)	(0.23-0.20)	(1.42-1.06)

Table 2. PLR metrics by concussion exposure group, NEC vs. AOC vs. LOC groups, **p* ≤ .05

IQR= Interquartile Range

Subfactor	MAX <i>r_s</i>	MIN <i>r_s</i>	PCH <i>r_s</i>	CV <i>r_s</i>	MCV <i>r_s</i>	LAT <i>r_s</i>	DV <i>r_s</i>
NSI-Affective	-.018	.092	-.272*	-.342**	-.289*	.302**	-.033
NSI-Cognitive	-.201	-.151	-.137	-.212	-.208	.212	-.095
NSI-Somatosensory	-.104	-.043	-.199	-.170	-.105	.038	.035
PCL-5-Altered Arousal	-.017	.021	-.095	-.053	-.115	-.002	.031
BAI-Somatic	-.046	.007	-.155	-.124	-.163	.053	-.130
BAI-Subjective Anxiety	-.033	-.018	-.078	-.140	-.199	.125	-.090

Table 3. Correlations (*r_s*) among subfactor scores and PLR metrics in participants with prior concussion with LOC (*n* = 72)

**Correlation is significant at the .01 level (2-tailed). *Correlation is significant at the .05 level (2-tailed).

PLR Metric	AUC	SE	<i>p</i>
MAX	0.53	0.09	.721
MIN	0.46	0.09	.616
PCH	0.67	0.08	.050*
CV	0.70	0.09	.022*
MCV	0.66	0.09	.071
LAT	0.31	0.08	.030*
DV	0.48	0.09	.823

Table 4. AUC for PLR metrics to distinguish between low and high affective tertiles in LOC group, **p* ≤ .05

RESULTS

The AOC group had shorter LAT than the NEC group after adjusting for age (*p* ≤ .05). Although overall associations between PLR and psychological measures lacked significance, specific correlations emerged: one PLR metric (MIN) was associated with cognitive symptoms in the AOC group, and four (PCH, CV, MCV, LAT) were associated with affective symptoms in the LOC group (*p* ≤ .05). Two PLR metrics (PCH and CV) significantly discriminated between low and high affective symptoms in the LOC group, with CV also showing acceptable sensitivity/specificity (AUC ≥ .70).

DISCUSSION

The present study demonstrated that primarily affective neurobehavioral symptoms were associated with four of seven PLR metrics in individuals with a history of concussion involving LOC. Within the LOC cohort, individuals with elevated affective symptoms exhibited a PLR pattern characteristic of reduced parasympathetic and increased sympathetic activation. CV acceptably discriminated between high and low affective tertiles. While this study is limited by the potential reporting and recall biases inherent in self-report measures, and its correlational design precludes causal conclusions, these findings warrant further exploration. Future research should validate these results in larger, more representative samples to clarify injury pathophysiology, which has critical implications for military occupations requiring peak readiness across diverse operational environments.

CONCLUSIONS

PLR metrics, particularly CV, may reflect unresolved affective post-concussive symptoms among those with a prior concussion with LOC. The results contribute to our understanding of the relationships between concussion, post-concussive symptoms, and autonomic functioning as assessed via PLR.