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RESEARCH ARTICLE

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Patterns of post-traumatic stress symptoms in mild traumatic brain injury and their relationship with outcomes: a latent profile analysis

Josh W. Faulkner[a], Deborah L. Snell[b], Alice Theadom[c], Ian de Terte[d] and Rachel Low[a]

[a]School of Psychology, Te Herenga Waka - Victoria University of Wellington, Wellington, New Zealand; [b]Department of Orthopaedic Surgery & Musculoskeletal Medicine, University of Otago, Christchurch New Zealand; [c]Psychology and Neuroscience, TBI Network, Auckland University of Technology, Northcote, Auckland; [d]School of Psychology, Massey University, Massey University, Wellington, New Zealand

ABSTRACT

Introduction: Post-traumatic stress symptoms (PTSS) are known to contribute to postconcussion symptoms and functional status following mild traumatic brain injury (mTBI). Identifying symptom cluster profiles provide an opportunity to better understand PTSS and their influence on these outcomes. In this study, latent profiles of PTSS following mTBI were identified, and their association with mTBI outcomes was examined. The predictive role of demographic and injury related variables on profile membership was also explored.

Method: Adults (N = 252) completed self report measures of PTSS and mTBI outcomes (post-concussion symptoms and functional status) within three months of mTBI. These measures were re-administered six months later (N = 187). Latent profile analysis (LPA) was used to ascertain the latent class structure of PTSS, and regression analysis to examine predictors of profiles. ANCOVA, with general psychological distress as a covariate, revealed the relationship between profiles and mTBI outcomes.

Results: LPA identified a four-profile model to best describe PTSS at baseline. This included a resilient (49.6%), moderate (30.6%), moderate with high intrusion/avoidance (14.3%) and a highly symptomatic profile (5.6%). A secondary school education or less and/or unemployment before mTBI was significantly more likely in the highly symptomatic profile, as well as sustaining an mTBI due to an assault or motor vehicle accident. PTSS latent class membership was significantly associated with mTBI outcomes even when controlling for general psychological distress. The resilient group had significantly better outcomes at baseline and six-month follow-up. However, no significant differences in mTBI outcomes emerged between the moderate, moderate with high intrusion/avoidance and the highly symptomatic profiles.

Conclusion: The current study provides novel information on the symptom profiles of PTSS in mTBI, predictors of profile membership and their relationship with mTBI outcomes. Although future research using this approach is needed, the current study offers a more in-depth understanding of PTSS in mTBI to inform clinical care.

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Mild traumatic brain injury; post-traumatic stress; latent profile analysis; outcomes

For some individuals sustaining a mild traumatic brain injury (mTBI) can be traumatic and may involve a threat to one's life. This can be due to the nature of the event that caused the mTBI or due to the implications of the injury and its associated symptomology on one's sense of safety. Consequently, a mTBI can precipitate post-traumatic stress symptoms (PTSS; Broomhall et al., 2009; Harvey & Bryant, 1998). PTSS includes reexperiencing (i.e., flashbacks, nightmares, repetitive and distressing images or sensations), avoidance and emotional numbing (i.e., trying to avoid being reminded of the traumatic event, avoiding certain places or people, isolation, withdrawal) and hyperarousal (i.e., feeling on edge, angry outbursts, sleeping problems; Yehuda et al., 2015). The presence of PTSS in mTBI is highly variable and dependent on the characteristics and context of the studied sample. Rates of PTSS and comorbid mTBI are high in military populations due to combat exposure where physical injury and psychological trauma are common (Hoge et al., 2008; Schneiderman et al., 2008). In nonmilitary environments, PTSS following mTBI has been found to be higher than in the general population ranging from approximately 11% to 24% (Van Praag et al., 2019). For example, Hoffman et al. (2012) found that 17% of the participants (n = 234) with mTBI enrolled in the emergency department, had PTSS at six months after their injury.

The presence of PTSS after mTBI is consistently associated with a range of neurobehavioural outcomes including worse scores on measures of depression,

CONTACT Josh W. Faulkner josh.faulkner@vuw.ac.nz School of Psychology, Victoria University of Wellington, PO Box 600, Wellington, New Zealand

anxiety, post-concussion symptoms, life satisfaction, functional disability and overall physical health (Combs et al., 2015; Haarbauer-Krupa et al., 2017; Jackson et al., 2016; Lange et al., 2020, 2021; MacDonald et al., 2014). For example, in a four-way group design, Merritt et al. (2019) compared psychiatric and post-concussion symptoms and functional outcomes in military veterans with comorbid mTBI and PTSS, mTBI only, PTSS only and combat control. Veterans with comorbid mTBI and PTSS had significantly more severe symptoms, as well as higher rates of service-connection disability and a greater perceived decline in work and education-related abilities. Interestingly, in a recent study, Lange et al. (2021) examined 536 service members and veterans in the subacute to the chronic phase of recovery after mild, moderate and severe TBI; PTSS was found to be a stronger predictor of neurobehavioural outcomes than TBI severity. Furthermore, the presence of PTSS also increases the risk of experiencing persistent symptoms and longer recovery after mTBI (Haagsma et al., 2015; Lange et al., 2020; Scheenen et al., 2017; Stulemeijer et al., 2008). For example, Stulemeijer et al. (2008) found that in 539 individuals presenting to the emergency department following mTBI, absence of premorbid physical problems, low levels of post-concussion symptoms and PTSS early after the injury had a 90% chance of predicting those remaining free of post-concussion symptoms six months later. These findings highlight the importance of identifying and examining PTSS in mTBI to inform prevention, as well as intervention efforts.

A growing body of research has utilized Latent Profile Analysis (LPA) to examine PTSS in a range of different populations. LPA is a statistical method that allows for the identification of heterogenous subtypes within a clinical presentation based on a certain set of variables (Armour & Hansen, 2015; Hansen et al., 2015; Maguen et al., 2013; Murphy et al., 2019). LPA has been applied to understand the manifestation of PTSS in a range of populations including community samples (Breslau et al., 2005), earthquake survivors (Eisma et al., 2019), childhood sexual abuse (Hébert & Amédée, 2020) and refugees (Sengoelge et al., 2019). LPA investigations of psychological trauma have resulted in profiles classified primarily by symptom severity, and the number of identified profiles ranges from two to six.

The use of LPA to examine PTSS in mTBI is currently very limited. Straud et al. (2023) applied this approach to a sample (n = 315) of service members who were within one week of a blast injury. Of note, mTBI was not formally assessed and diagnosed in this study; however, this mechanism is known to induce injury to the brain (Hernandez et al., 2018). Further in this study, differences in post-concussion symptoms were examined across latent profiles. A 3-profile solution was identified as being the best fitting model with the groups defined based on symptom severity. These profiles were defined as follows: 1) resilient (46.4%), 2) moderate hyperarousal/dissociation (33.3%) and 3) at risk (20.3%). Blast-injured service members in the at-risk group had significantly higher PTSS. Furthermore, profiles 2 and 3 were more likely to demonstrate post-concussive symptoms compared to profile 1. A three-profile solution of PTSS is consistent with other veteran research studies that did not include mTBI (Armour et al., 2015; Contractor et al., 2015; Steenkamp et al., 2012). Although, additional PTSS studies with veteran samples have identified five and six-profile solutions (Maguen et al., 2013; Murphy et al., 2019). Given the unique characteristics and environmental context associated with veteran and service member research, there is a need to explore PTSS profiles in civilian samples. Thus, the overall aim of this research study is to begin this endeavor and extrapolate the latent class structure of PTSS in an mTBI civilian sample. Furthermore, this study also aims to investigate predictors of class membership by demographic (i.e., gender and education) and injury-related variables (i.e., the mechanism of injury). Finally, the association between latent class membership and baseline (within three months of injury) and long-term (six month post-injury) mTBI outcomes (post-concussion symptoms and functional status) will also be examined.

Method

Study design

This is a longitudinal study recruiting adults on presentation to outpatient mTBI clinics throughout New Zealand. This is a secondary analysis from participants recruited as part of two studies utilizing similar methods of recruitment and outcome measures. At recruitment sites, a clinician used the inclusion and exclusion criteria to identify potentially eligible participants and invited them to participate. Inclusion criteria : 1) were 17 years or older; 2) were sustained an mTBI according to World Health Organization Neurotrauma Taskforce criteria (Holm et al., 2005); 3) were less than three months post-injury; 4) were able to answer questions in English; and 5) had no prior neurological condition or severe unstable medical condition. Details of eligible and consenting participants were then shared with the research team who contacted the participant within one week and formally enrolled them into the study. Participants

then completed baseline questionnaires via REDCap (Eisma et al., 2019), a secure web-based platform, or via telephone. Data were collected at baseline, on average 6.34 weeks after injury and six months later (on average 31.85 weeks post-injury). Ethical approvals for the study were obtained from the Auckland University of Technology ethics committee (ref: 20/32) and the National Health and Disability Ethics Committee (ref: 18/CEN/79).

Measures

Clinical and Demographic Variables: A range of demographic and clinical variables were ascertained via a self-report questionnaire. Demographic variables included: age, sex, highest education level, pre-injury employment status, as well as pre-injury history of mental and physical health conditions including concussion history. Injury-related variables included time since injury, mechanism of injury, and other injuries sustained concurrently with mTBI.

Post-traumatic stress symptoms

The Impact of Events Scale-Revised (IES-R). This is a 22-item self-report symptom scale that assesses PTSD symptoms in accordance with the DSM-IV criteria associated with a specific traumatic event. It utilizes a 5-point Likert scale with 0 = "not at all," 1 = "a little bit," 2 = "moderately," 3 = 'quite a bit, and 4 = "extremely" (Weiss, 2007). The IES-R compromises three subscales: Intrusion, Avoidance, and Hyperarousal. The IES-R asks respondents to indicate the degree to which they experienced each symptom in the past week. Higher IES-R scores indicate higher perceived psychological distress. Consistent with previous research (Creamer et al., 2003), the IES-R had high internal consistency in this study (Cronbach's alpha = 0.95). Total scores were calculated by combining each of the subscale scores, ranging from 0 to 88.

mTBI outcomes

Post-concussion symptoms. The Rivermead Post-Concussion Symptom Questionnaire (RPQ) is a 16-item self-report questionnaire that assesses common symptoms following mTBI (King et al., 1995). The RPQ consists of somatic symptoms (headaches, dizziness, nausea and vomiting, noise and light sensitivity, sleep disturbance, and double vision); cognitive symptoms (forgetfulness/poor memory, poor concentration, and taking longer to think); and emotional symptoms (being irritable/easily angered feeling depressed or tearful, feeling frustrated or impatient). Participants rated the presence and problem status of these symptoms on a scale of 0–4 (0 = not experienced at all; 1 = no more of a problem than before injury; 2 = a mild problem; 3 = a moderate problem; 4 = a severe problem). Scores of 1 were recoded to 0 following the recommendations of King et al. (1995).

Functional status. The 12-item World Health Organization Disability Assessment Schedule (WHODAS 2.0) is a questionnaire of functional status representing six domains including cognition, self-care, mobility, interpersonal functioning, life activities, and participation (Üstün et al., 2010). The WHODAS 2.0 asks respondents how much difficulty they have had in the past 30 days in relation to all their health problems for each of the 12 items. The Likert scale options are: 0 = none, 1 = mild, 2 = moderate, 3 = severe, and 4 = extreme/cannot do (higher scores represent greater disability). Consistent with previous studies (Saltychev et al., 2021), the 12-item WHODAS 2.0 showed high internal consistency in mTBI (Cronbach's alpha = 0.88).

Psychological distress. The Depression, Anxiety and Stress Scale-21 (DASS-21; Lovibond & Lovibond, 1995) is a 21-item self-report with three subscales that measure depression, anxiety, and stress over the previous week. It utilizes a 4-point Likert scale with 0 = never, 1 = sometimes, 2 = often, and 3 = always. Higher scores on this measure are indicative of elevated levels of depression, anxiety, and stress symptoms. The DASS-21 has good psychometric properties (Cronbach's alpha = 0.73–0.81; Lovibond & Lovibond, 1995) and is a valid measure of depression, anxiety and stress symptoms in people with ABI (Ownsworth et al., 2008). In this study, total DASS-21 scores were calculated to reflect an indication of general distress (Zanon et al., 2021). This measure encapsulates a more general manifestation of psychological difficulties than the IES-R which only includes negative affect, and the RPQ which contains specific items to quantify feelings of depression, irritability, and frustration.

Data analysis

Prior to conducting the LPA on the baseline data, the IES-R was converted into mean symptom cluster scores corresponding to PTSS of intrusion, avoidance, and alterations in arousal and reactivity. Symptom clusters were used in this analysis to allow for a reduced number of indicators to account for the current sample size and to facilitate interpretation. Models with an increasing number of latent profiles were estimated with MPlus 8.0 (Murphy et al., 2019) using the symptom cluster scores

at baseline. Relative model comparisons were completed using Log Likelihood (LL), Akaike Information Criterion (AIC), Consistent AIC (CAIC), Bayesian Information Criterion (BIC) and Sample Size Adjusted BIC (SABIC) fit statistics (SABIC) fit statistics (Samuelsen & Raczynski, 2013). Lower values on these indices suggest a better model fit and can be informative for explanatory purposes. Entropy values were also used to determine the model fit. Entropy values approaching 1.0 (<.80) indicate good class separation and model fit (Masyn, 2013). The Lo-Mendell-Rubin adjusted likelihood ratio test (VLMRA) and Bootstrapped likelihood ratio test (BLRT) were used to compare models with different numbers of profiles. A significant p value ($p < .05$) on the VLMRA and BLRT indicates that the current model has a better fit in comparison to the previous model (Nylund et al., 2007). When deciding on the optimal number of profiles, parsimony, meaningfulness and ease of interpretation were also considered. In addition, the smallest profile percentage was calculated to inform the utility of additional profiles. Profiles with fewer than 5% of the participants in the sample can be considered spurious or nonviable (Nylund et al., 2007). Once the optimal model was decided upon, each participant was assigned to their most likely profile. This procedure has some degree of classification error; however, if entropy values are high, the error is minimal. Each symptom profile was labeled to reflect the distribution of symptoms within each class.

After selecting the optimal latent class model, we next examined the role of demographic and clinical variables on class membership using multinomial logistic regression. Demographic factors (i.e., age, gender, pre-injury employment status, medical, concussion and psychiatric history) and clinical variables (i.e., mechanism of injury and other injury sustained) were entered into a model to determine the variable that was significantly associated with PTSS latent class membership. Finally, we examined the association between class membership and mTBI outcomes (post-concussion symptoms and functional status) at baseline and six-month follow-up using analysis of covariance (ANCOVA). Psychological distress at baseline and at six months was entered in as a covariate in each analysis to control for the effects that general psychological distress may have on the relationship between PTSS class membership and mTBI outcomes. When the tests produced significant differences, post-hoc analyses with Bonferroni tests were used to examine these differences.

Results

Participant characteristics

The demographic and clinical characteristics of the sample at the baseline (n = 252) and at the six-month follow-up (n = 187) are presented in Table 1. There were no significant differences between the characteristics of the baseline and the six-month follow-up group.

Latent profile membership

We conducted six LPA model solutions for PTSS, and the model fit statistics are presented in Table 2. Model fit indices indicated that as the number of profiles increased the AIC, BIC, SABIC fit indices generally improved. All entropy values were greater than .80 across models. Taken together, the fit statistics did not point to a single superior model, and the BRLT was significant for all models. However, models 5 and 6 contained profiles of

Table 1. Participant characteristics.

Demographic Characteristics	Baseline (N = 252)	Six Month Assessment (N = 187)	P value
Age [Mean (SD, range)]	37.02 (14.17, 17–76)	37.53 (14.15, 17–76)	.171
Sex (female) [N (%)]	160 (63.5%)	122 (65.2%)	.705
Ethnicity [N(%)]	170 (67.5%)	132 (70.6%)	.040
– NZ European	82 (32.5%)	55 (29.4%)	
– Other			
Education – n with post-secondary school qualification [N(%)]	163 (64.7%)	122 (65.2%)	.904
Pre-Injury Employment Status [N(%)]	185 (73.4%)	155 (82.9%)	.019
– Working	67 (26.6%)	32 (17.1%)	
– Not working			
Prior Mental Health History (yes) [N(%)]	135 (53.6%)	100 (53.5%)	.984
Prior Concussion History (yes) [N(%)]	112 (44.4%)	82 (43.9%)	.901
Pre-injury Medical Diagnosis (yes) [N(%)]	99 (39.3%)	80 (42.8%)	.461
Clinical Characteristics			
Time Since Injury (weeks) [Mean (SD, range)]	6.29 (2.48, 2.0–12.0)	31.59 (3.37, 24.0–42.0)	
Mechanism of Injury			.284
– Transport accident	38 (15.1%)	26 (13.9%)	
– Fall	90 (35.7%)	66 (35.3%)	
– Assault	23 (9.1%)	15 (8.0%)	
– Head versus object	101 (40.1%)	80 (42.8%)	
Other Injury Sustained (yes) [N(%)]	137 (54.4%)	104 (55.6%)	.795

Table 2. Model Fit Information Determining Number of Latent Class.

Profiles	AIC	BIC	SSABIC	Entropy	VLMRA (*p* value)	BLRT
1	5087.50	5108.77	5089.75	-	-	-
2	4663.84	4699.29	4667.58	0.923	<.001	<.001
3	4506.18	4555.81	4511.43	0.892	0.154	<.001
4	**4398.55**	**4462.36**	**4405.30**	**0.914**	**0.012**	**<.001**
5	4367.72	4445.71	4375.96	0.929	0.149	<.001
6	4342.71	4434.88	4352.46	0.933	0.096	<.001

Note. AIC = Akaike Information Criteria; BIC = Bayesian Information Criteria; SABIC = sample size adjusted BIC; VLMRA = Lo-Mendell-Rubin adjusted likelihood ratio test, BLRT = Bootstrapped likelihood ratio test. Optimal model in bold.

less than 5% of the sample and therefore contained groups with such small numbers of individuals that inferences from these would be limited. For example, model 6 contained a profile with just 7 individuals and only 2.73% of the sample. Thus, the four-profile solution was deemed most optimal for the data. The four-profile solution demonstrated good model fit indices (e.g., AIC = 4398.55, BIC = 4462.36), Entropy above 0.80 (0.88), and significant lo-Mendell-Rubin adjusted likelihood ratio test (p = 0.012) and bootstrap ratio likelihood ratio test (BLRT, p < 0.001). The latent profile classification probabilities of membership for the four-model solution were all greater than 90%, with overall good discrimination between latent profile membership. Membership proportions for each of the four profiles were as follows: 49.6% in Profile 1, 30.6% in Profile 2, 14.3% in Profile 3 and 5.6% in Profile 4. Overall, the first profile had low scores across symptoms and was therefore defined as "Resilient." The second profile was defined as "Moderate" based on moderately raised scores across symptoms. The third profile was defined as "Moderate High Intrusion/Avoidance (Int/Av)" with moderately elevated symptoms but higher intrusion and avoidance symptoms. The final profile (profile 4) was defined as "Highly Symptomatic" based on elevated severity scores across all PTSS (see Figure 1)

Predictors of class membership

A multinomial regression analysis was conducted with the resilient profile as the reference to examine the demographic and clinical factors that influence the likelihood of participants belonging to the latent classes (see Table 3). Participants who had a secondary school education or less or who were unemployed before their mTBI were significantly more likely to be in the highly symptomatic profile (odds ratio [OR] = 0.19, p = 0.021 and OR = 8.00, p = 0.002, respectively). In regard to clinical characteristics, compared to the resilient profile, participants who experienced their mTBI from a motor vehicle accident or assault were significantly more likely to be in the moderate (OR = 3.84, p < 0 .001), then the moderate with high int/av (OR = 4.57, p = 0.01), and then the highly symptomatic profile (OR = 7.16, p < 0.001).

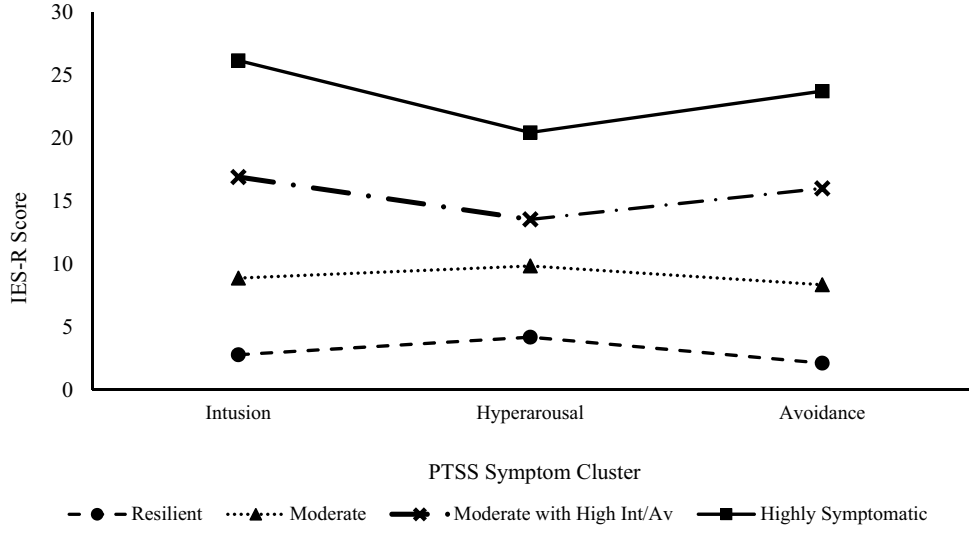

Figure 1. Mean PTSS cluster scores in the three latent profiles.

Table 3. Multinomial regression analysis for the latent classes of PTSS.

	B	SE	Exp(B)	95%CI	*p*
Moderate					
Age	−0.01	0.01	1.00	0.98–1.02	.942
Gender	0.15	0.33	1.16	0.61–2.20	.657
Education	−0.24	0.31	0.78	0.41–1.50	.461
Pre-Injury Work	0.64	0.36	1.90	0.95–3.82	.070
Medical History	−0.02	0.33	1.00	0.53–1.87	.998
Concussion History	−0.12	0.31	0.89	0.48–1.64	.701
Mental Health History	−0.28	0.31	0.75	0.41–1.38	.363
Mechanism of Injury	1.35	1.46	3.84	1.89–7.84	<.001**
Other Injury	−0.11	0.31	0.90	0.49–1.65	.728
Moderate with High Int/Av					
Age	−0.01	0.02	1.00	0.97–1.02	.773
Gender	−0.64	0.41	0.53	0.23–1.18	.121
Education	−0.44	0.43	0.64	0.28–1.48	.299
Pre-Injury Work	0.69	0.46	1.99	0.81–4.85	.132
Medical History	−0.39	0.44	0.68	0.29–1.60	.377
Concussion History	0.05	0.42	1.05	0.47–2.40	.861
Mental Health History	0.07	0.41	1.08	0.48–2.40	.674
Mechanism of Injury	1.52	0.41	4.57	2.06–10.11	<.001**
Other Injury	−0.61	0.42	0.54	0.24–1.24	.146
Highly Symptomatic					
Age	0.01	0.51	1.00	0.96–1.06	.709
Gender	1.25	0.76	3.48	0.78–15.36	.100
Education	−1.69	0.73	0.19	0.04–0.78	.021*
Pre-Injury Work	2.08	0.68	8.00	2.12–30.15	.002**
Medical History	0.45	0.75	1.57	0.36–6.83	.549
Concussion History	−0.35	0.68	0.71	0.19–2.67	.606
Mental health History	−0.31	0.69	0.74	0.19–2.84	.657
Mechanism of Injury	1.97	0.51	7.16	2.62–19.61	<.001*
Other Injury	−2.65	`.09	0.07	0.01–0.60	.015**

[a]Reference group is the low symptom class.
** p < .05, * p < .01,
Referred to: male, post-secondary school education, working before mTBI, no medical history, no mental health history, no concussion history, mechanism of injury: accidental (head versus object, fall), did not sustain another injury when the mTBI occurred

Table 4. Comparison of mTBI outcomes at baseline and at six-month follow-up between each latent profiles of PTSS.

		Mean difference	Std. Error	95% CI	*p*
Post Concussion Symptoms at Baseline	Resilient vs.				
	Moderate	−5.67	1.63	−10.02 – −1.36	.003
	Moderate High Int/Av	−7.76	2.23	−13.68 – −1.84	.003
	Highly Symptomatic	−9.60	3.61	−19.19 – .001	.050
	Moderate vs.				
	Moderate High Int/Av	−2.07	2.12	−7.72–3.57	1.00
	Highly Symptomatic	−3.91	3.34	12.80–4.99	1.00
	Moderate High Int/Av vs				
	Highly Symptomatic	−1.83	3.41	−10.91–7.24	1.00
Post Concussion Symptoms at Six Month Follow-Up	Resilient vs.				
	Moderate	−4.04	1.65	−8.43–0.35	.091
	Moderate High Int/Av	−6.99	2.21	−12.89 – −1.10	.011
	Highly Symptomatic	−13.30	3.59	−22.88 – −3.73	.002
	Moderate vs.				
	Moderate High Int/Av	−2.95	2.35	−9.22–3.32	1.00
	Highly Symptomatic	−9.26	3.65	−19.00–0.47	.072
	Moderate High Int/Av vs. Highly Symptomatic	−6.31	3.94	−16.83–4.21	.668
Functional Status at Six Month Follow-Up	Resilient vs.				
	Moderate	−2.60	1.12	−5.59 -. 390	.129
	Moderate High Int/Av	−5.47	1.51	−9.49- −1.45	.002
	Highly Symptomatic	−9.64	2.45	−16.17 – −3.12	<.001
	Moderate vs.				
	Moderate Int/Av	−2.87	1.60	−7.14–1.40	.449
	Highly Symptomatic	−7.04	2.49	−13.67 – −0.47	.031
	Moderate High Int/Av vs				
	Highly Symptomatic	−4.17	2.69	−11.34–3.00	.734

Class membership and mTBI outcomes

PTSS class membership was significantly associated with higher post-concussion symptoms at baseline whilst including psychological distress as a covariate ($F(3,251) = 5.94$, $p < 0.001$). As shown in Table 4, post hoc comparisons revealed significantly higher post-concussion symptoms in all other groups compared to the resilient profile at baseline. There was no significant difference on post-concussion symptoms at baseline between the moderate, moderate high int/av and highly symptomatic profiles. PTSS class membership was not significantly associated with functional status at baseline when including psychological distress as a covariate ($F(3.251) = 2.03$, $p = 0.110$). At six month follow-up, PTSS class membership was significantly associated with higher post-concussion symptoms ($F(3,187) = 7.36$, $p < 0.001$) and lower functional status ($F(3,187) = 8.61$, $p < 0.001$). Posthoc comparison revealed that the resilient profile had significantly lower post-concussion symptoms and better functional status than the moderate high int/av and highly symptomatic profiles, but there was no significant difference with the moderate profile. There were no significant differences between post-concussion and functional status between the moderate, moderate high int/av and highly symptomatic profiles; except, the moderate profile had significantly better functional status than the highly symptomatic profile (see Table 4).

Discussion

The objective of this study was to examine the latent class structure of PTSS in a mTBI civilian treatment-seeking sample. We found that a 4-profile solution was deemed the most optimal model for fitting PTSS symptoms for individuals who were within three months of mTBI. These profiles were defined as "resilient," "moderate," "moderate with high intrusion/avoidance," and "highly symptomatic" based on the characteristics of PTSS. Despite our sample being treatment-seeking civilians with a mechanism of injury most likely to be head trauma from an object (40.1%), PTSS symptom elevation was fairly common. 30.6% of the participants clustered into the moderate profile, 14.3% in the moderate with high avoidance/intrusion profile and 5.6% in the highly symptomatic profile. These findings are consistent with a body of evidence that illustrates that individuals with mTBI are at risk of experiencing PTSS following injury (Carlson et al., 2011; Hoffman et al., 2012; Van Praag et al., 2019).

To the best of our knowledge, this is the first study that has examined the latent class structure of PTSS in a civilian mTBI sample. Regarding the factor structure of PTSS in other populations, there is marked variability in the literature, with studies ranging from two to six profiles. These differences are likely reflective of the differing traumatic experiences studied, the measures of PTSS used and the characteristics of the sample. However, our findings of a four-profile structure are aligned with some studies that have examined PTSS in other populations (i.e., firefighters; Chung & Breslau, 2008), flood victims (Zhen et al., 2020), and civilian trauma survivors (Shih et al., 2023). Specifically, regarding mTBI, Straud et al. (2023) identified a 3-profile solution in service members who had sustained blast injury within one week of injury. These differences are likely to reflect marked differences in the characteristics of injury (i.e., mechanism, acutely) and participants (i.e., military sample) when compared to our study using a civilian sample. Although, consistent with Straud et al. (2023) the profile solution in our study was characterized by symptom severity. Interestingly, Straud et al. (2023) identified a profile with moderate dissociation/hyperarousal. In our study, a profile emerged for individuals with moderately elevated symptoms with higher intrusion and avoidance. Although future research is needed, these findings suggest that unique patterns of PTSS symptoms may be evident following mTBI and symptoms do not differ quantitatively based on symptom severity in the same manner across PTSS. This supports the ongoing use of latent profile analyses for the examination of PTSS in mTBI to ensure that these unique patterns can be extracted.

This study also aimed to examine demographic and injury-related predictors of latent profile membership. Unsurprisingly, we found that the mechanism of injury had a significant effect. If the injury was sustained due to an assault or a motor vehicle accident, participants were significantly more likely to be classified as moderate, moderate with high int/av, and highly symptomatic profiles, with the odds ratio increasing across each of these profiles. MTBI occurring within this context is associated with actual or threatened death and serious injury, the defining features of trauma. Regarding demographic factors, only education and pre-injury work history were significantly associated with profile membership. More specifically, participants who had a secondary school education or less, and/or were unemployed before their mTBI were significantly more likely to be in the at-risk profile. Previous studies in the general population have shown that educational history is associated with inferior mental health outcomes and is a risk factor for the development of PTSS (Brewin et al., 2000; Tang et al., 2017). The effect of pre-injury employment on PTSS latent structure membership may

also reflect an indirect consequence of education history, as well as socioeconomic status and economic hardship, which is also a known risk factor for the development of PTSS (DiGangi et al., 2013).

The final aim of this study was to examine the association between PTSS latent class structure and mTBI outcomes. This occurred at two-time points; baseline (within three months of injury) and at six-month follow-up. First, regarding mTBI outcomes at baseline, significant differences were found based on the latent class profiles; however, this was only evident for post-concussion symptoms. Specifically, participants in the resilient profile had significantly lower post-concussion symptoms than all of the other profiles. This finding is consistent with evidence demonstrating that PTSS is significantly associated with more severe post-concussion symptoms after mTBI (Combs et al., 2015; Haarbauer-Krupa et al., 2017; Jackson et al., 2016; Lange et al., 2020, 2021; MacDonald et al., 2014). These findings are not surprising considering the non-specificity of the post-concussion symptoms and the high degree of symptom overlap between mTBI and PTSS (Stein & McAllister, 2009). For example, negative alterations in cognition and mood, behavioral impairment, sleep disturbances, avoidance and emotional lability are common in both conditions. Moreover, mTBI may also lead to emotional numbing, derealization, depersonalization and amnesia, which are also common PTSS (Zhang et al., 2021). In support of this, individuals with PTSS without mTBI, often report symptoms that mimic that of mTBI (Dieter & Engel, 2019). At six-month follow-up, consistent with baseline outcomes, the resilient profile continued to have significantly lower post-concussion symptoms compared to all other profiles. At this time point, this group also had significantly better functional status. Of note, these findings still emerged even when controlling for general psychological distress, which suggests that these findings may be driven by symptoms that are more specific to PTSS. However, interestingly, at six-month follow-up, there were no significant differences between the moderate, moderate with high int/av and the highly symptomatic profiles on post-concussion symptoms and functional status. Albeit, the moderate group had significantly better functional status than the highly symptomatic profile. These findings suggest that even moderately elevated PTSS symptoms may contribute to the persistence of post-concussion symptoms over time and result in poor outcomes. The clinical implication of this finding is significant. It highlights the importance of identifying PTSS in the early stages of mTBI recovery and ensuring treatments are put in place early to mitigate the influence these have on mTBI outcomes. In addition, clinicians may benefit from attending to and focusing on the management of intrusion and avoidance symptoms given the unique implications these symptoms have in differentiating symptom clusters and impacting longer-term outcomes. Our findings suggest that this should not only occur for individuals who present with severe PTSS but also if PTSS symptoms are moderately elevated.

Although this study provides unique insights into the nature and implications of PTSS in mTBI, there are limitations that need to be considered. First, PTSS was identified using three symptom clusters (avoidance, hyperarousal, and intrusions). Although these symptoms are considered central to PTSS (Yehuda et al., 2015), there are differences in the way researchers conceptualize PTSS. Although the ICD-11 continues to adopt a three-symptom cluster classification of PTSS (World Health Organization, 2019), the fifth edition of the Diagnostic and Statistical Manual of Mental Health Disorders now includes a fourth symptom cluster: negative alterations in mood and cognition (American Psychiatric Association, 2013). In addition, it has also been proposed that dissociation is a hallmark feature of PTSS (Armour et al., 2014; Nugent et al., 2012). The literature is varied with LPA being used with three symptom clusters of PTSS (e.g., Armour et al., 2015; Contractor et al., 2015; Steenkamp et al., 2012) four symptoms (e.g., Itzhaky et al., 2017; Zhen et al., 2020) and five (e.g., Maguen et al., 2013; Murphy et al., 2019). It is important that future research adopting an LPA approach to understand PTSS in mTBI also considers these additional symptom clusters. Second, participants were recruited through specialty rehabilitation outpatient clinics who were referred to this service for treatment. Thus, our sample represents a sub-population of people with mTBI, with higher levels of risk factors and the potential for poorer long-term outcomes. Our sample is therefore not representative of the wider mTBI population. Also, we did not assess the re-occurrence of mTBI between the baseline and the six-month follow-up period. This would need to be addressed in future studies. In addition, our study did not include a measure of symptom validity and therefore this needs to be kept in mind when interpreting the results of these findings. Recent research has modified the Rivermead Post-Concussion Symptom Questionnaire to include endorsement of atypical post-concussion symptoms (i.e., hemiplegia; Sullivan et al., 2023). These modifications were not included in our measure, and future research could benefit from its inclusion. However, the inclusion of these items may only identify those with overt malingering and similar measures, such as the Mild Brain Injury Atypical Symptom Scale, have been found to

have low sensitivity (Lange et al., 2015). Future research should consider various explanations for issues with symptom validity, such as engagement, factitious disorder, motivation, and careless responding. These factors should be controlled and measured where possible in further research in this domain. Finally, the presence/absence of PTSS was determined in this study using a self-report measure, the Impact of Events Scale-Revised. This is a screening tool and, as such, does not allow for the formal diagnosis of post-traumatic stress disorder (PTSD). We also did not ascertain if the source of PTSS was from the mTBI itself, from another traumatic event, or was present before the mTBI. Future research would benefit from using LPA with a more rigorous diagnostic approach (i.e., Structured Interview for PTSD), as well as identification of the source of the trauma.

In conclusion, findings from the present study provide unique insights into the subtypes of PTSS following mTBI in a civilian sample with a four-profile structure identified. Latent profile membership was found to be significantly associated with mTBI outcomes both in the short and long term. Importantly, our findings suggest that the clinical identification and management of PTSS symptoms at even a moderately elevated level may be needed in order to mitigate poorer mTBI outcomes over time. Finally, specific demographic and injury-related characteristics were found to increase the risk of membership in certain PTSS latent profiles. However, future work is required to examine the latent structure of PTSS in accordance with differing conceptualizations and symptom classifications.

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ORCID

Josh W. Faulkner http://orcid.org/0000-0001-9555-4628

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