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Factors associated with variability in recovery after mild traumatic brain injury among adults referred to outpatient concussion clinics

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ABSTRACT

Background. To understand factors associated with symptom and disability recovery trajectories among adults referred to outpatient clinics after mild traumatic brain injury. **Methods.** Adults (n = 110; mean age 39 years, 36% men), were assessed at clinic intake (baseline mean 6.5 weeks), and monthly thereafter for 6 months. Validated questionnaires assessed distress, fear avoidance and catastrophising at baseline, and mild traumatic brain injury symptoms and disability. Using correlations and linear mixed modelling, we explored associations between demographic characteristics (age, gender), baseline psychological factors and recovery as a function of time. **Results.** The models predicted improvement in symptoms (R^2 = 0.22) and disability (R^2 = 0.37). After adjusting for baseline severity of symptoms and disability, higher distress was associated with slower recovery and greater variability for symptoms (P = 0.06) and disability (P < 0.01). Higher baseline catastrophising predicted less symptom improvement (P = 0.02). Those with higher fear avoidance behaviour at baseline showed greater variability in disability outcomes (P = 0.02), even when other psychological variables were accounted for. **Conclusions.** Participants showed improvements on average, in both symptoms and disability. Variability and rates of recovery were associated with distress, catastrophising and fear avoidance. Clinicians can target such psychological factors in treatment and anticipate recovery fluctuations, normalising these while maintaining cautiously optimistic messaging regarding expected good prognosis after mild traumatic brain injury.

Keywords: adults, catastrophising, distress, disability outcomes, fear avoidance, mild traumatic brain injury, mTBI symptoms, recovery expectations.

Introduction

Concussion, also known as mild traumatic brain injury (mTBI) when neuroradiology is negative or not clinically indicated (Silverberg *et al.* 2023), is a common injury (Silverberg *et al.* 2020). Recovery is expected within the first weeks to months after injury (Belanger *et al.* 2010; Karr *et al.* 2014; Iverson *et al.* 2019), although it is clear that cognitive, emotional and somatic symptoms, along with functional difficulties, can persist for some (Theadom *et al.* 2016, 2017; Dikmen *et al.* 2017; Cancelliere *et al.* 2023). A more nuanced understanding of factors associated with mTBI recovery and recovery variability may help direct treatment efforts and improve outcomes.

There are a few longitudinal studies that have examined symptom recovery trajectories, primarily inception cohort studies; that is, studies recruiting in the acute setting after mTBI. For example, a recent study used growth curve modelling to identify patterns of symptomatic recovery 3 and 6 months after mTBI, among people presenting to an emergency department (ED; Keatley *et al.* 2023). In that study, different trajectories were identified, with some participants endorsing few

symptoms at assessment points, some clearly improving between assessment points, and some participants endorsing worsening difficulties. Another study examined factors associated with different recovery trajectories 3 and 12 months after mTBI, also among people attending an ED or Level 1 trauma centre (Fordal *et al.* 2022). Those with significant persisting post-concussion symptoms at both baseline and follow up were more likely to have preinjury and psychological risk factors, such as distress, negative recovery expectations, reduced employment, pain, poor sleep, low resilience, high neuroticism and pessimism, and a psychiatric history. In keeping with these findings, King *et al.* (2025) identified heterogeneity in both symptom presentation and 12-month symptom recovery patterns associated with catastrophising, activity avoidance and depression among 180 adults with mTBI presenting to an ED in the Netherlands. Although these studies underscore variability in symptom recovery trajectories, less is known about other recovery patterns and outcomes in people seeking treatment at dedicated outpatient concussion services, who likely represent a unique sub-population with differing risk factors, particularly those in the psychological domain (Mikolić *et al.* 2023).

Outcomes, as measured by symptoms versus functional disability, may not follow the same trajectories. Although symptom burden and functional difficulties appear to be correlated (Wågberg *et al.* 2023; Magnusson *et al.* 2024), it is unclear whether symptoms and functional difficulties improve at similar or different rates, how closely they track or when each plateaus, and in what order. That is, do symptom improvement and functional gains occur together, do symptoms lag behind functional gains (or vice versa), is recovery more rapid in early weeks or is symptomatic and functional recovery steady over time? Furthermore, individuals are often referred to tertiary services, such as concussion services, because they have risk factors for slow recovery, such as a high symptom burden and functional difficulties. Accordingly, recovery trajectories may vary between this subgroup and the more unselected cohorts recruited from EDs and primary care.

Study objectives

The objectives of this study were to describe symptom and functional disability recovery, measured every 4 weeks for 6 months after baseline assessment, among treatment-seeking adults referred to specialty outpatient clinics after mTBI. We report on recovery rates, comparing symptom and disability outcomes, and characterise recovery variability patterns. We were also interested in demographic and clinical variables associated with recovery variability, with special focus on early psychological factors including anxiety, stress and depression symptoms, catastrophising, and fear avoidance.

Materials and methods

Study design

This was a prospective observational study following participants after mTBI for 6 months following baseline assessment. Participants were recruited from outpatient clinics providing rehabilitation services for mTBI in New Zealand between February 2019 and October 2021. Participating clinics were funded by New Zealand's government-funded injury insurance scheme with standard operating procedures across all clinics, and provision of occupational therapy, physiotherapy, medical assessment, psychology and neuropsychology as indicated at initial clinic triage assessment. Data were collected at enrolment (baseline assessment: mean 6.5 weeks after injury (s.d. 2.8), range 2–13 weeks), once every 4 weeks thereafter by phone, and then at a final assessment 6 months after the baseline assessment (final assessment: mean 30.6 weeks post-injury (s.d. 3.9), range 23–40 weeks). Data collection was undertaken remotely during periods of restriction and lockdown in New Zealand during the COVID-19 pandemic.

Participants

Eligible potential participants were approached by a clinician from the outpatient clinic to invite participation. Eligibility criteria were: (1) aged ≥16 years, (2) sustained an mTBI according to World Health Organization Neurotrauma Taskforce criteria (Holm *et al.* 2005), as applied by medical review, (3) were no more than 12 weeks post-injury at enrolment, (4) were fluent in English, and (5) had no prior neurological condition or severe unstable medical condition (e.g. respiratory illness, cancer), including a past history of moderate-to-severe traumatic brain injury. A prior history of mTBI was not an exclusion criterion.

Data collection and measures

Demographic and clinical variables

Demographic and clinical data to characterise the sample were collected and managed using REDCap electronic data capture tools hosted at the University of Otago, following invitation and written consent to participate in the study. These included age at injury, gender, ethnicity, highest education level, mechanism of injury, self-reported post traumatic amnesia, mental health history, history of previous mTBI and treatment received in the outpatient service. For gender and education, we asked participants to state their gender and highest educational qualification, respectively. For ethnicity, we used the standardised ethnicity categories provided by the New Zealand Department of Statistics (www.stats.govt.nz).

Symptom outcome

The Rivermead Post-Concussion Symptoms 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). A total score was calculated by summing all 16 items, with scores of 1 recoded to 0, as recommended by King *et al.* (1995). Rasch analysis has shown that the RPQ total score demonstrated good internal consistency in a traumatic brain injury sample (person separation index = 0.87; Balalla *et al.* 2020). Symptoms were measured using the RPQ at all assessment points.

Functional disability outcome

The World Health Organization Disability Assessment Schedule (WHODAS 2.0) is a 12-item questionnaire evaluating functional disability representing six International Classification of Functioning and Health activity and participation domains. These include cognition, mobility, self-care, interpersonal functioning, life activities and participation (Üstun *et al.* 2010; Federici *et al.* 2017). The WHODAS 2.0 asks respondents how much difficulty they have had in the past 30 days for each of the 12 items, with Likert options: 1 = none, 2 = mild, 3 = moderate, 4 = severe, 5 = extreme/cannot do (high scores mean greater disability). The interview version was used in this study. The WHODAS 2.0 has been validated for mTBI (Snell *et al.* 2017*a*, 2020*b*). Total ordinal WHODAS 2.0 scores were converted into interval scores using Rasch tables provided for mTBI (Snell *et al.* 2020*b*). Functional disability was measured using the WHODAS 2.0 at each assessment point.

Psychological measures

Depression, Anxiety and Stress Scale-21. The Depression, Anxiety and Stress Scale-21 (DASS-21; Lovibond and Lovibond 1995) is a 21-item self-report scale measuring depression, anxiety and stress symptoms over the previous 7 days. Total scale scores were calculated (range 0–63), with higher scores indicating higher distress (Zanon *et al.* 2021). The DASS-21 total score has shown good internal consistency and unidimensionality in general population and mTBI samples (Zanon *et al.* 2021; Faulkner *et al.* 2024). The DASS-21 was administered at baseline assessment only.

Pain Catastrophising Scale. The Pain Catastrophising Scale (PCS; Sullivan *et al.* 1995) is a 13-item scale evaluating the extent to which participants experienced thoughts and feelings associated with symptoms, scored on a 5-point Likert scale from 'not at all' to 'all the time'. Items include fears about non-recovery, feelings of loss of control, feeling overwhelmed by symptoms and intrusiveness of symptoms. The PCS was originally developed for the chronic pain population. There is evidence noting the similarity in symptoms between people with chronic pain and those with persisting post-concussion symptoms following mTBI (Smith-Seemiller *et al.* 2003; Snell *et al.* 2018). We adapted the wording of the original PCS by replacing 'pain' with 'symptoms' throughout following Terpstra and colleagues (Terpstra *et al.* 2021). We calculated a total score for the PCS, with scores ranging from 0 to 52. Catastrophising was measured at baseline assessment only.

Fear Avoidance Behavior after Traumatic Brain Injury Questionnaire. The Fear Avoidance Behavior after Traumatic Brain Injury Questionnaire (FAB-TBI) includes 16 items sourced from fear avoidance scales originally developed for chronic pain and has been validated for mTBI (Snell *et al.* 2020*a*). Items are rated on a 4-point scale ranging from 0 (strongly disagree) to 3 (strongly agree) and summed to produce a total score ranging from 0 to 48, with higher scores meaning more avoidance. Items refer to the avoidance of activities that might make symptoms worse (e.g. 'I should not do my normal work with my present symptoms', 'I purposely avoid doing activities that might elicit a headache'). The FAB-TBI has been validated using the Rasch model in an mTBI sample and shown good internal consistency (person separation index = 0.91; Snell *et al.* 2020*a*). In this study, FAB-TBI total ordinal scores were converted to total interval scores using previously developed Rasch conversion tables (Snell *et al.* 2020*a*). Fear avoidance was measured at baseline assessment only.

Impact of Events Scale-Revised. The Impact of Events Scale-Revised (IES-R; Weiss and Marmar 1997) is a 22-item self-report questionnaire measuring distress associated with stressful life events, focusing on intrusion, avoidance and hyperarousal symptoms over the preceding week. Items are rated on a 0–4-point scale indicating how distressing each difficulty has been from 'Not at all' to 'Extremely'. The IES-R provides novel

information about impacts of stressful life experiences after mTBI (Faulkner *et al.* 2023). The total scale score was calculated (0–88) and the IES-R was administered at baseline assessment only.

Data analyses

Data were analysed using SPSS version 29 (IBM CORP 2020) and R (R Core Team 2021). Demographic and clinical characteristics were summarised using descriptive statistics, such as means, standard deviation, ranges, frequencies and correlations.

To examine recovery trajectories, participants' RPQ and WHODAS 2.0 scores at each assessment timepoint were descriptively summarised as line plots, and means and standard deviations calculated. Preliminary data visualisations indicated that the rates of recovery tended to be fastest soon after injury and slowed as they approached the scale floor, causing the data to be skewed right with an excess of zeros, particularly at later timepoints.

Recovery trajectories were therefore treated as longitudinal semicontinuous data and changes over time estimated using linear mixed-effect two-part (hurdle) models, fitted using the R glmmTMB package with a lognormal link function (Brooks et al., 2017; Farewell *et al.* 2017). Time since injury in weeks was added as a second-order polynomial fixed effect to allow outcomes to follow a decelerating decline. Individuals were fitted with random intercepts and slopes. Within-participant variability (recovery fluctuations) over time was investigated by calculating the standard deviation of the model residuals for each individual. Linear regression models were used to explore relationships between baseline variables (age, gender, DASS-21, FAB-TBI, PCS and IES-R) with individual-level intercepts, slopes and standard deviations of residuals. First, independent variables were fitted one at a time (univariable models), then all at once (multivariable model) to assess the relative importance of each factor. Independent variables in multivariable models were checked for multicollinearity by calculating the variance inflation factor and this was considered to be low (all variance inflation factors <3). Variability in WHODAS 2.0 scores between adjacent assessment points were considered large if change in scores exceeded the minimally important difference (Snell and Silverberg 2023). In the absence of reported minimally important difference for the RPQ, variability was considered to be large if change in scores between adjacent assessment points exceeded 10% of the scale range.

Estimates are reported with two-sided 95% CIs. Small, medium, and large effect sizes were respectively defined as $|0.1–0.3|$, $|0.3–0.5|$ and $|\geq 0.5|$ for Pearson's r (Cohen 1988). We used list-wise deletion, the default SPSS approach, to account for missing data. For linear mixed effects models, those with data recorded during at least one timepoint (including baseline) were included. Sample sizes at each data collection point are reported.

Ethics and participant consent

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Ethical approval to conduct the study was obtained from New Zealand's National Health and Disability Ethics Committee (ref 18/CEN/79).

Results

Description of study sample

The sample (n = 110) was on average aged 38.9 years (s.d. 15.3 years, range 16–69 years). There were fewer men (36.4%) and a majority reported their ethnicity as New Zealand European (72.7%). Participants endorsed high levels of education, with 37.3% describing their highest education level as university or other tertiary education provider. The most common injury mechanisms were falling and transport-related accidents (each 28.2%). Over half of the sample reported a mental health history (60.6%), and 48% endorsed a prior history of mTBI. In terms of treatment accessed in the outpatient service, almost all participants endorsed having seen an occupational therapist (90%), and the majority also participated in physiotherapy (82%). These findings are shown in Table 1.

Description of symptom and functional disability outcomes over time

Fig. 1 and Table 2 and 3 show distributions of scores across time for the RPQ, and show levels of endorsed symptoms steadily reduced over time. Fig. 1 shows recovery trajectories were steepest in the first 8 weeks, and Table 3 shows mean RPQ scores had approximately halved by approximately 16 weeks. There was considerable variability between assessment points, with some participants showing large fluctuations in scores. Fig. 2 and Table 2 and 3 show distributions of interval scores for the WHODAS 2.0, and show levels of disability steadily reduced over time with greater improvement in functional disability evident earlier post-injury. As for the RPQ, Fig. 2 shows recovery trajectories were steepest in the first 8 weeks, and Table 3 shows mean WHODAS 2.0 scores had approximately halved by approximately 16 weeks. There was variability between assessment points.

Table 2 shows mean scores for the RPQ and WHODAS 2.0, at each assessment timepoint. At baseline assessment,

Table 1. Demographic and clinical characteristics of participants at baseline assessment ($n = 110$).

Variable	M (s.d.) or *n* (%)
Demographic characteristics	
Age (years), mean (s.d.), range	38.9 (15.3), 16–69
Gender male, *n* (%)	40 (36.4)
Ethnicity, *n* (%)	
New Zealand Māori	9 (8.2)
New Zealand European	80 (72.7)
Other	20 (18.2)
Highest education level, *n* (%)	
High school or less	41 (37.3)
University/tertiary	41 (37.3)
Trade	15 (13.6)
Other	13 (11.8)
Previous mild traumatic brain injury (yes), *n* (%)	53 (48.2)
Previous mental health history (yes), *n* (%)	66 (60.6)
Injury and clinical characteristics	
Time to baseline assessment in weeks, mean (s.d.), range	6.5 (2.6), 2–13
Mechanism of injury, *n* (%)	
Transport-related	31 (28.2)
Fall	31 (28.2)
Assault	9 (8.2)
Hit by object	10 (9.1)
Other	29 (26.4)
PTA, *n* (%)	
No PTA	42 (38.2)
PTA <1 h	49 (44.5)
PTA >1 h, <24 h	19 (17.3)
Treatment, *n* (%)[A]	
Occupational therapy	99 (90.0)
Physiotherapy	90 (81.8)
Clinical psychology	34 (30.9)
Neuropsychology	52 (47.3)
Symptoms at baseline assessment (RPQ total), mean (s.d.), range	32.1 (11.1), 0–59
Functional disability at baseline assessment (WHODAS 2.0 Interval Score), mean (s.d.), range	24.7 (4.5), 16.3–42.9

PTA, post-traumatic amnesia; RPQ, Rivermead Post-Concussion Symptoms Questionnaire.; WHODAS 2.0, 12-item World Health Organization Disability Assessment Schedule 2.0.

[A]Treatment experienced by participants during the course of study participation.

the mean RPQ score was 30.9 (s.d. 11.9), and at final assessment, this was 14.2 (s.d. 11.0). The mean WHODAS 2.0 interval score was 24.7 (s.d. 4.3) at baseline assessment, and at final assessment, this was 19.7 (s.d. 3.0). The RPQ and WHODAS 2.0 total scores showed large correlations at each assessment point (baseline assessment: $r = 0.6$; phone follow up 1: $r = 0.6$; phone follow up 2: $r = 0.8$; phone follow up 3: $r = 0.7$; phone follow up 4: $r = 0.8$; final assessment: $r = 0.7$). Table 2 shows that the final assessment occurred at a mean of 30.6 weeks (approximately 7 months) with a standard deviation of 3.9 weeks (approximately 1 month). It can be seen in Fig 1 and 2 that the WHODAS 2.0 appeared to stabilise at 6 months post-injury, and there were few datapoints after 34 weeks (8 months) for both outcome measures.

Relationships between symptom and disability outcomes over time

Table 3 shows estimated group means and mean change with 95% confidence intervals for RPQ and WHODAS 2.0 interval scores as a function of time. Improvements were initially fast and then flattened off as group averages approached the floor of each scale. For the RPQ, small improvements are still seen between 24 and 32 weeks. For the WHODAS 2.0, there was less improvement observed between 24 and 32 weeks. Estimated random slopes showed improvements in symptoms (RPQ) were associated with improvements in disability (WHODAS 2.0; $r = 0.5$).

Factors associated with symptom and disability outcomes and within-person variability

Correlations between measures

Table 4 shows correlations between psychological measures and outcomes at baseline assessment. There were large correlations between the DASS-21 and IES-R ($r = 0.7$), suggesting a shared general distress factor. Correlations between these measures and the FAB-TBI and PCS, in contrast, were in the medium range ($r = 0.4$–0.6). Psychological measures showed medium correlations with symptoms and disability measures at baseline.

Symptom outcomes (RPQ)

In univariate analyses, lower baseline depression, anxiety and stress symptoms (DASS-21, $P = 0.01$), symptom catastrophising (PCS, $P < 0.01$), distress associated with stressful life events (IES-R, $P < 0.01$), but not fear avoidance (FAB-TBI, $P = 0.13$), were associated with greater speed of symptom improvement over time (RPQ total scores). In multivariable modelling, after adjustment for severity of RPQ scores at baseline, associations between PCS ($P = 0.02$) and IES-R ($P = 0.06$) at baseline and speed of improvement in symptoms were attenuated, but still statistically significant (final model $R^2 = 0.22$).

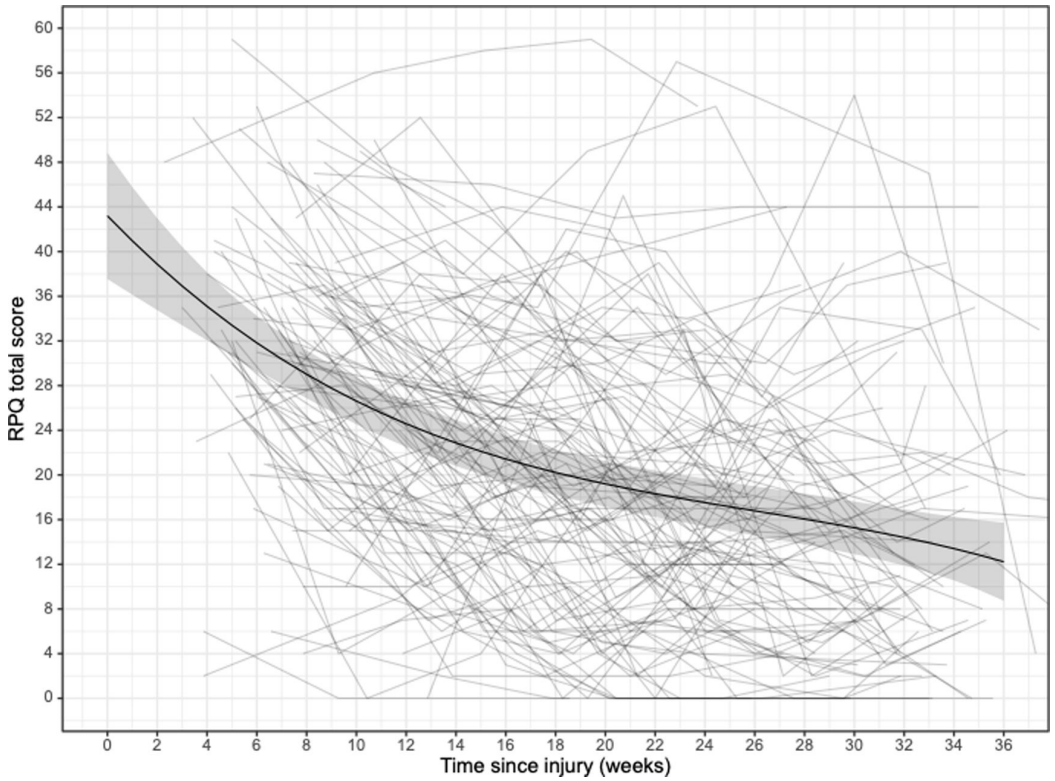

Fig. 1. Variability and reduction in symptoms by assessment (weeks) measured with the Rivermead Post-concussion symptoms questionnaire (RPQ). Thin grey lines connect repeated measurements taken from each individual and are used to indicate that individual's unique recovery path. The thick black line with grey shading represents the estimated group mean score with 95% confidence interval as estimated from a linear mixed-effects model.

Table 2. RPQ and WHODAS 2.0 scores at each assessment point for the sample (n = 110).

Assessment point	Weeks post-injury M (s.d.), range	RPQ[A] sample size	RPQ[A] M (s.d.)	WHODAS 2.0[B] sample size	WHODAS 2.0[B] M (s.d.)
Baseline assessment	6.5 (2.6), 2–13	104	30.9 (11.9)	102	24.7 (4.3)
Phone FU 1	13.0 (3.6), 5–23	108	22.8 (12.3)	107	21.0 (3.2)
Phone FU 2	17.5 (3.6), 10–28	107	19.8 (12.8)	107	20.1 (2.9)
Phone FU 3	21.9 (3.6), 14–32	96	17.9 (12.7)	98	19.9 (3.4)
Phone FU 4	26.4 (3.7), 18–36	93	15.9 (13.7)	93	19.1 (2.9)
Final Assessment	30.6 (3.9), 23–40	107	14.2 (11.0)	108	19.7 (3.0)

FU, follow-up assessment.
[A]RPQ = Rivermead Post-Concussion Symptoms Questionnaire.
[B]WHODAS 2.0 = 12-item World Health Organization Disability Assessment Schedule 2.0 interval score.

When within-person variability (s.d.) in RPQ scores over time was considered, in univariable analyses, gender (being female), higher DASS-21 and IES-R scores at baseline predicted greater variability in RPQ symptom scores over time. These associations did not remain significant in the final adjusted multivariable model (final model R^2 = 0.12). Shared variance between the DASS-21 and IES-R may have impacted the performance of these variables in the multivariable model.

Functional disability outcomes (WHODAS 2.0)

In univariate analyses, lower depression, anxiety and stress symptoms (DASS-21), fear avoidance behaviour (FAB-TBI), symptom catastrophising (PCS), and distress

Table 3. Estimated population-derived change in symptoms and disability at each assessment point compared with baseline assessment.

Weeks post-injury[A]	Percentage with a score of zero (95% CI)	Estimated mean score (95% CI)	Ratio versus baseline (95% CI)	*P*
RPQ Total				
0	0.1 (0.0, 2.7)	41.6 (36.3, 47.7)		
8	1.0 (0.3, 4.0)	28.1 (25.8, 30.6)	0.68 (0.60, 0.76)	<0.01
16	4.4 (2.6, 7.2)	20.7 (18.9, 22.7)	0.50 (0.41, 0.60)	<0.01
24	9.0 (6.0, 13.3)	16.6 (14.9, 18.5)	0.40 (0.33, 0.49)	<0.01
32	9.7 (5.7, 16.0)	14.5 (12.5, 16.7)	0.35 (0.28, 0.43)	<0.01
WHODAS 2.0 Total				
0	0.0 (0.0, 0.3)	25.5 (23.3, 27.9)		
8	0.5 (0.1, 2.3)	17.4 (16.5, 18.3)	0.68 (0.63, 0.74)	<0.01
16	6.3 (3.9, 10.2)	13.4 (12.6, 14.2)	0.53 (0.46, 0.60)	<0.01
24	19.2 (14.5, 25.0)	11.7 (10.9, 12.6)	0.46 (0.40, 0.53)	<0.01
32	17.0 (11.3, 24.8)	11.5 (10.4, 12.7)	0.45 (0.39, 0.52)	<0.01

CI, confidence interval; RPQ, Rivermead Post-Concussion Symptoms Questionnaire; WHODAS 2.0, 12-item World Health Organisation Disability Assessment Schedule 2.0 interval score.
[A]Week 0 = baseline assessment.

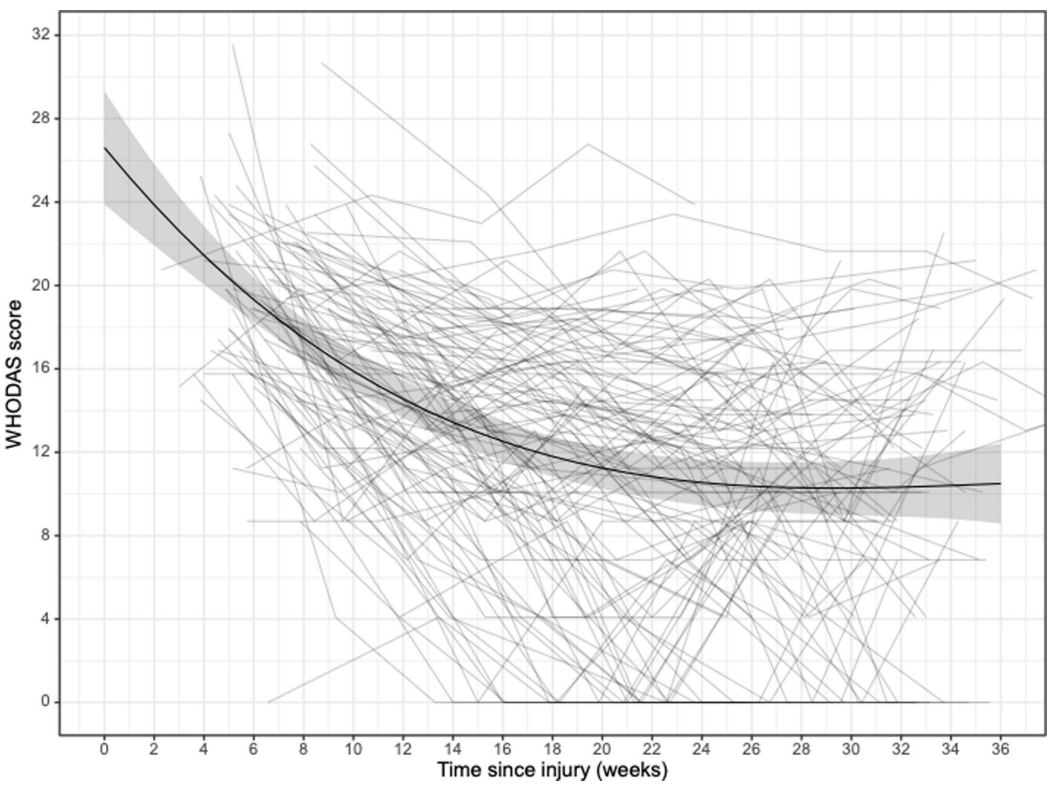

Fig. 2. Variability and reduction in disability by assessment (weeks) measured with the WHODAS 2.0 (n = 110). Thin grey lines connect repeated measurements taken from each individual and are used to indicate that individual's unique recovery path. The thick black line with grey shading represents the estimated group mean score with 95% confidence interval as estimated from a linear mixed-effects model. (WHODAS = World Health Organisation Disability Assessment Schedule 2.0).

Table 4. Correlations between measures at baseline assessment ($n = 110$).

	RPQ	WHODAS 2.0	DASS-21	IES-R	PCS	FAB-TBI
RPQ	1	0.6[A]	0.4[A]	0.6[A]	0.4[A]	0.4[A]
WHODAS 2.0		1	0.4[A]	0.3[A]	0.3[A]	0.3[A]
DASS-21			1	0.7[A]	0.6[A]	0.4[A]
IES-R				1	0.7[A]	0.4[A]
PCS					1	0.5[A]
FAB-TBI						1

DASS-21, Depression Anxiety and Stress Scale; FAB-TBI, Fear Avoidance afterTraumatic Brain Injury; IES-R, Impact of Events Scale-Revised; PCS, Pain Catastrophising Scale; RPQ, Rivermead Post-Concussion Symptoms Questionnaire; WHODAS 2.0, 12-item World Health Organisation Disability Assessment Schedule 2.0 interval score.
[A]$P<0.01$.

associated with stressful life events (IES-R), measured at baseline, were associated with greater improvement in functional disability (WHODAS 2.0 scores) over time (all $P < 0.01$). In multivariable modelling, after adjustment for severity of WHODAS 2.0 scores at baseline, only the IES-R predicted speed of improvement ($P < 0.01$). The final model explained 36.9% of the variance ($R^2 = 0.37$).

When within-person variability (s.d.) in WHODAS 2.0 scores over time was considered, in univariable analyses, only baseline fear avoidance behaviour (FAB-TBI) was significantly associated with within person variability (β = –0.12, 95% CI –0.20 to –0.03, $P = 0.01$). When all variables were entered into the multivariable model, fear avoidance behaviour remained the only significant independent predictor (β = –0.13, 95% CI –0.24 to –0.03, $P = 0.01$). In the final multivariable model adjusting for severity of WHODAS 2.0 scores at baseline, fear avoidance behaviour continued to demonstrate a significant association with within-person variability (β = –0.12, 95% CI –0.22 to –0.02, $P = 0.02$). The final model explained 17.2% of the variance ($R^2 = 0.17$). Fear avoidance behaviour was the only variable to uniquely predict variability in WHODAS 2.0 scores after accounting for demographic and other psychological factors.

Discussion

In this study, we examined symptom and functional disability improvements in a sample of adults attending outpatient rehabilitation services after mTBI. Our findings show participants continued to experience improvements in both symptoms and functional disability on average, over the months following clinic intake, with improvements initially rapid and then levelling off as group averages approached the floor of outcome measures. The change in functional disability, as measured with the WHODAS 2.0, appeared to stabilise at 6 months post-injury, with little evidence of further improvement after this time. The change in symptoms measured with the RPQ continued to show small improvements from 6 months until 8 months post-injury, after which time there were insufficient data to estimate further changes. These findings suggest participants may continue to experience symptom improvements beyond return to activity and participation. There was also considerable within-person variation over time. Some participants showed large fluctuations between consecutive assessments.

Many studies have shown that symptoms and disability are correlated positively during early months after mTBI. Consistent with our findings, Lunden and colleagues (Lundin *et al.* 2006) found that symptoms and disability were moderately correlated ($r = 0.6$) at 3 months post-injury. In a systematic review and meta-analysis including 43 studies (Cancelliere *et al.* 2023), the prevalence of both symptoms and disability remained high between 3 and 6 months post-injury, although findings varied based on the way outcomes were defined. Our findings suggest variability in estimating the prevalence of symptoms and disability after mTBI might also depend on timing of outcome measurement, with prevalence estimates potentially impacted by fluctuations in recovery.

We also demonstrated marked fluctuations within participants and over time for both symptom and functional disability endorsement. Previous studies have demonstrated such fluctuations for symptomatic recovery. Fordal *et al.* (2022) investigated post-concussion symptom trajectories between 3 and 12 months after mTBI ($n = 335$), and noted intra-individual variability was obscured by group -level stability in the prevalence of symptoms over time. Differing trajectories of recovery appeared associated with a range of pre-injury person factors, such as gender, work status at injury, mental health history and personality styles. Magnusson *et al.* (2024) showed that both symptoms and disability persisted to 5 years post-injury in 49 adults sustaining mTBI. They also noted more participants endorsed post-concussion symptoms (80%) than disability (24%) at 5 years post-injury, with the most common symptoms being fatigue and poor concentration. The authors acknowledged these are nonspecific symptoms not necessarily attributable to mTBI at 5 years post-injury, noting increased risk for recall bias with time. In keeping with trends evident in our data, however, this could suggest people return to function such as work and other forms of productivity, while still remaining symptomatic and that symptoms can persist over time, with potential to jeopardise functional status. It is not possible to differentiate in our data whether participants are returning to activities prematurely because of administrative or social pressures, for example, or if they are using symptom self-management

or accommodation strategies that enable them to participate in valued daily activities.

We used estimated individual slopes (speed of improvements over time) to investigate what baseline factors were associated with recovery patterns. Factors associated with greater fluctuations in both symptoms and functional disability included female gender, distress, catastrophising and fear avoidance. Other studies have shown differences in rates of symptoms and disability over the first 6 months after mTBI on the basis of gender, with women reporting more difficulties than men (Mikolić *et al.* 2021; Wågberg *et al.* 2023). There is also a growing evidence base supporting psychological mechanisms as drivers of slow recovery after mTBI (Silverberg and Mikolić 2023). In our study, fear avoidance at baseline assessment was a significant predictor of variability in recovery, especially for return to function. This is consistent with previous research investigating associations between early fear avoidance and later symptom and functional disability outcomes (Silverberg *et al.* 2018). Models of fear avoidance and learning theory (Krypotos *et al.* 2015; Zale and Ditre 2015) would suggest for those with early high fear avoidance, associations between feared stimuli (e.g. worsening of symptoms) and certain activities (e.g. cognitive activity or work) may be negatively reinforced by persistent avoidance of symptom triggers and/or reinforced by boom and bust patterns. One mechanism worth considering in future research that might underpin such fear avoidant fluctuations and also distress is psychological flexibility (Faulkner *et al.* 2021). Targeting psychological inflexibility is a core component of acceptance and commitment therapy approaches (Hayes *et al.* 2012), and there is increasing support for acceptance and commitment therapy interventions for people with persistent difficulties following traumatic brain injury (Whiting *et al.* 2020; Faulkner *et al.* 2021).

Finally, understanding factors associated with such post-injury fluctuations is likely to be of great value in terms of conveying recovery expectations. Clinicians may communicate unrealistic prognostic information, positive or negative, in response to such fluctuations (Cancelliere *et al.* 2023), and patients themselves may develop increased distress and avoidance of triggers as fluctuations challenge their recovery expectations (Snell *et al.* 2017*b*). Clinicians can be encouraged to normalise such fluctuations and to maintain a measured communication of positive recovery expectations over time. Findings provide reassurance to patients and their families that improvements after mTBI continue to be observed many months after injury, and this information could be incorporated into educational resources.

Strengths and limitations

Although both a strength and a weakness, our sample was a clearly defined subpopulation of adult participants engaged in multidisciplinary treatment after mTBI, primarily physiotherapy and occupational therapy. This supports external validity, but means our findings cannot be generalised to the wider population of people sustaining mTBI. In particular, people are referred to outpatient clinics in New Zealand on the basis of the presence of risk factors, including high symptom burden, prior mental health history, previous mTBI, comorbid psychological distress, gender and age. These aspects are reflected in the high rates of mental health histories and prior mTBI among study participants, which could have impacted the associations between psychological symptoms and outcomes in our study. More nuanced information about the nature of pre-injury mental health histories would have strengthened our understanding of the sample and improved generalisability. One other strength of this study was high retention rates, especially for final visits up to 9 months post-injury, as shown in Table 2.

Although the WHODAS 2.0 has been validated for mTBI, some participants reached the floor of the scale during follow up, and this could suggest the measure is less sensitive to residual problems over time and/or does not reflect the way activities are adapted to facilitate participation. This raises a question about how recovery should be defined and measured after mTBI. Return to productivity and function is just one indicator of recovery, but may not reflect the interests of the individuals themselves who may prioritise other outcomes, such as resolution of specific symptoms; for example, headaches and/or cognitive symptoms. In addition, in our sample at final assessment 6–9 months after injury, some participants not only endorsed post-concussion symptom and disability levels below general population cut-offs (Sjonnesen *et al.* 2016; Thompson *et al.* 2016), they also scored low or at zero on the RPQ and WHODAS 2.0 at one assessment point, and then scored at higher levels at a subsequent timepoint. Without a comparative assessment or a non-mTBI control sample, we do not know if such participants have recovered from their mTBI, but go on to endorse post-concussion symptoms for other reasons. Post-concussion symptoms are not specific to mTBI and can overlap with other conditions, such as chronic pain and depression (Iverson and Lange 2003; Asken *et al.* 2017; Snell *et al.* 2018).

Large correlations between broad distress measures (DASS21, IES-R), and moderate associations with catastrophising and fear avoidance have been shown in other mTBI studies, possibly reflecting a shared underlying dimension of emotional distress (Hecker *et al.* 2025). This may have impacted the performance of these variables in our multivariate models, because regression coefficients reflected only the unique contribution of each construct after shared variance was removed. However, catastrophising and fear avoidance may represent related but distinct cognitive–behavioural processes that could contribute to the maintenance

of symptoms and poorer recovery outcomes (Buzzanca-Fried *et al.* 2024; Trbovich *et al.* 2026).

Finally, it is possible that impacts of the pandemic contributed to higher distress levels among participants recruited during 2020–2022. In mitigation, New Zealand's COVID-19 cases were lower than comparable countries in the first 2 years of the pandemic, the economy recovered faster and New Zealanders spent less time in lockdown than many other countries (ANON 2024; French *et al.* 2025).

Conclusions

In this study, we described recovery up to 9 months after mTBI, taking a closer look at recovery at monthly assessment points. We showed that participants on average demonstrated improvements in both symptoms and functional disability, with improvements initially rapid and then levelling off as group averages approached the floor of the measures. There was also considerable within-person variation over time, with some participants showing large fluctuations between consecutive assessments. Fluctuations and rates of recovery were associated with baseline psychological distress and fear avoidance. Clinicians can target such psychological factors in treatment and anticipate fluctuations, normalising these while maintaining cautiously optimistic messaging regarding expected return to symptom and function baselines after mTBI.

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Ethics and participant consent. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Ethical approval to carry outconduct the study was obtained from New Zealand's National Health and Disability Ethics Committee (ref 18/CEN/79).

Data availability. Data are available on request.

Conflicts of interest. The authors declare that they have no conflicts of interest.

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