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A Cognitive Concerns Phenotype Remains Common In Chronic Phases of mTBI and is Uncoupled from Cognitive Screening Performance

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A Cognitive Concerns Phenotype Remains Common In Chronic Phases of mTBI and is Uncoupled from Cognitive Screening Performance

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Consent to Participate: An official waiver of consent was obtained by the University of California, Irvine IRB Board under protocol #2283 due to the retrospective nature of the study.

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Abstract

Background: Cognitive concerns are common after mild traumatic brain injury (mTBI). We hypothesized that a cognitive concern phenotype (CCP) persists across time-since-injury groups, with limited association with Montreal Cognitive Assessment (MoCA) performance.

Methods: We retrospectively analyzed 190 mTBI clinic patients. CCP defined as primary disabling cognitive concern and a Rivermead Post-Concussion Symptoms Questionnaire cognitive item score >2. CCP prevalence across time-since-injury groups (<6 months, 6-12 months, 1-2 years, 2-5 years and >5 years post-injury) was evaluated using descriptive and spline analyses. Exploratory analyses compared four CCP/MoCA groups on Center for Epidemiologic Studies Depression Scale (CES-D), Patient-Reported Outcomes Measurement Information System (PROMIS) self-efficacy, PROMIS psychosocial illness impact, and Glasgow Outcome Scale-Extended (GOSE).

Results: CCP prevalence was 32.6% (62/190) and remained common across time-since-injury groups (25.4%, 50.0%, 46.7%, 50.0%, and 36.8%). Odds of CCP were higher at ≥1 versus <1 year after injury (odds ratio 1.96, 95% confidence interval [CI] 1.00–3.84; p=0.048). Among 111 patients with MoCA data, 62 (55.9%) scored <26: 23/38 (60.5%) with CCP and 39/73 (53.4%) without CCP. CCP was not significantly associated with MoCA impairment (p=0.608) or adjusted MoCA scores (β=-1.06, 95% CI -2.74 to 0.62; p=0.213). Self-efficacy and GOSE differed across groups (both p=0.005); CES-D did not.

Conclusions: CCP remains common and disabling, years after mTBI, and is not fully captured by MoCA. Self-efficacy and functional differences suggest symptom-burden beyond screening performance.

Introduction

Mild traumatic brain injury (mTBI) is a major public health concern and is increasingly recognized as a chronic disease. There remain limited treatments for persistent symptoms, especially cognitive, after concussions. Recent systematic reviews estimate that persistent symptoms occur in 18.3%–31.3% of adults at 3–6 months after mTBI, depending on the symptom definition [1], and that post-concussion symptoms and disability may continue to affect quality of life, return to work, and healthcare utilization months after injury [1,2]. Cognitive concerns, including poor concentration, slowed thinking, “brain fog”, memory difficulty, and mental fatigue, are particularly important since they directly impede daily functional activity (e.g. driving) and return to work [2,3].

A clinically understudied subgroup is patients who identify cognition as their primary post-mTBI concern and describe cognitive symptoms as the dominant problem limiting work, school, or daily functioning. The mechanisms and correlates of this subtype of TBI or “phenotype” remain incompletely understood. Prior studies suggest that subjective cognitive concerns after mTBI do not consistently correspond to severity of injury or cognitive test performance and therefore may relate to affective distress, illness perception, self-efficacy, general functional outcome, or a combination of these factors [3-5].

This dissociation between subjective symptoms and objective performance is especially understudied in the chronic phase of mTBI. Much of the existing literature focuses on the first several months to one year after injury, whereas less is known about patients who present years after mTBI with persistent cognitive concerns [2,5]. This gap is clinically relevant because patients in chronic phases may differ markedly from early post-injury populations in symptom persistence and functional status, frequently creating a diagnostic conundrum where enduring complaints are misattributed to progressive neurodegenerative conditions such as early-onset dementia or traumatic encephalopathy syndromes [6,7]. Past studies demonstrate that subjective cognitive concerns may not be strongly associated with objective cognitive performance measured with bedside screening tools such as the Montreal Cognitive Assessment (MoCA). Further, functionally disabling concerns often persist in patients who score within normal screening limits, whereas subthreshold performance can occur in individuals without a primary cognitive concern [3,8-10]. Whether this discordance persists across multi-year intervals and how it aligns with broader functional recovery remain poorly defined.

In this study, we examined an mTBI clinic cohort of patients to characterize the prevalence of a cognitive concern phenotype (CCP) across time following TBI. CCP was defined independently of MoCA performance; depressive symptoms, PROMIS measures, and GOSE were examined as clinical correlates rather than components of the phenotype definition. We evaluated whether this phenotype was associated with cognitive impairment defined as MoCA <26 and whether depressive symptoms, Patient-Reported Outcomes Measurement Information System (PROMIS) self-efficacy, PROMIS psychosocial illness impact, and Glasgow Outcome Scale-Extended (GOSE) differed across CCP groups. We hypothesized that cognitive concerns following mTBI reflect dimensions of subjective experience that overlap with but are not fully explained by objective cognitive performance and may fluctuate in the chronic post-mTBI state.

Methods

Study design

We conducted a single-center, retrospective cohort study of a concussion clinic database of sequentially evaluated TBI patients from the Neurology Traumatic Brain Injury & Concussion (NTBIC) Program at the University of California, Irvine (UCI).

Ethical Statement: The study was approved by the institutional review board (IRB) at University of California, Irvine (IRB # 2283). The requirement for informed consent was waived.

Consent to Participate: An official waiver of consent was obtained by the University of California, Irvine IRB Board under protocol #2283 due to the retrospective nature of the study.

Participants

The study sample was identified from the UCI Neurology Traumatic Brain Injury & Concussion (NTBIC) clinical registry (8/2024-7/2026). The NTBIC Program operates as a specialized outpatient referral center affiliated with an academic Level 1 Trauma Center, capturing patients transitioning directly from acute traumatic injury admissions as well as ambulatory community

referrals from primary care providers and regional neurologists for evaluation of protracted post-concussion symptoms.

Eligible individuals were adults aged 18 years or older with a clinically verified diagnosis of mild traumatic brain injury (mTBI) fulfilling the 2023 American Congress of Rehabilitation Medicine (ACRM) diagnostic criteria [11]. Patients presented with an acute Glasgow Coma Scale (GCS) score of 13 to 15 documented at the time of injury, encompassing both uncomplicated cases without acute radiographic lesions and complicated cases demonstrating intracranial traumatic abnormalities on initial neuroimaging. Mechanisms of trauma were confirmed through clinician chart review. Individuals were excluded if they presented with moderate-to-severe initial injury (GCS <13), uncorroborated head trauma history, pre-existing premorbid functional disability, active head trauma-related litigation, current pregnancy, incarceration, active substance use/abuse, or marked physical or cognitive deficits that precluded participation in standardized clinical questionnaires and interviews as per previous large TBI studies [12, 13].

Demographics and time intervals
Patient age, sex, and educational attainment were extracted from clinical records for inclusion as model covariates. Time since injury was calculated in years from the reported injury date to clinic assessment. However, for descriptive analyses, time since injury was categorized into five groups: <6 months, 6-12 months, 1-2 years, 2-5 years, and 5+ years. Chronicity thresholds were also evaluated at ≥1, ≥2, ≥3, and ≥5 years. All demographic information was collected at the first (index) clinic visit.

Cognitive concern phenotype
The primary independent variable was the patient-defined cognitive concern phenotype (CCP), defined retrospectively using data collected at the initial clinical visit. The clinic's standard intake protocol included a standardized interview and administration of the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) to all patients. CCP required both of the following criteria:

1. Identifying cognitive disturbance as their chief, most disabling post-injury concern on standardized clinical intake (specifically responding to *"What is your most disabling symptom you have experienced after TBI that impacts your life [like ability to go to work and socialize]?"*), and
2. Endorsing clinically meaningful cognitive symptom burden on the RPQ [13], defined as a rating greater than 2 on any cognitive item (i.e. *"poor concentration"*, *"taking longer to think"*, or *"forgetfulness, poor memory"*).

On the RPQ, symptoms were scored on a 5-point Likert scale (0 = "not experienced at all" to 4 = "a severe problem"), with ratings of 1 ("no more of a problem than before injury") rescored to 0 to exclude unchanged pre-existing symptoms from the total RPQ score. Patients who did not meet both criteria simultaneously were classified into the non-phenotype comparison group.

MoCA screening performance
The Montreal Cognitive Assessment (MoCA), a cognitive screening measure, was the primary outcome of interest. Cognitive screening impairment was defined as MoCA <26, the traditional screening cutoff [14]. Analyses involving MoCA were restricted to patients with available MoCA data

Functional, psychosocial, and depression measures

Exploratory outcome measures were obtained at the index clinic visit and included global functional recovery (GOSE), depressive symptom severity (CES-D), self-efficacy (PROMIS General Self-Efficacy), and illness-related psychosocial burden (PROMIS Psychosocial Illness Impact) [15-17].

Global functional recovery (GOSE)

Post-traumatic functional outcome was assessed using the GOSE, a standardized, validated instrument capturing injury-related functional limitations and disability across independence, vocational productivity, social participation, and daily activities [17, 18]. Scores are graded along an ordinal continuum from 1 to 8: 1 indicates death, 2 indicates a vegetative state, 3 to 6 reflect severe-to-moderate disability, and 7 to 8 denote good recovery. Structured patient interviews following standardized administration guidelines from major traumatic brain injury observational cohorts were conducted by trained clinical research staff [17]. In group-level comparisons and regression modeling, GOSE was evaluated continuously, with lower scores reflecting greater functional disability.

Depressive symptoms (CES-D)

Depressive symptom severity was evaluated using the CES-D, a 20-item self-report instrument widely validated in general and neurologic populations for quantifying the frequency of affective and somatic symptoms of depression over the preceding week [15]. Items are scored on a 4-point Likert scale ranging from 0 ("rarely or none of the time") to 3 ("most or all of the time"), generating a continuous total score from 0 to 60. Higher composite scores represent≥ 16 traditionally considered indicative of clinically significant depressive distress. The CES-D was analyzed continuously across phenotype-by-screening groups and within multivariable models.

Self-efficacy (PROMIS General Self-Efficacy)

Patient-perceived confidence in managing life demands was measured using the Patient-Reported Outcomes Measurement Information System (PROMIS) General Self-Efficacy Short Form [16]. This validated measure captures an individual's belief in their ability to navigate unexpected challenges, manage stress, and achieve daily goals despite chronic health symptoms. Items are evaluated on a 5-point Likert scale (1 = "I am not at all confident" to 5 = "I am very confident"), yielding summary scores where higher values reflect greater confidence and self-efficacy.

Psychosocial burden (PROMIS Psychosocial Illness Impact)

Subjective illness impact was quantified using the PROMIS Psychosocial Illness Impact item bank [16]. This instrument assesses the perceived emotional, interpersonal, and functional disruption directly attributable to an ongoing medical condition, evaluating the extent to which symptoms interfere with social roles, identity, and personal relationships. Higher summary scores indicate greater perceived negative psychosocial consequences and greater subjective life disruption resulting from post-concussive illness.

Statistical analysis

Cognitive concern phenotype prevalence was summarized for each time-since-injury group using the number of patients with CCP, the total number of patients in the group, percentage prevalence, and 95% confidence interval. A logistic regression model with a natural spline term for time since injury was used to model the predicted probability of cognitive concern phenotype across time.

Chronicity threshold analyses compared CCP prevalence at ≥1, ≥2, ≥3, and ≥5 years to assess whether prevalence differed between patients assessed before versus at or after each time threshold. MoCA analyses were restricted to patients with available MoCA data. Comparisons across CCP/MoCA groups additionally required available data for the outcome being analyzed. CCP was compared with abnormal MoCA status using chi-square testing, and continuous MoCA performance was modeled using linear regression adjusted for age, sex, and education.

Four phenotype/MoCA groups were created: cognitive concern + abnormal MoCA, cognitive concern + normal MoCA, no cognitive concern + abnormal MoCA, and no cognitive concern + normal MoCA (Table 2, Panel B). Group differences in CES-D, PROMIS self-efficacy, PROMIS psychosocial illness impact, and GOSE were evaluated descriptively and using one-way ANOVA across the four groups. Within the CCP group, a post hoc exploratory comparison of PROMIS self-efficacy between patients with MoCA <26 and those with MoCA ≥26 used a two-sided Welch's t-test.

Depression was examined using CES-D as a continuous predictor in logistic regression adjusted for age, sex, education, and years since injury. Functional and psychosocial outcomes of cognitive concern phenotype were evaluated in an exploratory analysis using linear models adjusted for age and sex. Primary analyses evaluated CCP prevalence across time and its association with MoCA screening status. Analyses of secondary psychosocial and functional outcomes (CES-D, PROMIS measures, GOSE) were pre-specified as exploratory; therefore, unadjusted nominal p -values and 95% confidence intervals are reported without correction for multiplicity. Analyses were performed in R (version 4.6.1). Statistical significance was defined as $p<0.05$.

Consent to publish statement: not applicable.

Results

Cohort characteristics and cognitive concern phenotype prevalence

The analytic sample included 190 eligible patients with mTBI/concussion. Of these, 62 patients (32.6%) met criteria for cognitive concern phenotype. Among the 190 patients, MoCA data were missing for 79 (41.6%) and CES-D data for 98 (51.6%). PROMIS self-efficacy, PROMIS psychosocial illness impact, and GOSE data were missing for 61 (32.1%), 60 (31.6%), and 1 (0.5%), respectively.

Cognitive concern phenotype across time since injury

CCP was observed across all time-since-injury groups (Table 1, Panel A). Prevalence was 25.4% (31/122) among patients assessed <6 months after injury, 50.0% (9/18) among those assessed 6-12 months after injury, 46.7% (7/15) among those assessed 1-2 years after injury, 50.0% (8/16) among those assessed 2-5 years after injury, and 36.8% (7/19) among those assessed 5+ years after injury. Spline modeling demonstrated persistence of cognitive concern phenotype across the observed time spectrum without a clear monotonic decline or discrete chronicity threshold (Figure 1).

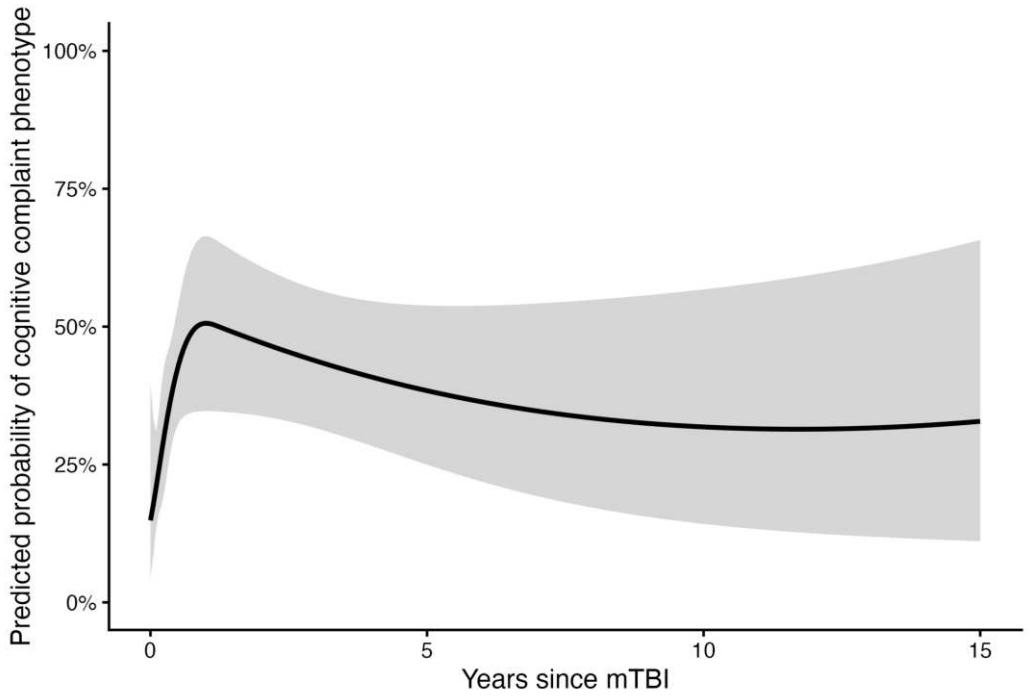


Figure 1. Predicted probability of cognitive concern phenotype across time since mTBI. Predicted probability was estimated using logistic regression with a natural spline term for years since injury. Gray shading represents the 95% confidence interval. The widening confidence interval at later time points reflects smaller sample sizes in the very chronic post-injury groups.

Chronicity threshold analyses showed higher associated odds of cognitive concern phenotype at ≥1 year compared with <1 year (44.0%; OR 1.96, 95% CI 1.00 to 3.84; p=0.048). However, this association was not sustained at later thresholds, including ≥2 years (42.9%; OR 1.72, 95% CI 0.80 to 3.65; p=0.156), ≥3 years (40.7%; OR 1.51, 95% CI 0.64 to 3.46; p=0.334), and ≥5 years (36.8%; OR 1.23, 95% CI 0.44 to 3.23; p=0.680) from TBI (Table 1, Panel B).

Table 1. Cognitive concern phenotype prevalence across time since mTBI. CCP = Cognitive Concern Phenotype. CCP, cognitive concern phenotype; CI, confidence interval; mTBI, mild traumatic brain injury; OR, odds ratio; RPQ, Rivermead Post-Concussion Symptoms Questionnaire. CCP required cognition being identified as the primary post-mTBI complaint and RPQ cognitive >2. Odds ratios compare patients at or beyond each chronicity threshold with patients before that threshold.

Panel A. Prevalence by time-since-injury group.

Time since injury	N	CCP, n	Prevalence, %	95% CI, %
<6 months	122	31	25.4	18.0 to 34.1
6-12 months	18	9	50.0	26.0 to 74.0
1-2 years	15	7	46.7	21.3 to 73.4
2-5 years	16	8	50.0	24.7 to 75.3
5+ years	19	7	36.8	16.3 to 61.6

Panel B. Chronicity threshold analyses

Threshold	N at or beyond threshold	CCP, n	Prevalence, %	OR (95% CI)	p value
≥1 year	50	22	44.0	1.96 (1.00 to 3.84)	0.048
≥2 years	35	15	42.9	1.72 (0.80 to 3.65)	0.156
≥3 years	27	11	40.7	1.51 (0.64 to 3.46)	0.334

≥5 years	19	7	36.8	1.23 (0.44 to 3.23)	0.680

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MoCA screening performance and cognitive concern phenotype

MoCA data were available for 111 patients. Overall, 62 of 111 patients (55.9%) had abnormal MoCA screening performance, defined as MoCA <26. Among patients with cognitive concern phenotype, 23 of 38 (60.5%) had abnormal MoCA screening performance and 15 of 38 (39.5%) had normal MoCA screening performance. Among patients without CCP, 39 of 73 (53.4%) had abnormal MoCA screening performance and 34 of 73 (46.6%) had normal MoCA screening performance. Abnormal MoCA screening performance was not significantly associated with CCP (60.5% vs 53.4%, p=0.608) (Table 2, Panel A).

In adjusted linear regression controlling for age, sex, and education, cognitive concern phenotype remained not independently associated with MoCA score (β=-1.06, 95% CI -2.74 to 0.62; p=0.213) (Supplementary Table 1).

Functional, psychosocial, and depression measures across CCP/MoCA groups

Patients were classified into four groups based on CCP and MoCA screening status: 20.7% (n=23) had cognitive concern + abnormal MoCA, 13.5% (n=15) had cognitive concern + normal MoCA, 35.1% (n=39) had no cognitive concern + abnormal MoCA, and 30.6% (n=34) had no cognitive concern + normal MoCA.

PROMIS self-efficacy differed significantly across the four CCP/MoCA groups (p=0.005). Mean PROMIS self-efficacy was lowest among patients with cognitive concern phenotype and abnormal MoCA screening performance (10.61), followed by cognitive concern phenotype with normal MoCA screening performance (11.73), no cognitive concern phenotype with abnormal MoCA screening performance (13.68), and no cognitive concern phenotype with normal MoCA screening performance (14.94) (Table 2, Panel B).

In an exploratory comparison restricted to patients with CCP, PROMIS self-efficacy did not differ significantly between those with MoCA <26 and those with MoCA ≥26 (means 10.61 versus 11.73; mean difference −1.12, 95% CI −4.20 to 1.95; Welch's t-test, p=0.461). GOSE also differed significantly across groups (p=0.005). Mean GOSE was lowest among patients with cognitive concern phenotype and abnormal MoCA screening performance (5.52) and highest among patients without cognitive concern phenotype and normal MoCA screening performance (6.68) (Table 2, Panel B). Among the 15 patients with CCP and normal MoCA screening performance (≥26), 11 (73.3%) had GOSE scores of 4–6, consistent with moderate or severe functional disability.

CES-D did not differ significantly across phenotype/MoCA groups (p=0.218). Mean CES-D was 14.69 in the cognitive concern + abnormal MoCA group, 16.08 in the cognitive concern + normal MoCA group, 11.10 in the no cognitive concern + abnormal MoCA group, and 13.59 in the no cognitive concern + normal MoCA group. PROMIS psychosocial illness impact also did not differ significantly across groups (p=0.739) (Table 2, Panel B).

Table 2. MoCA screening performance and functional outcomes by cognitive concern phenotype. ***CCP,*** **cognitive concern phenotype. CES-D, Center for Epidemiologic Studies Depression Scale; GOSE, Glasgow Outcome Scale-Extended; MoCA, Montreal Cognitive Assessment; PROMIS, Patient-Reported Outcomes Measurement Information System. Abnormal MoCA screening performance was defined as MoCA <26. MoCA was treated as a cognitive screening measure rather than a comprehensive neuropsychological battery. Higher PROMIS self-efficacy indicates greater self-efficacy. Higher GOSE indicates better global functional outcome. Group comparisons in Panel B used overall tests across the four phenotype/MoCA groups.**

Panel A. MoCA screening performance by cognitive concern phenotype

Group	N with MoCA	MoCA <26, n (%)	MoCA ≥ 26, n (%)	Overall p value
CCP	38	23 (60.5%)	15 (39.5%)	0.608
No CCP	73	39 (53.4%)	34 (46.6%)	
Total	111	62 (55.9%)	49 (44.1%)	

Panel B. Functional, psychosocial, and depression measures across CCP/MoCA groups

Phenotype/MoCA group	Group N	CES-D, mean ± SD (n)	Self-efficacy, mean ± SD (n)	Psychosocial impact, mean ± SD (n)	GOSE, mean ± SD (n)
CCP + MoCA <26	23	14.69 ± 7.91 (n=16)	10.61 ± 4.68 (n=23)	14.04 ± 3.40 (n=23)	5.52 ± 1.20 (n=23)
CCP + MoCA ≥26	15	16.08 ± 7.91 (n=12)	11.73 ± 4.45 (n=15)	13.73 ± 2.69 (n=15)	6.00 ± 1.13 (n=15)
No CCP + MoCA <26	39	11.10 ± 8.01 (n=31)	13.68 ± 4.98 (n=38)	14.56 ± 3.78 (n=39)	5.90 ± 1.21 (n=39)

No CCP + MoCA ≥26	34	13.59 ± 7.57 (n=32)	14.94 ± 4.57 (n=34)	15.03 ± 5.71 (n=34)	6.68 ± 1.32 (n=34)
Overall p value		**0.218**	**0.005**	**0.739**	**0.005**

Adjusted models of depression and functional outcome
In adjusted logistic regression among patients with available CES-D data (n=92), CES-D was not significantly associated with cognitive concern phenotype after controlling for age, sex, education, and years since injury (OR 1.05, 95% CI 0.99 to 1.12; p=0.112) (Supplementary Table 1).
In adjusted linear models controlling for age and sex, cognitive concern phenotype was associated with lower GOSE (β=-0.40, 95% CI -0.77 to -0.02; p=0.037) (Supplementary Table 1).

Discussion

Nearly one-third of individuals evaluated for mild traumatic brain injury in a specialized outpatient mild TBI cohort presented with a primary, disabling CCP. Among patients assessed at least one year after injury, 44% met criteria for CCP. Rather than showing a pattern of gradual resolution, this subjective cognitive burden remained elevated across multi-year intervals, including among patients seen more than five years after injury. Crucially, patients with CCP had lower mean self-efficacy and disability scores, even when patients performed within normal limits on brief bedside cognitive screening. These findings highlight the heterogeneity of post mTBI cognitive outcomes, identifying a subgroup (i.e. phenotype) with persistent cognitive concerns associated with functional disability, and therefore represents an underrecognized public health problem. Overall, these observations demonstrate that subjective cognitive concerns represent a chronic disabling post-TBI syndrome that is only partially related to decreased self-efficacy, emphasizing the growing need to better understand this phenotype and potential treatments.

Our observations add to an expanding literature establishing that mild traumatic brain injury is an enduring chronic disease. Among patients assessed at least 1 year after injury with available MoCA data, 29/40 (72.5%) exhibited either a primary CCP, abnormal MoCA screening performance, or both well beyond the first post-injury year, challenging the traditional expectation that full recovery occurs within a brief acute window. Treating mTBI as a chronic condition carries significant clinical implications. Clinicians require rigorous diagnostic boundaries to avoid incorrectly labeling persistent non-specific post-concussive concerns as progressive neurodegenerative diseases like traumatic encephalopathy syndrome or early-onset dementia [6,7]. At the same time, this persistent state of chronic cognitive concern and decreased self-efficacy may represent an understudied vulnerability state relevant to later-life cognitive decline.Post-mTBI cognitive symptoms may reflect neurobiological alterations that remain incompletely understood, secondary behavioral adaptations such as withdrawal from work, social disengagement, and physical inactivity, or both.

Our findings also offer insight into the potential mechanisms underlying the CCP, specifically that patient-reported cognitive disability cannot be dismissed as a secondary byproduct of

mood disorders. Depressive symptom severity did not associate with phenotype status in adjusted analyses, directly countering previous clinical assumptions that cognitive concerns are driven primarily by affective distress. Further, our findings align with prior evidence of a disconnect between patient-perceived cognitive limitations and brief psychometric testing performance [3,10]. Cognitive functioning encompasses more than performance on tests of memory or processing speed. Subjective fogginess, perceived changes in cognitive efficiency relative to pre-injury baseline, symptom exacerbation with cognitive exertion, and cognitive endurance represent additional dimensions that may not be captured by a single screening score. Three possible mechanisms may explain this dissociation. First, brief bedside screeners lack the granularity and cognitive load to detect subtle deficits; higher-demand neuropsychological testing sensitive to processing speed and cognitive fatigue may be needed to unmask an objective substrate [19]. Second, subjective concerns may reflect post-injury alterations in metacognition or the capacity to accurately monitor and regulate one's own thinking [20]. Post-TBI network disruptions can impair metacognitive abilities, causing patients to experience heightened internal mental effort and catastrophization of minor or self-perceived cognitive mistakes despite intact performance accuracy [21]. Third, chronic post-concussive concerns may share mechanistic overlap with functional neurological disorder, specifically functional cognitive disorder, where internally focused attention and altered cognitive predictive processing generate disabling symptoms without overt psychometric impairment [22,23]. Our study adds to the literature by establishing that this mismatch persists years after injury without spontaneous attenuation, highlighting the need for future work to directly evaluate these distinct etiologies given our study suggests subjective cognitive concern is a disabling condition. The potential contribution of headache, including migraine, and other chronic pain conditions to cognitive concerns warrants further investigation. Longitudinal studies should examine whether reductions in pain following treatment are accompanied by improvements in cognitive concerns.

Furthermore, our data reveal an association between the CCP and low self-efficacy. Prior neurotrauma research highlights that an individual's perceived capability to manage symptoms plays a central role in long-term functional recovery [24,25]. Within the CCP group, self-efficacy did not differ significantly by MoCA screening status. However, the small subgroup sizes warrant cautious interpretation, and this finding does not establish equivalence between the groups. When individuals endure persistent cognitive symptoms, a diminished confidence in handling demanding occupational and personal roles can develop. This breakdown in self-efficacy can trigger heightened symptom hypervigilance, catastrophic interpretations of routine cognitive lapses, and subsequent social and societal withdrawal. Therapeutic approaches that focus on rebuilding self-efficacy such as providing early targeted psychoeducation and teaching adaptive cognitive strategies may prove vital for restoring functional recovery in this group.

While these preliminary findings add to the limited understanding of post mTBI cognitive changes several limitations to the study should be noted. Our sample was recruited from a single tertiary academic outpatient concussion center, which limits generalizability to broader community populations. Patients pursuing subspecialty evaluation years after an injury may harbor distinct care-seeking habits or heightened symptom sensitivity; however, our center does not triage patients by chief complaint, and individuals with active litigation were excluded. Incomplete data for the MoCA and depression inventories, secondary to changes to the clinic’s protocols, limited sample size, and the retrospective cross-sectional design cannot rule out

selection bias. Additionally, the MoCA is a screening instrument rather than a full neuropsychological battery, and subtle executive or attentional deficits driving patient concerns could not be characterized. Finally, the study was not powered for causation, and given the small sample size, correlations between self-efficacy and cognition are preliminary. Similarly, these findings should not be interpreted as evidence that an individual patient's cognitive concerns will necessarily persist. Future prospective investigations should follow the longitudinal course of this cognitive concern phenotype using detailed neuropsychological testing and evaluate whether targeted self-efficacy interventions improve long-term functional recovery.

Conclusion

In conclusion, subjective cognitive concerns after mTBI are common even years after injury and may not be fully captured by brief cognitive screening. These findings support reframing mTBI as a condition that can become chronic in a subgroup of patients, with persistent cognitive symptoms associated with lower self-efficacy and worse functional recovery. Earlier comprehensive neuropsychological assessment may help distinguish subjective cognitive concerns from objectively measured deficits and guide evaluation of potentially treatable contributors. These findings underscore the need for future studies to better characterize this unique chronic cognitive concern phenotype and evaluate interventions aimed at improving self-efficacy and long-term functional recovery.

Declarations

Ethics approval and consent to participate

The study is approved by the institutional review board (IRB) at University of California, Irvine (IRB # 2283). The requirement for informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

All authors consent to publication.

Availability of data and materials
Anonymized data not published within this article will be made available by request from any qualified investigator.

Competing interests
No competing interests.

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Author Contributions
AN and PMC contributed to study data curation, conception and design, performed the investigation, analyses, and writing the manuscript. PMC was responsible for data collection, investigation, funding, supervision and writing and revision. MTP, STV, ML, MC, SS, CG, TB, SB, JN, DVN, BBA, MMA contributed to manuscript supervision, writing and revision. AF provided data collection, curation, analysis and reference management.

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None

Clinical Trial number: Not Applicable

Supplementary Table 1. Adjusted regression models for MoCA score, cognitive concern phenotype, and GOSE

Analysis	Outcome	Predictor	Model type	N	Estimate type	Estimate	95% CI	p value	Covariates
Continuous MoCA model	MoCA score	Cognitive concern phenotype	Linear regression	111	β	-1.06	-2.74 to 0.62	0.213	Age, sex, education
Depression model	Cognitive concern phenotype	CES-D	Logistic regression	92	Odds ratio	1.05	0.99 to 1.12	0.112	Age, sex, education, years since injury
Functional outcome model	GOSE	Cognitive concern phenotype	Linear regression	189	β	-0.40	-0.77 to -0.02	0.037	Age, sex

Note. The MoCA model was adjusted for age, sex, and education; the depression model for age, sex, education, and years since injury; and the GOSE model for age and sex. Models were interpreted cautiously because of missingness and subgroup size. Positive CES-D odds ratio represents higher odds of cognitive concern phenotype per one-point increase in CES-D. Negative β for GOSE indicates lower GOSE among patients with CCP.

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