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Introduction of a classification interview for post-traumatic headache after concussion

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Abstract

Background Mild traumatic brain injury (TBI) can cause temporary disruption to brain function, with up to half of those affected complaining of functional limitations up to 12 months after the initial injury. Mild TBI can cause a range of sequelae, most commonly post-traumatic headache (PTH). The incidence of PTH varies post mild TBI, with up to 80% affected by three months and 60% by one year, with heterogenous phenotypes reported. We aimed to introduce a standardised interview to identify and characterise PTH. The primary outcome was to identify PTH, and the secondary outcome to characterise the phenotype of PTH.

Methods Participants were prospectively recruited from a tertiary centre hospital and a military rehabilitation centre in the United Kingdom. Inclusion criteria included a diagnosis of mild TBI or concussion; normal brain imaging; aged 17 years and older; and head injury within the last 12 months at time of screening. We have excluded those with serious underlying pathology; secondary causes of headache (excluding PTH), and non-English speakers. The non-headache specialist phoned the patient primarily to run through the structured headache interview. Following this, the headache specialist conducted a telephone clinical consultation as 'gold-standard'. Both interviewers defined PTH as headache developing ≤ 7 days as definite, probable (8–30 days) and unlikely (> 30 days). Cohen's Kappa estimates the inter-rater reliability across categorical variables. We calculated prevalence-adjusted bias-adjusted kappa (PABAK), which adjusts the kappa value for differences in prevalence and bias across variables.

Results A total of 194 people were screened and 63 completed paired interviews. The mean age was 26.2 (SD 8.5) years and 19% were female. Most participants displayed a migraine-like phenotype (94%), followed by tension-type-like headache (13%). A very good agreement was demonstrated between the non-specialist and specialist in diagnosing PTH (PABAK 0.90) and differentiating migraine-like versus tension-type-like headache (PABAK 0.83). There was a good agreement for migraine-like versus other headache sub-phenotypes (PABAK 0.75).

Conclusions There is currently no standardised interview that aids healthcare professionals with identifying PTH and its sub-phenotype. This structured interview can be used to diagnose PTH and its sub-phenotype.

Keywords Post-traumatic headache, Traumatic brain injury, Concussion, Migraine, Tension-type headache, Classification, Diagnosis, Military

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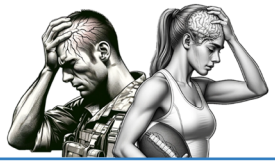
Graphical Abstract

Introduction of a Classification Interview for Post-Traumatic Headache after Concussion

Key Message

Post-traumatic headache (PTH) is the most common symptom following mild traumatic brain injury (TBI). Without accurate sub-phenotyping, many patients may not receive the most effective treatment. Our classification structured interview offers a reliable tool for non-specialists to diagnose and classify PTH, supporting better care for individuals with mild TBI.



Methods

Classification interview designed → Patients with mild TBI and headache identified → Non-specialist uses classification interview tool → Headache specialist evaluation → Classification tool redesigned with three iterations

Analysis
PABAK adjusts the kappa value for differences in prevalence and bias across variables.

Proportion of concordance assesses the degree of agreement between two raters.

- Total: 63 patients with mild TBI and headache
- Cycle 1: 21 patients with mild TBI and headache
- Cycle 2: 22 patients with mild TBI and headache
- Cycle 3: 20 patients with mild TBI and headache

Results

Overall the level of agreement was very good for post-traumatic headache, and good to very good for its sub-phenotypes.

Total Comparison N=63	Proportion of concordance	PABAK
Definite PTH vs probable PTH vs unlikely PTH	95%	0.90 (very good)
Migraine* vs other⁺	87%	0.75 (good)
Migraine* vs TTH	92%	0.83 (very good)

Cycles Comparison	Proportion of concordance			PABAK		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Definite PTH vs probable PTH vs unlikely PTH	90%	95%	100%	0.81 (very good)	0.91 (very good)	1.00 (very good)
Migraine* vs other⁺	81%	82%	100%	0.62 (good)	0.64 (good)	1.00 (very good)
Migraine* vs TTH	89%	86%	100%	0.78 (good)	0.71 (good)	1.00 (very good)

**Migraine includes chronic migraine, episodic migraine, migraine less than three months duration or probable migraine; ⁺other includes tension-type headache, cervicogenic, and primary stabbing headache.*
TBI traumatic brain injury, PTH post-traumatic headache, PABAK prevalence-adjusted bias-adjusted kappa, TTH tension-type headache

Background

Traumatic Brain Injury (TBI) refers to an alteration in brain function or other evidence of brain pathology caused by an external force. It can be categorised into mild, moderate, or severe. Even when classified as mild (mTBI), it can lead to a temporary disruption in brain function, and half of those affected report ongoing functional impairments a year following the injury [1]. Annually, head injuries account for 1.4 million hospital visits in England and Wales, with approximately 200,000 of these cases requiring hospital admission [2]. Although a significant number of mTBI cases do not seek hospital treatment, they represent 70–90% of all brain injuries. Estimates based on population data indicate the actual incidence of mTBI might be over 600 per 100,000 person-years [3]. Mild TBI is notably prevalent among military forces, with an estimated prevalence, within deployed UK military personnel, of 4.4%, rising to 9.5% among those engaged in combat roles [4]. It is also suggested that between 21 and 38% of all TBIs occur during sporting activities [5–7]. Rugby, football, equestrian activities, and cycling exhibit the highest rates of TBI in adults. In Europe, traffic incidents and falls are the primary contributors to TBI cases [8]. Approximately 63% of mTBI occur in adults aged 16 to 64, highlighting its impact on the working-age population [9].

Mild TBI can cause a range of sequelae, most commonly post-traumatic headache (PTH), which has garnered increasing attention among researchers [10, 11]. PTH may manifest independently or as part of post-concussion syndrome, encompassing symptoms such as dizziness, fatigue, sleep disturbances, mood changes and cognitive impairments [12]. Incidence rates of PTH associated with mTBI range widely, from 16 to 79% at three months [10, 13–15], and 15–58% at one year [10, 13, 16]. As per the International Classification of Headache Disorders, 3rd edition (ICHD-3), PTH is defined as a new or worsening headache attributed to head injury and occurring within seven days of trauma, after regaining consciousness or recovering the ability to sense and report pain [17]. However, it is acknowledged that this timeframe is somewhat arbitrary, with the potential of delayed onset headaches being caused by the trauma. PTH can be categorised as acute if resolved within three months or persistent if lasting beyond that period [17].

The pathophysiology of PTH involves the disruption of cellular homeostasis by mechanical force, leading to a complex cascade of neurochemical and neurometabolic changes [12]. PTH is underpinned by multifaceted and overlapping theories, including impaired descending pain modulation and cortical spreading depression, potentially stemming from diffuse axonal injury and neuroinflammatory responses [18, 19]. These mechanisms can also disrupt the trigeminal sensory system, suggesting its involvement in PTH development [12].

The clinical characteristics of PTH have been extensively studied, and evidence has emerged that clinical features often resemble those of primary headache disorders [17, 20, 21]. It is important to appropriately classify the headache sub-phenotypes, as it may enable more targeted management approaches [22]. Within the ICHD-3 criteria, there are no specific headache characteristics to diagnose PTH [17]. This study aimed to prospectively develop and validate a diagnostic classification tool that can be used by non-headache specialists to diagnose PTH and classify these headaches. We hypothesised that the tool would achieve a very good agreement (PABAK ≥ 0.8) between non-specialists and headache specialists in diagnosing PTH and its main sub-phenotypes.

Methods

Development of the classification interview

Initially, a scope of the literature was performed to identify any existing tools to classify or diagnose sub-phenotypes of PTH. This search revealed that no formal diagnostic tools currently exist. However, the most comparable approach was found in the Chronic Headache Education and Self-management Study (CHESS), which focused on classifying chronic headaches [23]. We based our interview on the ICHD-3 criteria. This is primarily used in research and is not intended as a substitute for a clinical diagnosis [24].

A clinical classification interview aimed to:

1. Confirm whether the participants have PTH and distinguish this between unlikely, probable, and definite.
2. Exclude serious pathology (secondary headaches other than PTH and medication-overuse headache).
3. Distinguish between migraine-like, probable migraine-like, tension-type-like headache (TTH), and other headache types i.e. trigeminal autonomic cephalalgias (TAC).
4. Distinguish between chronic and episodic migraine-like headaches.
5. Distinguish between migraine-like headaches with aura and without aura.
6. Identify medication-overuse.

We invited a multi-disciplinary group across different professions and levels of seniority for input into the interview design. Eleven professionals were involved in the development of the interview. This included three general resident doctors, three neurology resident doctors, two specialist headache consultants, two headache nurse specialists, and one psychologist. The team drew on their experience and ICHD-3 headache definitions to ensure it would be clear to a non-specialist. They devised nine sections to cover demographics, PTH, red flags, migraine-like (including probable migraine), primary stabbing headache-like, TTH-like, TAC-like, headache frequency, and medication-overuse (Additional File 1). Headache severity was assessed using a numeric pain rating scale from 0 (no pain) to 10 (worst possible pain). Any components of the interview that were not universally agreed upon were discussed amongst the group. The classification interview was not intended to be rigid, but the sequence and further explanations were determined by individual consultation style and the participant's responses. We planned for two improvement points to the classification interview with data analysis performed for all three cycles, as shown in Fig. 1.

The interviewers asked about headaches within the first three months of head injury. Only the main headache phenotype was used for analysis. PTH was subdivided into three categories:

1. Definite PTH new headache developed or worsened 7 days or less since head injury.
2. Probable PTH new headache developed or worsened 8–30 days since head injury.
3. Unlikely PTH new headache developed or worsened 31 days or more since head injury.

If there was no headache reported, then the interview was stopped. The detailed sub-phenotype diagnosis of TAC was not in the scope of this interview. If 'likely TAC', the non-specialist would discuss this case with the headache specialist. Additionally, we did not diagnose medication-overuse headache as the patient needed to have withdrawn from the medication to see the effect, but we did note down any medication-overuse. If the headache was suggestive of a secondary cause or possible TAC, the non-specialist was asked to discuss with the headache specialist.

Strategy

The first cycle ($n = 21$) took place using the above initial classification interview developed through a consensus multi-disciplinary group.

In the second cycle ($n = 22$), a change was implemented to the classification interview where, if a diagnosis of migraine-like or probable migraine-like was made,

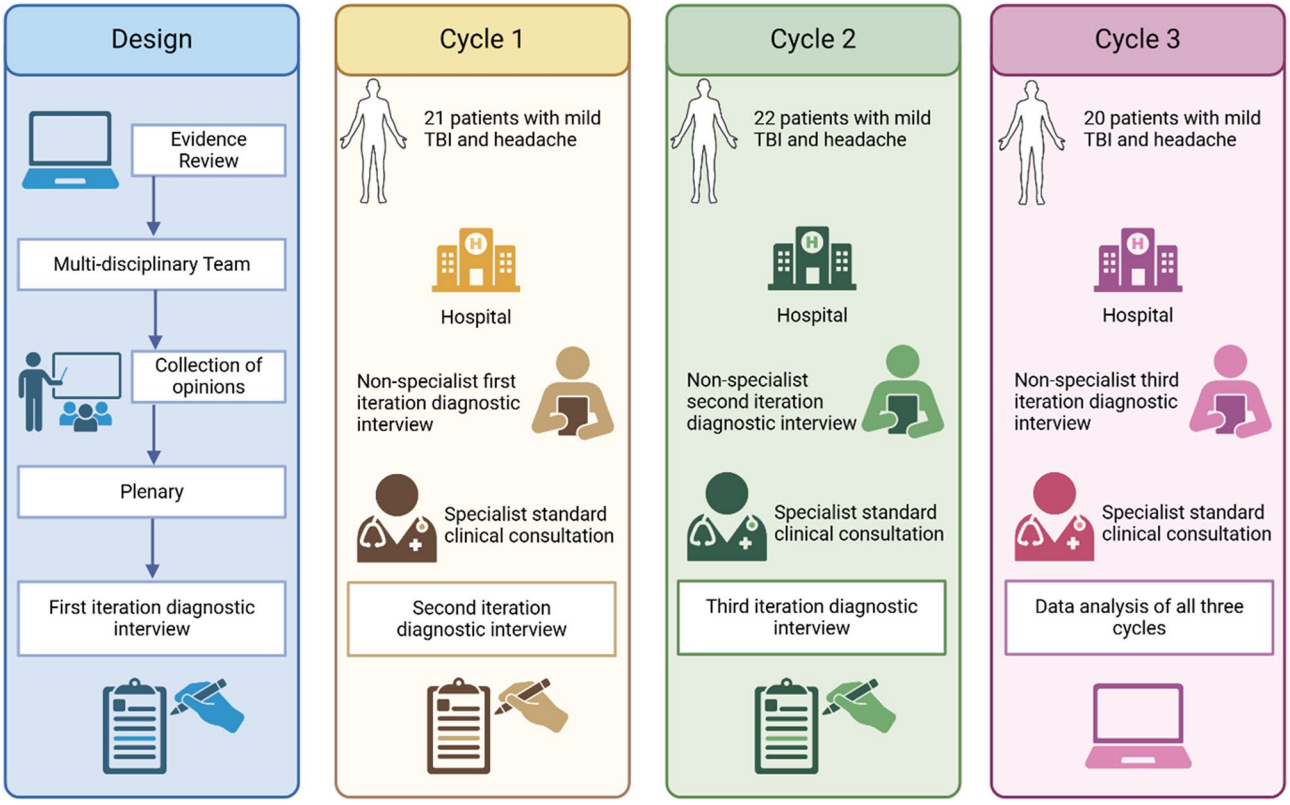


Fig. 1 Overview of the Classification Interview Process

TBI traumatic brain injury

TTH-like and TAC-like were not diagnosed alongside. This was due to diagnostic challenges with distinguishing migraine and TTH and whether to treat them as related conditions [25, 26]. As this interview is to be delivered by non-headache specialists, it limits confusion between the overlap of migraine-like and TTH-like phenotypes.

In the third cycle ($n = 20$), further changes were made to the classification interview. This optimised the question flow, and clarification on certain components i.e. aura where the tool was optimised to guide the non-specialist. The aim of successive cycles was that the level of agreement between specialists and non-specialists would increase.

Validation of the classification interview

To validate the classification interview, we performed paired telephone interviews with patients recruited from the hospital Concussion Service that included both military and civilian patients. Routine clinical care was provided by the headache specialist. This was registered as a Quality Improvement Project within Queen Elizabeth Hospital Birmingham (QEHB) (registered 01/11/2022, CARMS-18660) and Defence Medical Rehabilitation Services (DMRC) (registered 08/03/2024).

Prospective recruitment of follow-up and new patients was conducted from 23rd January 2023 from a UK Concussion Service. Screening was performed by the headache specialist via referral letters to ensure they met the inclusion and exclusion criteria. Inclusion criteria included diagnosis of mTBI or concussion by a headache specialist or a qualified healthcare professional with training in concussion assessment e.g. team physician, Sport & Exercise Medicine physician, or pitch-side physiotherapist; brain imaging within normal limits; and aged 17 years and older. We aimed to speak to patients within a year of head injury. We have excluded those with serious underlying pathology; secondary causes of headache (excluding PTH), non-English speakers, moderate or severe TBI, or an abnormal brain scan. A minimum age of 17 was chosen given the similar sequelae to adults post-TBI and to aid recruitment, especially amongst sporting concussions. We excluded those who had a head injury over a year ago at time of screening to avoid recall bias, although one participant was reviewed by the specialist at 419 days post-injury. Participants who met the criteria took part in two paired telephone interviews. A non-specialist healthcare professional phoned the patient to run through the classification headache interview. Within one month, the headache specialist conducted

the 'gold standard' clinical consultation. Both the non-specialist and specialist were blind to each other's results.

Training and definitions

Three non-specialist resident doctors and one psychologist were involved in the telephone interviews, each having at least two years' experience in the National Health or Defence Medical Services. They each received a presentation slide-based training pack with information on red flags in headache, primary headache disorders, and definitions. The non-specialists were initially observed by a headache specialist using the interview on patients not included in analysis. They also had the opportunity to observe headache telephone clinics. Headache specialist doctors worked within a UK-based specialist headache centre. The specialist doctors were asked to use their routine approach to a headache assessment and were not provided with the structured classification interview.

Statistics

To estimate the 'agreement' between the non-specialist and the specialist doctor, we used Cohen's Kappa (with 95% CI) [27]. Cohen's Kappa estimates the inter-rater reliability across categorical variables. Interpretation of Cohen's Kappa was as follows: 0 indicates totally due to chance, 0.01–0.20 poor, 0.21–0.4 fair, 0.41–0.6 moderate, 0.61–0.8 good, 0.81–0.99 very good, 1.0 perfect [28]. Given that we expect most headaches to be definite PTH, we also calculated prevalence-adjusted bias-adjusted kappa (PABAK), which adjusts the kappa value for differences in prevalence and bias across variables. The PABAK was used to account for the unequal prevalence across categories in the analysis. Additionally, we calculated the proportion of concordance, which looks at the degree of agreement between two raters. Demographics, along with headache phenotype data, were summarised as mean and standard deviation (SD), or frequency and percentage as appropriate. Analysis of monthly headache days and analgesic use was limited to participants who experienced headaches lasting more than two weeks ($n = 58$).

It was estimated that a sample size of at least 62 paired interviews would give an 80% power (at the 5% significance level) to detect a difference in expected Cohen's kappa from 0.55 (null hypothesis) to 0.9 (alternative hypothesis) for the three-way classification of definite vs. probable vs. unlikely PTH. Although the structured interview was refined across three iterative cycles, the power analysis and agreement estimates were based on the full combined dataset ($n = 63$). The revisions focused on improving usability and clarity but did not alter the core diagnostic structure, allowing results to be interpreted as validation of the tool as a whole.

We hypothesised that the structured interview would yield a very good agreement (PABAK ≥ 0.8) between non-specialist and specialist interviewers in diagnosing PTH and identifying migraine-like phenotype.

Results

Validation of the classification interview

A total of 197 patients were screened from the hospital Concussion Service, with 63 paired interviews as shown

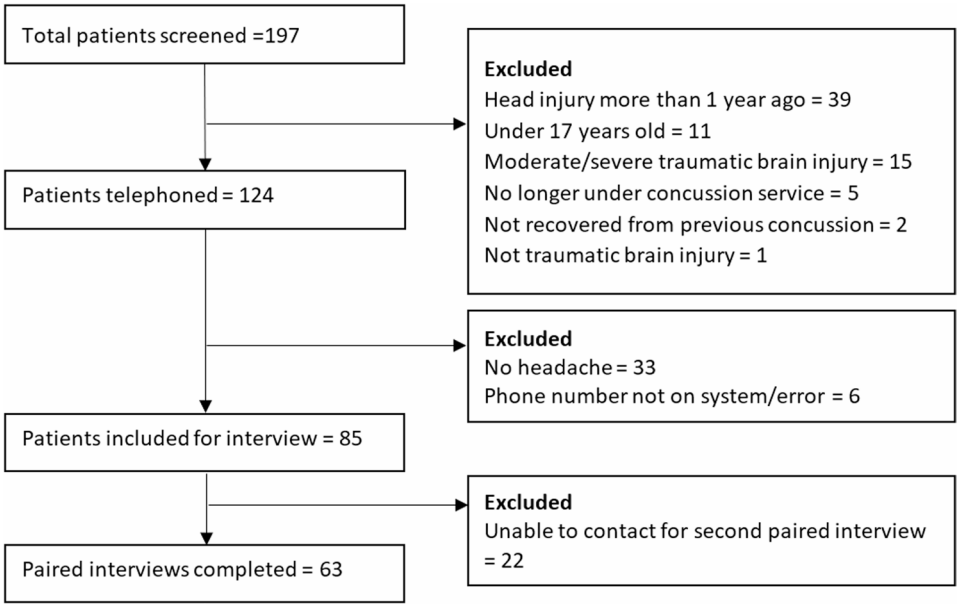


Fig. 2 Consort diagram

Table 1 Baseline characteristics

	Mean (standard deviation, SD)
Time since head injury (days)	132.5 (94.7)
Age at interview (years)	26.2 (8.5)
Number of previous recovered concussions	2.1 (2.8)
	Number of patients (%)
Female	12 (19)
Military	32 (49)
Army	23 (72)
Royal Navy	5 (16)
Royal Air Force	3 (10)
Royal Marines	1 (3)
Athlete	22 (35)
Academy	5 (23)
Semi-pro	7 (32)
Professional	10 (45)
Previous concussion (recovered)	44 (70)
Previous migraine diagnosis	13 (21)
Childhood migraine	4 (6)
Family history migraine	7 (11)

Table 2 Causes of head injury

	Number of patients (%)
Sport	42 (67)
Rugby	30 (71)
Football	2 (5)
Cycling	2 (5)
Skiing	2 (5)
Hockey	1 (2)
Triathlon	1 (2)
Surfboarding	1 (2)
American football	1 (2)
Swimming	1 (2)
Boxing	1 (2)
Assault	6 (10)
Fall	6 (10)
Direct blow (non-assault)	6 (10)
Road traffic accident	3 (5)

in Fig. 2. Cycle one was completed by 21 patients, cycle two by 22 patients, and cycle three by 20.

Baseline characteristics

The mean age was 26.2 (SD 8.5, range 17–54) and 19% were female, as shown in Table 1. Whilst we saw patients within a year of their injury, there was a large spread of time since injury with a mean time being 133 days since injury (SD 94.7, range 18 to 419). The cohort was composed of 49% military personnel and 51% civilians, of which 35% were athletes. The majority of injuries were caused by sport (67%), followed by assaults, falls, and direct blows equally, as shown in Table 2. Due to a large proportion of our cohort having sporting injuries, a large proportion (70%) had repeated concussions, with an average number of 2.1 (SD 2.8, range 0 to 12). Patients with a previous primary headache disorder were included in the study, with 19% having a previous migraine diagnosis, childhood migraine 6% and a family history of migraine 13%.

Table 3 Headache characteristics within three months of injury

	Mean (standard deviation, SD)
Headache Days per Month[a]	19.5 (7.7)
Painkiller Days Per Month[a]	4.1 (6.6)[b]
Headache Severity	5.5 (1.8)
	Number of patients, N (%)
Medication-overuse	3 (5)
Photophobia	55 (87)
Phonophobia	47 (75)
Kinesiophobia	43 (68)
Nausea	31 (49)
Vomiting	5 (8)
Character	
Throbbing/pulsating	39 (62)
Tension	14 (22)
Dull/ache	8 (13)
Sharp/stabbing	2 (3)
Autonomic features	6 (10)
Aura[c]	27 (43)
Visual	16 (59)
Vestibular	12 (46)
Sensory	2 (8)

[a]Only recorded for patients with at least 2 weeks of headache

[b]Not recorded in four patients

[c]Three patients reported two types of aura

Headache characteristics

The headache specialist reported deep phenotyping characteristics of the primary sub-phenotypes (Table 3). There was a wide range of headache days per month (range 1 to 28), with a high frequency mean of 19.5 headache days per month, along with a mean max headache severity of 5.5 (SD 1.8, range 2 to 10). Most patients displayed headaches with accompanying photophobia, phonophobia, kinesiophobia and nausea. The majority of the headaches had a throbbing or pulsing character, followed by pressure. Autonomic features were reported in 11% of patients, but there were no other features to indicate a TAC-like phenotype. Just under half (43%) of the patients reported an aura prior to their migraine-like headache, which was mostly visual and/or vestibular. Five patients had single red flag symptoms which were brought to the attention of the headache specialist, and no further action was taken following review by the specialist [29].

Table 4 Headache phenotype and sub-phenotype

Post-Traumatic Headache	Number of patients (%)
Definite	62 (98)
Likely	1 (2)
Unlikely	0
Headache Sub-Phenotype	
Migraine	59 (94)
Chronic migraine-like	21 (33)
Episodic migraine-like	18 (29)
Migraine-like[a]	8 (13)
Probable migraine-like	12 (19)
TTH and probable TTH-like	8 (13)
Primary stabbing-like	7 (11)
Cervicogenic-like	3 (5)

[a]for migraine-like headaches that are less than three months duration and so do not reach ICHD-3 criteria for chronic migraine-like

Table 5 Frequency of agreement and disagreement between non-specialist and specialist classification interviews for PTH

		Specialist Classification			
		Definite PTH	**Likely PTH**	**Unlikely PTH**	**Total**
Non-Specialist Classification	Definite PTH	59	0	0	59
	Likely PTH	3	1	0	4
	Unlikely PTH	0	0	0	0
	Total	62	1	0	63

PTH Post-traumatic headache

Table 6 Overall summary of proportion of concordance, simple kappa coefficient (95% confidence interval, CI), and prevalence-adjusted bias-adjusted kappa (PABAK)

Comparison *N* = 63	Proportion of concordance	Kappa (SE)	95% CI Kappa	PABAK
Definite PTH vs. probable PTH vs. unlikely PTH	95%	0.384 (0.273) (fair)	−0.152–0.920	0.90 (very good)
Migraine-like[a] vs. other[b]	87%	0.372 (0.169) (fair)	0.041–0.702	0.75 (good)
Migraine-like[a] vs. TTH-like	92%	0.404 (0.212) (fair)	−0.012–0.820	0.83 (very good)

SE Standard error

[a]Migraine-like includes chronic migraine, episodic migraine, migraine less than three months duration or probable migraine

[b]other includes tension-type-like headache, cervicogenic-like, and primary stabbing headache-like

Headache phenotype

Using the headache specialist diagnoses, the majority of patients had a definite PTH, a headache that started within seven days of a head injury, as seen in Table 4. Among the 63 patients assessed by the specialist, 77 distinct headache types were found, reflecting dual phenotypes in some individuals. Overall, 94% experienced migraine-like headaches, including 19% classified as probable migraine-like. 13% patients were diagnosed with TTH-like headache, 11% were diagnosed with primary stabbing headache-like, and 5% with cervicogenic-like headache. One patient was queried as a TAC and underwent an indomethacin trial, however there was no response.

Frequency of agreement

The proportion of concordance between the non-specialist and specialist in diagnosing PTH was 95% (Tables 5 and 6), a very good agreement. However, the kappa coefficient was 0.384 (95% CI −0.152 to 0.920), a fair agreement. The PABAK was used to account for the unequal prevalence across categories in the analysis, with more diagnoses of definite PTH. This was 0.90, a very good agreement. When looking at agreements for the sub-phenotype (Tables 6 and 7), only the most severe headache reported per participant was included, with data from TTH-like, primary stabbing headache-like (as sole headache diagnosis), likely TAC or other phenotypes being grouped as 'others.' In the first agreement tests, definite and probable migraine-like were grouped as 'migraine-like' because this is most useful for clinical use and treatment choices. The sensitivity agreement was similar for migraine-like vs. other and migraine-like vs. TTH-like. PABAK was very good for migraine-like vs. TTH-like, and good for migraine-like vs. other.

Interpretation of Cohen's Kappa: 0 indicates agreement totally due to chance, 0.01–0.20 poor, 0.21–0.4 fair, 0.41–0.6 moderate, 0.61–0.8 good, 0.81–0.99 very good, 1.0 perfect agreement.

PABAK adjusts the kappa value for differences in prevalence and bias across variables, with interpretation analogous to that of Cohen's Kappa.

Proportion of concordance assesses the degree of agreement between two raters.

Analyses of individual cycles (Table 7) showed that all cycles were 'very good' when diagnosing PTH, with PABAK increasing to 100% concordance in cycle three. When diagnosing migraine-like vs. other phenotypes and TTH-like, cycle three showed very good levels of agreement.

PABAK adjusts the kappa value for differences in prevalence and bias across variables. 0 indicates agreement totally due to chance, 0.01–0.20 poor, 0.21–0.4 fair, 0.41–0.6 moderate, 0.61–0.8 good, 0.81–0.99 very good, 1.0 perfect agreement.

Proportion of concordance looks at the degree of agreement between two raters.

The proportion of agreement and PABAK improved across all three cycles.

Table 7 Cycle one, two and three summaries of proportion of concordance, and prevalence-adjusted bias-adjusted kappa (PABAK)

Comparison	Proportion of concordance			PABAK		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Definite PTH vs. probable vs. unlikely PTH	90%	95%	100%	0.81 (very good)	0.91 (very good)	1.00 (very good)
Migraine-like[a] vs. other[b]	81%	82%	100%	0.62 (good)	0.64 (good)	1.00 (very good)
Migraine-like[a] vs. TTH-like	89%	86%	100%	0.78 (good)	0.71 (good)	1.00 (very good)

[a]Migraine-like includes chronic migraine, episodic migraine, migraine less than three months duration or probable migraine

[b]other includes tension-type headache, cervicogenic, and primary stabbing headache

Discussion

We have developed and validated a telephone classification interview that non-headache specialists can use to diagnose PTH and classify its common sub-phenotypes. Agreement was very good for PTH diagnosis and ranged from good to very good for sub-phenotype classification. These findings suggest that our structured interview tool may support earlier identification of PTH in settings without access to headache specialists, improving consistency in diagnosis and enabling timely intervention. This structured interview is intended to support but not replace clinical assessment by appropriately trained healthcare professionals. It should be used in conjunction with clinical judgment, and any concerning or atypical features should prompt referral to a specialist. The Landmark study found that one in four patients with migraine went undiagnosed by the General Practitioner (non-headache specialists) [30]. Whilst over- or inappropriate diagnosis is at risk, underdiagnosis also restricts accurate care. US studies have shown that just over half of those who met criteria for daily migraine prevention received it and less than 11% will receive a triptan or ergot [31, 32].

This structured interview can take approximately 10 min to conduct. PTH not being appropriately sub-phenotyped may result in many of these headaches potentially not receiving tailored treatment. Phenotyping headaches may be clinically important, as it can help guide management strategies. While distinct headache phenotypes often require different treatments in primary headache disorders, the evidence supporting phenotype-driven treatment efficacy specifically for PTH remains limited and requires further research [22]. For example, novel treatments such as calcitonin gene-related peptide (CGRP)-based therapies have shown promise in migraine management, but their role in PTH treatment is not yet well established [33]. Ongoing research in this area includes an open-label study of erenumab, which has shown preliminary efficacy in PTH [34]. However, placebo-controlled randomised controlled trials are needed to confirm these findings. Furthermore, PTH often coexists with other persistent post-concussion symptoms, such as mental health concerns (i.e. PTSD), physical symptoms, and cognitive disturbances [12, 35, 36]. Prompt treatment of headache symptoms may facilitate a faster return to normal activities, reduce avoidant behaviour, decrease the likelihood of pain catastrophizing and emotional distress, and overall support a smoother recovery process [12].

The individual with suspected TAC was correctly identified by both the non-specialist and the specialist doctor. The success of the interview in guiding decision-making may be attributed to the use of a visual flowchart, which can direct the non-specialist through the process and highlight when to consult a specialist. The structured and detailed nature of the interview may also have contributed to its effectiveness.

There is growing interest in developing structured diagnostic tools for primary headache disorders, particularly for use by non-specialists. A 2019 systematic review identified 30 such tools—including the HARDSHIP questionnaire and ID-CM—the former distinguishes between chronic migraine and chronic TTH, while another review of 19 tools for use in nonclinical settings similarly highlighted HARDSHIP as a strong candidate for migraine diagnosis [37–40]. Additional systematic reviews have explored tools for less common conditions such as cluster headache and trigeminal neuralgia, reflecting broader efforts to standardise headache classification [41, 42]. While our telephone-based interview was not conducted within primary care use, it contributes to this expanding field by focusing on PTH, a condition absent from existing tools.

However, interviews could be challenging due to patient recall [43, 44]. To address this, we advise the use of a headache diary in clinical situations. The greatest disagreement observed was between diagnosing "probable" or "definite" chronic migraine-like, which may be influenced by recall bias, though this distinction is less critical in clinical management. There were also discrepancies in diagnosing TTH-like, including debate as to whether it is a separate entity or part of migraine spectrum [45]. All but one patient had a definite PTH, which agrees with the ICHD-3 definition that PTH occurs within seven days of injury. In addition, the majority of patients having a migraine-like, followed by TTH-like sub-phenotype is consistent with the current literature [46].

The non-specialist group in this study comprised resident doctors and one psychologist, which does not fully represent the wider range of healthcare professionals who may use the tool in practice. Future validation studies should assess usability across a broader range of professionals such as nurses, primary care physicians, and rehabilitation

specialists. Our cohort of patients were pulled from specialist concussion clinics, thereby allowing selection bias as they are likely to have more severe symptoms than those who either do not present initially or never require specialist input. Our cohort also included those with previous concussions, as this is seen commonly amongst athletes. Whilst they had all symptomatically recovered from their past TBIs, literature shows that repeated concussions can have worse neurological outcomes [47]. Men are approximately 40% more likely than women to sustain a TBI in adulthood [48]. Therefore, although only 19% of our study cohort were female, this likely reflects the demographics of the recruitment sites, particularly the military rehabilitation centre, where males predominate. This gender imbalance is a limitation, as sex differences may influence the presentation of PTH [48]. Future research should aim to include a more balanced representation of sexes to better understand potential differences in PTH phenotypes and improve the generalisability of classification tools. Another limitation of our study was the relatively low kappa values. Notably, for diagnosing PTH and differentiating migraine-like from TTH-like, the 95% CI for kappa included negative values. This suggests the possibility that agreement may be worse than chance. However, we reported the PABAK, which is more appropriate for our study design.

Traumatic brain injuries occur in various community settings, such as sports fields, workplaces, primary care facilities, or emergency departments [49]. Therefore, it is important for non-headache specialists to recognize that PTH has different sub-phenotypes and to identify them accurately. While this approach is not a substitute for a detailed clinical diagnosis, we believe it can significantly improve the quality of classification in people with PTH. For our study we trained non-specialist resident doctors and a psychologist, but we believe this method could be utilized by other healthcare professionals to aid in diagnosis and facilitate prompt treatment. The proportion of agreement between civilian and military patients was at least good, therefore, the interview could be used in both populations. Future directions could include refining the interview to reduce discrepancies and exploring its use in different clinical settings. Additionally, implementing e-training modules for non-specialists could further enhance diagnostic accuracy. While this structured interview is intended for use by appropriately trained healthcare professionals, broader awareness of concussion and headache features among non-clinical support staff i.e. coaches, can support early recognition and referral, particularly in sports or community settings [50].

Conclusion

The development and validation of the classification interview for PTH has yielded promising results. The level of agreement was very good for PTH, and good to very good for its sub-phenotypes. There is currently no standardised validated interview that aids healthcare professionals in identifying PTH and its sub-phenotypes. Our classification structured interview shows promise as a reliable tool for diagnosing PTH. The collaboration among the team of professionals and careful consideration of ICHD-3 criteria contributed to the interview's effectiveness. Importantly, this tool is intended to support appropriately trained healthcare professionals and should be used alongside clinical judgment, with specialist referral advised for complex or atypical cases. Integration of our standardized interview tool into clinical practice will contribute to improving the classification and management of PTH, ultimately benefiting patients with mTBI.

Abbreviations

TBI	Traumatic brain injury
mTBI	Mild traumatic brain injury
UK	United Kingdom
PTH	Post-traumatic headache
ICHD-3	International Classification of Headache Disorders, 3rd edition
CHESS	Chronic Headache Education and Self-management Study
QEHB	Queen Elizabeth Hospital Birmingham
DMRC	Defence Medical Rehabilitation Centre
PABAK	Prevalence-adjusted bias-adjusted kappa
TTH	Tension-type headache
TAC	Trigeminal autonomic cephalalgia

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

Study concept was from HSL and AS. HSL, JLM, and AS designed the study with input from MM. HSL and JLM conducted the headache specialist reviews. MS, HB, AL, and BJ conducted the non-headache specialist reviews. HSL, MT, AY, and JLM designed the initial structured interview before multidisciplinary approval. HSL and MT designed the second revision of the interview. HSL, HB, and AL designed the third revision of the interview. HSL analysed the data with senior statistical input from VH. HSL drafted the manuscript and editing from MT, AY, SD, HE, MM, LJH, JLM, AJM, and AS. All authors reviewed the manuscript critically for intellectual content and approved the final version.

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Data availability
Anonymised raw data are not publicly available, but are available for research upon request.

Declarations

Ethics approval and consent to participate
Both Queen Elizabeth Hospital Birmingham (registered 01/11/2022, CARMS-18660) and Stanford Hall Defence Medical Rehabilitation Centre (registered 08/03/2024) approved and registered this study as a Quality Improvement Project. Informed consent was obtained from all study participants regardless. As the primary purpose of the study was service quality improvement, it was deemed to fall outside the scope of national research ethics review. Data relating to individual patients were collected anonymously and held in accordance with General Data Protection Regulation.

Consent for publication
Not applicable.

Competing interests
AY reports speaker fees for an education talk from TEVA UK (unrelated to this topic). Alexandra Sinclair reports she has consulted for Novartis, AbbVie, Vertex and Orion Pharma and speaker fees from Teva Uk and Novartis on unrelated topics. She was previously a Director and Chief Scientific Officer (CSO) with shares at Invex Therapeutics (unrelated to this topic). MSM is chair of the medical advisory board of the CSF Leak Association; has served on advisory boards for AbbVie, Autonomic Technologies Inc, Eli Lilly, Novartis, Pfizer, Salvia and TEVA; has received payment for educational presentations from AbbVie, electroCore, Eli Lilly, Novartis and TEVA; has received grants from Abbott, Medtronic and electroCore; and has a patent on system and method for diagnosing and treating headaches (WO2018051103A1, issued). All other authors declare no competing interests. Authors declare no other financial relationships with any organisation that might have an interest in the submitted work and no other relationships or activities that could appear to have influenced the submitted work.

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