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Posttraumatic Migraine as a Predictor of Recovery and Cognitive Impairment After Sport-Related Concussion

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Investigation performed at the University of Pittsburgh, Pittsburgh, Pennsylvania, and Humboldt State University, Arcata, California

Background: Although previous research has demonstrated that patients with posttraumatic migraine (PTM) after concussion report more symptoms and cognitive deficits after injury than do those without PTM, it is not known whether these effects persist beyond the first week of injury or whether PTM predicts recovery time.

Purpose: To determine whether PTM during the first week after injury predicts (1) cognitive impairment and symptoms in the second week after injury and (2) overall recovery time.

Study Design: Cohort study; Level of evidence, 2.

Methods: Participants were 138 male high school football players with a mean age of 15.96 years (SD, 1.18 years; range, 13-19 years). They were classified into 3 groups: PTM (headache, nausea, and photosensitivity or phonosensitivity), headache (headache without the other PTM symptoms), or no headache (no headache or PTM symptoms). The Immediate Post-concussion Assessment and Cognitive Test (ImPACT) was used to assess cognitive performance and symptoms at baseline, postinjury days 1-7, and postinjury days 8-14. Recovery time data were collected from medical records.

Results: The PTM group performed worse on verbal memory than did the headache group at 8-14 days after injury. The PTM group performed worse on visual memory, reaction time, and symptoms than did the other groups at 1-7 days and 8-14 days after injury. The PTM group was 7.3 times (95% confidence interval, 1.80-29.91) more likely to have protracted recovery (>20 days) than the no headache group and 2.6 times (95% confidence interval, 1.10-6.54) more likely than the headache group.

Conclusion: Results suggest that PTM is associated with cognitive impairments and protracted recovery and that headache alone is not a good predictor of recovery.

Keywords: concussion; headache; migraine; mild traumatic brain injury; sports; symptoms

Approximately 1.6 to 3.8 million sport-related concussions occur each year in the United States.[11] In high schools alone, it is estimated that 136,000 concussions occur each academic year.[5] Football accounts for 56.8% of all high school sports concussions followed by (combined girls and boys) soccer at 18.5%.[21] Common symptoms in athletes with a concussion include headache, dizziness, difficulty concentrating, confusion, and visual changes. The majority of these symptoms resolve within 1 week (83.4%), whereas 16.6% require prolonged recovery time, sometimes lasting a month or longer.[21] Despite the growing literature on the mechanisms, symptoms, and natural history of concussions, we still know little about which factors are prognostic for better or worse outcomes following injury.

One factor that may play a role in predicting outcomes after a concussion is the presence of posttraumatic migraine (PTM) symptoms. Headaches are the most common symptom reported after a concussion.[2,21,24] Posttraumatic headache (PTH), as defined by the *International Classification of Headache Disorders, 2nd edition*,[9] is a secondary headache disorder occurring in close temporal relationship after a head injury. However, not all PTHs are alike. In fact, PTHs may include but are not limited to mixed, tension-type, cluster-like, and migraine-like headaches.[18] The International Headache Society defines a migraine as an episodic, unilateral, pulsatile headache with associated symptoms including nausea, vomiting, photophobia, phonophobia, and aggravation with activity.[9] Posttraumatic migraine has been documented

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after concussion and may influence clinical outcomes after injury.[22]

Previous research supports a common molecular pathophysiological cause of migraines and mild traumatic brain injury.[6,12,17,18,26] Extracellular potassium and intracellular sodium, calcium, and chloride are increased in the brain after a mild traumatic brain injury and migraine. Furthermore, both mild traumatic brain injury and migraines appear to result from an excess release of excitatory amino acids and opioids, such as glutamate and beta-endorphins, respectively.[6,26] Studies suggest that preinjury migraine history may in fact be an independent risk factor for sustaining a concussion[8,23] as it is with other neurological entities such as stroke.[4] Further proof that PTM and atraumatic migraine headaches share similar pathogenesis lies in the effectiveness of triptan medications in managing both types of migraines.[3,18]

Initial studies suggest that PTM symptoms occurring within the first few days after a concussion may indicate a more severe injury. Mihalik and colleagues[22] observed that patients with PTM symptoms approximately 4 days after concussion exhibited more total symptoms and cognitive deficits than did patients with nonmigraine headaches or no headache. Several studies that focused on identifying predictors of prolonged recovery reported that patients with higher somatic symptom scores that include migraine-like symptoms at mean 2 to 3 days after injury were more likely to have a protracted recovery (greater than 10-14 days).[13,14,16] In terms of migraine headache, this would not be entirely unexpected. Without proper treatment, atraumatic migraine pain can last for days and occasionally weeks in duration. Given the multimodal pathological mechanisms of trauma, including cervicogenic whiplash and coup-contrecoup injury, among others, those with PTM may take longer to recover. Whether PTM also interferes with the recovery process of other concussive symptoms is unknown.

Although previous research has demonstrated that patients with PTM after concussion report more symptoms and cognitive deficits after injury than do patients without PTM, we do not know whether these effects persist beyond the first week of injury. We also do not know whether PTM within the first few days of injury (ie, subacutely) predicts recovery time. Therefore, the purpose of this study was to determine whether PTM during the first week after injury predicts cognitive impairment, symptoms in the second week after injury, and recovery time. Drawing on the initial studies on PTM after concussion, we hypothesized that patients with PTM after concussion would report more symptoms and worse cognitive deficits than those reporting only headache or reporting no headache. We also hypothesized that PTM would be a risk factor for protracted recovery time from concussion.

MATERIALS AND METHODS

Design

The study involved a multisite prospective cohort design over a 5-year period. The independent variable for the study was PTM symptoms within the first week of injury. Dependent variables included cognitive performance, symptoms, and recovery time.

Participants

The participants included male high school football players who had a diagnosed sport-related concussion at 1 of 2 data collection sites in northern California and western Pennsylvania over a period of 2 to 5 years. Participants were excluded before the study if they had a history of 1 or more of the following: (1) moderate to severe (Glasgow Coma Scale <13) traumatic brain injury, (2) substance abuse, (3) psychiatric disorder, and (4) other neurological disorder. During the study, 174 athletes incurred a sport-related concussion and met the inclusion and exclusion criteria. A total of 36 (21%) participants were excluded from the study because they had incomplete data, they dropped out of the study, or they sustained an injury that occurred at the end of the season (ie, were lost for follow-up testing). The remaining 138 (79%) participants were enrolled in the study. We collected complete cognitive and symptom data from the entire remaining sample (N = 138). Using the same criteria as Lau et al,[15] we divided the participants into prolonged (>21 days) and rapid (<7 days) recovery groups. Among participants for whom we had completed recovery data, there were 36 (37%) participants in the prolonged recovery group and 61 (63%) in the rapid recovery group. The remaining 30% (n = 41) of the original 138 participants recovered in 8 to 20 days and were therefore excluded from the recovery time analysis.

Measures

Concussion. A concussion was defined as a trauma to the brain involving direct or indirect biomechanical forces.[20] Certified athletic trainers (ATCs) identified potentially concussed athletes based on the presence of common signs and symptoms (eg, loss of consciousness [LOC], amnesia, confusion, dizziness) at the time of injury. Athletes were then referred for follow-up assessment and cognitive testing. A diagnosis of concussion was confirmed by trained clinicians based on the following criteria: (1) presence of concussion symptoms at follow-up, and/or (2) cognitive impairment as evidenced by a clinically significant decline on at least 1 cognitive test score. None of the concussions in the study involved prolonged (>30 seconds) LOC or amnesia lasting longer than 24 hours.

Posttraumatic Migraine and Headache. Participants were classified based on self-reported symptoms within 1-7 days after injury into 1 of the following 3 mutually exclusive groups: PTM (headache, nausea, and photosensitivity or phonosensitivity), headache (headache without the other PTM symptoms), and no headache (no headache or PTM symptoms). It is important to note that the no headache group included some participants who reported nausea, photosensitivity, and/or phonosensitivity among other symptoms but who did not report headache.

Cognitive Performance and Symptoms. The Immediate Post-concussion Assessment and Cognitive Test (ImPACT) computerized cognitive test battery was used to assess cognitive performance and symptoms at baseline and after concussion. The ImPACT test includes demographic information, the 22-item Post-concussion Symptom Scale (PCSS), and 6 cognitive test modules. The cognitive modules are aggregated into verbal memory, visual memory, visual processing speed, and reaction time composite scores. The PCSS yields a total score as well as symptom factor scores for cognitive, somatic, emotional, and sleep-related symptoms. Test-retest reliability, validity, and specificity/sensitivity data for ImPACT are reported elsewhere.[15,16]

Recovery Time. Recovery time in days was calculated by subtracting the date of return to activity from the date of injury. The date of return to activity was based on the following criteria as determined by a trained clinician (ie, neuropsychologist or physician): (1) symptom-free at rest, (2) back to baseline cognitive performance at rest, and (3) symptom-free after exertion. Recovery times were then divided into protracted and rapid categories as previously discussed.

Procedures

The respective universities' institutional review boards approved the study protocol and all consent forms. We then obtained written informed consent from parents and assent from all participants before the study. The ATCs in the study identified and referred for testing all athletes who met the criteria for the study. Trained clinicians evaluated all athletes with a suspected concussion to confirm their injury and eligibility for the study. Eligible participants completed the ImPACT test and PCSS at baseline, postinjury days 1-7 (mean $\pm$ standard deviation [SD], 2.70 $\pm$ 2.67 days), and postinjury days 8-14 (mean $\pm$ SD, 8.91 $\pm$ 4.07 days). Participants were tested only once during each time interval. We collected recovery time data from participants' medical records.

Data Analysis

Descriptive data were used to characterize the sample and variables in the study. A series of 3 (group: PTM, headache, no headache) $\times$ 3 (time: preinjury, postinjury days 1-7, postinjury days 8-14) analyses of variance (ANOVAs) with post hoc Scheffé tests were used to compare the cognitive performance and symptom factor scores (cognitive, somatic, emotional, sleep) of participants. The symptom factor scores were composed of the following symptoms: (1) cognitive: fatigue, fogginess, drowsiness, difficulty remembering, difficulty concentrating; (2) somatic: dizziness, vomiting, numbness, balance problems, vision problems; (3) emotional: irritability, nervousness, emotionalism, sadness; and (4) sleep: trouble sleeping, sleeping more or less than usual. The PTM-related symptoms (eg, headache, phonophobia, photophobia, nausea) were excluded from the somatic symptom factor, as they were used to delineate the groups. A series of chi-square analyses with odds ratios (ORs) and 95% confidence intervals (CIs) were used to assess the risk of protracted recovery associated with the PTM, headache, and no headache groups.

RESULTS

A summary of demographic data for the total sample and recovery time subsample is provided in Table 1. The mean age for the total sample (N = 138) was 15.96 years (SD, 1.18 years; range, 13-19 years). The mean age for the recovery time subsample (n = 97) was 15.92 years (SD, 1.28 years). A total of 40.6% (n = 56) of the total sample were in the PTM group, 45.7% (n = 63) were in the headache group, and 13.8% (n = 19) were in the no headache group. A total of 33% (n = 32) of the recovery subsample were in the PTM group, 46.4% (n = 45) were in the headache group, and 21.6% (n = 20) were in the no headache group. The PTM, headache, and no headache groups from the 2 samples did not differ significantly on any of the demographic variables including age, migraine, headache, and concussion history. In addition, the protracted and rapid recovery groups did not differ on any of the demographic variables.

The results of a series of 3 (time) $\times$ 3 (group) ANOVAs with Bonferroni correction for multiple comparisons supported several significant differences in cognitive performance among the 3 groups. Specifically, the results supported significant time $\times$ group interactions for verbal (Wilks λ = .92; $F_{4,134}$ = 3.02; P = .02; η^2 = .04) and visual memory (Wilks λ = .88; $F_{2,134}$ = 4.29; P = .002; η^2 = .07) and reaction time (Wilks λ = .87; $F_{4,134}$ = 4.96; P = .001; η^2 = .07). A summary of the means and standard deviations for the groups across the 3 time periods is presented in Table 2. The following differences are based on comparisons with baseline scores. The PTM group performed significantly worse on verbal memory than the headache only group at 8-14 days after injury (Figure 1). Interestingly, the no headache group performed worse than the headache only group at 1-7 days after injury. The PTM group performed significantly worse on visual memory than the other 2 groups at 1-7 days and 8-14 days after injury (Figure 2). The PTM group also performed significantly worse (higher score = slower performance) on reaction time than the other 2 groups at 1-7 days and 8-14 days after injury (Figure 3). The groups did not differ significantly on processing speed (Wilks λ = .96; $F_{4,134}$ = 1.45; P = .22; η^2 = .02).

The results also supported main effects for time for verbal (Wilks λ = .64; $F_{4,134}$ = 38.44; P = .001; η^2 = .37) and visual memory (Wilks λ = .74; $F_{4,134}$ = 22.32; P = .001; η^2 = .27), processing speed (Wilks λ = .81; $F_{4,134}$ = 16.25; P = .001; η^2 = .20), and reaction time (Wilks λ = .76; $F_{4,134}$ = 21.19; P = .001; η^2 = .24). Specifically, subjects scored lower on each composite score at 1-7 days after injury compared with baseline, and all scores at 8-14 days were higher than those at 1-7 days after injury (Table 2). Both verbal and visual memory scores at 8-14 days were still below baseline levels (Table 2).

The results of a series of 3 (time) $\times$ 3 (group) ANOVAs with Bonferroni correction for multiple comparisons supported several significant differences in the symptom factors among the 3 groups. Specifically, the results supported significant time $\times$ group interactions for cognitive (Wilks λ = .77; $F_{4,113}$ = 7.87; P = .001; η^2 = .12), somatic (Wilks λ = .73; $F_{2,134}$ = 9.72; P = .001; η^2 = .15), emotional

TABLE 1
Comparison of Demographic Factors Among Groups in the Total Sample and Recovery Time Subsample[a]

		Age, y		No. of Previous Concussions		Other Factors, No. of Patients			
	No.	Mean	SD	Mean	SD	ADD/ADHD	LD	Headache	Migraine
Total sample (N = 138)									
No headache	19	16.16	1.07	0.47	0.86	0	0	3	2
Headache	63	15.94	1.19	0.74	0.86	4	2	7	4
PTM	56	15.91	1.21	0.41	0.88	2	1	10	7
Total	138	15.96	1.18	0.47	0.78	6	3	20	13
Recovery time subsample (n = 97)									
No headache	20	15.75	1.21	0.75	1.52	0	1	3	1
Headache	45	15.98	1.39	0.36	0.61	3	1	4	3
PTM	32	15.93	1.19	0.44	0.91	0	0	3	2
Total	97	15.92	1.28	0.47	0.95	3	2	10	6

[a]ADD/ADHD, attention deficit disorder/attention deficit hyperactivity disorder; LD, learning disability, PTM, posttraumatic migraine; SD, standard deviation.

TABLE 2
Neurocognitive Scores at Baseline, Postinjury Days 1-7, and Postinjury Days 8-14 for the Study Groups[a]

	Baseline		Postinjury Days 1-7		Postinjury Days 8-14	
	Mean	SD	Mean	SD	Mean	SD
Verbal memory						
No headache*	86.21	6.15	68.37[c]	10.84	80.16	12.22
Headache	84.95	7.62	76.97	13.48	82.35	12.98
PTM*	84.34	8.03	73.38	13.06	75.54[c]	14.49
Total***	85.17	7.27	72.90[d]	12.46	79.35[d,e]	13.23
Visual memory						
No headache	74.89	7.33	70.53	8.69	74.93	14.45
Headache	77.26	10.60	66.62	15.54	76.15	15.15
PTM**	75.43	8.92	59.98[b,c]	13.04	64.79[b,c]	17.17
Total**	75.86	8.95	65.71[d]	12.43	71.96[d,e]	15.60
Processing speed						
No headache	37.97	6.91	36.40	8.60	39.32	8.89
Headache	35.64	5.21	34.05	9.22	37.01	8.02
PTM	34.52	5.14	29.73	7.76	33.74	8.11
Total**	36.04	5.76	33.39[d]	8.53	36.69[e]	8.34
Reaction time						
No headache	0.54	0.06	0.58	0.11	0.54	0.09
Headache	0.57	0.05	0.63	0.14	0.56	0.09
PTM***	0.57	0.06	0.73[b,c]	0.16	0.62[b,c]	0.13
Total***	0.56	0.06	0.65[d]	0.13	0.58[e]	0.11

[a]PTM, posttraumatic migraine; SD, standard deviation. *$P < .05$; **$P < .01$; ***$P < .001$.
Scores were [b]lower than no headache group; [c]lower than headache group; [d]lower than baseline; [e]higher than postinjury days 1-7.

(Wilks $\lambda = .90$; $F_{2,113} = 7.63$; $P = .02$; $\eta^2 = .05$), and sleep (Wilks $\lambda = .88$; $F_{4,113} = 9.68$; $P = .004$; $\eta^2 = .07$) symptom factors. The PTM group scored significantly higher on all 4 of the symptom factors than the headache and no headache groups at both 1-7 and 8-14 days after injury (Table 3). The headache group scored higher on sleep than the no headache group at 1-7 days after injury (Table 3). There were no differences among the groups in symptom factor scores at baseline.

The results also supported main effects for time for cognitive (Wilks $\lambda = .56$; $F_{2,113} = 45.37$; $P = .001$; $\eta^2 = .45$), somatic (Wilks $\lambda = .66$; $F_{2,113} = 29.17$; $P = .001$; $\eta^2 = .34$), emotional (Wilks $\lambda = .81$; $F_{2,113} = 9.68$; $P = .001$; $\eta^2 = .15$), and sleep (Wilks $\lambda = .88$; $F_{2,113} = 7.63$; $P = .02$; $\eta^2 = .12$) symptom factors. Specifically, subjects scored higher on each symptom factor at 1-7 days after injury compared with baseline, and all scores at 8-14 days were lower than those at 1-7 days after injury (Table 3). Both cognitive and somatic symptom factor scores at 8-14 days were still significantly higher than baseline levels (Table 3).

The results of a series of chi-square analyses with ORs are summarized in Table 4. The results indicated that

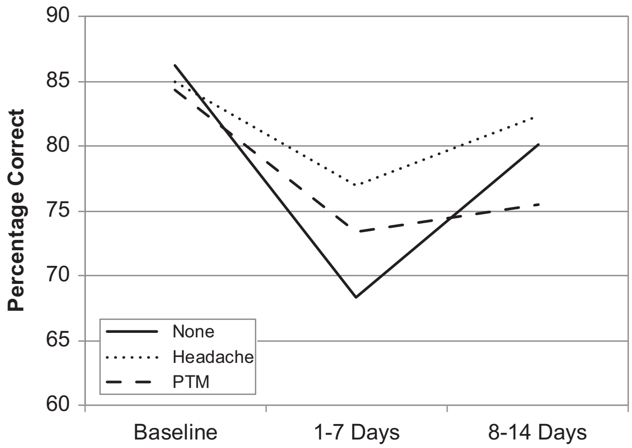

Figure 1. Verbal memory scores for posttraumatic migraine (PTM), headache, and no headache (None) groups.

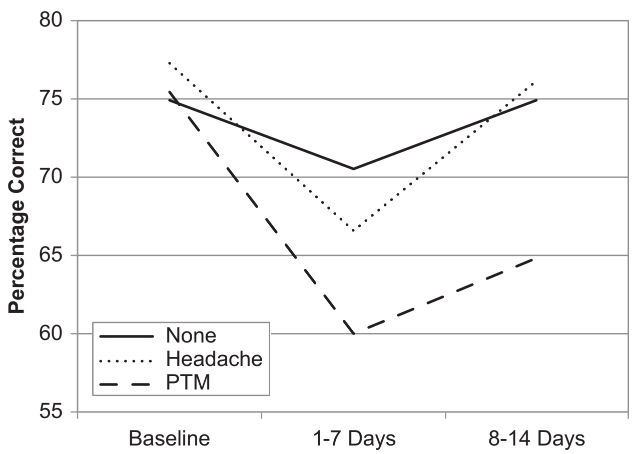

Figure 2. Visual memory scores for posttraumatic migraine (PTM), headache, and no headache (None) groups.

participants in the PTM group were 7.3 times (95% CI, 1.80-29.91; $P = .006$) more likely to have a protracted recovery time than those in the no headache group. The results also indicated that participants in the PTM group were 2.6 times (95% CI, 1.10-6.54; $P = .04$) more likely to have a protracted recovery time than those in the headache group. The analysis comparing the headache and no headache groups was not significant ($P = .14$).

DISCUSSION

Summary of Results

The purpose of this study was to determine whether PTM predicts cognitive impairment and recovery time after the occurrence of sports concussion. Overall, the results indicated that the presence of PTM after a concussion was associated with increased cognitive impairment and recovery time. Patients with PTM performed significantly worse

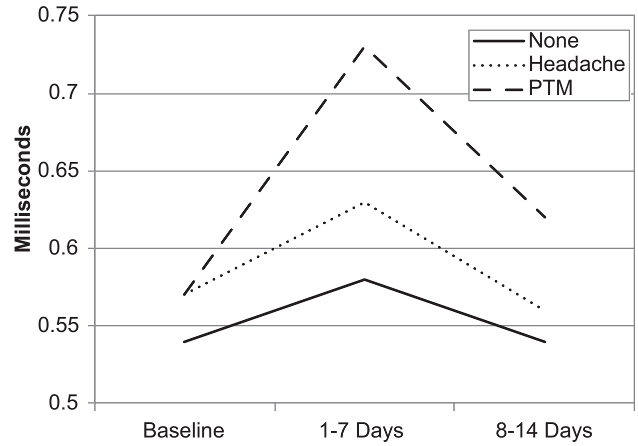

Figure 3. Reaction time scores for posttraumatic migraine (PTM), headache, and no headache (None) groups.

on computerized neurocognitive testing across the domains of visual memory and reaction time than did patients with no headache or headache only. Those with PTM scored significantly lower on testing of verbal memory compared with the patients with headache only. The PTM group also scored significantly higher on all 4 of the symptom factors (cognitive, somatic, emotional, sleep) than the headache and no headache groups throughout the course of recovery (1-7 and 8-14 days). Furthermore, patients with PTM had a 7.3 times and 2.6 times increased risk of a protracted recovery than the no headache group or headache group, respectively.

Headache as a Predictor of Concussion Severity and Recovery Time

The frequency and significance of headache as a symptom of concussion have been reported previously by researchers.[2,21,24] In one study, researchers reported a 93.4% prevalence of headache after a concussion.[21] In the current study, the prevalence of headache after concussion was 47%. The lower prevalence in the current study is likely attributed to the fact that headaches and PTM were classified separately, whereas previous studies often grouped them together. When the PTM and headache only groups are combined in the current study, the prevalence is 80%, approaching the prevalence previously reported.[2,21,24] The high prevalence of this symptom highlights the difficulty in using headache as a general symptom to distinguish concussion severity. The current study supports this notion, as headache without associated migraine-type symptoms was not significantly associated with protracted recovery time. To further complicate the use of headache as a predictor of concussion severity, patients in the current study without a headache performed worse on verbal memory than did patients with headache during the early recovery phase (1-7 days after injury). As such, the current findings suggest that headaches alone are not a good predictor of concussion severity.

TABLE 3
Symptom Factor Scores at Baseline, Postinjury Days 1-7, and Postinjury Days 8-14 for the Study Groups[a]

	Baseline		Days 1-7		Days 8-14	
	Mean	SD	Mean	SD	Mean	SD
Cognitive						
No headache	1.14	2.54	5.50	5.69	2.43	2.34
Headache	0.93	1.84	6.25	6.51	1.93	3.32
PTM***	2.18	3.28	14.14[b,c]	7.43	7.86[b,c]	7.42
Total***	1.48	2.66	9.47[d,f]	7.86	4.47[d,e]	6.06
Somatic						
No headache	0.43	1.34	1.86	3.25	0.50	0.65
Headache	0.28	0.88	1.80	2.92	0.59	1.42
PTM***	0.94	2.01	6.81[b,c]	3.91	2.67[b,c]	3.17
Total**	0.57	1.53	3.91[d,f]	4.19	1.45[d,e]	2.49
Emotional						
No headache	0.57	1.45	0.71	1.27	0.43	0.76
Headache	0.30	1.09	1.06	2.00	0.37	1.05
PTM***	0.80	2.25	3.29[b,c]	3.18	1.61[b,c]	2.18
Total**	0.54	1.71	1.95[c]	2.74	0.90[d]	1.70
Sleep						
No headache	0.71	1.54	0.50	0.76	0.36	0.74
Headache	0.63	1.64	1.78[b]	2.76	0.57	1.25
PTM***	1.45	2.34	4.43[b,c]	3.60	2.14[b,c]	2.94
Total***	0.98	1.98	2.74[d]	3.34	1.21[e]	2.23

[a]PTM, posttraumatic migraine; SD, standard deviation. *$P < .05$; **$P < .01$; ***$P < .001$.
Scores were [b]higher than no headache group; [c]higher than headache group; [d]higher than baseline; [e]lower than postinjury days 1-7; [f]higher than postinjury days 8-14.

TABLE 4
Chi-Square Analysis, Odds Ratios, and 95% Confidence Intervals for the Study Groups on Protracted Recovery Time (n = 97)

Variable	χ^2	P	Odds Ratio	95% Confidence Interval
PTM group vs no headache group	7.60	.006	7.29	1.80-29.91
Headache group vs no headache group	2.20	.14	2.83	0.72-11.20
PTM group vs headache group	3.93	.04	2.57	1.10-6.54

Posttraumatic Migraine as a Predictor of Concussion Severity and Recovery Time

Mihalik et al[22] suggested that PTM may be associated with increased concussion severity. Their findings demonstrated that PTM was associated with poorer performance on tests of verbal and visual memory, visual motor processing speed, and reaction time compared with groups with and without headache after a concussion.[22] Those with PTM also reported increased symptoms after a concussion compared with the other 2 groups.[22] In the current study, patients with PTM tended to have worse cognitive scores (verbal and visual memory, reaction time) and increased symptoms (cognitive, somatic, emotional, and sleep) throughout the first 2 weeks of recovery compared with patients reporting headaches or no headaches. The effect of PTM on visual memory may relate to concomitant visual impairments after concussion. Concussion has been reported to affect the oculocephalic pathways resulting in ocular-motor dysfunction including saccadic abnormalities and associated neurocognitive performance decrements.[10] Many of the patients seen by the clinical members of the current research team also experience nystagmus and visual accommodation deficits after concussion. In addition, PTM is thought to emanate from the brain stem and occipital regions, often resulting in blurred vision and aura phenomenon.[1] In conjunction with PTM pain, the effect of these separate mechanisms on the visual pathways may exacerbate decreased visual and overall cognitive performance.

Patients with PTM had a 7.3 times increase in risk for protracted recovery time (>21 days) compared with those not reporting any headache. These findings indicate that in contrast to the broader symptom of headache, the more specific symptoms of PTM are a strong predictor of concussion severity. There are several explanations for the preceding findings. It is possible that PTM leads to worse cognitive scores because athletes with PTM have more severe or frequent headaches than those in the headache group. Consequently, one would expect the PTM group to do worse on all things cognitive because they are in severe and constant discomfort. The differences among groups may also underlie a more malignant pathogenesis of PTM.

Posttraumatic Migraine Versus Headache

The majority of research involving concussion does not distinguish PTM from headaches and instead aggregates these groups into a broader headache classification.[2,3,21,24] In contrast, more recent literature suggests that although the pathogeneses of headaches and PTM are similar, there are also distinct differences.[1,25,27] For example, PTM symptoms may originate from brain stem components that affect sensory modulation of craniovascular afferents, which lead to a distinct constellation of symptoms.[7] Specifically, these symptoms typically include headache with photosensitivity and phonosensitivity.[9]

In the current study, athletes with PTM were 2.6 times more likely to have a protracted recovery than those athletes with headache without migraine symptoms. This finding suggests that concussed athletes with PTM symptoms, and not just headache, are at increased risk for a protracted recovery. Patients who are identified with PTM should be treated more conservatively to promote optimal recovery. Future research should explore whether patients with PTM after concussion will benefit more from initial cognitive and physical rest than patients with headache only and those with no headache.

Posttraumatic Migraine and Cognitive Impairment

Another important finding from the current study is the strong relationship between PTM symptoms and cognitive impairment in athletes sustaining concussion. Posttraumatic migraine and other symptoms are subjectively determined by self-report of the athlete. However, objective data in the form of cognitive testing had prognostic value in predicting more protracted recoveries after concussion. The current study lends support to the use of cognitive testing paradigms to identify specific cognitive deficits in patients with and without PTM symptoms after sports concussion. In the current study, the PTM group had significantly decreased cognitive scores across the domains of visual memory, verbal memory, and reaction time. These findings corroborate recent research that reported similar cognitive changes among patients with protracted recovery who reported higher migraine-somatic symptom factor scores.[13-16] Given the pronounced differences in the neurocognitive profile between headache and PTM patients in the current study, future studies should delineate a specific cognitive profile for PTM in patients following concussion. Such information can inform subsequent clinical treatment recommendations and improve clinical outcomes in patients with sport-related concussions.

Limitations

The current study is not without limitations. The sample was delimited to only male high school football players, which may limit the generalizability of the findings to females and other sports and age groups. Although the study had an adequate sample size, there were a number of participants whose data were lost to follow-up or for whom recovery time was unavailable. The criteria for inclusion in the PTM group were met based on self-reported symptoms. It should also be noted that the preinjury history of headaches or migraine did not predispose patients to more severe concussion or prolonged recovery time as prior studies have suggested.[19] A possible explanation for this finding is that patients with a history of headaches or migraines may develop a new biochemical baseline or threshold for pain. As such, they develop posttraumatic headaches and migraines at a similar prevalence to patients with no history of previous headaches and migraines. In addition, only patients' personal history of headache and migraine was considered. Family history of these conditions was not taken into account. Given the age of the patients, some of them may yet be diagnosed with migraine or chronic headache conditions. Moreover, we did not gather data regarding the specific type of migraine (eg, with aura, without aura, location). Given the preceding limitations, further research on the role of both personal and family history of migraine and the type of migraine is warranted. Although participants were tested only once during the 1-7 day and 8-14 day periods, some participants may have been tested 1 day and 8 days after injury; whereas another participant might have been tested 7 days and 14 days after injury. Finally, several of the statistically significant findings in the current study (eg, for symptom factors) represent small between-group differences that may have limited clinical meaning.

CONCLUSION

The results of the current study suggest that PTM is associated with cognitive impairments in verbal and visual memory and reaction time after concussion as well as protracted recovery. Concussed athletes with PTM were more than 7 times more likely to require 21 days or more of recovery compared with those not experiencing headache. These same athletes were more than 2 times more likely to experience protracted recoveries than those athletes experiencing headache without migraine-based symptoms. Future studies should explore further the prognostic ability of PTM and attempt to identify a concomitant cognitive profile. Our current findings may help to delineate a PTM clinical profile that may be useful in predicting more severe outcomes associated with concussion. This information in turn can help inform better clinical practice and treatment pathways for these patients. Patients with PTM may benefit from more conservative follow-up and different pharmacological interventions than those with headache or no headache after concussion. As such, future studies should also examine the efficacy of clinical management and treatment for PTM in relation to concussion outcomes.

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