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CONCUSSION AND HEAD INJURY (A FINKEL, SECTION EDITOR)

Factors Associated with Sport-Related Post-concussion Headache and Opportunities for Treatment

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Abstract

Purpose of Review The purpose of this review is to (1) describe factors both pre- and post-injury that are associated with post-concussion headache, (2) describe the influence of post-concussion headache on recovery following concussion, and (3) provide potential post-concussion treatment options that may reduce the burden of headache, as well as other symptoms to facilitate recovery.

Recent Findings Various factors may be associated with post-concussion headache presentation. These may include pre-injury or historical factors such as sex, family and self-history of headache and migraine, concussion history, and mood disorders. In addition, post-injury presentation factors for consideration may include injury mechanism, symptom clusters, cervicogenic dysfunction, and post-concussion physiologic dysfunction. Despite this complex interplay of factors, many treatment options may improve headache symptoms and recovery post-concussion including rehabilitation programs focusing on deficits such as visual-vestibular dysfunction, sub-symptom threshold exercise, and potential pharmacological interventions.

Summary Concussion is a complex injury that results in a variety of sequelae with headache being one of the most common. Understanding factors related to post-concussion headache presentation and the available options for treatment may improve patient care and outcomes post-concussion.

Keywords Post-traumatic headache · Exercise

Introduction

Concussion is a common injury occurring in a variety of sports. Concussive injuries are more common in contact, combat, and collision sports such as football or ice hockey; however, they can and do occur in every sport. The mechanism of concussion as well as other pre- and post-injury factors may influence both clinical presentation and outcome following injury. Moreover, it is a complex injury that results in a variety of sequelae that may present acutely or over some time period following injury. The most recent international concussion in sport group consensus statement [1] defines sport-related concussion as:

> … a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized in clinically defining the nature of a concussive head injury include:

- SRC may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.

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- SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.
- SRC may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.
- SRC results in a range of clinical signs and symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases, symptoms may be prolonged.

The most common acute post-concussion symptom is headache. However, in many individuals, this headache can last beyond the acute period and may be present in various forms. Headache presence post-concussion can complicate assessment and decision-making, as it is difficult to distinguish if presenting dysfunction and many associated symptoms are a result of the concussion or the headache-type [2•]. In addition, headache overall in athletes is relatively common [3••], specifically post-exertion headache and headache that may result from dehydration [4–6]. These factors also further complicate the management process as the source of the headache is often difficult to distinguish. Interpretation of these factors is especially difficult during pre-season training, dehydration is often prevalent [7], and athletes are exposed to frequent impacts to the head [8].

It is important to understand factors closely associated with post-concussion headache and the potential influence post-concussion headache can have on the assessment and management process following concussive injury. The symptoms associated with post-concussion headache are often treatable. Therefore, the purpose of this review is to describe factors both pre- and post-injury that are associated with post-concussion headache, to describe the influence of post-concussion headache on recovery following concussion, and to provide potential treatment options post-concussion that may reduce headache burden, as well as other symptoms to facilitate recovery.

Pre-injury Factors Associated with Headache

Premorbid factors associated with post-concussion headache continue to be examined and currently include sex [9, 10], family [11••] and self-history of headache and migraine [12, 13••], mood disorders such as depression and anxiety [14, 15••], and concussion history [16••, 17, 18]. Though there is some evidence concerning these factors, mixed results have been reported. Additional research is needed to characterize the influence of these factors on both the severity and duration of post-concussion headache. Many premorbid factors thought to be associated with post-concussion headache have also been reported as risk factors for persistent symptoms and prolonged recovery (Table 1). This underscores the importance of thorough self and family medical history documentation to allow for optimal post-concussion injury management.

Sex Differences

Females generally tend to be at a greater risk for injury (in sex-matched sports), report more symptoms and greater symptom severity, and in some cases experience prolonged recovery compared to their male counterparts. Post-concussion headache in particular is reported more often by females and at greater intensities [9]. Females report a higher prevalence of pre-existing headache and migraines both of which may influence the presence of post-concussion headache and recovery time [10].

Personal and Family Headache History

Personal and family headache and/or migraine diagnoses have been associated with acute and sub-acute post-concussion headache and persistent headache [11••, 12, 20]. Migraine history in particular has been confirmed as a predictable and possibly non-modifiable risk factor for poor outcomes and subsequent injury [13••, 21]. The genetically pervasive nature of migraine [30] is such that first-degree relatives of those with diagnosed migraines have a 2 to 19 times greater chance of diagnosis of concussion [22, 23].

Onset of primary migraines typically occurs in adolescent years where the lifetime prevalence is 18% for men and 40% for women [22, 31]. Pediatric prevalence of primary migraine is lower though estimated to have increased, and falls within 7% and 11% [20, 32]. Self-reported pre-existing headache is less examined in those with post-concussion headache where reported prevalence is similar to that of migraines, and varies between 16 and 45% [9, 20].

Mood Disorders

Pre-existing mood disorders such as depression and anxiety continue to be examined in the context of concussion injury and recovery [14]. It is known that these mood disorders are associated with primary headaches, making differentiating from concussive injuries and symptoms more difficult. An increased risk of post-concussion headache may be observed in these individuals, though pre-injury headache may be common and inherent to these disorders rather than concussion injury specifically. While the literature is mixed, premorbid depression and anxiety is associated with higher frequency

Table 1 Pre- and post-injury factors associated with post-concussion headache

Pre-injury factors	Post-injury factors
Sex [9, 10] • Females report post-concussion headache and headache severity more often than males • Pre-existing headache and migraines reported more often by females	Injury mechanism [19••] • Current research suggests that head impact characteristics are not associated with symptom profiles, when controlling for injury severity
Familial and self headache history [11••, 12, 20, 21•, 22, 23] • Family and self-history of migraine is associated with post-concussion headache and persistent headache • Migraine history is a concussion modifier for poor outcomes and injury risk • First-degree relatives of those with diagnosed migraine are 2–19 times more likely of also being diagnosed	Symptom cluster presentation [1, 24] • Post-concussion migraine symptom cluster and more severe headache associated with greater initial symptom burden • Lower neurocognitive scores and poor balance performance in athletes with migraine symptom cluster
Depression and anxiety [14, 15] • Pre-existing mood disorders may be associated with post-concussion headache • Headaches may be inherent to these disorders, important for proper management	Cervicogenic dysfunction [25, 26••, 27••] • Cervicogenic causes of headache should be considered in those with persistent headache • Post-concussion headache, dizziness, and postural instability may be due to "cervicogenic post-concussion disorder" • The cervical flexion rotation test (CFRT) may be useful in identifying those with cervicogenic headache
Concussion history [16••, 17] • Post-concussion headache reported more in those with a prior concussion history • Greater headache severity is reported in those with a concussion history	Physiologic dysfunction [26••, 28, 29] • Worsening of headache with physical exertion may be indicative of physiologic post-concussion disorder • Diagnosis of physiologic post-concussion disorder typically made with the Buffalo Concussion Treadmill Test (BCTT)

and severity of immediate post-concussion and persistent symptoms, including headache [15••].

Concussion History

Overall symptom burden, both in reported number and severity, has been examined in those with and without a concussion history. Recent studies have shown that individuals with a prior concussion history tend to report more symptoms post injury and experience greater symptom severity [16••, 17]. Moreover, those with a repeated concussion history (> 2 prior concussions) tend to report more symptoms and greater symptom severity than those without a history and those with only one prior concussion [16••]. The presence of post-concussion headache, and headache severity in particular, is more commonly reported in athletes with a concussion history compared to those without [16••, 18••].

Post-concussion and Injury-Related Factors Associated with Headache

Post-concussion headache presentation is associated with a number of concurrent and/or comorbid conditions. These may include head impact location or other aspects of mechanism, symptom cluster presentation, cervicogenic issues, and physiologic dysfunction following concussion. Understanding these factors related to presentation may be helpful in both the assessment and management process (Table 1). While acutely many of the presenting deficits in concussion patients are thought to be directly related to the concussive injury, subacute and persistent deficits are not well understood and may be the result of a variety of sources.

Assessment of individuals with prolonged headache and the relationship to their other symptoms is complex. It is recognized that many "post-concussion symptoms" are present in normal or index populations who have not sustained an injury [33•] and are consistent with other conditions commonly observed in athletes such as fatigue, burnout, and dehydration. As mentioned, headache in the athlete population is relatively common and sudden changes in activity level, such as that occurring during the relatively short return to play process, may further exacerbate headache-related symptoms [4–6]. However, there are few assessment strategies to tease out the headache vs. concussion-specific issues often leaving clinicians perplexed.

Injury Mechanism

While early work posited that head impact location may relate to symptom presentation and potential recovery, recent work has shown that impact location may not be the best indicator of the recovery process [34, 35]. A recent study [19] evaluating 319 concussed athletes found no association between head impact characteristics and symptom profile, when controlling for injury severity. Specific to headache, there is little empirical data to support specific

sport-related mechanisms more likely to result in headache or length of headache presence.

Post-concussion Headache Presentation Considerations

Although few studies have looked at specific headache presentations post-concussion, previous studies have illustrated that individuals with migraine-like symptoms (headache along with photo- and/or phonophobia and dizziness) and those with more severe post-concussion headache exhibit greater initial symptom burden after injury [1, 24]. Specifically, these athletes report an increased overall initial total symptom severity and more severe symptoms overall [24, 36]. Lower neurocognitive scores and poor balance performance have also been reported in individuals with these symptoms post-concussion [1]. Among service members, migraines are the most common type of headache presenting post-concussion [37•]; however, no studies of this type have been done in athlete-specific populations. Beyond clinical data, recent studies also support structural brain differences in individuals with post-traumatic headache following concussion compared to those without it. These changes may include less cortical thickness that is even more magnified in individuals with more frequent post-traumatic headaches [38••].

Work has begun to identify potential causative factors for the headaches experienced, especially those headaches more persistent in nature following concussion. Cervicogenic causes of headaches must also be considered when evaluating patients post-concussion. Biomechanically, the cervical spine is both a force conduit and absorber during rapid acceleration/deceleration of the cranium and body, and upon head impact. It has been shown that greater neck stiffness reduces the risk of sustaining high-magnitude head impacts [39]. Furthermore, the cervical spine houses complex neural pathways that are important to coordinating head and eye movement as well coordinating balance and postural adjustments through reflex pathways. The cervico-ocular reflex and vestibular ocular reflex both work to coordinate eye and head movement during object tracking [40], and the cervicocollic reflex and vestibulocollic reflex coordinate deep cervical stabilization during truncal movement [41].

Common concussion symptoms that could have a cervicogenic basis include neck pain or stiffness, and headache. It has been also postulated that there is a "cervicogenic post-concussion disorder" in which patients could present with symptoms such as dizziness and postural instability [25, 26]. The etiology for neck pain could be multifaceted as there are many structures in the cervical spine that have afferent pain pathways. These include joints, myofascial, discogenic, and nerve-related pain. Fractures are less common but should be considered in the differential diagnosis.

Cervicogenic headaches arise from structures innervated by the C1-C3 spinal nerves [42]. The most common causes include the C2-3 zygapophysial joint, the greater occipital nerve, and the lateral C1/2 joint [42]. Diagnostic imaging does not typically aid in the diagnosis. There are various approaches to treating cervicogenic headaches from a non-pharmacological standpoint. An interventional spine approach, as outlined by Bogduk, involves diagnostic blocks beginning at the third occipital nerve (innervates the C2/3 joint). If a negative block, then he recommends a lateral mass injection at C1/2. Greater occipital nerve injections have also been shown to relieve pain for a short to intermediate duration [43].

Physical examination tests to diagnosis cervicogenic headache have demonstrated mixed results [27••]. Clinical tests that evaluate the upper cervical spine, like the cervical flexion rotation test (CFRT), have been shown to have the highest accuracy and reliability values compared to others [27••].

Another possible cause of headache in a patient with prolonged concussion disorder is, what has been recently termed, physiologic post-concussion disorder [25, 26••]. A defining feature of this particular disorder is worsening of symptoms, of which headache is one symptom, with physical exertion. Early work indicates that the possible pathophysiologic mechanism is an alteration in cerebral blood flow that might be mediated by an imbalance in the autonomic nervous system response following a concussion [28]. The diagnosis of this condition is typically made using the Buffalo Concussion Treadmill Test (BCTT) [28, 29]. The presumption is that worsening symptoms with increased exertion are the result of physiologic post-concussion disorder [26••].

Headache and Recovery

Despite the initial differences and deficits described above, overall recovery time to symptom resolution has not been shown to be significantly different across headache groups [24]. However, one study observed a greater likelihood of prolonged recovery in those presenting with migraine-like symptoms, but this study did not examine time to recovery [1]. Regardless of the outcome, headache alone does not appear to be a good predictor of protracted recovery time. These studies have grouped headache related to severity, overall post-traumatic headache, and migraine-like presentation. However, the more pronounced symptoms clustered around migraine-like symptoms are, the longer the recovery time. Lau et al. identified a migraine symptom cluster severity cutoff of 15 as a predictor of prolonged recovery (recovery greater than 14 days) [44].

Perhaps more importantly though is the persistence of post-traumatic headache in a subset of individuals following sport-related concussion. Much of the work on

persistent post-traumatic headache has been conducted in military service members [37•]. However, examination among individuals with persistent post-traumatic headache following concussion in athletes suggested decreased brain activation patterns [38••] in those who presented with migraine-like symptoms as well as other symptoms. There is little empirical evidence on predicting those who will go on to develop persistent headache and what factors may contribute to this development over the course of concussion recovery in an athletic population.

Treatment Considerations

Treatment of post-concussive headache must be tailored to the individual patient following a detailed evaluation. While some general advice can be given to all patients in the post-concussive period, specific physical exam findings may indicate deficits that could be improved with directed therapy. General advice for the treatment of all headaches, sometimes called "headache hygiene," is also good advice for post-concussive headaches. This includes good sleep, eating healthy meals, staying hydrated, and managing stress [45••]. While studies are lacking to demonstrate specific improvement in post-concussive headache with these interventions, there is some evidence to suggest overall addressing these areas may be beneficial and including exercise as well as pharmacological intervention may be warranted in some patients.

Sleep Hygiene

Sleep disturbances are very common in the post-concussive period [46, 47] and these sleep disturbances have been associated with increased headache in both the acute and chronic phase of concussion [48••]. The first steps in attempting to improve sleep are sleep hygiene procedures, which include limiting evening caffeine, exercising daily, reducing nighttime stress using mindfulness activities, going to bed and waking at the same time each day, limiting naps to less than 30 min, and reducing noise in the sleeping environment [49].

Medication use to induce sleep in concussion patients has not been extensively studied. Small studies suggest that ramelteon [50], melatonin [46, 51], and amitriptyline [51] may be helpful for sleep following concussion. While other sleep aids are used, significant caution should be used as there is limited evidence to support their use in post-concussive patients and they are associated with significant side effects that often mimic other symptoms of post-concussive syndrome [52].

Rehabilitation and Exercise

For cervicogenic headache in particular, cervical manipulation has been shown to be more effective as compared to mobilization [53••]. Furthermore, Jull et al. showed that both therapeutic exercise and manipulation/mobilization were equally effective and that both were more effective than no treatment in the management of chronic cervicogenic headaches [54]. A recent review concluded that the management of headaches associated with neck pain should include the aforementioned activities to promote treatment of cervicogenic dysfunction [55].

Exercise is also felt to be beneficial for the treatment of concussion-related symptoms. Small trials have demonstrated improvement in concussion symptoms, in those with more prolonged symptom presence with sub-symptom-threshold daily exercise [56]. Furthermore, for headache that may be the result of potential physiologic post-concussion disorder, this type of sub-symptom-threshold exercise treatment may be effective. This treatment typically involves graded exercise training due to the pro-parasympathetic nervous system effects of aerobic training and decrease in the sympathetic nervous system response [56].

Vision Therapy

In patients found to have abnormalities on examination of their visual system, vision therapy provides significant benefit. A retrospective analysis of patients with mild TBI who underwent vision therapy for oculomotor signs and symptoms found that 90% had complete or marked improvement in their primary symptoms [57]. Subsequent small studies have found that oculomotor training improved saccades, fixation, and simulated reading [58], as well as improved convergence [59] and accommodation [60]. Improvements in these vision measures were all associated with improvement in reading-related symptoms, including headache. Larger studies are still needed to demonstrate the generalizability of these results, but given the low risk of this intervention, post-concussive patients with vision deficits should be referred to a neuro-optometrist for further evaluation.

Medications and Supplements

The role of medications in post-concussive headache remains unclear. Controlled studies of medications in post-concussive patients are lacking, and at this time, all medication use is considered off-label [61••]. Most often, medication regimens are begun by either a primary care provider or the patient themselves. Most patients use acetaminophen or a NSAID for early management [62], and there are data to support that combined use of acetaminophen and ibuprofen for 72 h may be beneficial for acute post-concussive headaches [63]. Liberating salt intake has also been shown to improve

headache in patients with autonomic dysfunction after concussion by improving intravascular volume [64].

Triptan usage has been recommended by several review articles, based on the theory that post-concussive headaches are the result of activation of the trigeminovascular system similar to that of migraines [2, 61, 65]. One study demonstrated improvement with sumatriptan nasal spray in soccer players with migraines [66]. However, large-scale studies focusing specifically on triptan usage in concussion patients have yet to be conducted.

For persistent headaches, prophylactic medication may be indicated. However, there remains a dearth of studies formally evaluating these. A prospective cohort study in children found that 64% had successful response to prophylactic medication, which included amitriptyline, melatonin, nortriptyline, flunarazine, and topiramate [20]. Of note, the topiramate group had the lowest response, and another retrospective study evaluating topiramate in chronic post-concussive headache found that only 16% of patients had greater than 50% reduction in headache [67].

Attention should also be drawn to medication overuse in headaches. Many post-concussion patients have been using medications to treat headaches since the time of their injury [62]. A study evaluating post-traumatic headaches presenting to a neurologist found that 70% of patients met criteria for medication overuse headaches, and 68% of those had complete resolution of headaches upon stopping medication [68].

Conclusions

In summary, post-concussion headache can be from the interplay of various pre- and post-injury factors that may influence headache presentation, duration, and type. There are no set diagnostic criteria to tease out headache vs. concussion effects, specifically early in the post-concussion recovery process. As such, sound clinical evaluation and a thorough understanding of the patient's history and concussion circumstances may aid in evaluation and management strategies. Recent research suggests reasonable options for potential treatment of post-concussion headache and the other sequelae that may result following sport-related concussion.

Compliance with Ethical Standards

Conflict of Interest Christina B. Vander Vegt, Michael Cools, and Kevin Carnerio declare no conflict of interest. Johna K. Register-Mihalik reports grants from NOCSAE, CDC/NCIPC, NFL, NCAA-DOD Grand Alliance, other from Allied Health Education, and other from Senaptec LLC, all outside of the submitted work.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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