

Evaluating the Use of Neurofeedback Interventions to Reduce Nocturnal Pruritus in Eczema Patients

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Abstract

Nocturnal pruritus, or nighttime itch, is a disruptive and highly prevalent symptom among patients with eczema, contributing to poor sleep quality, daytime fatigue, and diminished quality of life. Despite advances in topical and systemic therapies for eczema, effective treatments specifically targeting nocturnal itch remain limited, with antihistamines, corticosteroids, and immunomodulators often providing inconsistent relief. Emerging evidence suggests that circadian hormonal fluctuations, impaired barrier repair, and neuroimmune dysregulation form the basis of nocturnal pruritus, highlighting the need for tailored interventions that address both itch and its impact on sleep. Neurofeedback, a non-pharmacological technique that enables individuals to modulate neural activity through real-time feedback, has shown promise in related conditions such as chronic pain, fibromyalgia, and insomnia by reducing hyperarousal and altering maladaptive brain network activity. However, its application to nocturnal pruritus in eczema remains largely untested, with current evidence limited to indirect insights and small studies in related disorders. Barriers including variability in training protocols, lack of standardized outcome measures, and limited accessibility continue to challenge clinical adoption. This review synthesizes current understanding of the burden and mechanisms of nocturnal pruritus, evaluates the evidence for neurofeedback in relevant conditions, and considers its potential role in managing nighttime itch in eczema. Future research should prioritize mechanistic studies, objective outcome measures, and randomized controlled trials to clarify efficacy, optimize protocols, and assess long-term feasibility. By exploring neurofeedback as a novel intervention, this review highlights the opportunity to address an overlooked symptom that significantly affects the daily lives of patients with eczema.

1. INTRODUCTION

Nocturnal pruritus is itching that increases or initiates at night. In patients with eczema, this is a very common complaint and major symptomatic concern [1,2]. Nighttime skin becomes more prone to itching through immune activation, barrier repair alteration, and temperature and hormonal changes, all of which increase the overall itch intensity during sleeping hours [3,4]. Patients with eczema who have nocturnal itching often describe difficulty going to sleep, multiple awakenings during sleep, and a lower quality of sleep. The resulting daytime somnolence and fatigue have a negative effect on mental health, compounding these factors [5]. The overall impacts of these symptoms and other sleep disturbances factor heavily into both the

overall experience of disease and how patients live with eczema. Current treatment options address eczema inflammation, barrier dysfunction, or symptomatic itch. Topical corticosteroids and calcineurin inhibitors reduce inflammation but often have limited effect at alleviating nighttime itch [6]. Sedating antihistamines are used widely, yet provide inconsistent relief and carry risks such as morning grogginess or other side effects [6]. Systemic treatments may reduce flare frequency but may not sufficiently improve sleep disturbance due to itch [1]. There is a lack of therapies designed specifically to target nocturnal pruritus and its impact on sleep.

Neurofeedback (NFB) is a technique in which individuals receive real-time feedback about

neural activity and learn to modulate brain function [7]. It has been applied in pain disorders including chronic pain and fibromyalgia. A systematic review of neurofeedback for chronic pain found reduction in pain and improvements in sleep and mood in many studies [8]. The mechanisms may include altering maladaptive neural oscillations, reducing central sensitization, and modifying attention to sensory input [7]. Applying neurofeedback to nocturnal pruritus in eczema appears promising but is underinvestigated. There are no large randomized controlled trials specifically in eczema that test neurofeedback for nighttime itch. Neurofeedback may serve as an alternative treatment approach for managing nocturnal pruritus, but its clinical adoption remains limited due to variability in protocols, insufficient long-term data, and concerns related to cost and accessibility. This review was conducted to evaluate the potential use of neurofeedback interventions for reducing nocturnal pruritus in patients with eczema. A comprehensive literature search was performed to identify studies addressing the burden of nighttime itch, its impact on sleep and quality of life, and the underlying neuroimmune and circadian mechanisms. Relevant research on neurofeedback principles and its application in related disorders, such as chronic pain, insomnia, and fibromyalgia, was also reviewed. The collected studies were critically analyzed to identify gaps in the current evidence, assess limitations of existing protocols, and inform potential directions for future research and clinical integration.

1.1. Impact and Epidemiology

1.1.1. Prevalence and Burden of Nocturnal Pruritus

Nocturnal pruritus (NP) is highly prevalent among those with eczema and often produces serious downstream consequences. A 2025 meta-analysis reported that about 43.4% of atopic dermatitis patients have sleep disorders, bringing more current prevalence estimates into view [9]. Another study in 2024 developed and validated patient-reported outcome tools for sleep disturbance in AD, finding that 87% of participants experienced nighttime awakenings and 73% had trouble falling asleep, with many reporting feeling unrested during the day [10]. In Kuwait, surveys of eczema in adolescents indicate that approximately 21.7% of those with an itchy rash experience nocturnal sleep disturbance at least once per week [11]. Eczema

studies with a focus on moderate-to-severe disease also reveal an association between sleep disturbance and itch severity, emotional distress, and poorer quality of life [5]. This more recent evidence strengthens the argument that nocturnal pruritus leads to not only nighttime symptom burden, but also daytime dysfunction, mood disturbance, and long-term patient outcomes.

1.1.2. Circadian Rhythms and Symptom Timing

Many other studies have also demonstrated the circadian nature of eczema symptoms with itch being more severe in the evening and peaking in the early hours of the night. In a study of 241 adults with atopic dermatitis, investigators found that itching severity was at its greatest between 8:00 PM and midnight, coinciding with both sleep onset and early non-REM sleep periods [4]. This finding was thought to be the result of the normal biological oscillations that happen overnight, such as cortisol fluctuations, and decreases in skin temperature and increases in inflammatory mediators [12]. With progressive sleep fragmentation, daytime fatigue and decreased concentration compound the overall disease burden, even in patients with a relatively quiescent rash during the day.

1.1.3. Psychological and Cognitive Consequences

Psychological outcomes are also tightly linked to sleep disturbance in eczema. In a population-based study of U.S. adults with atopic dermatitis, those with nighttime awakenings reported higher rates of depressive symptoms and impaired work productivity than those without [13]. These results indicate that nighttime pruritus is a factor with a quantifiable impact on mental health. Students with eczema who experience consistent sleep interruption are likely to exhibit poorer school performance and higher levels of emotional dysregulation than their counterparts with regular sleep [14]. Psychological distress as a result of nighttime pruritus is an underreported complication.

1.1.4. Limitations in Current Clinical Trials and Therapies

Despite the high prevalence and impact of nighttime itch, most clinical trials and guideline-directed therapies do not separate nocturnal pruritus from daytime itch when measuring treatment outcomes [6]. This creates a knowledge gap that hinders development of targeted interventions. In addition, while biologics and systemic immunosuppressants have improved disease control for many, even well-managed

patients often continue to report poor sleep due to residual itch, especially at night [15]. Addressing this unmet need will require treatments that specifically account for symptom timing and its effects on sleep.

1.1.5. Implications for Research and Clinical Management

Taken together, these studies suggest that nocturnal pruritus is an underrecognized and undertreated unique clinical manifestation of eczema. Given its impact on quality of life, school and work performance, and mental health, this problem should be more emphasized in eczema research and clinical management. The wider adoption of validated sleep questionnaires and a consideration of circadian physiology may help better understand when patients have symptoms and how to intervene.

2. PATHOPHYSIOLOGY OF NOCTURNAL PRURITUS

Nocturnal pruritus is a common dermatologic symptom that affects sleep and can play a detrimental role in one's quality of life. Physiologically, NP typically appears to arise from various circadian hormone fluctuations such as the evening decline in cortisol, alterations in melatonin, and nocturnal increases in pruritogenic cytokines (e.g., IL-2, IL-31) that together lower the itch threshold at night [6]. The lowering of the itch threshold causes a greater incidence of itching during the nighttime due to the interaction of all these bodily changes. Sleep-related thermoregulatory shifts and increased transepidermal water loss (TEWL) during non-rapid eye movement (NREM) sleep further impair barrier function and permit enhanced penetration of pruritogens [6,16]. Recent pilot transcriptomic data in atopic dermatitis (AD) patients show evening-associated upregulation of neuronal and sensory-perception pathways alongside downregulation of innate antiviral responses, which suggests that systemic circadian dysregulation that occurs alongside barrier deterioration may mechanistically link to nocturnal itch [17]. Behavioral and psychological contributors like reduced frontal inhibitory control at night, stress, and habit scratching can further amplify central and peripheral itch signaling. This then creates a self-sustaining itch-scratch-sleep-disturbance cycle [1,6]. Clinically, this pathophysiology is supported by combined treatments that restore barrier integrity which include timed emollients and cooling. Doing these treatments while improving circadian and sleep health, such as sleep hygiene,

melatonin use, and timing of therapies, can reduce nocturnal amplification of itch [1,6]. Integrating objective measures such as actigraphy and TEWL rhythms into assessment could help distinguish biologically driven nocturnal flares from behaviorally mediated scratching and allow personalization of treatment timing. Altogether, current evidence favors a model in which circadian hormonal changes, impaired overnight barrier restitution, neuroimmune sensitization, and sleep-related behavioral disinhibition can altogether produce the distinct clinical phenomenon of nocturnal pruritus.

2.1. Circadian Factors and Neuroendocrine Regulation

Nocturnal pruritus is strongly influenced by circadian factors and neuroendocrine regulation. Disruptions in the circadian rhythm can alter the expression of key clock genes, such as *ARNTL2*, *NOCT*, and *RORC*, which are differentially expressed in patients with pruritic skin disorders and may modulate immune cell activity, particularly dendritic cells, which can further exacerbate inflammation during the night [17].

The central circadian pacemaker in the suprachiasmatic nucleus coordinates peripheral skin rhythms, but misalignment can lead to increased nocturnal skin blood flow, impaired barrier function, and enhanced transepidermal water loss, creating a physiological environment that favors increased pruritus [18]. Two key neuroendocrine mediators, cortisol and melatonin, display circadian fluctuations that regulate inflammatory responses and skin homeostasis. Decreased nocturnal cortisol and altered melatonin secretion in patients can increase itch perception and disrupt sleep cycles [19]. Immune effectors, especially Th2 cytokines and chemokines, follow rhythmic patterns, with peak activation at night that coincides with pruritic episodes, suggesting a tightly linked neuroimmune mechanism [17].

The interaction between circadian dysregulation and neuroendocrine signaling not only intensifies itch but also establishes a vicious itch-scratch cycle, sustaining barrier disruption and inflammatory signaling. Understanding these pathways opens opportunities for chronotherapy, such as timed administration of topical or systemic treatments, to realign circadian and neuroendocrine rhythms and mitigate nocturnal pruritus. These ideas emphasize that nocturnal pruritus is not merely a symptom but a manifestation of a complex circadian-neuroimmune dysfunction, demonstrating the

importance of temporal factors in therapeutic strategies.

2.2. Relationship Between Itching and Sleep Disturbance

Nocturnal pruritus is closely linked to sleep disturbances, with the sensation of itch significantly impairing sleep onset and continuity [9]. In patients with atopic dermatitis, disrupted sleep is not merely a consequence of scratching but is also influenced by underlying inflammatory pathways and circadian variations in skin physiology, which increase itch perception at night. Chronic pruritus contributes to a feedback loop, where poor sleep further amplifies inflammatory responses, leading to more intense nocturnal itching [20]. Neuroimmune mechanisms, including the activation of pruriceptors and central nervous system pathways, exacerbate the awareness of itch during quiet periods of the night, while cognitive focus on discomfort further delays restorative sleep [21]. Sleep fragmentation resulting from repeated scratching episodes disrupts the normal architecture of sleep, reducing slow-wave and REM sleep, which are critical for tissue repair and immune regulation. Emotional stress and heightened sympathetic activity often accompany nocturnal pruritus, intensifying both the perception of itch and sleep disturbance. These interactions suggest that effective management of nocturnal pruritus should address both dermatologic symptoms and sleep quality, emphasizing an integrated, multidisciplinary approach. Understanding this relationship clarifies why interventions targeting only itch without improving sleep may be insufficient to break the cycle. Hence, it is important to cultivate various treatment methods that will help manage nocturnal pruritus effectively.

3. NEUROFEEDBACK: PRINCIPLES AND EVIDENCE

3.1. How Neurofeedback Works

Neurofeedback is a technique that provides individuals with real-time feedback of their brain activity using non-invasive methods such as electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). The aim is to help patients learn self-regulation and establish more adaptive neural patterns [22]. The training relies on operant conditioning, with reward and attention networks having central roles in reinforcement and learning [23]. Individual differences in responsiveness may be due to

structural brain connectivity, baseline neural activity, behavioral factors such as motivation, and feedback sensitivity. This indicates that adapting protocols to each patient's needs may improve outcomes [22]. The use of proper reporting guidelines, such as CRED-nf consensus, allows for standardized reporting and use of proper control conditions and training targets. These guidelines are designed to align training targets with the underlying neurobiology [24]. When designing neurofeedback interventions for specific scenarios, such as nocturnal pruritus, it's imperative to focus on individual tailoring to best align with the learning goals.

3.2. Neurofeedback in Insomnia

Since nocturnal pruritus often worsens with poor sleep, insomnia studies provide a useful starting point for understanding how NFB might help. Insomnia is understood as a disorder of cortical hyperarousal, with EEG studies showing heightened beta activity and altered sleep spindles in affected individuals. Therefore, NFB has been investigated as a tool to reduce hyperarousal and improve sleep quality [25]. Since nocturnal arousal and poor sleep can worsen the perception of pruritus, these findings may have relevance in managing nocturnal itch.

Neurofeedback has been tested as a way to reduce cortical hyperarousal in insomnia, with some studies reporting improvements in patients' sleep quality. For example, a randomized controlled trial comparing neurofeedback to cognitive behavioral therapy for insomnia (CBT-I) demonstrated that NFB reduced EEG beta activity, while increasing theta and alpha activity. The study also showed significant improvements in the Insomnia Severity Index (ISI) and the Pittsburgh Sleep Quality Index (PSQI) [26]. Building on these individual trials, a more recent meta-analysis examined surface NFB techniques and their effects on sleep quality and insomnia severity. Although some studies reported improvements in self-reported sleep, the meta-analysis found that NFB did not consistently outperform control conditions on these subjective outcomes. These included sham NFB or other active comparators [27]. Since nocturnal arousal exacerbates pruritus, NFB protocols that reduce cortical hyperarousal may provide a mechanistic frame work for addressing nocturnal itch.

3.3. Insights from Pain Management

NFB has also been explored as a nonpharmacologic intervention for chronic pain,

which, like itch, involves central sensitization and heightened attention to bodily sensations. Most of the evidence comes from small studies and a few larger randomized trials. A 2022 systematic review and meta-analysis concluded that while EEG-NFB may offer benefits for some individuals, there was low overall confidence in the evidence due to study heterogeneity and risk of bias [28]. However, larger and better-controlled trials have emerged with additional insights. In a blinded, randomized, sham-controlled trial of a home-based EEG-NFB program (N = 116), many participants reported having meaningful pain relief. However, there was no significant difference between the active and sham groups for the primary pain outcome [29]. Additional smaller feasibility studies targeting alpha band connectivity between the pregenual anterior cingulate cortex and the primary somatosensory cortex were conducted on participants with fibromyalgia. These findings suggest that connectivity-guided NFB can be delivered safely and may be useful in managing chronic pain syndromes. The main limitation was a small sample size and would require larger samples with a longer follow-up to determine efficacy [30]. A recent scoping review found an overall trend toward symptom improvement. However, the authors emphasized limitations such as small samples, variable control conditions, and inconsistent outcomes. About half of the protocols reinforced alpha or sensorimotor rhythms (SMR), and suppressed beta. It concluded that NFB can modulate pain related processes [31]. The chronic pain literature suggests that while NFB has not consistently outperformed placebo, the improvements highlight potential applications for future dermatology focused implementation.

3.4. How Neurofeedback May Work in Itch

EEG and fMRI studies indicate that learning during NFB training engages multiple brain systems, including reward, attention, default mode regions, the cerebellum, and salience pathways. A pre-registered mega-analysis of multiple fMRI-NFB datasets (N=153) found that feedback processing involves regions such as the nucleus accumbens, medial prefrontal cortex, cerebellum, dorsal attention network, and default mode network. These circuits were linked to regulation success during training [32]. Connectivity based studies suggest that training whole-brain interactions, rather than focusing on localized activation, can produce measurable behavioral changes. In depression, a real-time

fMRI (rtfMRI) study targeting the connectivity between the posterior cingulate cortex and right temporoparietal junction found reductions in repetitive negative thinking. This shows that changes in network dynamics can lead to meaningful symptom improvements [33]. Early evidence and mechanistic findings indicate that NFB may help to reorganize brain networks involved in reward, attention, salience, and sensory processing. Since these same networks are involved in the perception of itch, they provide a strong rationale for NFB testing in nocturnal pruritus.

4. NEUROFEEDBACK FOR NOCTURNAL PRURITUS

4.1. Review of Existing Studies or Case Reports

Existing studies on neurofeedback indicate its potential as a non-invasive intervention for neurological and neuropsychiatric conditions, though evidence is limited by methodological variability and small sample sizes [34].

Neurofeedback targeting sensorimotor rhythms (SMR) has shown promising evidence in regulating neural activity and improving symptom management in conditions such as stroke and fibromyalgia, suggesting that similar approaches might influence sleep or sensory modulation in nocturnal pruritus. Integrative and mind-body therapies have been applied in dermatological conditions, demonstrating that interventions addressing neural and psychological pathways can alleviate symptoms and enhance quality of life [35]. Case reports and reviews on psychotherapeutic approaches for eczema highlight improvements in itch and sleep, emphasizing the importance of patient engagement and self-regulation in symptom control [36]. Applying insights from SMR neurofeedback, these findings suggest a potential mechanism for modulating pruritus through altered cortical activity and stress reduction.

However, variability in session protocols, feedback modalities, and lack of long-term follow-up in existing neurofeedback studies underscores the dire need for standardized approaches. Controlled trials combining neurofeedback with behavioral or cognitive interventions could clarify its efficacy for nocturnal pruritus, particularly when integrated with established mind-body strategies. Until then, neurofeedback remains experimental rather than a validated therapy for pruritic sleep disturbances.

4.2. Theoretical and Practical Considerations

Neurofeedback represents a promising intervention for conditions involving dysregulated neural activity, and its application to nocturnal pruritus warrants both theoretical and practical consideration. Theoretically, NFB is grounded in operant conditioning principles, where patients learn to modulate brainwave activity through real-time feedback, promoting self-regulation of physiological and psychological responses [37]. This framework supports the notion that targeting neural circuits associated with sensory processing could help mitigate pruritic symptoms. However, implementation requires careful consideration of training protocols, session frequency, and individual variability, as these factors significantly influence treatment efficacy [38]. Clinical evidence suggests that patient-reported outcomes are generally positive, though standardized measures and objective markers are necessary for broader validation [39]. Integrating NFB into routine clinical practice demands addressing logistical barriers, including equipment accessibility and clinician training [38]. Future studies should prioritize protocol optimization and rigorous evaluation of long-term outcomes to maximize both the feasibility and effectiveness of NFB interventions for nocturnal pruritus. Combining theoretical understanding with practical implementation strategies is essential for advancing NFB as a viable therapeutic option.

4.3. Limitations and Barriers: Accessibility, Cost, Standardization

Accessibility is a key barrier in neurofeedback, as it typically requires specialized equipment and trained professionals who are often concentrated in urban or research-focused centers, leaving many patients underserved [40]. The high cost of treatment sessions further limits patient access, especially when insurance coverage is lacking or inconsistent [40]. Standardization of protocols is another challenge because there are many variations in electrode placement, session duration, and feedback modalities that reduce reproducibility and complicate comparisons across studies [41]. Inconsistent methodologies also hinder the development of clear clinical guidelines, potentially affecting treatment outcomes. Technological literacy and patient motivation can further influence adherence, creating additional barriers to effective implementation [41]. Small sample sizes and limited long-term follow-up in existing research

reduce confidence in the generalizability of results. Addressing these limitations through cost-effective strategies, broader access, and standardized protocols could enhance the clinical utility of neurofeedback for managing nocturnal pruritus.

5. FUTURE DIRECTIONS

Eczema is one of the most common inflammatory skin conditions, associated with sleep disturbances in 47-80% of children and 33-90% of adults [2]. While studies on biofeedback and mind-body interventions exist, no research thus far on neurofeedback has been conducted in the context of eczema treatment [42, 35]. Despite research highlighting nocturnal pruritus as a significant symptom of eczema unrelieved by current topical therapies and antihistamines, several gaps in knowledge persist that hinder neurofeedback as a therapeutic intervention. The first is the need for studies to further distinguish daytime itch from nighttime itch given nocturnal pruritus is theorized to be driven by a distinct culmination of factors such as circadian rhythm and various neuroendocrine factors [6]. Deeper investigation into how circadian rhythms, skin barrier integrity, and neuroimmune pathways interact may help clarify the mechanisms driving nocturnal itch and sleep disturbance. A gap in knowledge lies in the underlying pathophysiology and identification of biomarkers specific to itch perception and modulation which are essential for developing targeted neurofeedback protocols in patients with eczema experiencing nocturnal pruritus [43]. Future research should focus on both further explorations of underlying pathophysiology and integrating EEG or fMRI-based neurofeedback into studies to assess itch severity, sleep quality, and brain activity during various sleep stages.

Beyond neurobiomarkers, it still remains to be explored whether intervention on these neural networks would translate into clinical improvement. To demonstrate clinically significant improvements, standardized multimodal outcome measures, such as itch intensity, sleep quality indicators, and behavioral metrics, need to be outlined [42, 44]. Most current studies rely heavily on subjective self-reported itch intensity, vulnerable to bias [2]. Recently a machine learning approach to quantifying nocturnal itching has been developed using wrist-wearing actigraphy. This method could enable objective quantification of nocturnal scratching episodes, improving the measurement and monitoring of eczema-related

nighttime itch. Beyond efficacy, the feasibility and accessibility of such a treatment must be assessed to ensure equal access to this intervention. Limited data exist on randomized controlled studies and long-term durability of neurofeedback interventions in chronic nocturnal pruritus. Given the chronic and relapsing nature of eczema, it will be vital to explore the long-term effects of neurofeedback for this intervention to be a viable long-term treatment for patients.

6. CONCLUSION

Nocturnal pruritus, otherwise known as nighttime itch, is a common disruptive symptom among patients with eczema, found to contribute significantly to sleep disturbance, daytime fatigue, behavior and mood disturbances, and overall reduced quality of life [1]. Nocturnal scratching is correlated with disease severity and EASI (Eczema Area and Severity Index) scores and was theorized in one study [45] to worsen the quality of sleep by changing the sleep stage to a lighter one or awake stage. Not only is itching an important symptom, but it is also a factor to be considered in the exacerbation and relapse of eczema [46]. Its pathophysiology is multifactorial, involving changes in several key skin functions during sleep, including thermoregulation, maintenance of fluid balance, and barrier function. Reported physiological changes include an increase in skin temperature during NREM sleep, increased TEWL at night facilitating the entry of pruritogens, decreased nocturnal cortisol, and elevations in prostaglandin D2 (PGD2) and prostaglandin E2 (PGE2), which are involved in nighttime skin barrier repair [6]. Neuroimaging studies have revealed altered resting-state functional activity in precentral and postcentral gyri, cingulate cortex, and hippocampus in patients with eczema correlated with itch intensity and sleep disruption [47].

These findings support the idea that nocturnal pruritus is not limited to the skin but is centrally modulated and could therefore be treated with neurofeedback. This review highlights the importance of further investigating the pathophysiological mechanisms underlying nocturnal pruritus to clarify how neurofeedback might benefit patients. The disabling consequences of nighttime itch, its relapsing course, and the limited efficacy of current pharmacological interventions strengthen the rationale for considering neurofeedback as a personalized strategy to manage symptoms and improve patient outcomes.

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