

EEG Biofeedback, Hemoencephalography Biofeedback and Thermal Biofeedback With 37 Migraineurs

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Background. -- Traditional biofeedback has grade A evidence for effectively treating migraines. Two newer forms of biofeedback, EEG biofeedback and Hemoencephalography biofeedback were combined with thermal handwarming biofeedback to treat 37 migraineurs in a clinical outpatient setting.

Objectives. – (1) to ascertain the effectiveness of two types of neurofeedback combined with one type of traditional biofeedback to treat migraines (2) to stimulate future research in using neurofeedback to treat migraines.

Methods. -- 37 migraine patients were given an average of 40 neurofeedback sessions combined with thermal biofeedback. Patients kept daily headache diaries a minimum of two weeks prior to treatment and throughout treatment showing symptom frequency, severity, duration and medications used. Treatments were conducted an average of three times weekly over an average span of 6 months. Headache diaries were examined after treatment and a formal interview was conducted. After waiting an average of 14.5 months following treatment, a formal interview was again conducted using questionnaires in order to ascertain duration of treatment effects.

Results. – Of the 37 migraine patients treated, 26 patients or 70% experienced at least a 50% reduction in the frequency of their headaches.

Conclusions. -- Objective one was met and it is our hope that this will generate an interest in meeting our second objective which is to generate more research into the noninvasive neurotherapies to treat migraine.

Keywords: EEG biofeedback , hemoencephalography, thermal biofeedback, migraine, neurofeedback, neurobiofeedback, neurotherapy

Abbreviations: EEG electroencephalogram, pIR HEG passive infrared hemoencephalography, qEEG quantitative EEG, CNV contingent negative variation

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Introduction

Migraine is a common, disabling and often progressive disorder characterized by increased excitability of the central nervous system.^{1,2} It occurs in 18% of women and 6% of men in the US with peak prevalence in individuals between the ages of 25 and 55.³ Economic burden of migraine in the US is estimated to be approximately 13 billion annually.⁴

Biofeedback is a common intervention in pain management. For migraine treatment, the most frequently used biofeedback methods have been peripheral skin temperature biofeedback, blood-volume-pulse and electromyography feedback. In a recent meta-analysis integrating 55 studies using these methods for the treatment of migraine, strong evidence was found for the efficacy of the above methods which proved stable over a 17 month follow-up phase.⁵ Numerous studies explore traditional biofeedback but scant studies exist on using neurofeedback methods to treat migraine.

There are EEG abnormalities in the migraine brain, therefore it is plausible that interventions involving the EEG might be of benefit.⁶ Children afflicted with migraine, those with and without aura, demonstrate increased theta frequencies compared to normal controls.⁷ One popular neurofeedback protocol for migraine emphasizes down training theta rhythms along the sensorimotor strip at the temporal lobes.⁸ Siniatchkin and colleagues demonstrated clinical efficacy in using neurofeedback at midline frontal and central areas to teach 10 young migraineurs to control their slow brain waves representing cortical excitability.⁹ Michael Tansey enabled four migraineurs to eliminate their migraines after neurofeedback training along midline frontal and central areas which showed that low frequencies became less dominant and higher frequencies were augmented.¹⁰

Neurotherapy is a broad term referring to the many types of biofeedback used to deliver information about the central nervous system which involve blood flow, thermal output from the brain or electrical activity. Neurofeedback (also called neurobiofeedback and EEG biofeedback) usually refers to frequency-based biofeedback that uses an EEG to give clients information about their brainwaves and gradually and subtly teaches people how to alter their brainwave activity. Sensors are attached to the scalp and brainwaves are converted via an amplifier utilizing a Fourier transform into video games that clients are instructed to manipulate or change. Neurofeedback training can also include a newer method called hemoencephalography, which targets the frontal lobe.¹¹ Passive infrared hemoencephalography (pIR HEG) is a form of biofeedback for the brain that measures and feeds back information on the thermal output of the frontal lobe. It involves watching a movie for feedback and the movie is in operation when the measured forehead temperature rises and the movie stops when the temperature drops. The therapist will increase the threshold as the client learns how to raise their forehead temperature. Clients are instructed to calmly concentrate on making the movie continue to play. Increases in the pIR HEG signal reflect a composite of thermal activity generated by vascular supply, vascular return and brain cell activity. It was shown in a study involving 100 IHS-diagnosed migraineurs to be very effective in reducing the frequency of migraine headaches.¹²

Unlike traditional biofeedback that monitors the status of peripheral aspects of the sympathetic and parasympathetic nervous systems (e.g. respiration, galvanic skin response), neurofeedback monitors central nervous system activity. A preliminary review of the literature on the clinical applications of neurofeedback suggests that it may be effective for a number of cognitive, emotional, and physical problems. Nevertheless the neurofeedback literature is still in its infancy, and with the exception of ADHD, there are few double-blind, placebo-controlled studies. The resulting skepticism and resistance on the part of the medical community has made it difficult for researchers to obtain funding to do the kinds of sophisticated, expensive, large-scale studies critics insist are essential to the future of neurofeedback. Nevertheless, the body of research is growing, and the practice-based studies that form the basis of much of the published literature are stimulating a great deal of interest in the field.

Methods

Participants.- Patients were recruited from the neurofeedback clinic of Neurofeedback Consultants where most were referred by their primary care physician or neurologist. Others responded to local media events covering their neurofeedback work in treating migraines. 74 headache clients presented to the clinic between 2004 and 2007. Selection criteria required that the client have migraine with or without aura and that this diagnosis be confirmed according to the International Headache Society classification criteria for headache disorders.¹³ Patients who had less than one migraine per month or more than 20 per month were excluded from the study. A total of 37 headache patients were eliminated from the study based on these criteria. Of the 37 remaining patients who were eligible for the study, 29 were females and 8 were males. Ages ranged from 9 to 79, with the majority (56%) between the ages of 16 and 52, and the remainder evenly split between the younger group (22% were between 9 and 15) and the older group (22% were between 55 and 79). In terms of medical history, most patients had long, stable histories of migraine and had tried multiple pharmaceutical treatments prior to neurotherapy. Most were still taking a combination of medications for migraine and other conditions and were not required to discontinue these during the study. About one-third of the patients had migraine with aura, and about three-fourths reported experiencing other kinds of headaches or one or more other significant conditions (e.g., anxiety, depression, problems with sleep or focus).

Initial Assessments.- A personal and family headache history was taken at initial evaluation and a diagnostic interview was performed to confirm the IHS-diagnosis of migraine with or without aura and to assess other symptoms and conditions. Prior to starting treatment sessions headache patients were asked to wait two weeks to begin treatment in order to keep a baseline daily headache diary to record headache frequency and severity, related symptoms, triggers, and medications used. At the first session and every 10 sessions thereafter, clients were asked to complete a checklist to indicate changes in headaches as well as other symptoms (e.g., anxiety, insomnia, other pain types, depression, and behavioral problems). Checklists and clinical interviews were used throughout treatment to help determine most effective protocols and placements which were modified accordingly.

Follow-up Data Collection.- The data reported in this study were collected after treatment through follow-up telephone surveys conducted by a research consulting firm not affiliated with Neurofeedback

Consultants. Interviewers introduced themselves and indicated that they were conducting a follow-up assessment of Neurofeedback Consultants migraine patients for research purposes, and asked for permission to continue. Prior to starting treatment patients had been informed that they might be asked to participate in a study and all had agreed. The follow-up interviews were conducted during the last half of 2007. The large majority of patients had completed treatment at least 6 months prior to the follow-up call, some as long as two years earlier. When asked about their post-treatment migraine history, participants were instructed to think about the 6 months immediately preceding the follow-up interview, not the entire time since their last treatment. When asked about their migraine pattern prior to treatment, participants were asked to recall the average number of migraines per month they were experiencing in the 6 months prior to seeking treatment. Interviewers had access to the migraine frequency data reported at the initial diagnostic evaluation, and if there were large discrepancies asked for clarification. In the 3 cases where participants could not be contacted or were not interested in completing the telephone interview, migraine frequency data from patient records was used instead of the telephone survey data.

Treatment Protocol.- The study involved treatment using EEG biofeedback, pIR HEG biofeedback and handwarming biofeedback for an average total of 40 sessions. Average length of time in treatment was 6 months. Subjects underwent an average of 30 frequency-based neurofeedback sessions and 10 pIR HEG sessions for 30 minutes at least twice weekly. Eleven patients had an interruption in their treatment after the initial 20 sessions of up to several weeks but returned for their remaining sessions.

A manually administered brain map of 10 sites at frontal, temporal, central, midline and parietal areas (F3, F4, T3, T4, C3, C4, FZ, CZ, P3, & P4) was performed to determine peak amplitude of specific frequencies within the 0-40HZ range. This information was used to guide frequency-based neurofeedback training protocols. Most migraine patients were treated with inhibit-based strategies involving eyes open down training of the highest amplitudes across the frequency spectrum. Typically interhemispheric bipolar electrode placements were used and training began at the temporal lobes (T3-T4). Based on patients' response, sessions would continue at the temporal locations (T3-T4) for three to five sessions and then move to central areas (C3-C4), then frontal (F3- F4), prefrontal (FP1- FP2), and parietal (P3-P4) for typically one to two sessions at each location.

For most patients 30 minutes of pIR HEG biofeedback was introduced at approximately their tenth visit. After two sessions the frequency-based neurofeedback training was reintroduced, and generally conducted pIR HEG every 2nd or 3rd session along with neurofeedback for the remainder of the treatment period. Rationale for changing the order and number of each of these protocols was based on patient tolerance and effectiveness of each protocol and was always subject to change based on patient feedback.

Thermal handwarming biofeedback was also used simultaneously with the EEG biofeedback during clinic sessions. All patients were given thermal biofeedback units to use at home on the days they did not have a clinic session. An analysis of biofeedback in combination with home training was found to be more effective than therapies without home training.⁵

Instrumentation.- Frequency-based EEG biofeedback protocols used the Neurocybernetics (EEG Spectrum, International, Canoga Park, CA) with Procomp amplifiers (Thought Technology, Montreal, Quebec, Canada) or the Brainmaster systems (Brainmaster Technologies, Oakwood Village, OH). Passive Infrared Hemoencephalography units were also used (Jeffrey Carmen, Manlius, NY). Thermal handwarming biofeedback utilized the SC-911 unit (Biomedical Instruments, Inc., Warren, MI).

Results

Table 1 shows the distribution of the pre-treatment and post-treatment migraine frequency data. The estimates are based on participant reports of the average number of migraines they experienced each month in the 6 months prior to treatment, and the 6 months immediately preceding the follow-up telephone survey. The small number of participants (n=7) who had completed treatment only 1 to 5 months before the follow-up interview, reported migraine frequency for this shorter post-treatment time period. The pre-treatment mean frequency was 7.6 migraines per month (S.D = 5.1) and the post-treatment mean was 2.9 migraines per month (S.D=2.8).

Table 1. Average number of migraines per month pre- and post-treatment

Average number of migraines per month	Pre-treatment % (n)	Post-treatment % (n)
0 (no migraines)	0	16% (6)
1 -2 per month	19% (7)	38% (14)
3 – 5 per month	19% (7)	30% (11)
6-8 per month	22% (8)	11% (4)
9-10 per month	22% (8)	5% (2)
11 – 20 per month	19% (7)	0

For each individual, the percent reduction in migraine frequency was calculated by dividing the difference between the pre- and post-treatment frequency estimates by the average number of pre-treatment migraines. As illustrated in Figure 1, 70% of the sample showed a 50% or greater reduction in the frequency of their migraines, and only 16% failed to improve at all.

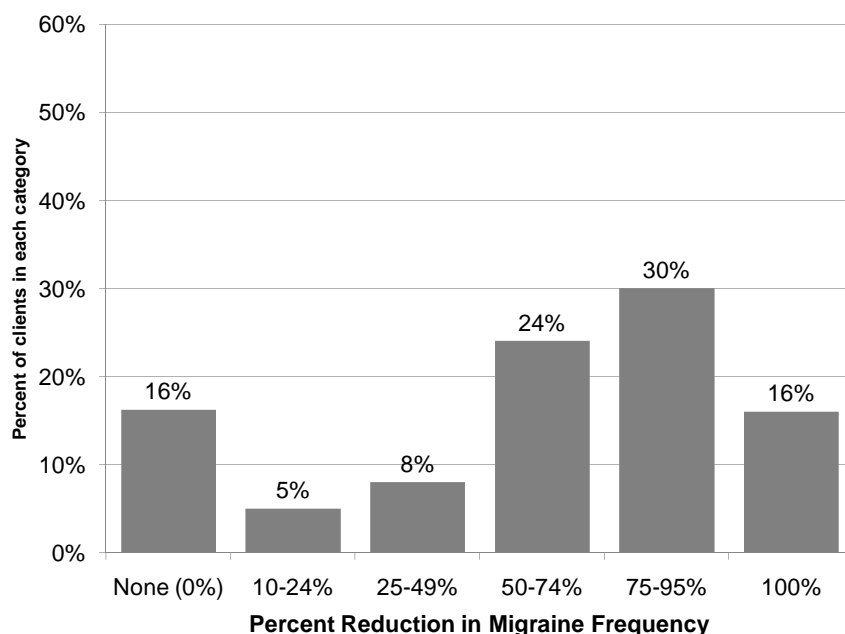


Figure 1. Percent of the total sample who experienced different levels of improvement following neurotherapy

The significance of the observed changes was examined using the Wilcoxon signed ranks test, a non-parametric alternative to the t-test for small sample studies where the dependent variable is not normally distributed. In the Wilcoxon signed ranks test the differences between pre- and post-treatment scores are rank ordered, and the significance test is based on ranks, eliminating the potential biasing effects of large, spurious differences in either direction. If the treatment has no effect the sum of the ranks where the difference is positive should be nearly equal to the sum of the ranks where the difference is negative.

In the present case, there was a large difference; in 31 cases post-treatment scores (average number of migraines per month) were less than pre-treatment scores, in 6 cases scores were equivalent, and there were no cases where post-treatment scores were greater than pre-treatment scores. The resulting z-score of -4.86 was statistically significant at the $p < .001$ level.

Although the focus of this study was on migraine headaches, patients seeking neurotherapy are typically experiencing more than one problem, and migraine patients are no exception. In the follow-up interviews we asked participants to (a) indicate which of several other common symptoms they were experiencing when they first sought treatment, and then (b) use a 5-point scale to rate the level of improvement they experienced following neurotherapy treatment. The response scale options were “no improvement” (0), “slight (10-30%) improvement” (1), “moderate (40%-60%) improvement” (2), “major (70-90%) improvement” (3), and “total (90-100%) improvement” (4). Table 2 shows the number

of individuals rating the 6 most common symptoms (migraine is included and the N of 34 indicates that we did not get ratings from 3 of the migraineurs who provided headache frequency data), and the percent reporting three levels of improvement: no/slight improvement, moderate improvement, and major/total improvement. Migraines were the most improved based on this scale, with 62% reporting major or total improvement, followed by “other headaches,” where 50% reported major or total improvement. The percent reporting major or total improvement on other symptoms ranged from 32% to 41%. Sleep problems were least likely to be substantially improved.

Table 2. Ratings of improvement on migraine and other presenting problems

	Number giving ratings	Slight or no improvement	Moderate improvement	Major or total improvement
Migraine headaches	34	21%	18%	62%
Anxiety	31	32%	36%	32%
Focus	29	35%	28%	38%
Other headaches	28	25%	25%	50%
Depression	27	33%	26%	41%
Sleep	22	46%	23%	32%

Discussion

The concept of an under or overaroused nervous system was first proposed by Nobel Laureate Walter Rudolph Hess who in the 1950s experimented with electrical stimulation of the brain which led to changes in arousal.¹⁴ Siegfried Othmer Ph.D., physicist and chief scientist at the EEG Institute and his physiologist wife, Susan Othmer, theorize that disorders of attention, affect and pain are due either to over or underaroused brain states, and that neurofeedback is effective for a variety of symptoms or symptom clusters because it improves the brain’s ability to regulate these arousal states.

Neurofeedback treatment protocols address the underlying arousal problem, obviating separate validation studies for every medical diagnosis.¹⁵ In this study, it appears that the biofeedback enabled the patients to gradually learn self-regulation skills in order to control their susceptibility to getting headaches. Generally, they began to notice gradual improvements early on in treatment, particularly in their ability to manage stress, which was impetus for continuing treatment. By session 20, most began to be aware of their ability to control or prevent their headaches. In most cases, by session 40, patients felt a sense of increased mastery over being better able to recognize when they were at risk (increased autonomic arousal in reaction to stress) and to take appropriate measures to be able to prevent

headaches. These patients described the biofeedback as helping them to acquire the ability to better self-regulate by learning to control their EEG and reducing muscle tension, slowing the rate of their breathing and warming their hands and forehead, all of which were necessary for the types of biofeedback they had undergone. Many would explain that during potentially stressful conditions they would imagine hearing or visualizing the neurofeedback games and this appeared to help them invoke the physiological state elicited during the actual sessions. Of the 37 patients in the study, five had fifteen or more migraines a month and all five improved significantly which may indicate that neurofeedback can be useful for preventing the progression from episodic to chronic migraine.

Central nervous system dysfunction may play a key role in the pathogenesis of migraine.¹⁶ As there are no apparent structural disturbances, clinical neurophysiological methods may be well-suited to study its pathophysiology. In both migraine with and without aura, evoked cortical potentials and nociceptive blink reflex studies show that lack of habituation is a reproducible central nervous system event with this population.¹⁶ This deficit of habituation involving cortical information processing is the most consistent neurophysiological abnormality in migraine patients between attacks.¹⁷ Siniatchkin et al demonstrated the vulnerability of the migraine brain by measuring the effects of experimentally-induced stress on the contingent negative variation (CNV) response which showed a susceptibility to stress-induced migraine provoking agents before an actual attack.¹⁸ Additionally, it has been observed that abnormal behavioral patterns such as hypersensitivity and perfectionism are often characteristic among migraine sufferers yet these psychological features may be the result of an innate cortical hypersensitivity in addition to associated social learning processes.¹⁹ In this study neurofeedback appears to have improved stress resilience and habituation regulation in the migraine participants. This may be due to the increase in self regulation brought about by the process of long term potentiation that results from the operant conditioning of the EEG during the neurofeedback training.

Presently, there is significant evidence for a neurological effect of neurofeedback. In a recent controlled study, functional magnetic resonance imaging was conducted on 20 ADHD children before and after neurofeedback training to measure the neural substrates of selective attention while they performed a Counting Stroop task. For both the experimental and control groups, no activation was noted in the anterior cingulate cortex in pre-treatment conditions. After neurofeedback treatment, only those assigned to the experimental group showed a significant activation of this area.²⁰ Brain maps or qEEGs (quantitative EEG) often reflect changes in electric physiological patterns paralleled with clinical improvements after neurofeedback training. For example, in a study involving subjects with Attention Deficit Hyperactivity Disorder (ADHD) (n=43 aged 7-17) 78% of them received a quantitative EEG (qEEG) before and after neurofeedback and demonstrated improvement in the following key EEG parameters following treatment: decreased relative and absolute power of theta activity, better symmetry between hemispheres, better posterior and anterior coherence and increased amplitude of beta waves.²¹ Another study (n=17, aged 8-15) found pre-post changes in the theta/beta ratios in 19 electrode site locations showing the effects of neurofeedback along widespread cortical areas even though only two electrode sites (FPZ-CPZ) were used.²² The author of this study and a researcher in the neurofeedback

field for over thirty years suggested that the changes these qEEGs reveal may be accounted for by the following mechanisms:

"We know that the cortex operates in terms of resonant loops between neocortical columns of cells known as local, regional, and global residences. The resonances determine the specific EEG frequencies and are often activated by groups of cells in the thalamus known as pacemakers. There are complex excitatory and inhibitory interactions within the cortex and between the cortex and thalamus that allow these loops to operate and provide the basis of learning. Neurofeedback is a technique for modifying these resonant loops, and hence, modifying the neurophysiological and neurological basis for learning and for the management of a number of neurologically based disorders".²³

According to the spectrum model of neurological disorders, many conditions that are currently classified as distinct entities might more usefully be viewed as simply different manifestations of an underlying spectrum of disorders. For example, ADHD is often viewed as a cluster of symptoms that lies somewhere near the middle of a spectrum of disorders that ranges from mild distractibility at one end, to autism at the other. The implication is that these disorders differ more in severity than in their underlying etiology.¹⁵

Migraine also has a comorbid association with a number of psychiatric conditions, including bipolar disorder, anxiety states, and depression, all of which are associated with perturbations in the serotonin and norepinephrine neurotransmitter substances.^{24,25} Depression is often comorbid with migraines and even when depression is not present, anti-depressants are often used to treat migraines.²⁵ Evidence that many neurological conditions are comorbid and alleviated by identical or very similar drugs supports three important principles in the spectrum paradigm: a) different symptoms are often manifestations of the same underlying instability or in balance, b) symptoms manifest differently depending on where they fall along the continuum of the underlying dysfunction, c) treatments need not be "disease specific" to be helpful.¹⁵ Neurologist Oliver Sacks' speculation that neurofeedback might prove useful for migraines after showing promise in treating seizures supports the spectrum concept of related disorders responding to one mode of treatment.²⁶

Migraine and tension type headache were linked after both types showed a significant response to sumatriptan. A convergence hypothesis was proposed speculating that the entire clinical spectrum of headache may share a common physiological pathway based on one type of medication exerting an effect on two distinctly different types of headache.^{27,28} Similarly, an older study shows that neurofeedback was effective for tension type headache²⁹ and our study finds that several types of biofeedback have an effect on migraines, other types of headache and other comorbidities.

Migraine may be a progressive disorder with an excellent response to preventive early interventions.^{30,31} Yet none of the pharmaceutical options are exceptionally effective. The best result that medication has achieved has been only about a 50% reduction in approximately 50% of migraine patients.³¹ In our study we achieved a 70% reduction in 50% of the participants which remained long after treatments ended. Neurofeedback appears to exert neuromodulatory effects as do the triptans

and antidepressants but, unlike these medications, the results appear to be more robust and enduring . Despite the different types of intervention used in our study (manipulation of the EEG, forehead temperature or hand temperature), it appears that they all offer promise for lasting preventive or abortive value for migraines and other disorders. It is our hope that this study will generate an interest in performing larger scale controlled studies in the non-invasive neurotherapies to treat migraine and other chronic and/ or progressive disorders.

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