Biofeedback and Neurofeedback Treatment for ADHD

Although many children, adolescents, and adults with attention deficit/hyperactivity disorder benefit significantly from evidence-based treatments, such as medication, behavioral therapy, and cognitive behavioral therapy, for some patients, these treatments are not helpful. Others refuse to try them, even though they may be beneficial.

To help these patients, a variety of complementary (ie, used together with established treatment) and alternative (ie, used in place of established treatment) interventions have been proposed. We focus here on biofeedback (BF) and neurofeedback (NF). After defining these approaches and their relevance to attention-deficit/hyperactivity disorder (ADHD), we will present a critical review of research on the BF and NF treatment of pediatric and adult ADHD, evaluate both approaches via the SECS criterion described in the preceding article (page 32), and conclude with clinical recommendations.

BIOFEEDBACK AND NEUROFEEDBACK DEFINED

BF and NF are thought to work via the classical and operant conditioning mechanisms of learning that train the body/brain to change its physiological activity to improve health and performance by providing it with real-time video/audio/tactile feedback.
BF has been used to regulate muscle tension (using an electromyograph [EMG] placed over a muscle); skin temperature (thermistors on a finger/toe); the sympathetic nervous system via sweat gland activity (electrodermograph [EDG] on fingers/wrist); respiration (pneumograph on chest/abdomen); exhaled carbon dioxide pressure (capnograph in nostril); cardio activity (electrocardiograph [ECG/EKG] on torso/wrists/legs); blood pressure (sphygmomanometer on upper arm); blood flow in the body (photoplethysmograph [PPG] on finger/temple); and blood flow in the brain (hemoencephalograph [HEG] on scalp).

A specific form of BF is NF, formerly called electroencephalographic (EEG) biofeedback and sometimes neurotherapy, which regulates the electrical activity of the brain. NF uses single or multiple electrodes (or channels) placed via the standardized 10-20 International System (so called because the distances between adjacent electrodes are either 10% or 20% of the total front-back or left-right distance of the skull).

First measured in 1924 by Hans Berger, the brain’s electrical activity, shown as brainwaves on the EEG, was hypothesized to change according to the functional state of the brain while awake, asleep, or in brain diseases, such as epilepsy. EEG is described in terms of rhythmic activity measured in hertz (Hz) or the number of waves per second. It is now known that most of the electrical activity from scalp EEG falls in the range of 1 to 20 Hz. EEG activity is typically divided into specifically named frequency bands. Up to 4 Hz is called delta (eg, slow wave sleep state); 4 to 8 Hz is theta (eg, drowsy/inattentive state); 8 to 12 Hz is alpha (eg, relaxed/wakeful state); and 12 to 30 Hz is beta (eg, active/attentive state). A specific type of low beta activity (12 to 15 Hz) seen over the sensorimotor cortex, particularly relevant to ADHD, is sensorimotor rhythm (SMR). SMR amplitude is higher when the corresponding sensory-motor areas are idle (eg, during states of immobility) and decreases when these are activated (eg, during motor tasks). In this manner, SMR is a measure of motor inhibition, strongest when the “brake is on” and weakest when the “brake is off” in these areas.

Besides these global spontaneous rhythmic activities, other more specific wave patterns, event-related potentials (ERP), sometimes called evoked responses, can be seen. ERP are elec-
trical representations of underlying sensory and cognitive processing in response to stimuli or events. One specific group of ERP, first identified in 1964, are slow cortical potentials (SCP), which are slow event-related direct-current shifts of the EEG that reflect the excitation threshold of large cortical cell assemblies.

Shifts in the negative direction, called the contingent negative variation (CNV), indicate a reduction of the excitation threshold. These shifts are thought to be related to cognitive preparation and increased cortical activation of a network, whereas shifts in the positive direction reflect an increase of the excitation threshold and a corresponding inhibition of activation.

**RELEVANCE OF BF AND NF TO ADHD**

Although there are a few isolated older case studies of BF for pediatric ADHD using body movement, skin temperature, and sweat gland activity, most of the non-NF research has involved the regulation of muscle tension via EMG. The use of EMG BF for ADHD is based on Braud, Lupin, and Braud’s theory that muscle tension and an inability to relax contribute to and can augment hyperactivity. EMG-BF typi-

cally uses the two frontalis muscles extending from the eyebrows to the hairline, which are accessible and a reliable measure of overall relaxation.

NF treatment of ADHD typically induces beta-band EEG rhythms, either sensorimotor (12 to 15 Hz) or higher (15 to 18 Hz) and suppresses theta rhythms (4 to 8 Hz) by visual and auditory feedback. More recently, researchers have examined NF of SCP, which involved training children to increase their cortical negativity to mobilize attentional resources and self-regulatory capacities.

The theoretical foundation of NF in the treatment of ADHD rests on the idea that brainwaves can be consciously modified; observations of excess theta in ADHD; neuroimaging, PET, and SPECT studies demonstrating a neurophysiological basis to ADHD; studies of EEG and SCP dysfunctions and their relationship to underlying thalamocortical mechanisms; and EEG changes associated with a positive medication response.

**RESEARCH ON BIOFEEDBACK OF ADHD**

**Pediatric ADHD**

EMG-BF was first used in 1960 to help patients with hemiplegia (ie, a limb weakness on one side of body) regain control over their paralyzed muscles. Fifteen years later, the first case-study of EMG-BF with a 6-year-old child with hyperactivity was published.

Although several open studies were published, without randomization results, these studies are difficult to interpret. The results may be due to the actual specific effects of EMG-BF but also to selection effects and associated expectations due to subjects/parents choosing their preferred treatment group; nonrandom subject experiences (ie, subject history); regression to the mean; maturation; practice with assessment measures; or to the interaction of any of these factors. Therefore, our review only considers randomized studies.

Based on a September 2010 PsychInfo and Medline search, six randomized studies of EMG-BF for pediatric ADHD were identified. All of them used EMG-BF of the frontalis muscles via visual feedback. On average, EMG-BF was given for six sessions (range 3 to 12); 14 minutes per session (range 8 to 26 minutes); 1.8 times/week (range 1 to 3/week); over the course of 7.3 weeks (range 1 to 12 weeks).

Three studies used the same EMG-BF software (Toomin 502A electromyometer). In conjunction with EMG-BF, most (83%) of the studies also used audio-taped instructions for progressive muscle relaxation (ie, systematic alternative tensing and relaxing major body muscle groups). In all, 247 subjects (M = 41.6, range = 30 to 56), mostly male (91%) and older than 12 years of age (60%, range = 6 to 16 years of age) have been examined. The studies predated Diagnostic and Statistical Manual of Mental Disorders, fourth edition, and selected subjects by high scores on behavioral rating scales of ADHD. Where possible, we calculated effect-sizes using Cohen’s d, which offers a standardized way of reporting multiple results across several studies.

For reference, d’s between 0.2 to 0.4 are considered small, 0.5 to 0.8 medium, and greater than 0.8 large. The overall mean effect size for all 10 significant results reported was d = 1.31 (large). Although only two studies examined inattention and impulsivity using neuropsychological tests, the four significant results had large effects (d = 0.91 to 0.93).

Although the above studies all used randomization, none of them adopted a double-blind design to control for subject, rater, and experimenter expectancies of treatment outcome (ie, the placebo response).

Furthermore, only one study used a single-blind sham EMG-BF control condition (ie, similar to real EMG-BF in every way except feedback was not contingent on actual EMG) to adequately control for nonspecific treatment effects, such as merely sitting still, paying attention, and/or receiving social attention from trainers for 14 minutes twice a week for 7 weeks.

Without such controls, it is impossible to know whether the reported results are actually due to the specific effects of EMG-BF or to subject, rater and/or experimenter expectancies, non-specific treatment effects or even a combination of all three components. Another limitation was that 83% of the studies combined EMG-BF with a relaxation tape.
so it was impossible to know which treatment component or combination caused the reported results.

Interestingly, the single study that examined EMG-BF and relaxation separately found significant reductions for both groups in EMG scores, parent ratings of behavior problems, and neuropsychological testing. Only EMG scores were significantly lower for EMG-BF compared with relaxation. However, groups showed significant and large pre- and post-percentage decreases in EMG muscle-tension (87.4% and 58.8%, respectively), suggesting, at least for this study, EMG-BF may not add that much more to treatment than a relaxation tape.

In summary, despite research in this area coming to an abrupt halt in the mid-1980s (primarily due to the field’s two main researchers [Denksowski and Omizo] switching to non-EMG research), initial randomized studies produced promising results with large effects, suggesting this approach merits further research.

However, because of the methodological limitations, the evidence is not yet conclusive. EMG-BF appears safe, easy, and sensible, but it is not cheap because of its expensive equipment and need of a technician (price ranges from $50 to $200 per treatment, with an average of six treatments). Because it was often paired with relaxation and appeared to produce similar results across a few short sessions and seems safe, easy, cost-effective, and sensible, clinicians first may want to recommend and monitor a short trial of progressive muscle relaxation for adults with ADHD. However, it is possible that the progressive muscle relaxation exercises discussed in the previous section may offer benefit to some adults with ADHD.

While informing adult patients of the lack of evidence, clinicians also may want to consider the following two CDs on scientifically based relaxation methods, *Progressive Relaxation and Breathing and Applied Relaxation Training*.22,23

**It is possible that progressive muscle relaxation exercises may offer benefit to some adults with ADHD.**

**RESEARCH ON NF FOR ADHD**

**Pediatric ADHD**

Our literature search did not identify any studies using EMG-BF treatment for adults with ADHD. However, it is possible that the progressive muscle relaxation exercises discussed in the previous section may offer benefit to some adults with ADHD.

While informing adult patients of the lack of evidence, clinicians also may want to consider the following two CDs on scientifically based relaxation methods, *Progressive Relaxation and Breathing and Applied Relaxation Training*.22,23

Researchers on NF for pediatric ADHD have evolved a great deal since the first randomized study was published in 1996.24 There are now five published randomized studies.24-29 This advance came at a rapid rate, with most of the studies (80%) conducted in a 3-year period between 2006 and 2009.

All of the studies used theta/beta training by inhibiting excessive amplitudes in the 4- to 7-Hz EEG frequency range (theta) while simultaneously rewarding the 12- to 18-Hz range (beta). One of those studies used theta/beta or SCP, and another theta/beta and SCP. On average, NF was given for 30.2 sessions (range 18 to 40), 49 minutes per session (range 30 to 60 minutes), 3.9 times/week (range 2 to 6/week) throughout 13 weeks (range 3.5 to 24 weeks).

All five studies used different NF software, two-thirds of the studies used a single (unipolar) electrode at the center of the top of the head (ie, Cz placement in the 10 to 20 International System), and the remaining used two (bipolar) electrodes at Cz and another position. In total, 199 patients (M = 39.8, range = 15 to 94), mostly male (84%) and older than 12 year of age (80%, range = 5 to 15 years old) have been examined, with DSM-IV ADHD Combined (69%; or Inattentive Type (19%)).

The overall mean posttreatment effect size compared to the control condition was d = 0.58 (medium), with little difference between inattention (d = 0.63) and hyperactivity/impulsivity (d = 0.59). Three studies also showed neurophysiological changes specifically associated with NF (fMRI,25 EEG,28 and N2-amplitude29).

Unfortunately, none of the five randomized studies adopted a double-blind design to control for subject, rater, and experimenter expectancies of treatment outcome or a sham-NF control condition to adequately control for non-specific treatment effects. The studies also lacked posttreatment follow-up assessments to examine any long-term effects of NF or if (and how many) booster sessions are needed.

Additionally, although NF is frequently reported as safe and without side effects by clinicians, none of the studies identified or measured any adverse events related to NF. Finally, none of the five studies examined the necessary number, length, frequency per week and overall treatment dura-
tion of NF sessions required to obtain clinical improvement and to sustain that improvement over time.

In summary, the evidence for NF is increasing in quantity and quality, suggesting a medium effect from randomized studies of about $d = 0.58$, somewhat less than FDA-approved medication, a standard established treatment. A recent meta-analysis that used different methods reported higher mean effect sizes, including 1.02 for inattention, 0.71 for hyperactivity and 0.94 for impulsivity. However, it included a mix of randomized and nonrandomized studies, none of which had double-blind and sham-controlled designs. However, because of some questions about methodology in all of the published studies, the evidence is not yet conclusive. Although NF appears safe and sensible, it is neither easy nor cost-effective.

**Adult ADHD**

Our literature search only identified three published case-studies on NF for adult ADHD. The first, in 1998, involved a chart review of 13 medication-free adults (seven 17- to 18-year-olds and six 28- to 63-year-olds) with DSM-IV ADHD. They attended forty 50-minute twice-weekly sessions of theta/beta NF combined with metacognitive training and, for some patients, temperature and electrodermal BF. Pre- and posttreatment results revealed significant improvement on a computerized continuous performance task measuring attention span, reaction time and variability; a standardized achievement test of arithmetic; and a standardized intelligence test of overall, verbal and performance IQ; and marginally significant improvements in EEG theta/beta ratio.

Seven years later, a single case study described a 29-year-old man, previously diagnosed with ADHD, treated with 40 twice-weekly NF sessions as an adjunct to mixed amphetamine salts. Whereas a pretreatment computerized continuous performance test while on medication indicated extremely impaired attention, post-treatment testing while off medication showed normalized attention scores. Also in 2005, a case study described a 42-year-old woman, who was taking medication for features of ADHD, panic and social anxiety, and who received 52 sessions of NF at various scalp locations and with various frequency ranges. She also received EMG-BF to train relaxation of the frontalis muscle, diaphragmatic breathing, and cognitive strategies. Following treatment, this patient reported no more panic attacks, did not meet diagnostic criteria for ADHD or anxiety disorder, discontinued medications, and attained certain social and career goals.

In summary, unlike the evidence base for pediatric ADHD, research on NF for adult ADHD is still in its infancy and lacks studies using standardized diagnostic procedures, randomization, double-blinding and sham-control. Because of the current sparse and methodologically weak research and difficult and expensive nature of NF, the evidence base for using NF to treat adult ADHD remains weak at this time.

**SUMMARY AND CONCLUSIONS**

For patients who do not respond completely to evidence-based treatments, practitioners are often expected to offer advice about alternative treatments. To provide such advice, one needs to consider the current level of scientific support, level of interest of the family, and how safe, easy, cheap and sensible (SECS) the treatment is for that individual patient. In many cases, families and individuals will experiment with such treatments on their own if they sense that their professional advisor is not willing to be involved. It is clearly better for such individual empirical trials to be guided professionally.

As noted by the Association of Applied Psychophysiology and Biofeedback (AAPB) in 2007, “insurance reimbursement for biofeedback [and neurofeedback] continues to be inconsistent and unpredictable” and out-of-pocket session “fees range from $50 to $200 per hour for biofeedback therapy … EEG therapy will customarily be higher because further specialized training is required.”

As patients and families have only so much time, energy, and money, they should be encouraged to evaluate whether to direct these limited resources to a promising but yet unproven, expensive, and time-consuming treatment, to other treatments with stronger evidence, or to other more pressing family needs. However, for more affluent families, especially if conventional treatment has been unsatisfactory, a trial of NF might make sense at our current state of knowledge.
The best resources for identifying local practitioners is the Biofeedback Certification Institute of America (BCIA) Practitioner Directory (www.bcia.org). BCIA is recognized as the certification body for the clinical practice of BF and NF by the AABP (www.aabp.org) and the International Society for Neurofeedback and Research (ISNR, www.isnr.org). The former two organizations also provide helpful tips for consumers looking for these interventions.

Aside from these two complementary and alternative approaches, when making future treatment decisions, clinicians, patients and families also may want to consider empirical evidence and SECS criteria for the inestimable biomedical and nonestimable approaches we recently reviewed for pediatric ADHD;35 and those recently reviewed for adult ADHD.36,37

As for any treatment, all individual patient trials should be carefully monitored. For pediatric ADHD, the Swanson, Nolan, Pelham, fourth edition (SNAP-IV) parent and teacher rating scales38 and the Vanderbilt scales and their scoring guidelines can be downloaded free from www.adhd.net and www.psychiatrictimes.com/clinical-scales/adhd/vadrs/, respectively. The former two organizations isnr.org). The former two organizations and the International Society for Neurofeedback and Research (ISNR, www.chadd.org), which also lists regional support-groups. Arnold’s A Family’s Guide to ADHD41 may also be useful.

REFERENCES


