

SPECIAL ISSUE

Applied Biofeedback in Pediatric Pain

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Biofeedback is an effective tool for treating pediatric pain. As biofeedback professionals, we often work within an interdisciplinary team for complicated cases of pain. This interprofessional care of pediatric chronic pain presents both advantages and potential hurdles to the biofeedback clinician. In this article, we detail two current biofeedback services affiliated with interprofessional pediatric pain management. We then use case examples to demonstrate key issues in interprofessional care. We conclude with opportunities for further development of interprofessional care involving biofeedback and lessons learned from our practice that may be beneficial to others in the field.

Applied Biofeedback in Pediatric Pain

Biofeedback has long played an important role in the health of children. Over the years, we have seen developments in biofeedback interventions for a variety of conditions, from ADHD and asthma to trauma and TBI (Schwartz & Andrasik, 2003; Yucha & Montgomery, 2008). In the field of pain, there has been significant progress in biofeedback for both adults as well as children (Hermann & Blanchard, 2002; Schwartz & Andrasik, 2003). Interestingly, when biofeedback is reviewed, a commonly reported limitation is the inability to isolate the effect of biofeedback when integrated with other forms of medical care (Eccleston et al., 2014; Glombiewski, Bernardy, & Hauser, 2013). While integrating biofeedback into interdisciplinary programs may hinder the researcher's ability to isolate the therapeutic effects directly tied to biofeedback, it should not be assumed that integration is a bad thing clinically (Nestoriuc & Martin, 2007; Powers et al., 2013). To the contrary, an effective integrative program, including biofeedback, can be more than the sum of its parts (NIH Technology Assessment Panel on Integration of Behavioral and Relaxation Approaches into the Treatment of Chronic Pain and Insomnia [NIH], 1996). Further, with the implementation of the Affordable Care Act, there has been a major focus on interprofessional care, with the aims of optimizing healthcare provision and patient outcomes (Rozensky, 2012a, 2012b; Rozensky & Janicke, 2012). Interprofession-

alism has long been at the heart of treating pediatric pain (Odell & Logan, 2013; Young & Kemper, 2013). In this paper, we reflect on our experiences integrating biofeedback into interprofessional health care programs for pediatric pain. We first describe two programs that treat pediatric pain, an inpatient and an outpatient program, using case examples to illustrate how biofeedback is integrated in an interprofessional care team. We then highlight the practical benefits, potential limits, and future possibilities of an integrated service.

Inpatient Rehabilitation for Pediatric Chronic Pain

At the Cleveland Clinic (CC), the Pediatric Pain Rehabilitation Program is an interprofessional program that treats children with a variety of chronic pain conditions (e.g., complex regional pain syndrome, chronic daily headache, recurrent abdominal pain, fibromyalgia). The program integrates rehabilitation therapies (e.g., occupational, physical, and recreational), behavioral health services, medical subspecialty care, alternative therapies (aromatherapy, acupuncture, biofeedback, and Reiki), and school in an individualized but coordinated manner. Patients are typically enrolled in our program for three weeks, with up to 6 hours of individual or group therapy per day. To date, our program has demonstrated clinically significant changes in the lives of our patients (Banez et al., in press).

Patients in the CC program may proceed in either of two separate biofeedback programs. First, a biofeedback program is provided teaching self-regulation skills specific to chronic pain or anxiety (Appelhans & Luecken, 2008; Conrad et al., 2007; Hermann & Blanchard, 2002; Yucha & Montgomery, 2008). Patients are taught various breathing exercises and provided heart rate variability (HRV) biofeedback (Humphreys & Gevirtz, 2000; Lehrer, Vaschillo, & Vaschillo, 2000; Storella et al., 1999), with a goal of increasing the relative percentage of low-frequency heart rhythms, self-awareness, and self-modulation of HRV with and without feedback. Second, a select number of patients are seen through a Motor Control Program using a variant

of surface electromyography called Quantitative Surface Electromyography (QSEMG). The focus of QSEMG biofeedback is to internalize the correct muscle pattern recruitment within the constellation of muscles rather than relying on only one or two muscles (Bolek, 2012). Typically, some muscles need to be activated and some relaxed. For example, upright sitting may be enhanced by targeting the lower trapezius to be active with minimal use of the upper trapezius. When this constellation of muscle groups is on target (i.e., the thresholds met), positive feedback in the form of a video reward is activated.

Outpatient Biofeedback for Recurrent/Chronic Pain

At Alberta Children's Hospital (ACH), the outpatient biofeedback clinic primarily serves a large pediatric headache population, with an expanding role over recent years in the adjunctive assessment and treatment of postconcussion syndrome, chronic pain, and dysautonomias.

Following medical evaluation and treatment planning by a pediatric neurologist, the patient is referred for physiotherapy, occupational therapy, social work, psychology, and biofeedback as required. Upon referral, patients undergo a psychological assessment in order to identify any underlying comorbidities, which often may include depression or an anxiety disorder. Patients are provided education on behavioral treatment for headache management (relaxation training, pacing, trigger avoidance, coping, etc.). Patients then proceed to the psychophysiology lab for assessment of respiration, peripheral temperature, skin conductance, heart rate variability, and end-tidal carbon-dioxide. Measurements are taken in five 5-minute segments: baseline, patient-guided relaxation, paced-breathing, working memory/math stressor, and stress recovery. Patients then proceed through a treatment protocol which typically involves stepwise mastery of abdominal breathing, heart rate variability to increase LF%, and temperature (hand-warming) training. Surface electromyography (SEMG) training is substituted for temperature or added in case of tension-type headache symptoms. Patients are considered to have "mastered" the program once they can normalize baseline values unaided and also complete a series of stress-recovery conditions intended to mimic common headache or pain triggers (e.g., social performance, light and sound stimulation, etc.). During training, a combination of biofeedback and cognitive-behavioral techniques are used to develop an awareness of: individual stress responses, somatic and cognitive precursors of migraine or pain episodes, adoption of behavioral methods for addressing

headache/pain triggers, and specific coping techniques to manage/abort headaches when they do occur (e.g., initiating rapid ANS-mediated hand-warming during migraine aura).

Case Studies

In order to demonstrate how interdisciplinary treatment occurs in our settings, we present three separate patients, followed by a description of the benefits and hurdles of integration.

Case One: Anna

"Anna" is a 15-year-old female with Complex Regional Pain Syndrome and Dystonia referred to Cleveland Clinic for interdisciplinary pain rehabilitation. Among other symptoms, she was experiencing locking sensations in both thumbs, which interfered with daily life activities (e.g., dressing, eating, writing) and caused significant pain. In addition to the standard interventions of our interdisciplinary program, she was evaluated via the Motor Control Program using QSEMG to determine if any pathology in the use of her muscles was contributing to her pain. Patients with pain sometimes unknowingly use aberrant muscle activation strategies such as guarding, co-contraction of agonist and antagonists, and an inability to inhibit muscle activation. While this was the case, additional observations suggested that there was a great deal of overall tension at work and her hand pain was one of many symptoms of a common underlying pathology. This prompted further evaluation, indicating that symptoms of obsessive-compulsive disorder (OCD) were more impairing than she previously was aware, and there was potential for trauma reactions influencing her physical and psychosocial presentation.

Anna underwent additional training with biofeedback. Initially, the focus of training was somatosensory awareness and self-regulation. While she demonstrated some increase in temperature and reduction in muscle tension, she reported *no awareness* of this and limited direct control. Strikingly, her respiration rate during each feedback session was greater than 21 breaths per minute and often greater than 30 breaths per minute, raising concern about hyperventilation exacerbating her anxiety. Additional training was focused on breath training, both with and without feedback given her aversive response to feedback at times (likely due to relaxation-induced anxiety). We used paced breath training and home monitors of temperature to provide reinforcement for an increased relaxed state. Unfortunately, she met overall functional goals for the program and was discharged before completing more

biofeedback training. At follow-up 6 weeks later, she demonstrated minimal hand cramping following weightlifting, which resolved soon after with gentle massage. She was still reluctant to address the psychological component to her presentation, although she and her mother are better informed and aware of the treatment needed and following other team recommendations to enhance daily functioning. She does not live close to an outpatient biofeedback provider.

Case Two: Bradley

“Bradley” is a 16-year-old male who presented to Cleveland Clinic with chronic daily headache and post-concussion syndrome following a sports-related head injury several months prior. He also presented with ADHD, Inattentive Type, and significant anxiety. He struggled managing his pain in an outpatient setting and often resorted to cigarettes or marijuana for relief. After beginning the standard pediatric pain rehabilitation program (Banez et al., in press), he underwent biofeedback assessment to evaluate the potential for additional services to augment his rehabilitation. This assessment included a 5-minute baseline, two separate stressor tasks with recovery periods, a task of relaxation prior to any training from our staff, and a postbaseline assessment (Table 1).

We agreed to begin respiration and HRV biofeedback training, with possible addition of surface electromyographic (SEMG) biofeedback (Figure 1). In his first session, he was taught diaphragmatic breathing with a goal of slowing his respiration rate and increasing HRV (visual analog feedback provided); paced breathing was slowed from 12 breaths/min to 6 breaths/min (session 1). He continued practicing with a home trainer HRV biofeedback tool (with 6 breaths/min pacer) twice daily. As practice

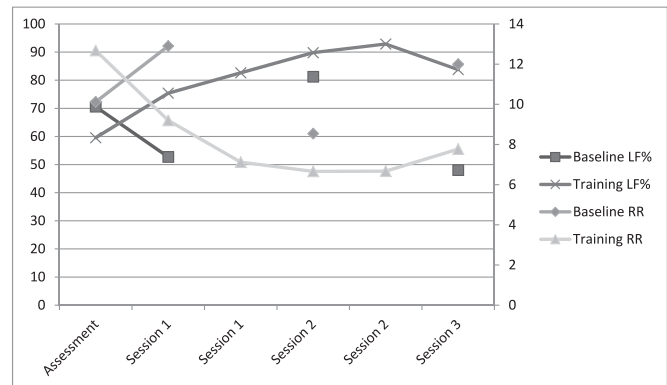


Figure 1. Biofeedback data (respiration rate and LF%) of Case 2 (Bradley, chronic daily headache and postconcussion syndrome).

continued and he began using this skill in other activities in our program (e.g., prior to PT exercises, during myofascial release), he demonstrated continued benefit from paced breathing (6 breaths/min); he then received only reinforcement of HRV, with analog visual feedback of breathing and audio-visual feedback of LF% above 80% (session 2). By his third week in the program, he reported frequently using the skills and practicing regularly. We then re-evaluated his baseline and asked him to practice the skill without any feedback provided (session 3). Bradley reported using skills learned in biofeedback during additional physical therapies and during his quiet time in his room. Physical and occupational therapy staff monitored and rewarded use of these skills on a regular basis. With frequent practice and social reinforcement, he was able to identify the underlying anxiety that influenced his pain and generate thoughts and behaviors consistent with a more relaxed and positive attitude.

Table 1. Psychophysiological assessment of Case 2 (Bradley, chronic daily headache and postconcussion syndrome). Sensor placement: RESP (abd); TEMP (L 3rd digit); HRV (BVP L 2nd digit); EMG (frontalis Placement) Artifact Rejection: SEMG ampl > 100uV and HR > 150.

	Temp (°F)	Respiration Rate (per minute)	EMG ampl	HR	HRV LF%	HRV SDNN
Baseline (5 min)	95.58	10.12	6.07	72.82	70.58	114.97
Stroop task (2 min)	95.68	13.27	11.98	79.60	68.49	109.38
Recover (2 min)	96.22	18.25	4.62	74.99	34.79	91.09
Math task (2 min)	96.07	21.51	6.54	83.26	56.36	109.06
Recover (2 min)	96.61	15.08	4.98	77.82	48.22	113.84
Relax (3 min)	96.94	12.68	5.60	73.85	59.56	146.47
Postassessment (2 min)	96.75	17.68	4.62	79.83	30.72	85.33

Table 2. Psychophysiology assessment of Case 3 (Jane, chronic daily headache with migraine and postconcussion syndrome). Mean data are presented. Sensor placement: RESP (abd); Skin Conductance (R 2nd & 3rd digits) TEMP (L 3rd digit); HRV (BVP L 2nd digit).

	Temp (°F)	Respiration Rate (per minute)	SCL (μ siemens)	HR (bpm)	HRV (LF%)
Baseline (5 min)	82	9	9.6	96	73
Relax on own (5 min)	79	9	8.9	90	76
Math task (2 min)	79	12	9.8	89	37
Recover (2 min)	85	12	10.4	86	48
Relaxation (20 min)	85	11	10.3	86	56

Note. SCL = skin conductance level.

Case Three: Jane

“Jane” is a high-achieving 14-year-old female with a history of ear deformity/hearing loss at birth and complex sequelae of symptoms (new onset daily headache, nausea, dizziness, and acute migraine attacks with aura) following a sport-related mild concussion one year ago. Initially followed by the medical team at ACH with referrals to social work, physiotherapy, massage, and acupuncture, Jane’s symptoms remitted over the summer months following her injury, only to return in the fall leading to significant impairment, school/activity absence, family dysfunction, and conflict with the medical team over the cause of her pain. She presented with significant internalizing symptoms of anxiety, depression, and withdrawal, although she denied these were occurring. Her symptoms had failed to respond to various medication trials for pain and headache prophylactic. Despite initial resistance, Jane participated in individual psychological assessment and brief therapy leading to identification of behavioral treatment goals, including resumption of physical activities in a highly structured and gradual progression (pacing). These were initially successful in reducing her pain levels. She also began to develop an awareness of somatic

responses to stress (butterflies in stomach, sweating palms) and long-standing performance anxiety we conceptualized around genetic (parental anxiety disorder) and developmental factors, including the fact we learned Jane had always been socially anxious as a child given hearing loss and being unable to understand conversation during social activities.

Jane’s lab assessment was telling: She evidenced highly decompensated physiology during baseline (see Table 2, with respiration, skin conductance, peripheral temperature, heart rate, and HRV), which she was both unable to recognize (subjectively felt “normal”) or modulate. Over successive treatment sessions she continued to present with low baseline hand temp (usually 80°F), but gradually began to normalize to well above 90°F using a variety of clinician-guided techniques (respiration training, progressive muscle relaxation, guided imagery/hypnosis). Within four lab sessions over a 2-month period, Jane’s headache pain, migraine attacks and associated PCS symptoms had largely remitted in association with improved baseline and achievement of normal values with intentional autonomic nervous system (ANS) control. Her skin conductance however, continued to remain high throughout training.

Table 3. Psychophysiology final session of Case 3 (Jane, chronic daily headache with migraine and postconcussion syndrome). Mean data are presented. Sensor placement: RESP (abd); GSR (R 2nd & 3rd digits) TEMP (L 3rd digit); HRV (BVP L 2nd digit).

	Temp (°F)	Respiration Rate (per minute)	SCL (μ siemens)	HR (bpm)	HRV (LF%)
Baseline (5 min)	73	6.8	4.5	90	81
Relax on own (5 min)	77	7	4.3	91	80
Relaxation (10 min)	90	6	5.3	85	81
Stress challenge (2 min)	85	11.3	7.7	90	42
Recover (5 min)	87	7	6.4	86	77

Note. SCL = skin conductance level.

At this point in her treatment, Jane returned to school in the fall with and experienced a full rebound of her headaches, although fortunately other symptoms did not return. Based on the pattern of her symptoms in association with school and continuously high skin conductance values (over 10 micro-ohms), Jane was enrolled in a focused multimodal treatment for anxiety including individual and group cognitive behavioral therapy, the addition of a selective serotonin reuptake inhibitor (SSRI) medication (she was no longer taking pain medications), and social work consultations with her parents. She was provided with lab-based biofeedback training and portable take-home training to modulate her skin conductance values. After several weeks of outpatient sessions, her symptoms began to remit over the school year as she learned to down-regulate this previously constant autonomic nervous system hyperarousal triggered by daily anxiety in social or performance situations (Table 3). Her parents also came to understand the connection between autonomic activation and Jane's physical symptoms. Reconceptualizing their own anxiety and active monitoring of her headaches as behaviors that increased Jane's anxiety allowed her parents to develop reduce their focus on Jane's headache and learn new coping techniques for parenting a child in pain.

Benefits of Integration

One of the primary benefits we have observed in an interprofessional team is the shared invested interest in a treatment plan. All treatment providers, the family, and the child work together to reduce pain or impairment and increase functioning or quality of life. This unity of forces facilitates a constant review and reinforcement of all treatment modalities. In the case of Bradley, he was prompted and reinforced for self-regulation skills and HRV biofeedback across multiple treatment locations throughout the day. He was able to apply the skills as needed and receive feedback from multiple professionals who understood the nature and purpose of this intervention, strengthening his resolve to use it and his belief in its effectiveness.

A second benefit is the multiple perspectives, which can clarify a clinical presentation and better inform treatment planning. In the case of Anna, she was referred for previously diagnosed chronic pain and dystonia, but detailed evaluation and real-time information sharing among treatment providers helped to quickly clarify that a psychological process was the primary suspect. Therefore, while our medical doctors ensured her physical health and stability, our rehabilitation therapists encouraged stretching and strengthening in a way that reduced increased anxiety about her symptoms and our psychologist focused on addressing the generalized anxiety

and OCD symptoms. In the case of Jane, the inclusion of psychological treatment of anxiety increased her treatment outcomes in both physical and psychological domains.

A multidisciplinary team also increases the potential access to the patient. Biofeedback interventions can be time intensive from a patient's standpoint (NIH, 1996). We typically use 5–10 sessions for a biofeedback treatment protocol. In our inpatient program, having daily access to a patient allows more frequent training with the equipment. In our outpatient programs, patients usually arrive on a day they have additional visits, either with medicine or rehabilitation therapies. This has helped to increase consistency and show rate for our patients.

One of the primary goals of biofeedback in our practice is generalization of skills. The knowledge gained from a biofeedback session can be immediately translated into a physical therapy session later that day. For example, biofeedback to reduce muscle tension or prevent bracing in pain-related movements can be applied quickly after training in a physical therapy appointment. In addition, patients may use the techniques at night with the aid of nurses and portable biofeedback devices to create a state of calmness/drowsiness that promotes sleep onset. Further, with the aid of multiple clinicians (physical therapy, occupational therapy, nursing, school teacher, social work, parents) in multiple settings (physical movement, sustained stationary poses, independent versus planned motor activity, episodes of increased pain sensitivity), we truly have a 360-degree assessment of and attention to the implementation of biofeedback skills for timely remediation or rapid progression through a biofeedback protocol.

Hurdles and Opportunities of Integration

As our programs have grown, we have uncovered several hurdles to (or rather opportunities for) successful integration. A first problem to introducing or expanding any new therapy is finding the time and space. In the CC program, theoretically, a biofeedback clinician could treat 9–10 patients 3–5 times per week; however, scheduling these same nine patients with six different therapists across a 5-day week can look like children fighting over the last scraps of dinner. Working in an integrated care setting requires flexibility of the individual professional to serve the larger need of the interprofessional team—and this influences access to patient care. It takes tremendous patience, flexibility, and teamwork to implement an effective biofeedback program in this setting. For example, while Bradley responded well to biofeedback, he only received four formal training sessions during his 3 weeks, in part due to competing demands for his time.

A second issue is the appropriate application of an assessment/treatment protocol. While following a standardized biofeedback protocol in a multidisciplinary practice offers the advantage to treat a relatively large number of patients efficiently, not all patients will require or respond to the same protocol. It can prove a struggle to individualize protocols in a busy, streamlined multidisciplinary program. However, we do not recommend strict adherence to a biofeedback protocol in this setting given individual differences influencing care. This perhaps is truer for patients with complex or multiple medical conditions presenting to interprofessional teams, which is not what existing protocols were designed or evaluated for. As is the case with most interprofessional programs, our patients often present with long-standing, complicated medical and psychological conditions and disorders. Existing biofeedback protocols are a helpful foundation but do not adequately address how to handle these complex cases. Still, we are in the unique position to study these complex cases and improve biofeedback protocols. With careful deliberation, consultation with experts in the field, and ongoing collaboration with our peers in other disciplines, we can pursue various methods of research to expand the knowledge and the effectiveness of biofeedback for these patients who have a history of failing other treatments.

A third concern is reimbursement (NIH, 1996; Pelletier, Astin, & Haskell, 1999). Insufficient payment or approval is one of the largest barriers to providing biofeedback to our patients. At times, the family is unaware of what their insurer provides. More often, the insurer has a “line in the sand” to deny biofeedback outright—requiring appeals and ongoing education to insurers and patients alike. In an interdisciplinary program, denial for biofeedback services does not prohibit entry into the program. Therefore, we often see patients for whom biofeedback is a readily available, noninvasive, clinically effective intervention that we unfortunately cannot provide. This is frustrating for our patients and our team members alike. Related to this, cost reduction of multidisciplinary healthcare through the application of complementary services such as biofeedback requires further investigation to support its use (Pelletier et al., 1999). Once achieved, this will greatly enhance our ability to promote biofeedback incorporation into pain and rehabilitation programs for conditions that represent a significant financial burden to public and private medical systems alike.

A final problem of interprofessional care, particularly when patients are seen in cohorts, is answering the question “Why can’t we all get this?” Although increasing patient demand and shared clinician knowledge about biofeedback seems like a benefit, secondary problems can develop. We

often observe our patients requesting, or demanding, a treatment not recommended for them when they observe benefit in a fellow patient. At times team members do not know how to address this issue and may inadvertently support a biofeedback treatment that is not ideal. It is important for an interprofessional team to communicate effectively and regularly with each other, clarify the treatment plan and how it will be presented to the patients so that each patient understands they are getting the most appropriate treatment regimen for his or her specific condition and treatment goals.

Future Directions in Integration: Learning from Each Other

When comparing our notes regarding interprofessional care, the programs at CC and ACH have learned from each other and identified core issues to further the effective integration of our biofeedback programs. These include:

- Efficient and timely assessment of each patient identified by the team.
- Sufficient staffing, clinical time, and treatment protocols to address the various patients presenting to the team.
- Ongoing and regular communication with team members to: (a) ensure the right patient is getting the right treatment, (b) the team understands and supports the interventions of each discipline, and (c) the aims of biofeedback support the larger unified aims of the program.
- Ongoing quality improvement to develop enhanced iterations of an integrated biofeedback service.
- Strategic clinical and research plan to further the knowledge of treating the complex cases that often present to interprofessional care teams.

Conclusions

Interprofessional care is becoming more commonplace among clinical environments, especially with the new Affordable Care Act. However, this type of integration has been at the heart of pain management for years. When integrating biofeedback into programs for pediatric pain, a clinician may profit from the interprofessional team. However, working in a team also produces unique hurdles that influence patient care. Further, interprofessional teams often see the most complicated cases, which impacts the application of empirically supported biofeedback treatments. As these interprofessional care teams develop, they should capitalize on their unique clinical experiences to expand and strengthen the field of psychophysiology and biofeedback.

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