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Current applications of biofeedback to physical medicine and rehabilitation

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Clinical biofeedback has a 35 year history of developing applications to disorders in physical medicine and rehabilitation. The authors summarize the paradigm of biofeedback, discuss its mechanisms, and review current protocols for the treatment of asthma, epilepsy, fibromyalgia, headache, myofascial pain disorders, repetitive strain disorders, and urinary incontinence. Biofeedback interventions are compatible with and often augment the therapeutic effects of conventional medical, pharmacologic and manual interventions. Biofeedback offers evidence-based alternative therapies for a variety of common disorders in rehabilitation.

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Clinical biofeedback

Biofeedback is an evidence-based, non-pharmacologic treatment developed over the past 35 years, with documented applications to many common disorders in physical medicine.[1-3] The biofeedback treatment paradigm is simple. The biofeedback therapist places a sensor or several sensors on the surface of the body, measuring specific physiologic processes. The biological signal is processed electronically, and an auditory or visual signal is displayed to the patient. With feedback, the patient develops more awareness of the physiological process, and gains partial or complete control over the process.

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Biofeedback instrumentation is able to monitor musculature throughout the body, peripheral temperature, respiration, cardio-vascular rhythms, blood pulse volume, electrodermal activity, cortical rhythms, and other physiological processes. Biofeedback instrumentation can be used for general relaxation, or more strategically, to modify specific physiological mechanisms contributing to a disorder.

The use of surface electromyography

Surface electromyography (SEMG) is critical to many applications of biofeedback within physical medicine and rehabilitation. Recently, a large data-

base of normative values of electrical activity potentials and resting potentials has been accumulated for more than 130 muscles. At present the database exceeds 6500 discrete muscles encompassing the 10 major joints and the facial musculature. The values reflect asymptomatic individuals performing the range of motion (ROM) of various joints at the minimum level of muscular effort.[4, 5] The database serves as a means of comparing the activity and resting values of asymptomatic muscles with symptomatic ones. In general symptomatic muscles have larger activity and resting potentials than normal, asymptomatic ones.[4] Neuromuscular re-education with biofeedback focuses on reducing this difference in amplitude potentials and normalizing muscle tonus at rest and in motion in the course of the treatment process.[6, 7]

For example, consider a patient with spasmodic torticollis and accompanying pain. The biofeedback therapist investigates first the electric tonus of the pertinent muscles, *e.g.*, the sternocleidomastoid (SCM), by placing SEMG sensors over the muscle in a standardized protocol fashion and reads the amplitude values. The electromyograph provides a visual display and an auditory tone, communicating varying levels of muscle tension and spasm to the patient.

The same principle applies to the treatment component using SEMG biofeedback. The therapist guides the patient through a series of trials, tensing and relaxing the SCM muscle through the cervical range of motion. The therapist and the patient continuously observe the audio-visual feedback. This biological monitoring, along with specific muscle exercises, allows the patient to gain increased awareness and control over the SCM muscle, and to reduce or cease the spasm and pain.

The final SEMG evaluation refers to the post-treatment investigation of the cervical ROM of the patient no longer suffering from the torticollis symptoms. The clinician expects to find a normal cervical ROM with normally acting muscles whose activity potentials and resting tonus are within the expected range of the database for asymptomatic individuals.[4-12]

If there are psychological factors aggravating a physiological dysfunction, then the biofeedback instrumentation is helpful in teaching the patient the reality of the effects of negative thoughts and emotions on the body. The biofeedback therapist frequently conducts a physiological stress profile, recording baseline values in physiology, the physiological effects of stress trials, and the extent of recovery. The therapist invites the patient to visualize work site stress or family conflicts, and the patient can clearly observe the bodily changes which follow. This is a valuable lesson for the patient regarding the effects of mind on body, and many patients spontaneously begin to identify stress in everyday life more effectively, and to manage that stress differently.

Biofeedback techniques can be used effectively in conjunction with many medical, pharmacological, and manual therapies, often adding efficacy to conventional therapies. However, biofeedback also provides an independent treatment alternative for patients who fail to respond or have adverse effects with traditional pharmacological and medical therapies.

Two review panels of the American National Institutes of Health evaluated biofeedback protocols and held them to be effective interventions useful for the treatment of urinary incontinence in adults,[13] and for chronic pain and insomnia.[14] The National Headache Foundation published standards of care for headache and recommended inclusion of biofeedback as an excellent treatment for the long-term management of migraine and tension type headache disorders.[15]

The efficacy of a wide range of biofeedback applications has recently been reviewed by Yucha *et al.*,[16] on an efficacy scale ranging from 1 to 5. Ratings 3 and above indicate probable efficacy, based on (at least) multiple observational studies, clinical studies, wait list controlled studies, and within subject and intra-subject replication studies. The following applications have earned a rating of 3 or better:

— alcoholism;
— anxiety;
— arthritis;
— attention deficit and hyperactivity disorder;
— chronic pain;
— epilepsy/seizure disorders;
— headache, including pediatric migraine and adult tension and migraine headache;
— hypertension;
— insomnia;

— temporomandibular joint disorders;
— urinary incontinence;
— vulvar vestibulitis.

Better efficacy research is currently accumulating for additional disorders, including asthma,[17] depression,[18] fibromyalgia,[19] and anorectal disorders, including irritable bowel syndrome.[20] The following brief summaries, contributed by acknowledged experts in biofeedback assisted rehabilitation, overview specific biofeedback treatment protocols for common disorders.

Biofeedback with specific disorders

Asthma

Several biofeedback approaches have been used with asthma.[21] Early research focused on biofeedback for respiratory sounds and wheezing, with small positive results. Other early research showed modest improvements in asthma from relaxing the facial muscles, using frontalis surface EMG biofeedback. Several small studies have given biofeedback for respiratory resistance, using the forced oscillation method. In this method, the patient breathes through a tube through which a tone is passed. Pressure and flow are assessed at the mouth using a pneumotachometer, and resistance is assessed. Positive results also were reported, although there is a possibility that some of the results may reflect measurement artifact. Because β-sympathetic arousal is associated with bronchodilation, one study used biofeedback for increased heart rate, and found small improvements in asthma.

The most promising biofeedback approach thus far utilized biofeedback for increased heart rate variability.[17] Patients with asthma tend to have low 24-hour heart rate variability during asymptomatic periods, apparently reflecting diminished adaptive capacity. Patients learn to increase their heart rate variability by breathing at the resonant frequency of their cardiovascular system. For most people this is at about 0.1 Hz (6 times/min). Several small studies and one large controlled trial have found clinically significant improvements in asthma using this method. There is some evidence for a steroid sparing effect, as well as for an immediate rescue effect.

Chronic myofascial pain

Surface electromyography provides a powerful tool for both the assessment and treatment of chronic myofascial pain. Dynamic SEMG protocols are necessary for assessment and diagnosis of muscular dysfunction, and for the neuromuscular rehabilitation/SEMG biofeedback component of treatment.

Dynamic protocols are necessary for the objective investigation of myofascial conditions involving the major joints and regions of the body. The protocols involve testing of the classic segments of motion of the muscles within the context of the primary joint/region. The testing consists of investigating the affected muscle at rest and through a defined period of activity, *i.e.*, 9 second intervals for each. Those protocols have been described in textbooks.[4-7] The protocols consist of bilateral testing of at least 4 contralateral muscles of the primary myotatic unit. The results are statistically calculated to include amplitude potential (mV RMS) averages, standard deviations and coefficients of variation thereof in order to rule out patient consistent muscular behavior, and correlation coefficients in order to rule out the established intermuscular relationships of agonism and antagonism as well as stabilizing correlations.

The statistical results establish the objective basis for the biofeedback treatment. The aim is basically the normalization of muscular behavior during activity and rest. In sequence, the affected muscle(s) is/are trained to regain the range of the amplitude potentials established for asymptomatic muscles in terms of the resting tonus. The next step is to train the muscle(s) to regain the established range of amplitude potentials for each classic segment of primary joint ROM. Beyond that, muscles can be trained to act with the least possible physical effort and electrical exertion in terms of the myofascial dysfunction.[22, 23]

Epilepsy

The contemporary application of electroencephalographic (EEG) biofeedback to the treatment of seizure disorders has benefited greatly from advances in quantitative EEG (QEEG). Today, clinicians can use sophisticated quantitative and statistical methods for topographic EEG analysis to determine the locus and abnormal frequencies associat-

ed with both focal and generalized seizures. Combined with an expanded knowledge of the underlying neurophysiological mechanisms responsible for these EEG indications, they can devise EEG feedback protocols directed to the normalization of observed abnormalities in the background EEG. Emphasis is placed also on the important role of the sensorimotor cortical area in the propagation of motor disturbances. Thus, integrated training is provided to simultaneously reduce localized cortical hyper-excitability and support the normal thalamocortical regulation of both afferent and efferent sensorimotor pathways.[24, 25] Training methods have also been improved in recent years, with a stronger emphasis on more traditional operant conditioning learning principles. Rather than merely entertaining or challenging the patient to pay attention, these advanced methods seek to provide "exercise" in relevant neural pathways, promote true learning of voluntary control, and, ultimately, to normalize regulation. The objective is to reduce cortical excitability, prevent transient neuronal disturbances, and stabilize functional states. Numerous controlled studies have provided robust evidence for the efficacy of this alternative treatment. Findings confirm that medications can be reduced, both seizure frequency and severity attenuated, and quality of life improved.[25]

Fibromyalgia syndrome

Fibromyalgia presents a unique challenge to the biofeedback practitioner as its etiology is presently not that well understood. The dysfunction is characterized by the presence of diffuse pain of over 3 month's duration occurring in all 4 quadrants of the body. The American College of Rheumato-logy (-ACR) criteria includes the presence of pain on palpation at 11 of 18 potential tender points occurring throughout the body. In addition numerous studies show the co-morbid presence of IBS, headache, and cognitive difficulties (decreased memory, concentration and multi-tasking).[26]

Two studies demonstrated the presence of abnormal muscle activity in fibromyalgia sufferers seen in carefully controlled studies.[27, 28] The authors also demonstrated that quantitative EEG (QEEG) differences existed amongst the sufferers factoring out into 3 distinct sub-groups. They suggested that it may be possible to account for the diffuse nature of fibromyalgia symptoms on the basis of a dysregulation of the nervous systems (peripheral and central). The efficacy of biofeedback treatment of fibromyalgia has not been well documented, with few studies to date. Two reports [29, 30] indicated that EEG neurotherapy was effective in the reduction of symptoms. There are anecdotal reports that heart rate variability biofeedback training, focused on the reduction of sympathetically mediated activity, is also helpful.

Clinical experience to date indicates that the best biofeedback treatment protocol should include 1) surface EMG biofeedback training to reduce excessive muscle tension, correct right/left asymmetries in muscle tension, and reduce co-activation of functionally irrelevant muscles and 2) EEG neurofeedback to reduce hyperirritability of the nervous system and normalize cognitive function.[31] Further research is needed to document the efficacy of this protocol.

Headache

There are 2 basic approaches to biofeedback treatment for recurrent headache disorders. The 1st involves feedback of the physiological parameters generally indicative of autonomic arousal or excessive muscle tension to help fine tune relaxation (*e.g.*, temperature, electromyographic, or electrodermal biofeedback). This approach is quite similar to the host of other, non-instrumented relaxation treatments (*e.g.*, progressive muscle relaxation, autogenic training, meditation, etc.). The advantage to biofeedback is that it is the only approach to provide a concrete representation of how practice and treatment are proceeding. Individual studies, meta-analytic analyses, and comprehensive reviews by panels and task forces have shown that biofeedback is efficacious for uncomplicated forms of migraine and tension-type headache, that results endure over time, that improvement rates appear to rival those for pharmacological treatments, that certain treatment combinations can be more efficacious than single modality approaches, and that children respond better than adults (Andrasik *et al.* provide a summary of current findings).[32]

The 2nd approach is more direct and specifically targets those physiological parameters assumed to underlie headache (*e.g.*, blood volume pulse to

counteract blood flow disturbances, electroencephalographic biofeedback to alter brain wave patterns). These latter approaches remain somewhat experimental and are not readily available in clinical settings.

Both approaches are commonly accompanied by brief, focused therapy, designed to enhance abilities to manage stressors and stress reactions to headache (*e.g.*, cognitive and cognitive behavior therapy).

Researchers continue to explore the boundary dimensions for who is and who is not an ideal candidate for behavioral treatment. People experiencing cluster, menstrual, post-traumatic, drug-induced, or daily, unremitting headaches or certain co-morbid conditions present special challenges that can require integrative, multidisciplinary, and intensive treatment approaches.[33] It is expected that future research may identify certain headache types or situations that are uniquely suited for behavioral interventions, such as during pregnancy when women are advised to be very cautious about use of certain medications.[34]

In research studies patients are typically seen for 8-16 individual sessions. In clinical practice, sessions (and components) are tailored to individual needs. As a way to make treatments more cost affordable and more widely available, researchers are exploring alternative ways to administer treatment. These include substantially reducing therapist contact time,[35, 36] providing treatment in groups,[37] and using the internet.[38]

Repetitive strain injury

Repetitive strain injury (RSI) is a syndrome label that describes a cluster of symptoms that appear to be associated with repetitive movements that occur during typing at the computer, playing music, and industrial assembly work. The same condition has also been described as cumulative trauma disorders, overuse syndrome, work-related neck and upper limb musculoskeletal disorders or by the specific diagnoses (*e.g.*, carpal tunnel syndrome, dry eyes syndrome, and backache). Prevalence of RSI ranges from 15% to 70% for computer users.[39] The term "RSI" implies that the syndrome is caused by repetitive motions; however, repetition is often a minor factor. Factors that contribute to RSI include inappropriate ergonomics (forcing the person to adjust to the equipment instead of adjusting the equipment to the specific person), work and personal stress (*e.g.* dysfunctional work-style, lack of control, increased responsibility, increased workload, and low social support), increased level of sympathetic arousal, absence of momentary muscle relaxation, and reduced movement. A more accurate terminology for RSI is stress and immobilization syndrome (SIS). Usually people at risk for RSI are unaware that while working, their breathing rate increases and become shallow, their neck and shoulder muscle tension increases and their sympathetic system is activated. Interventions to prevent RSI include awareness of, and training in reducing physiological arousal, improving ergonomics, changing work-style, reducing work and personal stress, increasing movement and mastering regeneration.[40]

Biofeedback is a useful adjunct in the prevention of RSI.[41-43] Rest breaks with muscle relaxation are also helpful in reducing onset of RSI training.[40] The data entry assessment with biofeedback is used to identify unnecessary muscle bracing patterns, dysfunctional breathing and arousal patterns, and optimize ergonomic factors such as chair and keyboard locations and height. Biofeedback training consists of teaching the person to become aware of the dysfunctional physiological patterns, to learn to inhibit covert muscle bracing patterns of the trapezius and deltoid muscles activity, to practice rest breaks, and to breathe slower during data entry work.

Urinary incontinence and pelvic floor disorders

Biofeedback for urinary incontinence (UI) uses feedback from electromyographic and pressure sensors to correct physiological activity contributing to incontinence.[20] As UI can have several causes, it is recommended that several physiological channels be used. Depending on UI causes, training goals may include strengthening tone and contractions of the pelvic floor muscles, reinforcing bladder inhibition, or keeping bladder pressure stable while the pelvic floor muscles are tensed. Home biofeedback trainers are sometimes used to complement in-clinic training, but the advantages from this are unclear. UI biofeedback is often combined with other pelvic floor muscle exercises or habit training. Biofeedback has prov-

en most effective for stress and urge types of UI.[44] Successful biofeedback treatment is often brief (1-6 sessions).

Biofeedback provides effective treatment for functional fecal incontinence and pelvic floor dyssynergia type constipation. For both problems, average biofeedback success rates are approximately 70%.[45, 46] Two alternative types of sensors are used-an intra-rectal balloon pressure sensor, or an intra-rectal or peri-anal electromyographic sensor. There is little difference in effectiveness between these 2 methods. Treatment protocols vary greatly, but aim at improving coordination of pelvic floor muscle activity and/or muscle strength. Patient factors contributing to treatment success remain unclear.

Riassunto

Titolo italiano

L'utilizzo clinico del biofeedback presenta una storia lunga 35 anni, caratterizzata da un progressivo aumento delle sue applicazioni a diverse patologie in fisioterapia e riabilitazione. In questo lavoro gli Autori riassumono il paradigma del biofeedback, ne discutono i meccanismi e presentano una review dei protocolli attualmente utilizzati per il trattamento dell'asma, dell'epilessia, della fibromialgia, della cefalea, dei disturbi dolorosi delle fasce muscolari, patologie da stiramenti ripetuti e incontinenza urinaria. Gli interventi di biofeedback sono compatibili con le terapie convenzionali di tipo medico, farmacologico e manuale, e spesso ne incrementano l'efficacia. La metodica del biofeedback consente di eseguire una serie di terapie alternative, basate sulle prove di evidenza, per uno spettro variegato di patologie di frequente riscontro in riabilitazione.

PAROLE CHIAVE: Medicina fisica - Riabilitazione - Biofeedback.

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