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Biofeedback

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Definitions

"Bio" means life. "Feedback" is returning knowledge to origin. Then "biofeedback" (BF) means returning the biological knowledge created by the origin to origin in order to make the origin understand and control that knowledge. According to Grolier Encyclopedia, BF is to learn and control the physiological functions of the body. The physiological functions of the body are not only related to the voluntary (for example extremity muscles) systems but also to the involuntary ones (for example heart rate).

As a comprehensive definition, BF is a group of therapeutic procedures that uses electronic or electromechanical instruments to properly measure, process and feedback to patients in the form of auditory and/or visual feedback signals by using information about their normal and/or abnormal neuromuscular and autonomic activity. BF is used to help patients develop greater awareness of and an increase in voluntary control over their physiological processes that are otherwise involuntary and unfelt events by first manipulating the displayed signals and then by using internal psychophysiological cognitions to prevent, stop, or reduce symptoms (Schwartz and Schwartz 2003).

BF can be very important and helpful in clinical situations where therapeutic exercise is indicated. BF measures and shows the physiopathological events that are unfelt normally and lets the patient regulate the disorders by creating awareness. That means BF achieves knowledge where this information can not be taken by any conventional exercise. When a feedback signal warns the patient, augmentation of the motor performance will be better.

BF is often used in physiatry and psychiatry. Psychiatrists find BF useful for general relaxation and especially in tension headache and anxiety. In physiatry BF has been used in a wide range of clinical conditions such as motor weakness, balance and gait disturbances, spasticity, neurogenic bladder and bowel dysfunctions, speech and swallowing problems.

Mechanism

The exact mechanism of treatment effectiveness of BF is not clear. Basmajian determined the development of new pathways or recruitment of existing cerebral pathways (Basmajian 1982). Wolf suggested that feedback signals activate unused or underused synapses in executing motor commands (Wolf 1983). Although no data exists, the repetitive and concentrated practice performed in BF might be playing a role in brain plasticity (Dursun et al. 2004). In order to understand the mechanisms of recovery obtained by BF treatment, neuroradiological studies investigating cortical reorganization are also needed.

Types of BF

The application of BF in physiatry had begun with the use of electromyography (EMG) in diagnosis and research studies. In the 1940's, better muscle contractions were tried by letting the patients hear the sound of motor unite potentials during EMG tests. EMG BF is the most used form of BF in physiatry. Other than EMG BF, there are several BF applications like thermal BF, positional BF, electrogoniometric BF and electroencephalographic (EEG) BF.

EMG BF

EMG BF is used in many clinical conditions such as central and peripheral paralysis (stroke, spinal cord injury, serebral palsy, Bell's palsy etc.), gait disorders, pain (fibromyalgia syndrome, myofascial pain syndrome, etc.) various musculoskeletal problems (patellofemoral pain, temporomandibular disorders, postsurgery of meniscus and anterior cruciate ligament tears), neurogenic bladder/bowel dysfunctions. It has gained a firm place particularly in retraining muscles and inducing relaxation of spastic muscles.

The principle of EMG BF is based on converting myoelectrical signals sensed from muscles by surface electrodes to auditory and/or visual signals. Surface EMG can not measure muscle contraction directly and can not give results in units of force but it measures an electrical correlate of muscle contraction and gives the results in terms of electrical units (volts). So we can say that the EMG BF device is a voltmeter. Monitored electrical activity of the muscle is often referred to as "raw EMG". Raw EMG is a blasting sound that rises and falls in loudness in relation to muscle contraction. Commercial EMG devices produce an auditory tone where the pitch or repetition rate is comparable to the intensity of the raw EMG. Many forms of auditory tones are available and these can be continuous or pulsed. The forms of the tones are chosen according to the application requirements and propensity. Among various auditory signals there are clicks, tones or beeps. The device can be set up according to the clinical condition and the decision of the clinician. For example it is set up to produce a beep when a patient contracts a muscle and the EMG level is higher, and during relaxation the device emits no sound. In this way the patient is encouraged to work harder to get another beep if strengthening of a muscle needed in the rehabilitation programme. Or with the same device another option can be arranged; as the patient relaxes and the EMG activity decreases, a click occurs. In this way silence will take place during an increase of muscle tone. This procedure is useful for spasticity treatment. In the same way, various visual feedback sources like banks of lights, analog and digital meters are used for providing visual indication for muscle contraction or relaxation. When choosing the type of signals, the age of the patients and their physiological conditions, and type of the clinical condition should be assessed. For example patients who have inadequate sense of hearing should be trained with the help of visual signals. During functional gait training, auditory feedback would be proper because the patient must be careful about the environment while walking.

Positional BF

Positional BF is especially used in the training of balance and coordination. For many years physiatrists have tried to improve postural balance in cerebral palsy and hemiplegic patients. Positional BF is used to expose the convenient timing and coordination needed to control a movement. There are several examples where positional BF was used such as head control training in cerebral palsy (Leiper et al. 1981) and postural trunk control training in hemiplegic patients (Dursun et al. 1996). In our trunk control training study (Dursun et al. 1996), the BF system depends on a multidimensional, round on-off mercury switch placed on the midline of

the upper back portion of the body. When the patient tilts from the erect position in any direction, shifting of the mercury causes a short circuit, and the loudspeaker and the warning lamp give feedback to the patient. In this study, angular BF intervention provided earlier postural trunk control compared to controls.

Pressure or Force BF

Force monitoring can be used when information about force being transmitted through a body segment is needed. In balance deficits, patients can be informed by providing feedback from a force platform while balance activities are performed. The feedback can take visual and/or auditory form. For training of symmetrical standing or gait, a limb load monitor can be used to monitor the force transmitted through an extremity (Basmajian 1998)

Electrogoniometric BF

This BF system gives knowledge to patients about range of motion of their joints that are monitorized during gait training. By comparing their own goniometric traces with the normals, patients try to normalize their gait patterns. Or the goniometer can be set up to give signals on determined angles. For example regarding genu recurvatum in hemiplegic patients, the device can be adjusted to give feedback if the knee of the patient hyperextends (genu recurvatum) (Ceceli et al. 1996).

Thermal BF

Thermal BF is the reflection of vasoconstriction or vasodilatation of the peripheral vessels. More warm blood passes through dilated vessels compared to constricted ones resulting increase in temperature. If a patient can manage to relax, then the temperature on the finger tip will increase, which means more dilatation. On this basis the patient tries to change the skin temperature and help in treating certain circulatory disorders such as Reynaud's disease, hypertension and migraine headaches.

EEG BF

EEG BF supports the individual's ability to modify the amplitude, frequency or coherency of the neurophysiologic dynamics of the brain. Therapeutic application of EEG BF is often referred to as "Neurofeedback (NFB)". NFB has various clinical applications such as epilepsy, attention deficit hyperactivity disorder, alcohol abuse, and post traumatic stress disorder.

Sensorimotor rhythm (SMR) training is a commonly applied NFB protocol (Egner et al. 2004). SMR is normally associated with a quiet body and active mind. It is often depressed in anxiety, panic, chronic pain, migraine, attention deficit disorders, mood disorders, and other stress related disorders. Regarding chronic pain, NFB training aiming to enhance the SMR activity might be a useful therapeutic application in fibromyalgia syndrome (Kayiran et al. 2007).

Patient Information About BF

The most important part of the BF treatment is to give information to patients about the application of BF and the meaning of the display. Signal explanation is preferential. First, the relation between the signals and the body structures should be explained. At this point, the information might be as simple as "the bar graphic and the beeps are your muscle activity". Patients must be taught through trials how to make changes in the signals.

The next information should be about the relation of the signal to physiology. An example of an informative statement is as follows: “If you manage to lower that bar below the speckled line, then it means you are able to relax your muscle.” The speckled line is a threshold and if the muscle is sufficiently relaxed the bar would be under that threshold and the patient gets more scores. Patients learn if they get more scores and the muscle is more relaxed. Through this knowledge the relation between the signals and the physiology is understood well.

Main Clinical Applications of BF in Physiatry

BF is an adjunct application in physical medicine and rehabilitation. If the rehabilitation programme is insufficient, then BF therapy alone could be unsuccessful. On the other hand motivation and cooperation of the patient are very important; inability to follow the statements make BF therapy impossible.

In rehabilitation medicine, BF is largely used in motor reeducation and relaxation. If we take only these two into consideration it is obvious how wide an application area BF has in many clinical conditions. Below there are some clinical applications of BF in rehabilitation.

Stroke

Certainly, stroke is a main application area for BF in rehabilitation clinics. Frequently it is used in insufficient hand functions, footdrop and shoulder subluxation (Basmajian 1981). BF treatment in early phases of stroke promotes better results.

Wolf and Binder-Macleod found substantial improvements in upper extremity functions among chronic stroke patients with the application of EMG BF and they stressed that EMG BF is an adjunctive and not a total therapy (Wolf and Binder-MacLeod 1983). In their meta-analysis, Schleenbaker and Mainous showed that EMG BF improves functional outcomes in patients with hemiplegic stroke (Schleenbaker and Mainous 1993). The meta-analysis includes 192 cases. In most of the studies in this meta-analysis, as the duration of the disease was longer than 3 months, spontaneous recovery was almost excluded. Only the studies where complex neuromuscular activities such as gait analysis grading system or time to trace circle with olecranon were taken for the outcome measures were included. It was found that patients receiving EMG BF significantly increased upper and lower extremity function compared to controls.

BF is one of the important treatment modalities for footdrop. For this clinical condition, relaxation of the gastrocnemius and recruitment of the dorsiflexors are performed. Dual-channel monitoring of the muscles is used if relaxation and recruitment are trained at the same time.

Shoulder subluxation is a common complication in flask hemiplegic patients. Strengthening of the upper trapezius and anterior deltoid muscle fibers with EMG BF not only reduces subluxation but also improves the range of motion of the shoulder joint (Basmajian 1998)

In their meta-analysis, Moreland JD et al. examined the efficacy of EMG BF for improving lower extremity function in stroke patients (Moreland et al. 1998). They searched the literature covering the years 1976 to 1995 and evaluated controlled randomized studies in which the treatment group received BF alone or with conventional physical therapy and the control group received conventional physical therapy. The results indicated that EMG BF is superior to conventional therapy alone for improving ankle dorsiflexion muscle strength.

Spinal Cord Injury

BF is used for muscle relaxation and/or strengthening of the muscles especially in incomplete spinal cord injured patients. In paraplegics relaxation of hip adductors and gastrosoleus muscles is important. By adding BF treatment to the rehabilitation programme, improvement is achieved in active range of motion and function of the extremities particularly in incomplete paraplegic and tetraplegic patients.

Cerebral Palsy

In this group of patients, BF is used for spasticity treatment, balance training and strengthening of weak muscles. In cerebral palsy lower limb involvement is most apparent at the ankle joint. Dynamic equinus is a common deformity that worsens the ambulatory ability of both diplegic and hemiplegic conditions.

Colborne et al. compared physical therapy group with the BF group where in the BF group triceps surae muscle activity was fed back to children with hemiplegic cerebral palsy during gait (Colborne et al. 1994). They found that stride length, velocity, gait symmetry and ankle power for push-off were positively affected by the BF treatment and made a conclusion that the feedback protocol might be an effective adjunct to physical therapy in hemiplegic children.

In our study, we evaluated thirty-six children with spastic cerebral palsy and dynamic equinus deformity where the BF group consisted of 21 patients who performed exercises consisting of contraction of the tibialis anterior and relaxation of the spastic triseps surae muscles with EMG feedback (Dursun et al. 2004). The BF group displayed statistically significant improvements regarding tonus of plantar flexor muscles and active range of motion of ankle joints. Gait function showed statistically significant progress in the BF and control groups, but the BF group was superior to the controls. Thus children with cerebral palsy and dynamic equinus deformities may benefit from BF treatment for ambulation.

Post-Orthopeadic Surgery

Muscle weakness occuring after orthopeadic surgeries benefit from BF treatment. EMG BF is found to be effective in improving quadriceps muscle strength after meniscectomy (Kirnap et al. 2005; Krebs 1981) and anterior cruciate ligament surgery (Draper 1990).

Resulting joint contractures after the orthopedic surgeries may be very problematical. Joint positional and EMG BF may be helpful in recovering the contracture. After extremity amputations, particularly positional BF applications are useful.

Patellofemoral Pain Syndrome

Patellofemoral pain syndrome is a clinical diagnosis that is often seen in young adults which causes anterior knee pain. It is usually due to weakness of vastus medialis obliquus muscles. EMG BF is a training procedure that could be utilized during quadriceps exercises to improve balance between vastus medialis and vastus lateralis muscles. Ng et al. demonstrated that a combination of EMG BF and conventional exercise program may facilitate the activation of VMO muscle such that the muscle could be preferentially recruited during daily activities (Ng et al., 2008) In our study regarding patellofemoral pain syndrome, although the mean contraction values in the BF group of the vastus medialis muscles were significantly higher than those of the control group, no further clinical improvement was obtained (Dursun et al. 2001)

Chronic Pain

Patients with fibromyalgia syndrome have benefited from BF treatment involving EMG recording of the trapezius muscle (Sarnoch et al. 1997) Analysis indicated a significant reduction occurred in general intensity of pain and in EMG activity as well as a significant increase in muscular sensitivity.

If lower back pain is related to muscle tension or spasm, BF application can be effective. Relaxation of the body muscles with BF is useful in low back pain. EMG BF can be used especially in back, cervical and forehead muscles relaxation.

BF treatment combined with relaxation techniques has shown encouraging results in tension headache (Rokicki et al. 1997) Trapezius-based EMG BF has been found more effective than frontalis-based feedback (Arena et al., 1995)

Temporomandibular Joint Disorders

Temporomandibular joint disorders include a variety of conditions that cause pain and discomfort in the temporomandibular joint. This disorder is usually indicated by one or more of the following signs or symptoms: pain, limitation in jaw movement, joint sounds, muscle and joint tenderness. In their review McNeely et al. concluded that improvements in oral opening might result from BF training, low-level laser therapy treatment, and muscular awareness relaxation therapy but no evidence supported the use of electrophysical modalities to reduce temporomandibular pain (McNeely et al. 2006)

Incontinence

Incontinence is a major healthcare problem. The main types of urinary incontinence are stress, urge, mixed and overflow. Urge incontinence is often managed by anticholinergic drugs in inhibiting the involuntary bladder contractions that cause leakage. The most important part of the treatment of stress urinary incontinence is pelvic muscle re-education. The pelvic floor refers to the complex of muscles that close off the pelvic outlet and act as a "floor" to the abdominopelvic cavity. Pelvic floor muscle training (Kegel exercises), alone or with BF is effective in stress incontinence (Kielb 2005) BF enables the patient to improve pelvic muscle strength and coordination through muscle awareness.

Fecal incontinence is the involuntary loss of formed stool. Advancing age, diabetes, fecal impaction, stroke, and dementia are the main risk factors for fecal incontinence. BF is a way to strengthen and coordinate the pelvic floor muscles and help patients with fecal incontinence. EMG BF shows the muscle contractions while the patients do exercises (Kegel exercises). BF is advocated as first-line therapy for patients whose symptoms of mild to moderate fecal incontinence have not responded to simple dietary advice or medication (Wright et al. 2006)

Recent Developments

BF therapy should be delivered during functionally related dynamic movement to optimize motor function improvement (Huang et al., 2006). Regarding this, there are current developments in BF systems including information fusion and virtual-reality. Traditionally, BF devices have used unimodal sensory signals (visual or auditory) but multimodal sensory

signaling may be more useful. In information fusion, complex multisensing systems and fusion algorithms are applied. Virtual reality task-oriented BF, uses computerized animations to engross the patient in a structured virtual environs.

References

Arena JG, Bruno GM, Hannah SL, Meador KJ. 1995. A comparison of frontal electromyographic biofeedback training, trapezius electromyographic biofeedback training, and progressive muscle relaxation therapy in the treatment of tension headache. Headache 35(7):411-419.

Basmajian JV. 1981. Biofeedback in rehabilitation: A review of principles and practices. Archives of Physical Medicine and Rehabilitation 62:469-475.

Basmajian JV. 1982. Clinical use of biofeedback in rehabilitation. Psychosomatics 23:67-73.

Basmajian JV. 1998. Biofeedback in physical medicine and rehabilitation. In: DeLisa JA, Gans BM, editors. Rehabilitation Medicine. 3rd ed. Philadelphia: Lippincott-Raven. p 505-520.

Ceceli E, Dursun E, Çakcı A. 1996. Comparison of joint-position biofeedback and conventional therapy methods in genu recurvatum after stroke - 6 months follow up. European Journal of Physical Medicine and Rehabilitation 6(5):141-144.

Colborne GR, Wright FV, Naumann S. 1994. Feedback of triceps surae EMG in gait of children with cerebral palsy: a controlled study. Archives of Physical Medicine and Rehabilitation 75(1):40-45.

Draper V. 1990. Electromyographic biofeedback and recovery of quadriceps femoris muscle function following anterior cruciate ligament reconstruction. Physical Therapy 70(1):11-17.

Dursun E, Dursun N, Alican D. 2004. Effects of biofeedback treatment on gait in children with cerebral palsy. Disability and Rehabilitation 26(2):116-120.

Dursun E, Hamamci N, Donmez S, Tuzunalp O, Cakci A. 1996. Angular biofeedback device for sitting balance of stroke patients. Stroke 27:1354-1357.

Dursun N, Dursun E, Kiliç Z. 2001. Electromyographic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome. Archives of Physical Medicine and Rehabilitation 82(12):1692-1695.

Egner T, Zech TF, Gruzelier JH. 2004. The effects of neurofeedback training on the spectral topography of the electroencephalogram. Clinical Neurophysiology 115:2452-2460.

Huang H, Wolf SL, He J. 2006. Recent developments in biofeedback for neuromotor rehabilitation. Journal of Neuroengineering and Rehabilitation 3:11.

Kayiran S, Dursun E, Ermutlu N, Dursun N, Karamürsel S. 2007. Neurofeedback in fibromyalgia syndrome. Agri 19(3):47-53.

Kielb SJ. 2005. Stress incontinence: alternatives to surgery. International Journal of Fertility and Women's Medicine 50(1):24-29.

Kirnap M, Calis M, Turgut AO, Halici M, Tuncel M. 2005. The efficacy of EMG-biofeedback training on quadriceps muscle strength in patients after arthroscopic meniscectomy. New Zealand Medical Journal 118(1224):U1704.

Krebs DE. 1981. Clinical electromyographic feedback following meniscectomy: A multiple regression experimental analysis. Physical Therapy 61:1017-1021.

Leiper CI, Miller A, Lang J, Herman R. 1981. Sensory feedback for head control in cerebral palsy. Physical Therapy 61:512-518.

McNeely ML, Armijo Olivo S, Magee DJ. 2006. A systematic review of the effectiveness of physical therapy interventions for temporomandibular disorders. Physical Therapy 86(5):710-725.

Moreland JD, Thomson MA, Fuoco AR. Electromyographic biofeedback to improve lower extremity function after stroke: a meta-analysis. Archives of Physical Medicine and Rehabilitation 79(2):134-140.

Ng GY, Zhang AQ, Li CK. 2008. Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. Journal of Electromyography and Kinesiology 18(1):128-133.

Rokicki LA, Holroyd KA, France CR, Lipchik GL, France JL, Kvaal SA. 1997. Change mechanisms associated with combined relaxation/EMG biofeedback training for chronic tension headache. Applied Psychophysiology and Biofeedback 22(1):21-41.

Sarnoch H, Adler F, Scholz OB. 1997. Relevance of muscular sensitivity, muscular activity, and cognitive variables for pain reduction associated with EMG biofeedback in fibromyalgia. Perceptual and Motor Skills 84(3 Pt 1):1043-1050.

Schleenbaker RE, Mainous AG 3rd. 1993. Electromyographic biofeedback for neuromuscular reeducation in the hemiplegic stroke patient: a meta-analysis. Archives of Physical Medicine and Rehabilitation 74(12):1301-1304.

Schwartz NM, Schwartz MS. 2003. Definitions of biofeedback and applied psychophysiology. In: Schwartz MS, Andrasik F, editors. Biofeedback. 3rd ed. New York: The Guilford Press. p 27-42.

Wolf SL. 1983. Electromyographic biofeedback applications to stroke patients. A critical review. Physical Therapy 63:1448-1459.

Wolf SL, Binder-MacLeod SA. 1983. Electromyographic biofeedback applications to hemiplegic patient: changes in upper extremity neuromuscular and functional status. Physical Therapy 63:1404-1413.

Wright J Jr, Gehrich AP, Albright TS. 2006. The management of anal incontinence. Journal of Pelvic Medicine and Surgery 12(3):125-140.