

EMG-Biofeedback Therapy in Knee Rehabilitation: A Review

N.D.P.U. Nakandala

Department of Physiotherapy, Faculty of Allied Health Sciences, University of Peradeniya, Peradeniya, 20400, Sri Lanka

Abstract— Biofeedback (BFB) is a process where an individual's physiological responses are identified, measured and then provide feedback in the form of visual, auditory or tactile in the real time. If the individual's physiological responses are not normal, in order to regulate or correct them, feedback is provided via various cues mentioned above. As the magnitude of the abnormality or the correction can be instantly generated, this is identified as a relatively effective treatment method than the other conventional procedures used. Electro myo-graphic biofeedback (EMGBFB) is a method which provides feedback regarding the electrical activity of the muscles and thereby assisting the individual to increase or decrease the tension developed in the muscle. Since this procedure is not associated with any of the adverse effects, it is being used for a longer period in the rehabilitation set up. Various conditions have been treated with the use of biofeedback devices. Of them, the effectiveness of EMGBFB has been assessed mostly in knee conditions in the orthopedic and sports medicine. The effectiveness of this procedure is evaluated with the use of various measures such as pain scales, goniometric measurements, isokinetic dynamometric measurements etc. in literature. Therefore the significance of the addition of this method in the traditional treatment protocols has been emphasized. The aim of this study is to review the efficacy of the EMGBFB interventions in various knee conditions, in the rehabilitation setting.

Keywords— Biofeedback, EMG, Conventional procedures, Knee rehabilitation.

I. INTRODUCTION

The term 'feedback' can be defined as "sensory information that results from various movements" [1]. This feedback can be either augmented (extrinsic) or sensory (intrinsic) [1, 2]. The information provided from various sensory receptors such as proprioceptors, auditory and visual receptors [1, 3] are considered as intrinsic feedback. Biological information provided in therapeutic setting is considered as extrinsic feedback where the patient is provided with supplementary information beyond what is naturally available to them [1-5].

Biofeedback is a procedure which measures an individual's particular body functions such as heart rate, blood pressure, skin temperature, activity of the brain waves, sweat gland activity, muscle tension etc. [6] and transfer this biological information to the individual in real time [7]. This process allows the subject to regulate these physiological processes in a conscious manner which are considered as automatic responses of the autonomic nervous system [6]. Electro myo-graphic biofeedback (EMGBFB) is a process which helps an individual to identify and magnify the electrical activity of the muscle. Patient is provided with visual and auditory feedbacks regarding the tension developed

in the muscle [8]. Biofeedback therapy has been used for more than fifty years to assist normal movement patterns after an injury [9].

A typical biofeedback device consists of three main parts; physiological parameter sensor, signal processing and biofeedback algorithm software and audio or visual interface to the user [6]. However, later it was developed into an advanced form where the subject is exercising in a computer generated reality environment [7]. In this case, patient is provided with graphical or audiovisual animations that enables the patient to experience a real situation [10].

This tool is used in various therapeutic interventions in the rehabilitation set up. Biofeedback treatment method is very popular among the patients since it does not have any side effects and is safe to use [6]. This process has been used therapeutically in tension headache [11-14], recovery of motor function after stroke [15], fibromyalgia syndrome [16-19], Temporomandibular disorders [20, 21] facial paralysis [22, 23], fecal incontinence [24], urinary incontinence [25-29] and constipation [30, 31].

Most of the studies have focused on the biofeedback therapeutic interventions in treating various upper and lower limb motor deficits which results from neurological disorders [7]. In orthopedic and sports medicine, the effectiveness of EMGBFB therapy has been investigated more on knee conditions [8]. Therefore the aim of this review is to focus on the effectiveness of EMGBFB therapy on various knee conditions.

A. Knee Osteoarthritis

Osteoarthritis is known to be the most prevalent joint disorder in elderly persons [32, 33]. Even though it mainly affects the joint articular cartilage, the joint capsule, surrounding ligaments, synovial membrane and subchondral bone also can be affected [34]. Knee osteoarthritis is most commonly associated with pain and muscular weakness [35]. It is indicated that the Quadriceps muscle weakness is due to disuse atrophy which is caused by pain in the joint [36]. Moreover, the advancement of the disease is associated with the improper knee joint loading [37] and therefore several gait modifications have been introduced to the patients with the assistance of movement biofeedback in order to decrease the load on the affected knee joint [38].

Other than the gait modifications, the effect of EMGBFB therapy on muscular strength and pain also has been assessed in literature. A study had been done by Anwer et al., (2011) in order to evaluate the effectiveness of EMGBFB along with isometric quadriceps strengthening exercises in 30 patients

with knee osteoarthritis [36]. Intervention group had received EMGBFB guided isometric exercises for five days per week for five weeks. The control group had received only the exercises. Quadriceps strength had been measured with an electronic strain gauge device before the treatment, second, third and fifth weeks respectively. Strength was measured with the knee in 60 degree flexion which was found to be having the greatest torque output. Increased quadriceps strength was observed in the intervention group.

Choi et al., (2015) had compared the treatment effects of EMGBFB and Ultrasonic biofeedback (USBF) with conventional physiotherapy treatment on 30 females diagnosed with osteoarthritis [39]. Conventional therapy had included hot pack, TENS and ultrasound treatments where the intervention groups had received EMGBFB and USBF guided exercises focusing on vastus medialis oblique muscle (VMO). Both the intervention groups had significantly improved the maximum voluntary isometric contraction which was measured by a strength dynamometer with the knee at 70 degree flexion, VMO thickness was measured by Mylab™ One ultrasound system and the pain was measured by Visual Analogue Scale (VAS) compared to control group. Study lacks the long term observation on the patients and therefore was not able to discuss the long term effects of these methods.

However, a study which was performed to see the effect of EMGBFB in 40 patients diagnosed with knee osteoarthritis had shown no significant improvement in pain and muscle strength in the intervention group when compared with control group [32]. Intervention group had received EMGBFB with the exercises where the control group had received only the exercises. Pain was measured with VAS. Function was assessed with Western Ontario McMaster Osteoarthritis Index (WOMAC) and quadriceps strength was measured with a Cybex isokinetic dynamometer. The treatment procedure had been continued three times a week for three weeks. The intervention group had indicated significant improvements only in sleep and energy scores measured by Nottingham Health Profile (NHP) but not with pain and muscular strength.

B. Patella-Femoral Pain

Patella femoral pain syndrome (PFPS) can be identified as a dysfunction where the patella is unable to track in the trochlear groove properly [40]. It is most commonly found in young adults [41]. In the general population 10-28% are affected from this pain syndrome [42] where it represents 25% of all the knee injuries treated in the sports clinics [43]. Various conservative and surgical approaches have been introduced to treat this condition [41].

EMGBFB is also one of the conservative approaches which has been tested on individuals with patella femoral pain syndrome. Ng et al., (2008) have evaluated the efficacy of EMGBFB on 26 subjects with PFPS [44]. The intervention group had received the EMGBFB along with the exercises and the control group was given only the exercises. EMG ratios of vastusmedialis (VM) and vastuslateralis (VL); VMO/VL had been measured with a custom designed portable surface EMG system for six hours during their normal activities. Twenty percent maximum EMG was taken as the cut off value which

was found to be achieved by an individual during normal walking. At the end of eight weeks training session, significant changes in VMO/VL EMG ratios had been found in the group who received EMGBFB therapy but no any significant changes in the exercise only group. Further, they have concluded the ability to facilitate the VMO activity during daily activities by combining this EMGBFB approach into treatment sessions.

EMGBFB coupled with exercises was noted as effective also by Wise et al., (1984) [40]. During this procedure VMO activity had been selectively enhanced by anHyperion 31 2 integrated electromyographic biofeedback unit. Three phases had been introduced to the patient. In phase I, patient was asked to do pain free isometric quadriceps contractions without prioritizing any muscle group. In phase II, they were asked to selectively increase the electrical activity of the VMO muscle and to keep the VL activity in the base line. In phase III, They were instructed to in cooperate the increased VMO activity into functional movement patterns. It had resulted in changes in patella femoral forces as well as reduction in patients' complains of pain suggesting EMGBFB is an effective alternative treatment approach to conventional physiotherapy exercises.

Another study done by Yip & Ng, (2006) had also evaluated the effectiveness of EMGBFB on PFPS [45]. Twenty six subjects diagnosed with patella femoral pain had been included in the study. Intervention group only had the both EMGBFB and the exercises where control group had only exercises. All had eight weeks home program including flexibility, strengthening, balance & proprioception training and plyometric & agility training exercises. Pain level was assessed by patella femoral pain syndrome severity scale. Patella alignment had been evaluated by the McConnell test including patella gliding, tilting and rotation. Isokinetic knee extension strength had been measured with an isokinetic dynamometer. The results have indicated an insignificant pain reduction in both groups, significant reduction in lateral patella gliding, tilting and rotation in EMGBFB group and significant improvement in isokinetic peak torque in EMGBFB group.

Contradictory to these results, a study done by Dursun et al., (2001) had found no significant clinical improvement with EMGBFB on PFPS when compared to conventional exercise sessions [41].

C. Meniscectomy

Meniscal injuries are found to be the most prevalent type of injuries among athletes where the sports injuries account for more than 30% of all meniscal lesions [46]. The most common surgical intervention performed for this meniscal lesions are the arthroscopic partial meniscectomy [47]. Following arthroscopic partial meniscectomy, muscle power of the quadriceps femoris muscle and the activities performed by knee is known to be impaired [46]. This muscle weakness occurs as a consequence of reflex inhibition of the motor neurons [48]. Though surgical approaches are more pronounced, the need of continuation with rehabilitation protocols has been widely discussed, and the importance of

further randomized trials was also emphasized in literature [49-51]. Anyway, Physiotherapy exercise protocols have been developed and recommended following meniscetomy injuries [46]. The use of EMGBFB instrument along with physiotherapeutic exercises in muscle re-education and muscle relaxation following meniscetomy surgeries have been also discussed in literature.

A study done by Akkaya et al., (2011) had recruited 45 patients who had sustained meniscal injuries and have undergone arthroscopic partial meniscetomy in order to see the effectiveness of EMGBFB and the electrical stimulation in addition to the conventional exercises in treating the condition [52]. Patients had been divided into three groups; first group had received only the home exercise program, second group had received EMGBFB to quadriceps muscle and the exercises where the third group had received the electrical stimulation to the quadriceps muscle in addition to the exercises. EMGBFB for isometric quadriceps contraction had been provided with a Myomed 932 device for five days a week and for two weeks. Electrical stimulation had been provided with an Endomed 582 device for a similar time period. Pain was measured with VAS scale, gait velocity was assessed by the time taken to walk a 2m distance and function evaluation was done with a Lysholm Knee Scoring Scale. Muscle power had been evaluated with the EMGBF device. They have concluded that the introduction of EMGBFB to conventional exercise program had speeded up the knee extensor muscle power recovery and the knee function during early post-operative period.

A clinical report written by Sprenger et al., (1979) had also indicated the positive effects of the EMGBFB on vastus medialis muscle in a patient who had undergone a meniscetomy surgery [53]. The treatment was given for about 30 minutes daily for seven sessions in addition to the main stream Physiotherapy exercise program. A feedback monograph with speaker (BFT Model 401@t) and time-period integrator (BFT Model 215@i) had been used for both visual and audio feedback. Patient had been improved with the vastus medialis muscle control and full knee extension after four weeks. Similar results had been discussed in a study done by Kirnap et al., (2005) which was done using 40 patients who had done arthroscopic meniscetomy [48]. They also have demonstrated significant differences in knee range of motion, Lysholm knee score, maximum and average contraction values of VMO and VL muscles in biofeedback group when compared with the control group.

D. Anterior Cruciate Ligament Injuries

During last two decades, more studies had been done regarding the ACL injuries [54]. Literature shows that the immobilization for a longer period of time following the ACL reconstruction could be resulted in atrophy of the knee muscles and adhesion formation [55], decreased knee extension range of motion [56, 57], impaired strength of the quadriceps muscle [58, 59] and so on. It has been shown that the crucial point of the ACL rehabilitation protocols is to improve the quadriceps femoris muscle function and its force production [60]. The effectiveness of EMGBFB therapy on

increasing quadriceps muscle function has been evaluated in literature.

The effectiveness of EMGBFB facilitated exercises and exercise alone had been evaluated in group of 22 patients who had undergone ACL reconstruction [55]. Cyborg Model J33 portable biofeedback unit had been used to provide the EMGBFB. Quadriceps muscle isometric peak torque had been measured using Cybex^R II isokinetic dynamometer in 90, 60 and 45 degree angles of knee extension. Significant difference in peak torque was noted in all the three angles in EMGBFB group compared to control group thereby concluding, that the combination of EMGBFB with muscle strengthening exercises improves the recovery of quadriceps muscle function after ACL reconstruction.

Both EMGBFB and electrical stimulation have been tested along with isometric quadriceps exercises in 30 patients with ACL reconstruction [60]. MyoTracTM EMG biofeedback unit had been used to monitor the quadriceps femoris activity. Results have shown that the isometric peak torque of the quadriceps muscle of the operated limb had been significantly improved when compared with the adjacent non-operated limb, in the EMGBF group. Cybex^R II isokinetic dynamometer with dual-channel chart recorder had been used to record the torque.

The most commonly noted complication after this ACL reconstruction is the failure to achieve the full knee extension [61]. Christanell et al., (2012) had compared the success of introducing EMGBFB treatment for vastus medialis muscle in regaining the knee range of motion and the strength in 16 patients who have undergone endoscopic ACL reconstruction using patella tendon auto graft [62]. At six weeks post operatively, significant differences were noted in the intervention group who received the EMGBFB and standard rehabilitation protocol both, than the control group that received only the standard protocol in regaining passive knee extension. Ultimately they have concluded that addition of EMGBFB therapy to the early phase of rehabilitation after ACL reconstruction can be resulted in improving the knee range outcomes. Myotrainer© - Insight Instruments – Austria was used to provide the BFB therapy. High Heel Distance (HHD) test was used to measure the passive knee extension.

E. Total Knee Arthroplasty

Total Knee Arthroplasty (TKA) is the standard and most common surgical approach which is used in the patients with severe knee osteoarthritis [63-65]. It is known that this surgical procedure helps in alleviating the pain and associated problems of knee osteoarthritis [64, 66]. Although this procedure assists in reduction of pain and the improvement of the functional outcomes of the individuals, they are left with muscle strength and functional deficits after years of surgery [67]. Also it is noted that, unilateral TKA results in decreased weight bearing and reduced knee extension moments in the indexed knee and thereby having asymmetrical movement types in the lower extremities [68, 69]. These asymmetrical movement patterns during walking, stair climbing and raising from a chair that favors the non-operated limb could in turn impose more loads on that limb as well [70, 71]. Therefore,

the importance of rehabilitation of the individuals after TKR is emphasized in literature [63]).

A study done by Christiansen et al., (2015) had examined the effects of weight bearing biofeedback (WB-BFB) training on reeducation of symmetrical weight bearing and functional activities such as sit to stand and walking [72]. Twenty six randomly selected patients who were suggested to undergo unilateral TKR were divided into two groups and the intervention group was given the WB-BFB training along with standard rehabilitation care. Control group had been given only the standard rehabilitation care. The intervention group had received BFB training two times a week after the surgery. Nintendo Wii Fit Plus game and associated Wii Balance Board had been used for WB biofeedback training. While playing the game, they had been instructed regarding the correct movement patterns. Program was started with simple activities and had progressed into complex activities. They have concluded that the addition of WB-BFB training had no any significant effect on the reeducation of weight bearing symmetry during functional activities on lower extremity. However, the intervention group had improved the operated knee extension moment and the functional performance.

A case study has been done by McClelland et al., (2012) with 57 year old female patient who had undergone unilateral TKA, in order to see the effectiveness of biofeedback training on reeducation of symmetrical movement patterns after surgery [66]. Intervention had been consisted of two main interventions including progressive strengthening exercises and BFB training that had induced normal symmetrical movement patterns in lower limbs. BFB training had included weight bearing strengthening on the Sym Slide and a leg press device which was used to observe the force production through each limb. Movement symmetry was encouraged with a visual tracing displayed on a video monitor which had provided visual feedback. Results have concluded that the patient had improved and restored with the symmetry of the lower limb movements and correct knee biomechanics after BFB training.

Zeni Jr et al., (2013) also had studied the effect of BFB training to encourage symmetrical movement patterns in 11 patients who had TKA surgery [64]. A progressive symmetry restraining program had been introduced which included visual, tactile and auditory feedback to the patient to induce kinetic and kinematic symmetry between limbs. Feedback was provided with a SymSlide device (customKYNetics, Inc, Versailles, KY). The results have indicated that symmetry retraining program have improved the biomechanical symmetry during functional tasks and also have emphasized the importance of adding such programs postoperatively rather than having protocols which focus on range of motion, strength etc.

Another study had addressed the effect of BFB training on pain management after TKR surgery [73]. Since the pain management boosts the patient's recovery and avoids long hospital stay, it is an essential component in rehabilitation set up [74]. Sixty patients had been randomly selected for the intervention and control groups. Only the intervention group had received the BFB assisted progressive muscle relaxation

training simultaneously with the continuous passive motion (CPM). Pain had been measured using a numeric rating scale. Biofeedback Nexus-10 biofeedback machine (Gunjan Human Karigar, India) had been used to provide the BFB. Study has concluded that BFB assisted muscle relaxation is an effective treatment technique to manage the postoperative pain during CPM.

II. CONCLUSION

Various studies have been performed in order to evaluate the effectiveness of EMGBFB therapy on treating various knee conditions in the rehabilitation set up. Treatment efficacy has been proved with pain scales, range of motion of the knee joint, muscle strength, gait velocity, functional levels etc. Therefore it can be concluded that EMGBFB method is an effective and non-invasive treatment approach to treat various knee conditions.

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