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A Review of the Utilization of EMG Biofeedback

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A REVIEW OF THE UTILIZATION OF EMG BIOFEEDBACK

By

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This Independent Study, submitted by Jeanine Lee Forsgren in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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TABLE OF CONTENTS

ABSTRACT

Electromyographic (EMG) biofeedback is gaining popularity as a treatment modality in physical therapy. It is used in the areas of neurological and orthopedic rehabilitation as well as injury prevention and performance improvement. The use of this modality can aid in the rehabilitation process by identifying weak muscles which need to be strengthened. Physical therapy also utilizes EMG biofeedback to identify and change movement patterns which may contribute to injury through the overuse or incorrect use of various muscles. EMG biofeedback is used to assist the patient in learning how to control muscular movement to correct the problems which are identified.

Through the use of auditory or visual feedback, EMG biofeedback provides the patient and the therapist with immediate output on the level of activity in the targeted muscles or movement pattern. This is accomplished through the use of surface or needle electrodes appropriately placed on the desired area. Electrical impulses from the muscle are transmitted to the EMG unit which coverts the electrical signal into the visual or auditory feedback. The patient receives this feedback and is able to correctly learn voluntary control over specific muscles or movement patterns.

CHAPTER I

INTRODUCTION

Acquiring new motor skills is a basic human instinct. As a human grows and develops, it is of paramount importance that the individual be able to learn new motor skills. These activities may range from learning to lift your head as an infant to re-learning to grasp a cup after a cerebrovascular accident. Motor activities, such as the aforementioned and numerous others, are acquired through interaction and exploration of the environment. To learn and perfect motor skills, a person must be able to detect and correct flaws in a movement.

Four variables are considered in motor learning. They are: 1) stages of learning, 2) type of task, 3) feedback, and 4) practice. Of these four, feedback is one of the most influential.[1] Feedback is used to help the learner generate or modify each successive movement and to compare one movement to another. Feedback can be either intrinsic, which is internal, or physiologic, or extrinsic, which is external or augmented. Extrinsic feedback is further separated into two groups, knowledge of performance and knowledge of results.[1] Knowledge of performance is defined as feedback about the nature of the movement. A practical example of this type of feedback is when a therapist tells a patient that his/her elbow was bent during the attempt to swing at a pitched ball.

Knowledge of results is defined as augmented extrinsic information provided to the performer upon completion of a task. An example of knowledge of results is when a patient is told that he/she missed the ball on that attempt. Feedback of either type helps to facilitate and accelerate the learning process. Electromyographic (EMG) biofeedback is another practical example of extrinsic feedback. It is considered to be a form of knowledge of performance.

Biofeedback techniques are used to augment the learner's sensory (intrinsic) feedback through precise information about muscle activity. Feedback, in engineering terms, implies returning the output from a system back to the source to allow regulation of the system. In an EMG biofeedback system, the patient is the source and EMG biofeedback is the modality used to transform information regarding physiologic processes into understandable output. In turn, this output is displayed in an understandable form to the patient. Using the output returned via EMG biofeedback, the patient is able to self regulate these physiologic processes. By providing information about how movements are executed, EMG biofeedback is able to give the patient ideas on how to correct the movement pattern. This information is used by the patient as a basis for learning voluntary control of motor activities. In physical therapy, the motor learning process is very important in the rehabilitation and prevention of injury. Physical therapy treatments consist of teaching patients to use their muscles efficiently and correctly, and this is where EMG biofeedback is very helpful.

Several areas of physical therapy have implemented EMG biofeedback treatments and have conducted studies in the efficacy of EMG with various diagnoses. Patients with diagnoses such as patellofemoral pain, cerebrovascular accident (CVA), and chronic pain have all benefited from EMG biofeedback training. In addition to post-injury use, some clinicians are finding EMG to be useful in preventive medicine as well. Multiple research projects have studied the correlation between EMG biofeedback and rehabilitation or preventive medicine in various arenas associated with physical therapy. Most studies assessed the effectiveness and efficacy of EMG biofeedback alone or in conjunction with other treatments.

The purpose of this literature review is to explain the effects of EMG biofeedback and to illustrate protocols which include EMG biofeedback. EMG biofeedback is a technique used extensively in physical therapy which covers areas from hyperactive children to stroke rehabilitation. Due to the sizable amount of information available in the literature on this topic, the areas on which discussion will focus include use of EMG biofeedback for prevention and rehabilitation purposes. The primary goal of this literature review is to provide the therapist with a knowledge base concerning efficacy of EMG biofeedback in various physical therapy protocols. In the following chapters, a broad overview of muscle biology and muscle recruitment will be discussed along with the basics of EMG biofeedback. Then, EMG biofeedback and prevention will be explored, followed by the orthopedic and neurological uses for this modality.

Once again, the literature on EMG biofeedback is large and it is not the intent of this paper to cover every study but to simply state the rehabilitative and prevention ideas of the main literature. A further appreciation of the numerous applications of EMG biofeedback to various conditions seen in physical therapy can be gained through inspection of the bibliography at the end of this paper.

CHAPTER II

MUSCLE BIOLOGY AND EMG BASICS

Muscles found in the human body are divided into three types: cardiac, smooth, and skeletal.[2] Cardiac muscle is found in and around the heart. Its primary function is assisting the heart to beat synchronously and rhythmically. Smooth muscle can be found in most hollow viscera and is distinguished form other muscle types by its lack of striations.[2] Skeletal muscle comprises the somatic musculature. It is this type of muscle that is under voluntary control.[2]

Skeletal muscle is made up of muscle fibers that serve as the "building blocks" of the muscular system. Most skeletal muscles begin and end in tendons, and muscle fibers are arranged in parallel between the tendinous ends.[2] This arrangement will allow individual muscle fiber contraction to be added together to contract an entire muscle. Each muscle fiber is a very long single cell with multiple nuclei and is completely surrounded by a cell membrane which is called the sarcolemma. Muscle fibers are composed of many muscle fibrils, and the fibrils are divisible into individual filaments.[2] It is at the muscle filament level where the "sliding filament" theory of muscle contraction begins.

Physiological Process of Muscle Contraction

The theory of molecular muscle contraction is named the "sliding filament" theory due to the fact that thick and thin muscle filaments are observed as sliding over one another during muscle contraction. Muscle filaments are composed of contractile proteins such as actin, myosin, tropomyosin, and troponin.[2] These contractile proteins will move, detach, and reattach many times during contraction.[2] When individual muscle fiber contractions are summated, a large visible muscle contraction is seen. An example of a large visible contraction is seen when a person "flexes" his or her biceps.

The process by which the shortening of the contractile elements in muscle is brought about is named the "sliding filament" theory. Muscle shortening is due to the sliding of two filaments over the top of one another during muscle contraction. The sliding is produced by breaking and re-forming of the cross-linkage between actin and myosin.[2] The heads of the myosin molecules link to actin at a 90-degree angle and produce movement by swiveling and then disconnecting and reconnecting at the next linking site.[2] This process is repeated many times and very quickly during muscle contraction.

Occurring with the mechanical chain of events is an electrical component of muscle contraction. In normal muscle, both the mechanical, chemical, and electrical responses occur together to produce muscle contraction. The electrical component consists of continuous depolarization and repolarization events of the muscle fibers.[2] The process by which depolarization of the muscle fiber initiates contraction is called excitation-contraction coupling.[2] Muscle fiber membrane depolarization normally starts at the motor end-plate. This is the specialized structure found under the motor nerve ending. The action potential, the electrical stimulus, is transmitted along the muscle fiber. The action potential is then transmitted into all the fibrils via the T system. Once received by the fibrils, the action potential triggers the release of calcium from the terminal cisterns. Calcium released into the system will initiate contraction.[2]

Calcium initiates contraction by binding to troponin.[2] In resting muscle, troponin is bound to actin and tropomyosin covers the site where myosin heads bind to actin.[2] The result of calcium binding to troponin is that the bind between troponin and actin is weakened and permits the tropomyosin to move laterally. This uncovers the actin site and myosin is able to attach there and begin the contraction cycle.[2]

EMG Basics

The electrical changes during muscle contraction can be picked up using an EMG biofeedback machine.[2] The basic EMG biofeedback machine includes one ground electrode and two active surface electrodes, an amplifier, an audio speaker, and/or a video display. The electrodes are metal disks that may or may not need to be covered with electrode paste or gel to reduce skin resistance. Newer models have very high input impedance and do not require gel or paste. Needle electrodes may also be utilized with deeper muscles or to receive feedback from a specific muscle.[2] The rest of the equipment is somewhat more complex. For purposes of this paper, they will not be discussed in any detail but to recognize their existence within the machine.

The EMG electrodes will pick up a triphasic signal from the muscle membranes as they depolarize, reverse polarity, and then repolarize as a result of changes in ion flow.[2] This signal is then amplified, rectified into a smooth representation, and either heard or visualized on a monitor. It should be understood that an EMG surface electrode will summate all potentials beneath its surface.[2] The audible or visual output may be interpreted as either additional muscle fiber recruitment or an increase in the activity within individual muscle fibers that have already fired.

EMG biofeedback is used to convert the physiologic process of muscle recruitment into visual or audible representation. This translation allows the patient to receive extrinsic feedback and to monitor the electrical status of the muscle. The visual or audio display serves as knowledge of performance for a patient. EMG biofeedback techniques require that a patient engage in learning and using ongoing feedback until a skill is learned properly. This education of motor control over skeletal muscle may allow for early intervention for prevention or re-education of muscles during rehabilitation.

CHAPTER III

INJURY PREVENTION AND EMG BIOFEEDBACK

Preventing the occurrence or recurrence of injuries on the worksite, playing field, or in the home presents a great challenge to the health care industry. Ergonomic intervention in the form of activity or job site modification is one method to reduce risk and guard against injury. EMG analysis and biofeedback training offer another approach to prevention of injury. This type of evaluation and treatment may be used alone or in conjunction with other prevention methods. Some health care providers have stated that both EMG biofeedback and ergonomic intervention provide the most effective combination.[3,4]

Kinesiologic EMG analysis and biofeedback may offer one route to utilize to prevent injury. Kinesiologic EMG biofeedback is defined by Johnson as "the study of muscle recruitment or movement during specific activities."[5] This new science is used to pinpoint which muscles are used during specific functional tasks. In addition, it may also identify patterns of how individual muscles are recruited and how each muscle works with others during specific activities. The general aim of kinesiological EMG is to analyze the function and coordination of muscles in different movements and postures. Kinesiological EMG can be used on a variety of patients for many different actions and in numerous settings.[6]

Kinesiological EMG provides a way to measure muscular work via electromyographic (EMG) analysis with output recordings. EMG analysis is different from EMG biofeedback due to the fact that muscular output is recorded in a way that is readable only by a trained medical professional, and it only provides data on a single muscular effort. Biofeedback requires that the patient hear or see the data and practice repetitively to either reduce or increase output based on the desired outcome. McCormick and associates[7] state that EMG analysis is suitable to evaluate both static and dynamic muscular exertion during specific tasks. In addition, EMG is able to evaluate the level of physical exertion, or stress, placed on the muscles to perform various types of work activities. By decreasing the amount of physical exertion on the highly stressed muscles, certain types of injury may be prevented. This decrease in stress on certain muscles may be accomplished through ergonomic changes or teaching people how to properly utilize their muscles using EMG biofeedback.

The basis of prevention using EMG analysis and biofeedback includes knowledge of the muscle recruitment pattern required to perform a certain task. An example is identifying the recruitment of the vastus medialis oblique (VMO) before the vastus intermedius (VI) in knee extension, and pinpointing the extent to which both the VMO and VI are firing. In addition to identifying the muscles needed for certain tasks, EMG analysis can also be used to teach people which muscles have been recruited too heavily during activities. EMG studies can also identify the most physiologically efficient movement pattern for a specific task. This is accomplished by using the findings of EMG analysis studies which identifies overworked muscles and teaches patients how to find a balance between overworked muscles and those muscles not working hard enough. This is a basic principle in the rehabilitation/prevention of cumulative trauma disorders.

Nearly all cumulative trauma disorders (CTD) occur as a result of performing common repetitive motions. It should, therefore, be possible to eliminate the CTD by eliminating the repetitive motions.[8] This involves retraining the worker using EMG biofeedback training in proper ergonomic postures for safe performance of the job task. EMG biofeedback training is helpful to the area of safety and injury prevention because it is able to help train people to utilize their muscles correctly. If the muscles that are used during a specific task or activity can be earmarked, then these muscles may be strengthened or relieved of strain through ergonomic changes. By making these changes, there is less chance of injury during the activity or task. EMG biofeedback has been used in the athletic arena to increase efficiency of movement and to increase speed, endurance, or accuracy on the playing field. To a small degree, this has also been done in business and industry to reduce injury, but further research is needed to expand the knowledge of EMG biofeedback and its correlation to worksite injury prevention.

Several studies indicate the effectiveness of EMG training in athletes. In one study of seven top Japanese swimmers, EMG biofeedback was used to train the swimmers to use specific muscles.[9] The muscles selected were deltoid, pectoralis major, latissimus dorsi, and flexor carpi radialis. These particular muscles were selected on the basis of previous studies which determined that they are the muscles used during the arm pull in swimming.[9] This pattern of muscle firing in the arm pull was obtained from top level Olympic swimmers who have remained relatively injury free. The subjects were requested to improve the audible patterns of discharge in accordance with the desirable muscle pattern. The swimmers were instructed to wear a waterproof ear device and surface electrodes which enabled them to practice in vivo. Through practice with the EMG biofeedback, the swimmers achieved the desired pattern of muscle activity.[9] Their swimming speeds showed improvement after one or two months. Whether they had less injuries due to this training is not reported and further long-term studies are needed to prove that this type of EMG biofeedback training also reduces risk of injury.

Kayak paddlers have also found success by utilizing EMG biofeedback to enhance their performance.[10] In this study, a group of 14 men were assigned to either a treatment group or a control group. The biofeedback treatment group was instructed on the desired levels of exertion that they should achieve during each step in the arm pull movement.[10] The control group was instructed to practice their arm pull movement without any feedback. Ultimately, the men in the treatment group learned to increase their output during the arm pull movement using EMG biofeedback.[10] Results in this study conclude that after biofeedback training, the men in the treatment group are able to increase their force output and improve their level of performance.[10] The authors also state that receiving feedback is the key to training. The significance of this study is simply to show that people are able to learn patterns of muscle firing through EMG biofeedback training.

It is obvious from this study and others done by Clarys and Cabrini[6] that EMG biofeedback can improve the quality of athletic performance. The next step is to prove that in addition to improving athletic performance, EMG biofeedback also decreases the incidence of injury on the job or in athletic settings through selected muscle training. This conclusion requires further studies aimed at determining exactly that point. It can be hypothesized that by identifying the exact muscles which act and firing patterns which occur during specific jobs or activities we can apply this knowledge of select muscle movement for creating safer gross movement. This would be accomplished by analyzing workers or athletes who are relatively injury free to acquire baseline information on the specific muscle patterns and the level of exertion that is utilized by healthy subjects. The next step is to analyze injured patients to acquire the same information. The two sets of data can then be compared to help to construct a safer movement pattern along with movements or positions to avoid for the injured worker. The comparison of the two subject groups would allow health care providers to identify which movement patterns are optimal for each task and those that have the potential to put the individual at risk. This information can be used to format injury prevention guidelines where patients may use EMG biofeedback to increase or decrease recruitment of certain muscles to help assure safe movement. Of course, this is a very superficial discussion of what would be a very intricate process, but EMG biofeedback training could be utilized for injury prevention the same way that the Japanese swimmers or kayakers use it for increasing athletic performance.

EMG biofeedback is used on a limited basis for educational training of targeted muscle groups in the worker as well as the athlete. Panenmark et al[11] ran a trial using assembly line workers and analyzed their job requirements with EMG biofeedback. This study was designed to teach assembly line workers to keep the activity level of EMG below 10% of maximal voluntary contraction during work. This resulted in a 50% reduction in sick leave due to shoulder injuries of those participating in the EMG study. Other studies have demonstrated that there are large variations in the techniques used during manual type work.[12] By using an inappropriate or unsafe work technique, a worker may be more prone to injury. Training is used to improve technique and prevent injury. One drawback to these studies is that it is difficult to directly apply one study to another due to differences in job qualifications and duties performed on the job.[11]

The best way to avoid injury is to recognize which postures and activities stress which muscles and ligaments and then avoid those movements. This means that new techniques must be identified and taught to the employee in order to ensure that each employee is using the optimal technique for his/her individual work task. EMG analysis is already used to earmark certain muscle fatiguing positions. Why not use EMG biofeedback to alert workers when they have too much stress on certain muscles and educate them to utilize the most optimal techniques? This type of educational process would require a series of steps in order to be successful. The first step is to identify which job tasks or activities create harmful, unneeded stress. Next, decide what level of muscle exertion is needed to perform the task correctly while not stressing the muscle or other tissues. Finally, using EMG biofeedback, instruct the person on proper techniques including muscle exertion levels.

Certain types of work groups are more prone to injury because of the motions and positions that are required to perform the job. These work groups may include jobs that require a great amount of squatting, overhead work, or repetitive tasks. Recent studies report that the prevalence of shoulder pain in various working populations has gradually been increasing.[13] Occupations such as ship welders show an average prevalence of shoulder pain syndrome as high as 18.3% of the ship welding work force. The percentage of grocery store checkers with shoulder pain syndrome is around 15%.[13] Christenson and associates[4] found increased EMG activity levels in the deltoids of plant assembly line workers with shoulder pain. Higher levels of EMG activity in certain muscles may indicate too much stress on those muscles, which may lead to pain or injury. The study done by Christenson as well as others done by Suurkula and Hagg[14] demonstrate an association between elevated EMG levels and precursors to shoulder pain. If the elevated levels of EMG activity can be decreased by using EMG biofeedback to make workers aware of muscle exertion, then perhaps the pain may also be decreased.[14] A preventative step such as utilizing EMG biofeedback therapy to teach correct muscle utilization during specific tasks may help ship welders, assembly workers, and many others reduce their risk of injury.

EMG biofeedback therapy can definitely be utilized to teach awareness of certain stressful postures or techniques that may contribute to injury or put a worker at risk for injury. Whether it be increased EMG levels or incorrect body mechanics, EMG biofeedback is a good technique to employ to decrease undue stress on body parts. The following studies report success with EMG biofeedback therapy in reducing pain or injury, but more research is needed to confirm EMG biofeedback therapy as a preventative tool. Longitudinal effect-exposure studies would need to be done to determine standards and pattern recognition. This has already begun in the athletic populations, but this expertise needs to be applied to the working population.

In a study in the *Journal of Hand Therapy*, EMG biofeedback is used to determine which activities and arm positions actually promote muscle fatigue.

EMG electrodes are placed on certain muscles of the upper extremity and both audible and visual feedback is used to monitor the firing of certain muscle groups. After identifying the positions which seem to fatigue the muscles the quickest, the patients are urged to avoid these positions. This particular study focuses on previously injured keyboard operators and included workstation adjustment as well as positional changes to decrease pain and injury from repetitive keyboard motions.[15]

An article by Delitto[16] in *Physical Therapy* provides some of the information needed to use EMG biofeedback as a prevention tool. Delitto and associates[16] tested two squat lifting positions using EMG analysis. They analyzed the erector spinae (ES) muscle tension during two lifting techniques. They found that lifting with a back "bowed out" technique utilizing a decreased lumbar lordosis position was best for ES tension.[16] Their thought is that by decreasing the amount of exertion produced by the ES muscle group, the back will be less prone to injury. They conclude that a lifting technique that is not equivalent to the optimal pattern determined in the study may cause risk for injury.[16] This study implies that by teaching workers the optimal pattern of muscle activity for each job task, they will be at less risk for injury. One teaching tool is EMG biofeedback. Workers are able to monitor their muscle activity, via EMG biofeedback, while on the job or while practicing any job task. They are also able to constantly receive feedback and adjust their movement until they have perfected their individual task.

Finding problem areas and correcting them is the key to prevention. As in the lifting techniques described, if patients can learn to correct their body mechanics and muscle movements, they should be able to reduce their risk of injury. EMG biofeedback should be an effective learning tool.

Another area that may benefit from EMG biofeedback used as a preventative learning tool is patellar alignment problems. Certain injuries or disabilities can result from poor patellar alignment.[17] Chondromalacia of the patella and arthritis are examples of disabilities created by malalignment of the patella. To prevent patellofemoral joint problems, the extensor mechanism of the knee must be properly aligned.[18] EMG biofeedback is used to do precisely that, by attaining the proper quadriceps muscle balance. By training the VMO to contract at a certain level and at a certain time during knee extension, the patella may begin to track properly. This is due to the impact that both the VMO and vastus lateralis (VL) have on patellar tracking. The basic concept involves contraction of the VMO to pull the patella medially while the VL contracts to pull the patella laterally. If the muscles are correctly and equally contracted, the patella is able to track centrally. In turn, this reduces patellofemoral pathology.[17] Leaveau and Rogers[17] conclude in their study of patellofemoral tracking that EMG biofeedback is able to assist the patient in recruiting the VMO to properly contract. Whether or not this will decrease patellofemoral injury is something to be implied but not confirmed by their study.

Preventing injury in the workplace, at home, or on the playing field has become a vastly important area of health care. Time and money utilization may decrease and human suffering may be spared by simply preventing injuries before they occur. EMG biofeedback may prove to be a part of the movement towards prevention of injury. EMG biofeedback is able to identify errors in muscle patterns of recruitment and to correct those errors through patient education. Although the research involving EMG biofeedback and injury prevention is very limited, there are some disciplines utilizing EMG biofeedback methods that may be related to injury prevention. Athletes are effectively using EMG biofeedback to train muscles and movement patterns in various sporting activities. Swimmers, sprinters, and kayakers learn more efficient patterns of muscle recruitment in order to improve athletic performance. Another benefit resulting from these learned muscular patterns is safe, stable muscle utilization during activities. The same EMG methods can also be used in the study of humans in the work place. By identifying how different positions and designs of working stations or tools affect muscular function, better work environments and work positions can be designed.[5] In addition, EMG biofeedback is used to make the worker or patient aware of more beneficial utilization of muscle patterns to alleviate certain injuries. Athletes, industrial workers, and homemakers may all benefit from training using EMG biofeedback to improve the utilization of their muscles.

CHAPTER IV

ORTHOPEDIC REHABILITATION

Orthopedic injuries in the athletic and the general population are very prevalent. One out of every seven people in the United States will sustain an orthopedic injury or condition requiring rehabilitation.[19] Of the various physical therapy methods employed by therapists when rehabilitating this large population of people, EMG biofeedback is a highly viable option.

A clinician may wonder why biofeedback may be more effective than some traditional therapies. An explanation is best rendered by the use of an analogy. In the clinic, patients are given verbal feedback from a clinician based on what that clinician has observed. "Try a little harder" is an example of this verbal feedback. The feedback is often relatively vague, not consistently given, and usually verbalized after the task is completed. An EMG biofeedback machine offers the same type of feedback, but it is continuous and specific to one area. The advantages of EMG biofeedback are specificity and speed.[20,21] The previous analogy was not meant to discredit traditional physical therapy. In general, most research suggests EMG biofeedback be used as an adjunct treatment to traditional rehabilitation procedures.

EMG biofeedback is easy for the patient to use. When the central nervous system is intact, patients are able to interpret feedback signals and make adjustments in specific muscle movements and efforts.[22] After orthopedic surgery or limb immobilization, EMG biofeedback is used to restore functional motion or alleviate pain for orthopedic patients. Orthopedic problems such as chronic pain, post-orthopedic surgery, and amputation have all been addressed with EMG biofeedback with a great degree of success. Whether it is restoring functional movement or decreasing unwanted symptoms, EMG biofeedback is effective.

The application of EMG biofeedback with orthopedic injuries is simple and EMG biofeedback therapy is fairly easy to administer. Either surface electrodes or needles are placed in the desired area of activity. Next, a baseline recording is made of the activity of the muscle at rest. This reading is heard or visualized by the patient. Then the patient is asked to either increase or decrease the output, depending on the desired response. This means the patient must either increase or decrease the tone they hear or the level of activity that is shown. A set level or tone will be established and patient will attempt to achieve that level over repeated efforts. In essence, the patient is in control of his/her learning and becomes an active participant in the rehabilitation process. Orthopedic problems of the knee, back, shoulder, and many other areas have all utilized EMG biofeedback regimes to restore function and alleviate pain.

Chronic Pain

Chronic pain can be managed using EMG biofeedback. In the past, chronic pain patients have been treated with a multitude of therapies to improve their everyday function. EMG biofeedback is one type of therapy that is being used to treat this troubling orthopedic problem. For instance, chronic low back pain is successfully treated with EMG biofeedback as an adjunct to standard exercise.[23] The idea behind using EMG biofeedback with chronic low back pain (CLBP) is to use it to strengthen weakened muscles, thereby decreasing chances for further back injury and pain. It is believed by some authors that persons with CLBP have significantly less strength in their lumbar paraspinals when compared with people not experiencing back pain.[23] Applying EMG biofeedback to strength the weakened back muscles should help improve their range of motion and strength. In turn, this will improve the functional abilities of the CLBP patients and, hopefully, allow them more independence from pain.[23]

EMG biofeedback as a muscle re-education device in CLBP is the basis of a study reported in *Physical Therapy*.[24] This study focused on strengthening back muscles in a single case study of a 35-year-old male. The patient had utilized a number of other physical therapy treatments, such as resistance training and Williams flexion exercises. He completed 15 sessions of EMG biofeedback training to strengthen his paraspinal muscles. At the end of his sessions, he reported a pain rating of "very low." EMG biofeedback had helped him increase his back strength, decrease his pain, and had also helped him to reduce the amount of pain medication he was taking.[24]

In another study, EMG biofeedback was used to alter muscle activity levels through relaxation techniques. Herta Flor and Niels Birbaummer[25] conducted a study of chronic back pain and chronic temporomandibular pain and dysfunction. Their study compared conservative medical interventions, cognitive-behavioral therapy, and EMG biofeedback in the treatment of both populations. The results of their study indicate that EMG biofeedback may be a superior treatment for chronic musculoskeletal pain. Patients tested after receiving EMG biofeedback treatments report less pain than those using cognitive-behavioral strategies or conservative medical interventions.[25]

Patellofemoral Pain Syndrome

Patellofemoral pain is another diagnosis which may be treated with EMG biofeedback. The diagnosis of patellofemoral pain can be categorized as a chronic pain syndrome but, if left untreated, it may lead to more serious orthopedic problems. Patellar dislocation is the most prevalent orthopedic dysfunction to occur with chronic patellofemoral pain. Usually, EMG biofeedback treatment for patellofemoral problems consists of selective training of the vastus medialis. This is the training route for patellofemoral pain and with patellar dislocation problems. As explained in the previous chapter, this training allows the patella to track into the patellar groove and decrease risk of major injury and pain. Following patellar dislocation problems, EMG biofeedback will be incorporated with an aggressive resistance strengthening program.

After a dislocation-type injury, the patient must learn how to contract the vastus medialis during functional tasks as well as in a clinical setting to ensure proper rehabilitation of the injured knee. Vastus medialis training during walking is an important functional task that is practiced utilizing EMG biofeedback. In addition, patients may practice climbing stairs, kicking a ball, or whatever activity is needed to restore them to normal pain free function and decrease their risk of re-injury.

Orthopedic Knee Problems

EMG biofeedback is a popular treatment technique for patients with knee problems. In addition to the previous patellofemoral problems, patients with total knee replacements and meniscectomies benefit from this type of therapy. EMG biofeedback can substantially improve EMG output and muscle strength in those patients with paretic musculature following meniscectomy surgery as studied by David Krebs.[27] Krebs studied 26 patients who had undergone uncomplicated meniscectomy. They were divided into two groups. One group underwent EMG biofeedback training and the second group received traditional physical therapy. The EMG biofeedback group practiced isometric quadriceps femoris strengthening using visual feedback to monitor their progress. At the end of their hospital stay, the EMG biofeedback group had significantly higher scores on manual muscle tests than the other group who received conventional physical therapy. Although the results of this study indicate better resulting using EMG biofeedback rather than strictly traditional therapy, most meniscectomy rehabilitation programs noted in the literature would include a combined rehabilitation program.[3]

Another use of EMG biofeedback after surgery is following a total knee arthroplasty (TKA). Sometimes a knee joint is so badly damaged due to traumatic or degenerative changes that a TKA is needed to restore the patient to functional independence. After receiving a total knee replacement, rehabilitation of the surrounding muscle and tissue is a must and occasionally, EMG biofeedback is applied as a part of the treatment protocol. A case study reports that EMG biofeedback was utilized to train the quadriceps femoris during knee extension after a TKA. The study also looked at whether training effects could be maintained over time. Results of this study suggest that EMG biofeedback may provide a non-invasive means of teaching muscle control in patients following a total knee replacement.[28]

Hand Therapy

An extensive area of orthopedics that is taking advantage of EMG biofeedback is hand therapy. Hunter[29] reports that EMG biofeedback is most useful in treating the following conditions: "1) fractures of the shaft or head of the metacarpal, 2) individualized problems such as pollicitation procedures, 3) tendon transfers in regard to the re-learning of new patterns of motion, 4) muscle re-education in peripheral nerve injuries, and 5) arthritis." He also states that during the first two or three weeks post-tendon transfer surgery, patients profit greatly from EMG biofeedback therapy. That is, they begin active motion quicker and have increased gains in range of motion using EMG biofeedback therapy as compared to traditional therapies.[29]

Other Uses

Hunter and associates[29] advocate putting EMG biofeedback to use with brachial plexus lesions. Stabilization of scapular and glenohumeral musculature is a primary goal when rehabilitating a brachial plexus problem. Starting with the rotator cuff muscles and the scapular stabilizers, patients can learn to re-educate muscles as they slowly become re-innervated. This process is essential to prevent shoulder dislocation and various other orthopedic problems associated with weak scapular and glenohumeral muscles.

Another interesting example of a different use for EMG biofeedback involves a case study in which specific training of the gracilis muscle was accomplished with this modality. In this case, a patient's gracilis muscle was bifurcated longitudinally. Half of the muscle was detached from its insertion on the medial aspect of the knee and wound into a circular formation within the pelvis to form a new anal sphincter. Following surgery, the patient learned to contract the anal sphincter through EMG biofeedback training of the remaining adductor portion of the gracilis.[22] Although this is not a widely accepted procedure, it produced positive effects.[22]

Patients with amputations can utilize EMG biofeedback in several ways.[30] It is used in conjunction with manual therapy to help release muscle tightness usually found in hip flexors of lower extremity amputees. Another procedure requires placing the electrodes on the bulk of the quadriceps. This allows the patient with a below knee amputation to monitor the activity of his/her quadriceps during gait training or individual exercise. EMG biofeedback seems to be most helpful during gait training for both below knee and above knee amputees to help achieve the full stump extension necessary throughout the gait cycle. Successful and functional ambulation requires the proper balance and strength of all stump musculature and EMG biofeedback helps the amputee monitor the progress of their strengthening muscles. Whether during individual exercise for muscle tightness or during gait training, EMG biofeedback can deliver the audio or visual feedback necessary for the patient to learn more about the muscle activity within the stump.[30]

Yet another use for EMG biofeedback is with patients who have sustained a fracture. Even before patients are out of their casts, EMG biofeedback is contributing to the rehabilitation process by decreasing pain and increasing range of motion.[31] Facilitating the quadriceps femoris before patients are out of casts helps with both pain and range of motion when the cast is removed. Training is begun within one day of surgery. Holes are drilled in the cast to allow room for the surface electrodes to be slipped through. The patient is allowed to increase EMG levels as much as they can tolerate. This type of therapy would be the same as seeing their quadriceps isometrically contract and patella move upward if they were out of the cast. After cast removal, decreased time to achieve normal function should be expected without complications.[31] The same sort of training is used with patients in skeletal traction. Biofeedback can help maintain the patient's interest in doing isometric exercises by allowing goal-setting to reach and maintain specific values of muscle activity monitored by EMG biofeedback.[3]

It is obvious that EMG biofeedback can be used in a medley of orthopedic conditions. Other orthopedic diagnoses for which therapists and patients have capitalized on EMG biofeedback include myositis ossificans, adhesive capsulitis, whiplash, asymmetry in homologous trunk or back muscles, and torticollis.[3] The list is too extensive to be completed covered within this paper.

Although it seems as though EMG biofeedback is well researched, this conclusion is far from accurate. Many authors report the need for more research and documentation on EMG biofeedback uses and effectiveness. Long-term studies have not shown that learning under controlled conditions will extend to demands in actual competition on the playing field or on-the-job for workers.[32,33] The final verdict is the same with all orthopedic uses of EMG biofeedback--more scientific studies are needed to confirm the benefits observed in the clinic.

CHAPTER V

NEUROLOGICAL REHABILITATION

Neurological rehabilitation is an extremely broad medical area. Loosely defined, it may imply the restoration of patients to their fullest physical, mental, and social capability.[34] Neurological disabilities may not include a cure as a possibility and in that type of situation the objective is to help the patient to achieve the best possible quality of life. The rehabilitation process includes modalities, wheelchairs, orthotics, specialized devices, and most importantly, therapeutic exercise. Therapeutic exercise will be initiated for neuromuscular re-education. The utilization of exercise can be enhanced with the application of EMG biofeedback techniques.[3]

Cerebrovascular Accident

Cerebrovascular accident (CVA) or stroke rehabilitation programs have implemented EMG biofeedback for a number of restorative exercises. In a survey done in 1984, biofeedback was used for a wide variety of clinical conditions, but it was most extensively used for treatment of stroke patients.[35] A critical review of EMG biofeedback as it applies to stroke patients was done in 1986 by Weerdt and Harrison.[35] In this review, 32 papers were identified and the major points were highlighted. The conclusion of the review indicates that both the upper and lower extremities are effectively treated by implementing EMG biofeedback into the treatment plan.

Treatment regimes for stroke patients generally include conventional physical therapy techniques supplemented by biofeedback techniques. Most programs include giving a portable EMG biofeedback machine to the patient for use at home following discharge from the formal rehabilitation program. While in the program, patients use EMG biofeedback in much the same way as orthopedic patients. Electrodes are placed over the desired muscle and the patient is asked to increase the tone or level of muscle activity. One special concern of neurological rehabilitation is that patients must possess a moderately high cognitive level in order to utilize EMG biofeedback.[36] This is due to the fact that the patient must be able to interpret, adjust, and learn from the feedback received.

CVA treatment regimes using EMG biofeedback differ in regard to duration, frequency, and additional exercises incorporated. An example taken from a reportedly successful study by Crow et al[36] will help to demonstrate a possible program. A group of patients is selected using the following criteria: "1) patients are between two and eight weeks after stroke, 2) had at least a small amount of arm function . . . , 3) had not already spontaneously recovered . . ., and 4) did not have global aphasia or dementia. . ."[36] During each treatment session, the patient's most significant functional arm disability was identified. This information was then used to pick muscles to target for the remainder of the treatment session. Patients were given goals for EMG biofeedback and, in addition, received conventional physical therapy exercise. The study utilizing this training program lasted 12 weeks and concluded that EMG biofeedback was a positive factor when utilized within conventional physical therapy programs.[36]

John V. Basmajian,[3] the father of biofeedback treatment, states that the purpose of incorporating biofeedback into the rehabilitative process is to return a patient to his/her highest functional potential in the shortest time possible. He also indicates that EMG biofeedback is shown to be most effective with patients showing potential for voluntary control and sufficient motivation and cooperation.[3] Other studies completed by Wolf and colleagues[37] concluded that age, sex, hemiparetic side, duration of stroke, previous rehabilitation, and number of training sessions could not be shown to have a significant effect on rehabilitation. Becoming aware of which patients are the best candidates for EMG therapy will increase the effectiveness of EMG biofeedback in stroke rehabilitation. In addition, understanding the extent of the motor and sensory impairment and how it disrupts the function of the patient is critical. With this knowledge, EMG biofeedback may be incorporated with specific functional training.

One such functional activity is walking. Many devices and techniques are used to achieve normal gait following a CVA. EMG biofeedback is one such device. One of the first areas in which biofeedback training was utilized was for control of foot drop during ambulation of stroke patients.[3] For treatment of foot drop, both the dorsiflexors and gastrocnemius are monitored. The first step in treatment is relaxation of any plantarflexion spasticity that is present. Active recruitment of the dorsiflexors is initiated if spasticity is not a significant problem. To begin re-training dorsiflexion, the patient sits with the ankle unsupported. The next step is for the patient to initiate contraction of the dorsiflexors with the plantarflexors remaining completely relaxed. The patient with a synergistic pattern will be able to begin breaking the pattern by starting with voluntary dorsiflexion using EMG biofeedback.[3]

Once proper dorsiflexion is established, EMG biofeedback can continue to help during functional walking. A portable feedback apparatus will assist a patient to achieve a normal pattern of foot placement. This normal pattern consists of a gait sequence which begins at heel contact, progresses to foot flat, then to the ball of the foot, and finally to push off of the big toe. Major advantages to this type of system include the fact that it is portable, light weight, and has the potential for application in a variety of ambulatory and balance tasks.[38] The patient usually receives acoustic feedback with this type of system and it can be worn up to four hours during ambulation.

In normal subjects, EMG patterns during ambulation are formed by "angular changes and synchronous, phasic bursts of pretibial and calf muscle activity."[39] The pretibial and calf musculature are essential during gait because they control the motion and position of the ankle. The hemiparetic ankle cannot smoothly alter its position due to the decreased control over these muscles. This is where EMG biofeedback comes into play. One report published in 1994 suggests that patients are more attentive during functional ambulation training that utilizes EMG biofeedback.[40] This sustained attention is hypothesized to help increase the time and effort that a patient exerts into ambulation practice. In addition, the EMG biofeedback patients present with significant recovery on both the Adams and Basmajian scales.[40] The Adams scale is a global, neurological instrument for cognitive, motor, and sensory evaluation. The Basmajian scale is used to evaluate mobility and ambulation.[40] Patients in a study by Intiso received Bobath exercises and bi-phasic EMG biofeedback regime. In the first phase, the patients were taught to contract their dorsiflexors to a set level of acoustic feedback using EMG biofeedback in the clinic. During the Second phase, a portable EMG biofeedback unit was utilized. The patient obtains a "threshold" level or baseline level and an appropriate goal level is established. The goal level is usually slightly higher than the threshold level and is raised as the patient progresses. Patients are told during which phase in the gait cycle to initiate contraction and obtain their fixed level of acoustic feedback. As stated earlier, the biofeedback trained patients do significantly better during ambulation than those patients undergoing conventional physical therapy treatment.[3]

The encouraging results of the previously mentioned study are substantiated by a report compiled by Colborne and associates.[41] Their study used EMG biofeedback to retrain ankle joint angles. The treatment program was much the same as in the study by Intiso utilizing NDT principles of motor learning as well as EMG biofeedback for functional ambulatory care. The results confirm that EMG biofeedback can produce measurable changes in gait function.[41]

The hemiparetic upper extremity can also be treated using EMG biofeedback. Upper extremity program regimes for stroke patients can last anywhere from 2 to 28 weeks and, in many instances, the patient may benefit by using EMG biofeedback.[3] In some cases, bilateral exercise may be used to obtain a contraction of an affected muscle group. EMG biofeedback may be used in these cases. Basmajian[3] offers an example: "For example, with electrodes over the biceps, resistance to elbow flexion can be given to the unaffected side and the patient can be shown what the biceps on the involved side is doing, provided that the patient exhibits the synergist pattern." This method may help to focus the patient's attention on one specific muscle group and its electrical activity without actively contracting the muscle.

A second example compares the efficacy of EMG biofeedback with conventional physical therapy in the treatment of the upper extremity. Functional outcomes using either treatment are the primary focus of the paper. Within the discussion, the authors state EMG biofeedback may be worthwhile in patients who are less than six months post-stroke.[42] Furthermore, therapists should consider such factors as cost, ease of application, and patient preference when deciding whether or not to utilize EMG biofeedback.

A troubling problem when managing a hemiparetic patient is treatment within the chronic phase. This is the phase where a patient has reached a plateau in their functional progress utilizing conventional physical therapy techniques. EMG biofeedback is able to help during this phase.[43] Electromyographic and goniometric measurements prove that EMG biofeedback helps the patient achieve range of motion, lower spastic clonus, and higher activation of muscle tone.[43] Brundy and associates[44] reported that 61% of the chronic hemiparetics he studied profited functionally from EMG-supported biofeedback therapy. Together with Basmajian, they showed that patients were able to acquire control of muscle activation in order to grasp objects.[43] Once again, the literature advises that EMG biofeedback should be integrated with exercise aimed at functional tasks within the global treatment program.

As a final note on EMG biofeedback and stroke rehabilitation, an article reviewing the use of EMG biofeedback with stroke patients is consulted. Steven L. Wolf[37] compiled an article on stroke and EMG biofeedback therapy. The National Institute of Mental Health is quoted within his text as stating: "Without question the most widely accepted use of biofeedback is for the movement disorders. Usually done with EMG biofeedback, the training is considered an adjunct to other procedures used in rehabilitation of patients suffering from disabilities associated with neuromuscular disease."[37] After reviewing 33 reports published between 1960 and 1983, the conclusion Wolf[37] comes to is that the rehabilitation programs designed to use EMG biofeedback as part of the treatment have proven EMG to be an efficient modality in stroke rehabilitation. At the same time, the negative aspects of EMG biofeedback are discussed. Future research should address a number of concerns which are enumerated in his report in *Physical Therapy.*

A more recent meta-analysis compiled in 1993 proposed the same conclusion.[45] Due to conflicting reports on the efficacy and use of EMG biofeedback, Schleenbacker and Mainous[45] reviewed some of the main literature. In sum, overall EMG biofeedback was shown to be a useful therapeutic tool for stroke patients. The scope of this study included 192 cases representing both positive and negative outcomes of the use of EMG biofeedback with stroke patients. Once again, both the limitations and the successes of EMG biofeedback should be weighed when deciding whether or not to use it with a patient. This means that each stroke patient should be assessed for appropriateness and each regime should be tailored to the individual.

Spinal Cord Injury

Just as CVA rehabilitation benefits from EMG biofeedback, so can patients who have sustained a spinal cord injury. This is another huge area of neurological rehabilitation utilizing this wonderful adjunct to treatment programs. In the United States, there are more than 11,000 new cases of spinal cord impairment annually in accidents that traumatize the spinal cord. Traditional physical therapy programs include much of the same interventions as stroke rehabilitation with a strong emphasis on neuromuscular re-education. Within the last 15 years, muscle feedback has been incorporated into some rehabilitation programs. Traditional forms of crude feedback would be simple commands spoken by a therapist. These commands might not be as consistent or continuous as EMG biofeedback.

When used appropriately, EMG biofeedback is an effective component of spinal cord injury (SCI) rehabilitation. The appropriateness of this type of therapy is governed by the same rules as were described earlier when stroke rehabilitation was discussed. Basmajian[3] reports that muscle biofeedback applications will not produce significant functional outcomes in patients with limited sacral sparing. EMG biofeedback seems to be most effective with incomplete spinal cord injuries or those still recovering some muscle function.

In doing a review of the literature, reports of EMG biofeedback and SCI rehabilitation are discussed as far back as 1970. Wolf states in his literature that Dunn and associates demonstrated that three quadriplegics were able to effective gain control over muscle spasms using EMG techniques.[3] Other reports also state positive remarks about EMG biofeedback therapy during its first years of expanded use for spinal cord injury. Wolf also sites Toomin's abstract which gives an account of a patient where significant improvements were shown using EMG biofeedback with other techniques.[3] The same author collaborates with others and suggests that SCI patients may be candidates for effective EMG biofeedback therapy if they show some muscle activity below the level of the lesion.[3]

In Basmajian's book "Biofeedback: Principles and Practice for Clinicians," Schneider and colleagues[3] are quoted as saying that biofeedback may be used in four instances. They are: "1) identify muscles with low measurable potentials, 2) identify the types of reflexly induced movements capable of producing measurable muscle activity, 3) evaluate improvement in muscle strength, and 4) provide feedback to patients and therapists during exercise."[3] Their particular study focused on one paraplegic and one paraparetic patient and the use of EMG biofeedback in their rehabilitation. This study was completed and published in 1975. Research in the 1980s by Emory University also enumerated the benefits of EMG biofeedback. First of all, the modality is easily used with immobilized patients. Secondly, the patient is given immediate feedback regarding the level at which he/she is able to contract muscles. By informing the patient, EMG biofeedback may help SCI patients to increase these muscle contractions.[3]

The main goal when applying EMG biofeedback with SCI rehabilitation is much the same as with stroke treatment. First, any spasticity must be reduced and hyperactive muscles lengthened if needed. Once the patient has reduced his/her tone and demonstrates some motor control, the patient is then ready to begin voluntary recruitment of the muscles. Recruitment using EMG responses progresses from proximal to distal.[3] Stressing functional activities using EMG biofeedback is the last phase to which a patient advances. Two other aspects to consider when using biofeedback for SCI patients are the amount of distraction during the training session and frequency of feedback to the patient. Initially, the training environment should be one with minimal external disturbances and at a slow rate of feedback to the patient. As the patient progresses, feedback sessions should incorporate more complex everyday conditions and tasks with a more rapid rate of feedback.[3]

A case study on an acute, incomplete spinal cord injury patient highlights EMG biofeedback within the therapy regime. The patient presented with incomplete motor paraplegia at the T_{12} neurological level on the right and L_3 neurological level on the left. Voluntary motor activity below the level of the lesion was present after one month. This made him a candidate for EMG biofeedback therapy. EMG biofeedback was implemented during immobilization following surgery to stabilize the patient's spine and to prevent muscle atrophy and decreased muscle endurance. Biofeedback is a good exercise during this period because it does not put stress on the spine and strength gains can be objectively measured. EMG biofeedback was found to be effective for acute spinal cord injuries as reported by this case study.[46] The modality was a valuable adjunct to treatment to allow early exercise and muscle control. Advantages stated in this study of EMG biofeedback are slight strength gains, increased patient participation, and increased patient awareness.[46]

Not only patients with acute SCIs, but also patients in the chronic phase can utilize EMG biofeedback. During initial hospitalization, goals for maximizing functional independence are set with the patient and a team of health care workers. The patient then has goals to work towards achieving. At some point in rehabilitation, the patient reaches a plateau of functional gains and the patient is discharged from inpatient rehabilitation. A number of SCI patients look for methods for obtaining greater functional gains after reaching a plateau with other rehabilitation programs. One method is through the use of EMG biofeedback.[47] Klose and associates[47] have examined the effectiveness of three therapeutic modalities on chronically paralyzed, long-term SCI patients. Thirty-nine subjects at least one year post SCI, with a diagnosis of incomplete lesion, were included in the study. The three different plans were physical exercise therapy, electric neuromuscular stimulation, and EMG biofeedback. Of those three, EMG biofeedback stands alone as the only program of rehabilitation which does not have solid scientific studies to support its use with SCI.[47] The conclusion states that there is no significant statistical difference in the three therapies. The authors proposed that EMG biofeedback therapy is successful due to learning, while the gains of the other groups may be merely a result of practice.[47]

As stated before, there is no scientific evidence on the efficacy of EMG biofeedback with SCI patients. Furthermore, a relatively small number of case studies have been reported linking EMG biofeedback to SCI rehabilitation. The benefits of EMG biofeedback may not exceed those of conventional physical therapy, but that does not mean that health care providers should discard it as ineffective. EMG biofeedback therapy is meant to be used as an adjunct to regular therapy or to achieve more functional goals with the SCI population.

Restoration of neurologically impaired patients to the highest possible level of function is a difficult task. Yet, this is the basic understanding behind neurological rehabilitation. EMG biofeedback is one tool in an entire physical therapy tool box. When used with the proper patient population and within the correct treatment règime, EMG biofeedback can be helpful. Spinal cord injuries and stroke patients have both used EMG biofeedback effectively and have achieved functional goals with its help.

CHAPTER VI

CONCLUSION

Learning is a complex task and through research more is continually being discovered about the learning process. Learning can be defined as "the modification of a behavioral tendency by experience" or "knowledge of skill acquired by instruction."[48] While learning has always been a natural and essential trait of humanity, we have often employed many different ways to learn effectively. In the arena of medicine, rehabilitation or injury prevention, learning is a key factor to a successful treatment program. EMG biofeedback is a device used to augment learning. The biological processes of muscle comes alive in the form of auditory or visual feedback to the patient. This extrinsic feedback is then interpreted by the patient and he/she is able to make changes in his/her movement pattern or strength of contraction based on this information.

Throughout this paper, the role of EMG biofeedback as an adjunctive modality in rehabilitation or injury prevention has been discussed. This electronic device produces successful results if it is used in the correct manner with patients willing as well as cognitively able to participate in physical therapy treatment. Patients engage in ongoing, participative learning to re-educate or strengthen their muscles in conjunction with other physical therapy techniques.

It is one of the underlying thesis of this paper to stress the need for more research-oriented studies. Numerous reports of EMG biofeedback are in existence, but there are not many concentrated studies in one particular area. This type of research is needed before the enormous potential of EMG biofeedback can be fully exploited. Various clinical case studies are documented, some of which are presented in this paper, but the scientific basis of EMG biofeedback used in rehabilitation or prevention needs more specific attention.

Despite the need for more objective research, EMG biofeedback has been shown to be effective when treating a multitude of disorders. Neurological rehabilitation, orthopedic rehabilitation, and injury prevention are only three small areas utilizing EMG biofeedback. A wide range of professionals have seen the benefits of EMG biofeedback for improving functional gains at home, on the job, or on the playing field.

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