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Biofeedback in Physical Medicine and Rehabilitation[1]

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INTRODUCTION

Rehabilitation is a multidisciplinary process that includes the cooperative efforts of various medical specialists and their associates in related health fields to improve the mental, social, physical, and vocational aptitudes of persons who are handicapped, with the object of upgrading their ability to live happily and productively within their environment. The health professionals involved in physical medicine and rehabilitation services are specially trained physicians (physiatrists), physical therapists, psychologists, social workers, recreational therapists, occupational therapists, nurses, vocational counselors, speech therapists, and others. Because many health professionals are involved who are experts in their specialized areas, feedback techniques in rehabilitation settings are varied. Although electromyographic techniques are mainly used by physical therapists and psychologists, other kinds of feedback techniques include EEG, thermal, position sensing, and other devices that are used or could be used by various specialists.

Electromyographic feedback, audiovisual neuromuscular reeducation, and *neuromyometry* are synonymous terms used in the literature. They refer to treatment and evaluation of patients using electromyographic devices for the striated-muscle reeducation process. The clinical literature is

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abundant with clinical studies and basic studies done with electromyography on patients and normal subjects for various purposes.

Audiovisual neuromuscular reeducation techniques are an adjunct to all other therapies commonly used in rehabilitation medicine. To use them, one should be well versed in many other applied sciences, including electromyography, pathology, neurology, kinesiology, and muscle reeducation. Whatever the problem treated, the main techniques are (1) inhibition of spasticity, (2) recruitment of motor unit activity, and (3) muscle relaxation.

These three techniques are used in combination or alone, depending on the problem. In addition to EMG feedback, however, several other non-EMG techniques are used for feedback purposes in rehabilitation medicine: force, position, and joint-angle monitors for recording body posture and movement, and devices to aid training of visceral and respiratory responses in patients with spinal cord problems and respiratory problems.

Historically, feedback procedures relevant to rehabilitation medicine developed over a considerable period of time from several distinct and sometimes unrelated bodies of work. The earliest reports of feedback techniques were presented by Jacobson, early in this century. Not only did he develop treatment protocols for psychiatric patients for general relaxation but he also developed techniques of evaluation that he called electroneuromyometry (Jacobson, 1970).

Many rehabilitation clinicians involved in diagnostic EMG contributed obliquely to the development of this field. The first to record their observations (which remained unnoted until the 1970s) were Mims (1956) and Marinacci and Horande (1960). Important contributions also were made by research investigators using the EMG to study physiology and single motor unit control (Harrison & Mortenson, 1962; Basmajian, 1963a,b, 1967, 1972; Basmajian & Simard, 1967; Simard, 1969; Basmajian & Samson, 1973; Johnson, 1976), by those exploring cybernetic theories of motor learning and control (Smith & Henry, 1967; Herman, 1973), by others extending the principles of operant conditioning to the learning of autonomic responses (Katkin & Murray, 1968; Kimmel, 1967), and by still others studying involuntary skeletal muscle responses (Sachs & Mayhall, 1971; Lloyd & Shurley, 1976).

The types of patients now treated with EMG feedback techniques are those with (1) upper motor neuron lesions, (2) lower motor neuron lesions, (3) hysterical paralysis and dyskinesias, (4) orthopedic problems including tendon transfers, and (5) muscle spasms of unknown etiology causing pain.

UPPER MOTOR NEURON LESIONS

The utility of EMG feedback in muscle reeducation or regulation is generally well accepted. In this group of patients the central nervous system is known to have sustained damage from trauma or a disease process: spinal cord injuries, strokes or cerebrovascular accidents (CVAs), or lesion of the basal ganglia; these all are treated for their symptoms using EMG feedback techniques.

Hemiplegia or Hemiparesis Due to Stroke

In an early clinical study of EMG retraining, Marinacci and Horande (1960) reported an improvement of function in the upper extremity by 20% (Marinacci, 1968). Andrews (1964) studied 20 hemiplegics; although feedback techniques were used for very brief periods, he reported astonishing improvement in 17 of his patients. Unfortunately, his report lacked meaningful definitions, controls, and adequately described gains. Johnson and Garton (1973) used auditory and visual feedback with 11 hemiparetic patients who had residual paralysis of foot dorsiflexion. In addition to three training sessions along with other therapy, these patients were also loaned portable units so that they practiced two 30-minute sessions at home. Three of the 11 patients improved sufficiently to walk without a short leg brace, 4 had fair improvements, and 3 showed no change.

Perhaps the greatest problem with the existing case studies is lack of documentation and description in many of them. This makes it impossible to evaluate the nature and extent of improvements and the extent to which they might be largely attributed to the addition of EMG feedback techniques. This lack of description and documentation is particularly unfortunate. Only the report of Brudny, Korein, Grynbaum, Friedmann, Weinstein, Sach-Frankel, and Belandres (1976) provides follow-up information. Some single and multiple case studies are valuable because they cite the muscles involved and describe the treatment procedures very clearly (Amato, Hernsmeyer, & Kleinman, 1973; Swaan, van Wieringer, & Fokkema, 1974; Nafpliotis, 1976). Some case studies that included trials with and without EMG feedback are interesting because the treatment outcomes clearly demonstrate the efficacy of EMG feedback (Bird, Cataldo, & Cunningham, 1977; Spearing & Poppen, 1974; Middaugh, 1977b; Wooldridge, Leiper, & Ogsten, 1976).

In the first controlled study of EMG biofeedback for stroke patients, Basmajian, Kukulka, Narayan, and Takebe (1975) compared clinical outcome in two randomly assigned groups of hemiplegics; one group received treatment sessions of 40 minutes of therapeutic exercise, the other received 20 minutes of therapeutic exercise plus 20 minutes of exercise with EMG feedback. The EMG feedback group made gains in strength and range of motion that were double those made by the nonfeedback group. Criticized by Fish, Mayer, and Herman (1976) for its limited statistical treatment and for differences between the two groups with respect to time since injury, this study provided sufficient information to justify expanded controlled studies of the variables that influence the response to EMG feedback (Basmajian, Baker, & Regenos, 1977; Baker, Regenos, Wolf, & Basmajian, 1977).

As with other treatment techniques, patient variables are likely to be important, but they have not yet received much attention (see Inglis, Campbell, & Donald, 1976). One piece of information that must be documented is the extent that the EMG feedback training period differs from the other therapeutic period. To what extent would there be differences between the groups if treatment is truly identical throughout except for the presence or absence of EMG feedback?

Kleinman and co-workers (Kleinman, Keister, Riggin, Goldman, & Korol, 1975; Santee, Riggin, Kleinman, & Keister, 1976) started training with EMG feedback after a baseline period that involved identical training but without EMG feedback. In addition, half the subjects were begun on EMG feedback training sooner than the other half. This design permitted both within- and between-groups comparisons. The procedures are well described, the measures quantitative, and the results analyzed statistically.

In one of these studies (Kleinman et al., 1975) biceps hyperactivity during EMG feedback training was significantly reduced below baseline levels. This finding must be viewed somewhat tentatively since measurements were taken *without* EMG feedback during the baseline period but with EMG feedback during training. Also, the difference between groups at the point where the baseline period for half the subjects overlapped EMG feedback training period for the other half was only marginally significant. There was, however, a significant increase in active elbow extension from the baseline to the posttraining follow-up 11 weeks later. The second study (Santee et al., 1976) used a similar design to compare the results of a baseline period of active exercise without EMG feedback, with the *same exercise* with EMG feedback, and with EMG feedback plus incentive, on EMG activity and range of motion in the foot dorsiflexors of hemiplegic patients. The results are equivocal. EMG activity increased significantly from baseline to follow-up, but the largest increase came with the addition of incentive (monetary reward or equivalent value in cigarettes) rather than with the addition of EMG feedback. Increases in range of motion were marginal. These studies are indicative of a growing sophistication in experimental approach in the investigation of EMG feedback in therapeutic exercise in hemiplegia.

Two other studies examine the question of specific EMG feedback effects even more directly by comparing short-term performance within subjects during efforts to produce voluntary muscle contractions with and without EMG feedback (Lee, Hill, Johnston, & Smiehorowski, 1976; Middaugh, 1977b). The rationale was that if the added information provided by EMG feedback contributes to clinical outcome, then practice with EMG feedback must differ in some way from equivalent practice without EMG feedback. Lee et al. (1976) compared changes across a series of 5-second voluntary contractions of the deltoid muscle under three different conditions in each of 18 hemiplegic patients. The three conditions were an EMG feedback condition, a nonfeedback condition, and a false-feedback condition—counterbalanced for order of presentation. Both the EMG feedback and nonfeedback conditions showed similar changes under the conditions of the experiment as compared with the false-feedback condition. The investigators concluded that there is no specific effect of brief (5-second) EMG feedback that is dependent on precise cues from peripheral myoelectric signals. The equivalent procedure without EMG feedback produced equivalent results.

In a more recent study, however, Middaugh (1978) found that EMG feedback significantly improved the ability of normal human subjects to maximize and prolong a voluntary contraction in an unfamiliar and little used muscle. These findings suggested that the 5-second contractions in the Lee et al. study were simply too brief to allow the subjects to make effective use of the EMG display, and that improvements with EMG feedback might be demonstrated with somewhat longer trials. It takes time to attempt a contraction, note the information provided by the feedback display, and make improvements. Twelve subjects, half with brain damage, half with more peripheral nervous system damage (partial spinal cord injury and peripheral nerve injury), were asked to produce a series of 30-second muscle contractions in a muscle below functional strength. Feedback was provided on half of the trials. Feedback and nonfeedback trials were alternated and counterbalanced as to order of presentation. Voltage output on feedback trials was significantly greater than on nonfeedback trials. This effect was not related to site of nervous system damage or to time since injury. These results suggest that EMG feedback has a substantial positive effect on motor unit recruitment by providing useful information regarding the relatively small, marginally discriminable muscle contractions that were the common denominator among her subjects (Middaugh, 1977b).

Shahani, Connors, and Mohr (1977) studied 16 hemiparetic patients divided into two groups of 8. One group received conventional physical therapy 5 days a week and the other 8 received 45 minutes of EMG feedback three times a week in addition to conventional physical therapy. They concluded that the group receiving EMG feedback improved more rapidly in the area of motor power, gait, transferring, and general well-being than those with conventional physical therapy. In addition, they found that those patients with lacunar infarcts showed generally more satisfactory improvements than those whose stroke involved the cerebral surface MCA territory.

This is one of the few studies that point out the importance of noting the specific central nervous system lesions in relation to the treatment programs.

Brudny et al. (1976) recently tabulated the effects of feedback treatment on 45 cases of hemiplegia. Thirty-nine of their patients were treated for paralysis of the arm; 3 months to 3 years later, 20 of them had retained significant functional gains.

We conclude that confusion exists in some of the studies as to the kinds of patients studied: Are the patients hemiplegic or hemiparetic; are the symptoms treated flaccidity, spasticity, or clonus; are the EMG feedback techniques for the inhibition of spasticity the recruitment of motor unit activity or general relaxation?

The uses of EMG feedback as an attention-getter, as a general motivator, as an added evaluation tool for the therapist, and as a generator of new approaches to old problems are important. These uses in themselves probably warrant the widespread use of EMG feedback devices in the P M & R clinic. It is important, however, to differentiate between contributions to treatment outcome due to these and other *nonspecific* factors and contributions that may or may not be made by the EMG feedback per se.

A *specific* effect presumes that the added information provided by the EMG display enables the patient to attain a degree of strength, control, or relaxation that would not have been possible without that added information, or to attain it more rapidly or perhaps to retain it better. At this time, there is excellent evidence that treatment that includes EMG feedback is effective in producing improvements in many categories of patients with neuromuscular dysfunction, improvements that are useful and that are well maintained. There is, however, no direct and final evidence that these gains are due to the specific effects of EMG feedback. Although we believe that clinically important effects that can be attributed specifically to EMG feedback will be demonstrated in the future double-blind research, such an investigation has not yet been reported.

Spinal Cord Injuries—Incomplete Lesions

There is no place for EMG feedback techniques if there is no anatomical substrate to work with. However, most patients with spinal cord injuries do not have complete lesions, and hence there are always some anatomical pathways left for the transmission of neural impulses. These patients must be evaluated using diagnostic EMG equipment to determine whether the lesion is complete or incomplete. Those patients with residual function can be worked on using EMG feedback techniques to bring about desired movements as well as to inhibit spasticity. Only a few case reports in the literature confirm that these patients can benefit (Dunn, Davis, & Webster, 1978). Four reports (Schneider, Scaer, Groenewald, & Atkinson, 1975; Seymour & Bassler, 1977; Fernando, 1976; Toomim, 1976) all dealt with the question of single case studies on spinal cord patients. These studies reported EMG feedback techniques as a tool to identify which muscles were spared and then to work on them in the early stages. These patients were in other therapeutic programs as well and hence it is difficult to conclude that the results are mainly due to feedback. However, the feedback techniques helped these patients and the therapist to locate the target muscles, which were all below a "trace" of function. Brudny, Korein, Levidow, Grynbaum, Lieberman, and Friedmann (1974) reported on two quadriplegic patients with lesions at C 5 and C 6 levels; both had paralysis of the lower extremities with minimal functioning of the upper extremities; both improved with the EMG feedback techniques, one gaining the ability to resume activities of daily living, to type, and to drive an electric wheelchair 2 years later.

Cerebral Palsy

In addition to EMG feedback techniques, other feedback techniques are used in treating patients with cerebral palsy (CP), e.g., the Joint Position Trainer. Halpern, Kottke, Burrill, et al. (1970) used a mechanical head support on 14 CP subjects from ages 3 to 12. They found that in most of these children there was improvement in head control. Harrison and Connolly (1971) studied four CP subjects aged 18 to 25 together with a normal group. They found that these patients could achieve as fine a degree of motor control as the normal subjects although they took more sessions of training.

A group of studies have used added feedback in treatment of cerebral palsy in both adults and children. Several of these studies document specific feedback effects by comparing performance alternately under feedback and nonfeedback conditions (Wooldridge et al., 1976; Bird et al., 1977; Spearing & Poppen, 1974). One other study (Harris, Spelman, & Hymer, 1974) suggests a specific feedback effect in that control during feedback sessions changed appropriately with changes in the feedback settings (threshold settings). Another study (Finley, Niman, Standley, & Ender, 1976; Finley, Niman, Standley, & Wansley, 1977) demonstrated reversal of gains upon cessation of training and reinstitution of gains when training was resumed. While obviously the training situation was responsible for the well-documented gains, the specific role of the added feedback is still an open question. These studies as a whole suggest that CP children are sensitive to added feedback and many can improve motor control. The basic problem seems to be that of carry-over beyond the training period. In some cases, improved control is present only during feedback presentation; in others, there is carry-over to the nonfeedback situation during experimental sessions. The major problem appears to be lack of continuation of control once the child leaves the experimental session (Wolpert & Wooldridge, 1975; Wooldridge & Russell, 1976). In cases where control does extend beyond the experimental environment into the home or classroom, it may not be well maintained (Finley et al., 1977). Probably the problem arose from the use of children as subjects. With children, it was usually necessary to combine the feedback procedures with the use of a more overt reinforcer. Children also are less likely than adults to practice incorporating their newly acquired control into their everyday life. The one instance of feedback training in a group of *adult* CP subjects did demonstrate significant gains at follow-up 6 weeks after training (Finley et al., 1976).

Harris et al. (1974) have developed sensory aids to improve kinesthetic monitoring of the heads and limbs. Eighteen athetoid CP children (from 7 to 18 years old) were studied. The devices used were the Limb Position Monitor and the head control device, which both use visual and auditory feedback. The children were treated over periods of 2 to 12 months with sessions of 30 minutes of therapy using these devices. The children improved their postural stability and gained control over voluntary movements. All those who used the Limb Position Monitor showed a decrease or an elimination of tremor and improvement in smoothness and accuracy of their arm movements. Wooldridge and Russell (1976) studied 12 CP children using a Head Position Trainer, reporting it to be effective in the control of head position awareness. Other unpublished reports on the use of the device at several centers in Ontario are in accord (Walter Johnson, personal communication).

Silverstein (personal communication) stated that in 40 CP children 50% had no improvement, 25% had improvement only while on the machines, and 25% had maintained improvement during generalization. Most of those studies were single subjects, and no control group was possible due to wide individual differences. Possibly the significant progress seen was due to the effect of the therapists as well as of the biofeedback. However, even if the source of improvement was increased motivation and goal orientation on the part of the therapist, biofeedback was found to be better than the existing physiotherapy (see, for example, Wooldridge & Russell, 1976; Finley et al., 1976, 1977).

While biofeedback for CP is very interesting and promising, we still lack evidence of well-maintained, clinically significant gains attributable to added feedback. However, many CP studies employ quantitative measures, statistical analysis of results, and a level of experimental sophistication that is well above that of most studies of biofeedback related to physical medicine and rehabilitation.

LOWER MOTOR NEURON LESIONS

There are many single case reports in the literature that support the view that EMG feedback techniques could be useful in the management of lower motor neuron lesions. However, there are no studies to indicate that treatment of these patients accelerates axonal growth. It is beyond doubt that feedback techniques take some guesswork out of the treatment programs and reveal those muscles that need to be reeducated. EMG feedback techniques are started only when the first signs of regeneration are noted on electrodiagnostic testing (electromyography or strength-duration curves). In patients with lower motor neuron lesions, after the first signs of reinnervation are seen, EMG feedback techniques are an effective mode of treatment. The rehabilitation process can begin as early as when a few motor units are seen.

These patients should be evaluated with an EMG feedback setup that includes an oscilloscope to make sure that motor unit potentials are seen prior to commencement of treatment.

EMG feedback for treating lower motor neuron lesions was first reported by Marinacci and Horande (1960). Their goal of treatment was to increase muscle volume through single-unit conditioning. Although some functional improvement was reported, the results were not quantified and so remained as interesting anecdotes. Their largest series of patients was five Bell's Palsy patients and a longer series of poliomyelitis patients with residual paralysis. Booker, Rubow, and Coleman (1969) gave an interesting single case report of the use of EMG feedback due to peripheral nerve injury, and Jankel (1978) also effectively used feedback techniques in Bell's Palsy. Fernando's (1976) clinical experiences in patients with lower motor neuron dysfunction have been encouraging, and Brudny et al. (1976) mention the use of EMG feedback for facilitating muscle reeducation in four patients with peripheral nerve injury.

DYSKINESIAS

Spasmodic Torticollis

Spasmodic torticollis is a problem of unknown etiology. However, for many years it has been thought to be a problem in the basal ganglia. Others think it is a conversion hysterical phenomenon. Although conventional medical techniques have been unsuccessful in treating this disorder, EMG biofeedback has produced very encouraging results. Brierly (1967) was the first to report the use of a form of feedback for this condition. In two cases, he reported the successful long-term alleviation of symptoms using a shock-avoidance procedure. Wrist shock was paired with head position deviations.

Cleeland (1973) reported on a combination of shock and EMG feedback for 10 subjects with torticollis. The number of training sessions varied from 8 to 23 and 8 of the subjects showed a significant decrease in neck tension that was stable over a 19-month follow-up period. Cleeland has greatly expanded on his series with excellent clinical results (Cleeland, 1978).

Brudny and colleagues (Brudny, Grynbaum, & Korein, 1974; Brudny et al., 1976) reported results on 48 patients. The goal was to teach relaxation and to simultaneously increase the muscle force of the atrophied muscles of the neck. Of the 48 patients trained, 26 demonstrated major improvements. Follow-up reports showed some regression but they still achieved about a 40% success rate in patients who had had the condition for periods ranging in duration from 3 months to many years.

Fernando (1976) reported experiences with 10 patients, and since then he has seen another 15 patients. The protocol used is a combination of EMG feedback, psychological evaluation and counseling, and Jacobson relaxation exercises; it has shown a success rate of 20 to 30%. Grafman et al. (1978, personal communication) also treat spasmodic torticollis patients with generally satisfactory results. In addition to EMG feedback, they use psychotherapy if emotional difficulties exacerbate the problem. Jankel (1978), using an adaptation of a technique first described by Booker et al. (1969), first trained a subject to match the activity of the two sternocleidomastoids and then provided feedback contingent upon both muscles producing the correct response. Using this approach, the author was able to report success with both statistical and functional significance.

Blepharospasm

Blepharospasm consists of spasms of the eyelid and orbicularis oculi muscles along with some facila spasms. Some neurologists consider it to be a result of a lesion in basal ganglia. Ballard, Doerr, and Varni (1972) described a combined shock and feedback procedure that eliminated these spasms so that they remained absent in a 9-month follow-up. A similar technique has been successful in the clinic of Grafman (personal communication). Stephenson (1976) used relaxation training and forehead EMG feedback to demonstrate elimination of spasms and maintenance of these gains over a 6-month follow-up. Peck (1977) also reports success using EMG feedback for this problem.

Parkinson's Disease

Netsell and Cleeland (1973) reported considerable progress in reducing lip hypertonicity in a 64-year-old patient with Parkinson's disease. Nusselt and Legewie (1975) trained two Parkinson's patients to reduce hand tremors. In these studies the number of patients is too small to permit any conclusions.

Hemifacial Spasm

This is a disorder characterized by paroxysms of rapid irregular clonic twitching of the musculature on one-half of the face. It is suspected that the cause of the spasm is a lesion affecting the facial nerve in the cerebellopontine angle or the facial canal. EMG feedback paired with shock as for the treatment of spasmodic torticollis (Cleeland, 1973) have given quite satisfactory results based on clinical and quantitative evaluation during treatment and subsequent follow-up (Grafman, personal communication).

CHRONIC PAIN SYNDROMES

In the management of chronic pain, EMG feedback seems to be effective in those patients who are in severe pain due to muscle spasms; these aggravate pain and hence the vicious cycle of muscle spasm, pain, and more muscle spasm continues. Sometimes, this type of patient does not respond to other conventional therapies. EMG feedback seems to be effective in alleviating this problem.

Jacobs and Felton (1969) demonstrated the clinical use of relaxation for localized muscle spasm. Both normal and neck-injured subjects were better able to relax activity of the trapezius muscle during a single trial with EMG feedback than during a single trial that was identical except for the absence of EMG feedback. This study revealed a specific short-term effect that can be attributed to the EMG feedback per se.

Gottlieb, Strite, Koller, et al. (1977) reported successful use of EMG feedback in the rehabilitation of patients with low back pain. However, the EMG feedback was only one part of a comprehensive pain management program. In recent months, many clinics are reported to be actively exploring biofeedback general relaxation therapy for patients with chronic back problems (Basmajian, 1978).

Temporomandibular Joint Pain

Many patients suffering temporomandibular joint pain have been treated with EMG biofeedback. The masseter muscle is usually used for electrode placement for EMG feedback technique. Solberg and Rugh (1972) used EMG biofeedback in the treatment of TMJ pain, reporting that two-thirds of their 15 patients had significantly improved while wearing the device. Dohrmann and Laskin (1976) treated 24 patients with this problem; 16 were placed in an auditory EMG biofeedback situation and 8 received placebo treatment. Twelve of the 16 patients required no further treatment. They concluded that EMG biofeedback should be a useful modality for the management of this syndrome.

Carlsson and Gale (1977) treated 11 patients with long-term intractable pain related to the temporomandibular joint. The patients were trained in tension awareness and relaxation using feedback of muscle tension level in the masseter muscle. At the follow-up examination, 4 to 15 months after the termination of treatment, 8 of the 11 patients were totally symptom-free or significantly better, 1 was slightly better, and there was no effect for 2 patients.

Rosenthal (1976) used forehead EMG biofeedback therapy with seven TMJ patients. Because five of his seven patients had short masseteric silent periods and responded well to feedback therapy while the other two had long masseteric silent periods and did not respond, he concluded that biofeedback therapy would be effective for patients found to have short masseteric silent periods. Fernando (1976) reported two patients who responded to EMG feedback techniques including general relaxation, targeting on the muscles that are in spasm with Jacobson relaxation home-training program. Since then, Fernando's group have treated at least 10 more patients with good clinical results.

TENDON TRANSFERS AND MISCELLANEOUS CONDITIONS

Brudny et al. (1976) mention the use of EMG feedback on two patients following tendon transfers, observing that recovery "seemed to be facilitated."

Case studies have reported use of the EMG feedback in writer's cramp (Reavley, 1975), in conversion reaction involving motor disability (DeWitt

& Palacious, 1977; Fernando, 1976), in Guillain-Barré syndrome (Cohen, Crouch, & Thompson, 1976), and in traumatic injury to the hand (Kukulka, Brown, & Basmajian, 1975).

EMG feedback has been reported to be useful in teaching breathing exercises to emphysematous patients (Johnston & Lee, 1976). A chest expansion monitor has also been used to teach diaphragmatic breathing to asthmatics (Block, Lagerson, Zohman, & Kelly, 1969).

FORCE, POSITION, AND JOINT-ANGLE DETECTORS

A number of feedback devices have been described that provide information on body movements rather than on muscle contractions. The question as to whether there is an advantage or a disadvantage to training movements (and assuming the acquisition of control of the individual muscles) rather than training the individual muscles remains unanswered. Studies of feedback in cerebral palsy included use of head-position monitors (Wooldridge et al., 1976; Harris et al., 1974) and contact switches signaling foot placement (Spearing & Poppen, 1974). One study (Baker, Bowman, & Walters, 1977) included the use of a joint-angle detector as part of a program to train wrist extension in adult hemiplegic patients.

Several studies involve the use of limb-load monitors (e.g., Moore & Byers, 1976). The clinical objective may be either increasing the percent of body weight put on a limb or decreasing it. Two studies of normal human subjects report that success in limiting the percentage of body weight placed on the lower extremity during gait was related to the information content of the feedback signal and the criterion weight specified (Warren & Lehmann, 1975a,b). Other studies report clinical trials of the limb-load monitor in improving weight-bearing in patient populations. Craik and Wannstedt (1975) described improvements in ability to keep weight load within prescribed limits, or to increase loading, for patient groups with orthopedic and neurological conditions during clinical trials. A group of 12 long-term hemiplegic patients were trained in symmetrical standing (equal weight-bearing on both legs). Seven of the 12 subjects made gains that were well maintained at 1-month and 6-month follow-up. Wannstedt and Herman (1977) studied symmetrical standing in a group of ambulatory hemiplegic subjects, all 6 months or more postinjury. Success in achieving symmetrical loading and maintaining it at follow-up was related to laterality of lesion, extent of postural asymmetry prior to training, and response to the initial training trial. Patients with damage to the right hemisphere (left hemiparesis), considerable asymmetry, and poor immediate response to feedback did not do well even with prolonged training (Wannstedt & Herman, 1977). These studies are of considerable value because they represent an effort to look at predictive factors.

VISCERAL AND RESPIRATORY RESPONSES

Three studies have reported use of biofeedback procedures in modifying visceral and respiratory responses in spinal-cord-injured individuals. Brucker and Ince (1977) reported amelioration of postural hypotension with biofeedback training of blood pressure increases in one subject. Cheshire and Flack (1977) report improvements in vital capacity with clinical use of a respiratory monitor during breathing exercises in quadriplegic persons. Szymke and Price (1976) report using an air cystometrogram to provide feedback on bladder pressure in individuals with neurogenic bladders. In this case, the feedback is used to establish "indirect" control of bladder emptying by helping the patient (and therapist) identify which of several possible self-stimulation techniques are most likely to elicit reflex emptying.

CONCLUSIONS

Against a background where no effective means exist for the treatment of movement disorders—drugs, surgical methods, or physical medicine and rehabilitation techniques—biofeedback offers new hope but no miracles. As noted by Gonnella, Kalish, and Hale (1978), the effectiveness of current neurophysiological procedures and techniques is only partially supported by clinical reports; few systematic rigorous and appropriately designed investigations are evident. Quantification, systematic procedures, careful determination of ideal populations, and adequate theoretical frameworks are still lacking (Gonnella et al., 1978).

This is the current state of affairs in the treatment of central nervous system dysfunctions. More documented clinical and basic research has been done on patients and normal subjects with EMG biofeedback than with all other physical therapeutic techniques used in the treatment of central nervous system diseases. In fact, the literature in EMG biofeedback has provided a major impetus for the advance in our body of knowledge for treating neurological dysfunctions. We predict that EMG feedback techniques will become routinely used. The basic usefulness of EMG for patient evaluation, treatment planning, progress testing, and general motivation alone make it a valuable clinical tool. However, EMG feedback techniques will not replace, but rather will add to, the array of existing clinical tools.

RECOMMENDATIONS

The Task Force on Physical Medicine and Rehabilitation recommends the following.

General

1. EMG biofeedback should be considered an adjunct in the routine treatment of hemiplegic patients and, while further research is needed, it is no longer to be considered as an experimental mode.

2. In the treatment of lower motor neuron lesions, after the first signs of regeneration are seen, EMG biofeedback should be used by physicians and therapists.

3. In the treatment of cerebral palsy patients, the head-position monitors and limb-position monitors should be used along with other routinely used rehabilitation techniques.

4. In the treatment of spasmodic torticollis, EMG biofeedback techniques along with other physical therapeutic and psychotherapeutic techniques should be used routinely.

5. In the treatment of temporomandibular joint pain and low back pain due to muscle spasms, EMG biofeedback techniques are an acceptable part of the treatment.

6. In the treatment of patients with spinal cord lesions (incomplete and complete), Parkinson's disease, hemifacial spasm, and bleopharospasm, more controlled studies must be done before they can be treated routinely with biofeedback.

Clinical (Specific)

1. All clinicians and researchers should use a standard evaluation technique and record forms prior to treatment and prior to discharge. (A sample evaluation form may be obtained by writing to the chairman of the committee.)

2. All equipment should conform to Food and Drug Administration standards.

3. All evaluation equipment should include an oscilloscope to identify motor unit action potentials and artifacts.

4. For clinical work and research purposes, patients should be categorized under clinical entities rather than by symptoms alone.

5. Other therapies used with patients should be clearly described.

6. For the types of patients with whom EMG techniques are effective, physicians should be encouraged to refer patients prior to the initiation of other modalities.

Research

1. Careful attention should be given to experimental design.
2. The issue of generalization outside the laboratory conditions and clinic should be pursued vigorously.
3. Studies should document the schedule of treatment and the various reinforcers in addition to EMG feedback in the rehabilitation process.
4. With children, the problem in separating treatment effects from concurrent growth and development requires scientific study. (Martin & Epstein, 1976, and Barlow, Blanchard, Hayes, & Epstein, 1977, discussed this problem of experimental design involving both scientific and ethical questions.)
5. Consideration should be given to the role of motor or precentral cortex in the establishment of EMG control at various stages of disease. (Fetz, 1977, has begun to answer this question by observing cortical changes during peripheral movements.)
6. Studies should be done on whether subjects can be trained to control EMG levels and muscle functions in the absence of external feedback to determine the role of internal feedback as a factor in all areas of feedback applications.
7. Studies should be done to answer the question whether using EMG feedback techniques will accelerate the rate of axonal growth in lesions of peripheral nerves.
8. Studies should begin on the possible effects of EMG feedback techniques on the secretions of neurohormones for blocking pain.
9. Studies should be done to determine whether EMG feedback techniques do in fact modulate pain sensations at the spinal and thalamic levels.

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