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A Myofeedback Instrument for Clinical Use[a]

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Abstract—As a result of a collaborative effort by engineers, physical therapists, and patients, a myofeedback device called Myochirp was designed and constructed. This device was field-tested in six busy medical centers to determine its acceptance and usefulness to clinicians in the daily activities of their environments. As a result of this field evaluation, a second-generation device was constructed incorporating the suggested improvements. The second-generation Myochirp was accepted by physical therapists as a compact, portable, and lightweight device that was convenient and easy to use. The salient feature of the device which rendered it so useful in clinical environments was the dry electrode used to detect the electromyographic signals. Its usefulness as a myofeedback instrument was determined by the variety of its applications to treatment needs and by its ability to obtain immediate and quantifiable data that could be documented.

INTRODUCTION

Adaptation of motor output via augmented sensory feedback has its origins in the early motor-unit control studies of Basmajian et al. (1). This particular type of biofeedback (myofeedback) involves detecting the electromyographic (EMG) signal from the muscle(s) of interest and presenting a simplified, convenient representation of that signal to the subject, usually in the form of sound, light, or an oscilloscope display. This augmentation of sensory modality may enable the individual to obtain more functionally useful control of his musculature. Clinicians (physicians, therapists, and other health professionals) generally recognize myofeedback to be valuable in achieving rehabilitative goals of improving, restoring or maintaining a well-functioning sensory-motor system.

However, most applications of myofeedback have been limited to its performance in specialized clinics or laboratories, where both clinician and patient are self-motivated and predisposed to expect a successful outcome. The purpose of this study was to test the usefulness of myofeedback in a busy clinical environment when neither the patient nor the clinician was preferentially disposed to using myoelectric biofeedback techniques. In order to achieve this goal, it was first necessary to obtain a myofeedback device which would lend itself to convenient use in a busy clinical environment. Commercially available units were found to be inconvenient for one or more of the following reasons:

1. They were too big, and too heavy, and had limited their portability;
2. The visual and/or auditory presentation of the EMG signal was too complex for quick reference; and
3. The recording electrodes were too cumbersome to use. They required too much time for preparation, application, and removal.

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A collaborative effort between engineers, physical therapists, and patients was initiated to identify design considerations for an appropriate myofeedback instrument. As a result of this collaboration, a device called Myochirp was designed and constructed to meet the expressed and identified needs of clinicians in the delivery of patient care and management.

This paper describes the salient features of Myochirp and presents the results of a field test which was performed to determine the acceptance and usefulness of this myofeedback device in the daily operation of clinical departments. Usefulness of the instrument was determined by the variety of applications to treatment needs. Acceptance was reflected by comments on the features of Myochirp and by the degree of utilization of the instrument.

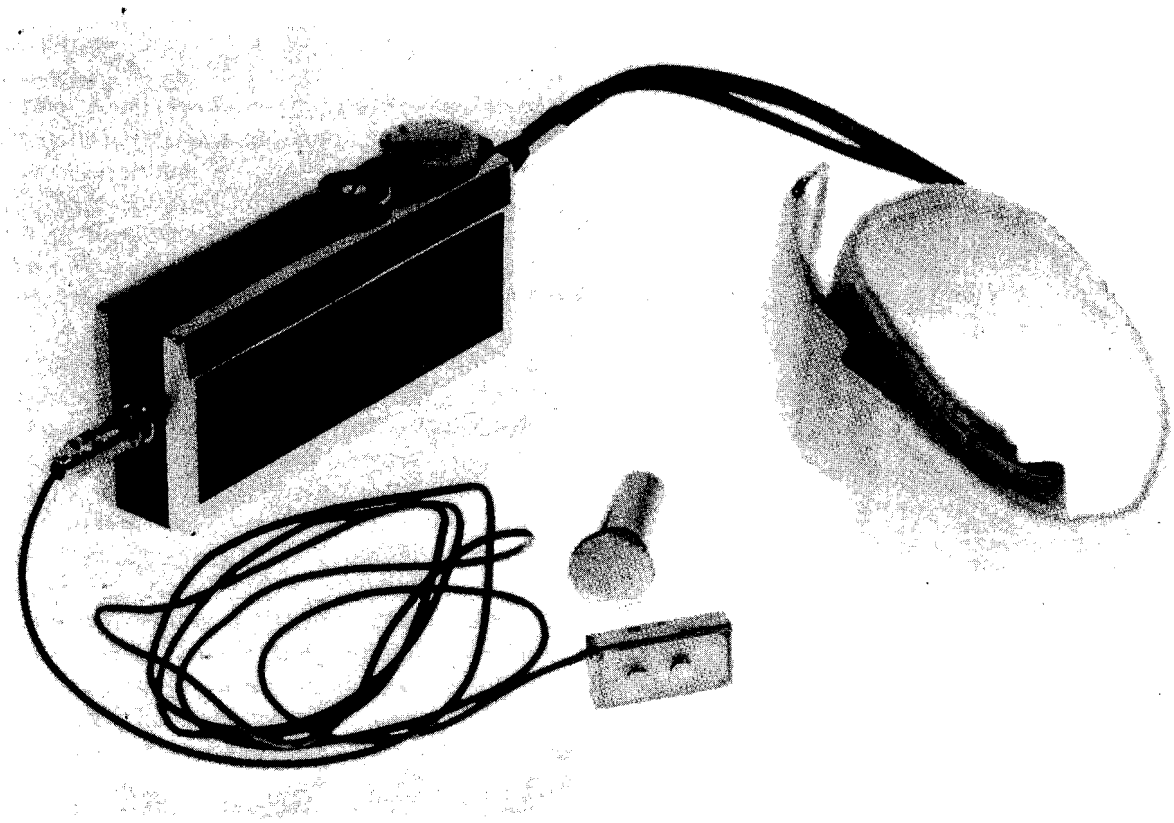
DESCRIPTION OF THE DEVICE

The myofeedback device was designed and constructed in our laboratory as a low-cost, lightweight, compact audio-electromyographic threshold device. The complete unit may be seen in Figure 1. It consists of a dry recording electrode assembly (with self-contained ground) which differentially detects the EMG signal on the surface of the skin. The detected signal is then fed to electronic circuitry which amplifies, rectifies, and filters (smooths) the value of the EMG signal. The processed EMG signal is then compared to a pre-set threshold level selected by the external switch. If it exceeds the threshold of the pre-set level, a tone is emitted and a small light flashes; otherwise, no audio or visual output occurs.

The small size (11 × 6 × 3 centimeters) and light weight (180 grams) of its electronic and control package make the device convenient for ambulatory use.

The control unit provides a total of 15 threshold levels which may be set using one switch. The levels correspond to EMG activity ranging from single motor-unit discharge to that associated with a maximal voluntary contraction. The threshold levels are not linearly related to the rectified value of the EMG signal; that is, a threshold level of position 10 is not twice as large as that of position 5. This non-linearity was purposely designed into the myofeedback device because, as recent investigations by Lawrence et al. [3] indicate, the relationship between the amplitude of the EMG signal and the force output of the larger limb muscles is non-linear. The non-linear threshold levels of the new myofeedback device are therefore more directly related to the force being produced by a muscle at a given EMG signal amplitude.

FIGURE 1
The Myochirp myofeedback device including the dry electrode and the electrode straps.



From the viewpoint of the user, the single most important aspect of the new myofeedback device proved to be the electrode. This electrode has the important feature of being able to detect the EMG signal on the surface of the skin without requiring conductive gel or paste or any form of skin preparation. It does not require a separate ground strap or contact. The electrode can detect the EMG signal 2 seconds after making contact with the skin. It has been used successfully and repeatedly on hairy and dry skin. It may be used as a probe to rapidly explore several muscles. Figure 2 shows the electrode and the myofeedback unit in the process of being used. (The design and specifications of the electrode have been reported previously (2).)

The Myochirp myofeedback device as shown in Figures 1 and 2 is a second-generation device which contains several modifications over its predecessor. However, both generations of the device were essentially similar in construction and design philosophy.

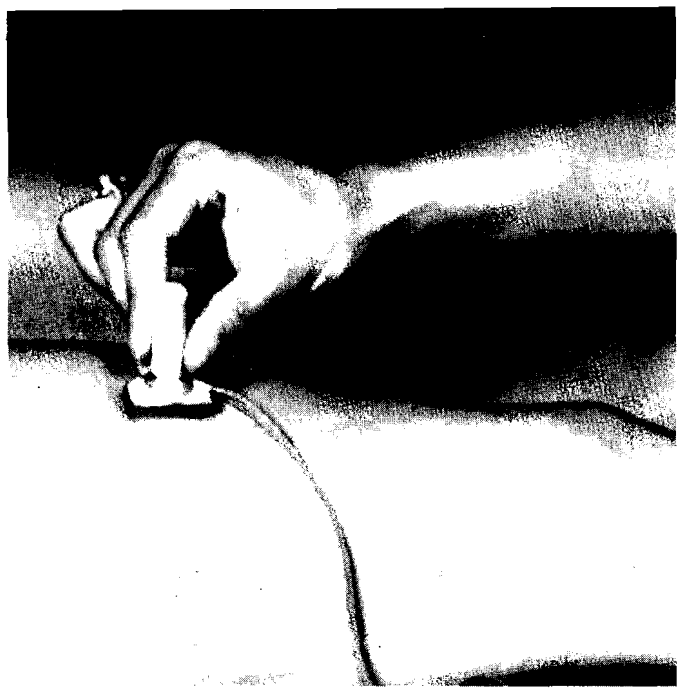


FIGURE 2
The dry electrode of Myochirp in the process of being applied to the skin of a subject. Note that the electrode (including the ground) may be used as a probe.

TABLE 1:
Final evaluation form: each therapist filled out a form with this text after each treatment session.

1. Using the following scale, please indicate the relative ease or difficulty in using the Myochirp:

   a. Evaluation — Easy 1 2 3 4 5 6 7 8 9 10 Difficult

   b. Treatment — Easy 1 2 3 4 5 6 7 8 9 10 Difficult

   c. Self-exercise — Easy 1 2 3 4 5 6 7 8 9 10 Difficult

2. Things you liked best about Myochirp:

3. Suggestions for further study:

4. Things you liked least about Myochirp:

5. What improvements or changes you would like to see in future versions of Myochirp:

FIELD-TEST METHODS

Seven first-generation myofeedback units were built and distributed to six medical facilities in the Greater Boston area. All six centers are affected by regulations on the length-of-stay of individual patients. The facilities chosen represent acute-general, rehabilitative, and specialty centers. Combined, the six hospitals provided a patient population diverse in age and type of dysfunction. The age of the patients ranged from 5 days to 98 years.

Each facility was visited by the physical therapist in charge of the field test. A general discussion on myofeedback was held and specific instructions on the operation of the myofeedback instrument were given to all interested staff. One or two therapists in each facility were assigned to the study. Each of these therapists had a minimum of 1 year of experience and a stated interest (but no significant experience) in biofeedback application. Each therapist was instructed to evaluate the unit daily by filling out the questionnaire after each treatment session. The text of the evaluation form can be found in Table 1.

The field test procedures called for the therapists to use the Myochirp in conjunction with their normal caseloads, to avoid intrusion upon and disruption of the typical operation of the departments. This approach also prevented any tendency to restrict use of the instrument to specific types of dysfunctions. The therapists were requested to docu-

ment the results under three categories: (i) evaluation, (ii) treatment, and (iii) self-exercise. Evaluation included the initial assessment completed upon receipt of a physician's referral, as well as an assessment of the effectiveness of a treatment session. Treatment referred to the implementation of a therapeutic program based on the objective and measurable results of the initial assessment. Self-exercise referred to those exercises or activities a patient performed without supervision. The therapists also recorded the number of times the device was used per day. Although this approach required a subjective evaluation of the device, documentative information expressing the perceived needs of the clinician and the usefulness of the device in the busy clinical environment was provided.

Second-generation instruments were built which incorporated suggestions derived from the evaluation of the first-generation unit. These were distributed to the same therapists. The evaluation of the second-generation myofeedback unit included the original question on relative ease or difficulty of operation of the instrument, as well as a rating on the same specific components of the unit identified in the initial field test.

RESULTS

During the initial field test, data were collected for 202 days. The Myochirp was used in 418 treatment sessions involving 720 muscles. The mean per-day utilization of the instrument represented an average of 21 percent of the mean daily caseloads of the therapists, or 2.0 ± 1.8 daily sessions (Table 2).

The results of the evaluation of the first-generation instrument, and the evidence of a high degree of daily utilization, were considered positive. The most popular features about Myochirp were the small size, the ability to measure and obtain quantifiable data for documentation,

TABLE 2: Utilization details on the variety of muscles tested and the number of applications of the device. Results from the field test of the first-generation device are included inside the parenthesis; the subsequent figures are from the second-generation device.

Muscle or muscle group	Evaluation	Therapeutic exercise	Self-exercise	Total
Quadriceps	(111) 123	(142) 97	(34) 26	(287) 246
Ant. Tib.	(41) 38	(64) 20	(14) 3	(109) 61
Hamstrings	(33) 37	(29) 33	(10) 1	(72) 71
Glut. medius	(22) 23	(32) 13	(14) 6	(68) 42
Glut. maximus	(11) 12	(14) 10	(4) 2	(29) 24
Gastroc-soleus	(12) 2	(9) 3	(0) 0	(21) 5
Hip flexors	(1) 0	(5) 0	(0) 0	(6) 0
Ext. dig. long.	(3) 8	(2) 4	(0) 0	(5) 12
Peroneals	(0) 0	(2) 0	(0) 0	(2) 0
Adductors	(0) 3	(1) 3	(0) 0	(1) 6
Ten. Fas. Lata	(0) 1	(0) 1	(0) 1	(0) 3
Intrinsics	(7) 0	(8) 0	(7) 0	(22) 0
Ext. carpi Rad.	(7) 2	(8) 3	(6) 1	(21) 6
Biceps	(3) 4	(17) 4	(1) 2	(21) 10
Mid. deltoid	(0) 1	(18) 1	(0) 1	(18) 3
Triceps	(3) 5	(10) 5	(1) 3	(14) 13
Ext. Dig. Com.	(0) 0	(13) 1	(1) 0	(14) 1
Finger flexors	(0) 0	(3) 2	(0) 0	(3) 2
Pron. teres	(1) 1	(1) 1	(1) 0	(3) 2
Post. deltoid	(0) 0	(2) 0	(0) 0	(2) 0
Scap. Ms.	(0) 3	(2) 5	(0) 0	(2) 8
Frontalis	(0) 2	(0) 4	(0) 0	(0) 6
Totals	(255) 265	(382) 200	(93) 46	(720) 521

Percentage of Applications

	Evaluation	Therapeutic Exercise	Self Exercise
Lower Limb	(39) 53	(50) 39	(13) 8
Upper Limb	(18) 35	(68) 51	(14) 14

and the dry electrode. The most criticized aspect of the first-generation instrument was the use of two separate gain switches which the designers had used to increase sensitivity levels. The use of two switches proved to be confusing to the therapists.

Recommendations by each therapist were incorporated in the design of the second-generation myofeedback instrument. As a result, the actual size of the unit had to be expanded slightly, but it remained pocket-sized and lightweight enough for easy portability. The major clinical recommendation was a request for a "relax mode", a mode where the Myochirp would continuously make a sound until the EMG signal surpassed the preset threshold level. This was provided.

In the second field test, data were collected over a total of 90 days during which the Myochirp was employed in 165 treatment sessions involving 521 muscles. The mean utilization of the device per day represented an average of 22.5 percent of the mean daily caseload, or 1.8 ± 1.3 daily sessions. The second set of field-test ratings of the Myochirp components and the dry electrode are contained in Table 3.

The relative ease in utilization of the myofeedback instruments in both field tests is demonstrated in Table 4, where results of the initial field test are noted first, with the results of the second field test shown in parenthesis. A comparison of both sets of results shows an increase in ease of utilization as an evaluative tool reported in four of the six facilities and no difference noted by users in the remaining two.

The rating for relative ease when used as a treatment tool increased in two, remained the same in two, and decreased in two of the facilities.

As an adjunct to self-exercise programs, there was an increase in rating in two and no difference in the way participants at four of the six facilities rated the ease-of-use in such programs.

DISCUSSION

The successful application of Myochirp to a wide variety of musculature demonstrates the universality and versatility of the instrument as a clinical tool (See Table 2). The numbers may seem to indicate that the unit is seen by users as more suitable for use in the lower limbs; however, it must be pointed out that the majority of patients seen in physical therapy departments have dysfunctions of the lower limbs. Also, the numbers of applications to various muscles is insignificant in that it is a representation of the particular dysfunctions encountered during the evaluations, rather than indications of preferential usage.

Table 2 also shows that the majority of the use of the device was for evaluation and therapeutic exercise. The relative lesser utilization for self-exercise appeared to reflect a hesitation by the therapists to part with the instrument. The therapists revealed this hesitancy in discussions held after the completion of the study. They all indicated that Myochirp had become such a useful tool for them that

Aspects of Myochirp

Facility location	Size	Ease of portability	Ability to measure	Single gain dial	Ease of utilization
A	1	1	2	1	1
B	1	3	1	1	1
C	1	1	1	1	1
D	2	2	1	1	1
E	1	1	1	1	1
G	1	1	1	1	1

Aspects of dry electrode

Facility location	Size	"Dry" feature	Reliability	Probe attachment	Strap attachment
A	1	1	2	1	1
B	1	1	2	2	2
C	1	1	2	1	2
D	1	1	1	1	1
E	1	1	2	1	2
G	1	1	2	1	2

TABLE 3:
Final ratings: each therapist was asked to evaluate the myofeedback device and the dry electrode on a scale of 1-3, where 1 = most liked and 3 = least liked.

they were reluctant to relinquish their only unit to individual patients. The therapists also grew to feel personally responsible for the integrity of the unit during evaluation, and consequently exhibited unwillingness to leave the unit with others.

Although subjective, the supportive ratings given to the various aspects of the myofeedback unit and the electrode (see Tables 3 and 4) demonstrate that the device does meet the perceived requirements and needs of clinicians involved in daily delivery of patient care in busy departments. The results obtained regarding the relative ease of use and wide variety of utilizations, as well as the high degree of daily utilization, are encouraging. The favorable response to the first-generation device precluded a significant increase in utilization of the second-generation version. However, subtle change toward use as an evaluative tool is positive. Such utilization reflects not only a high level of acceptance of the device by the clinicians, but most importantly, reflects a high level of usefulness of myofeedback in patient care.

Two aspects of Myochirp were universally singled out by the individuals involved in the evaluations as providing the features which did the most to make it a convenient instrument for them to use in a busy clinical environment: (i) the small size and light weight; and (ii) the dry electrode.

The portability of the unit meant that the therapists could carry the device in their pockets, assuring ready access to it when needed in unanticipated circumstances. The dry electrode eliminated the usual inconvenience and time-loss involved in preparing the skin, applying the conductive gel, and affixing the electrodes. These procedures require several minutes of valuable time, not always available to clinicians in busy environments. These two features, with advantages which seem to be obvious even on superficial consideration, cannot be found in any commercially available myofeedback unit. The authors see this deficiency in current designs as a demonstration of the importance of combining the efforts of engineers and clinicians in the design of instrumentation for clinical environments. Such instrumentation must meet the needs of those who use the instruments—the clinicians and the patients.

The successful outcome of this evaluation of the two prototypes of the Myochirp has prompted a redesign of the device for the purpose of producing a manufacturable version. The most recent (third-generation) version retains all the advantages and usefulness of the previous versions while incorporating technical improvements for further reliability, convenience, and usefulness, as well as simplification of manufacturing procedure ■

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TABLE 4:
Final evaluation of relative ease or difficulty in use: each therapist assessed the ease or difficulty of using Myochirp, accounting for the actual manner in which it was utilized during the treatment session. Use was rated on a scale of 1-10 where 1 = easy and 10 = difficult. Results of testing the first-generation device are inside parentheses, results from testing the second-generation device are the subsequent numbers. A dash indicates that the final evaluation was not available.

Facility location	Evaluation	Treatment	Self-exercise
A	(3) 2	(2) 2	(-) 3
B	(3) 1	(1) 2	(1) 1
C	(3) 1	(2) 1	(-) -
D	(2) 2	(2) 1	(5) 5
E	(-) 2	(1) 2	(1) 1
F	(-) -	(2) -	(3) -
G	(2) 2	(2) 2	(-) 1

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